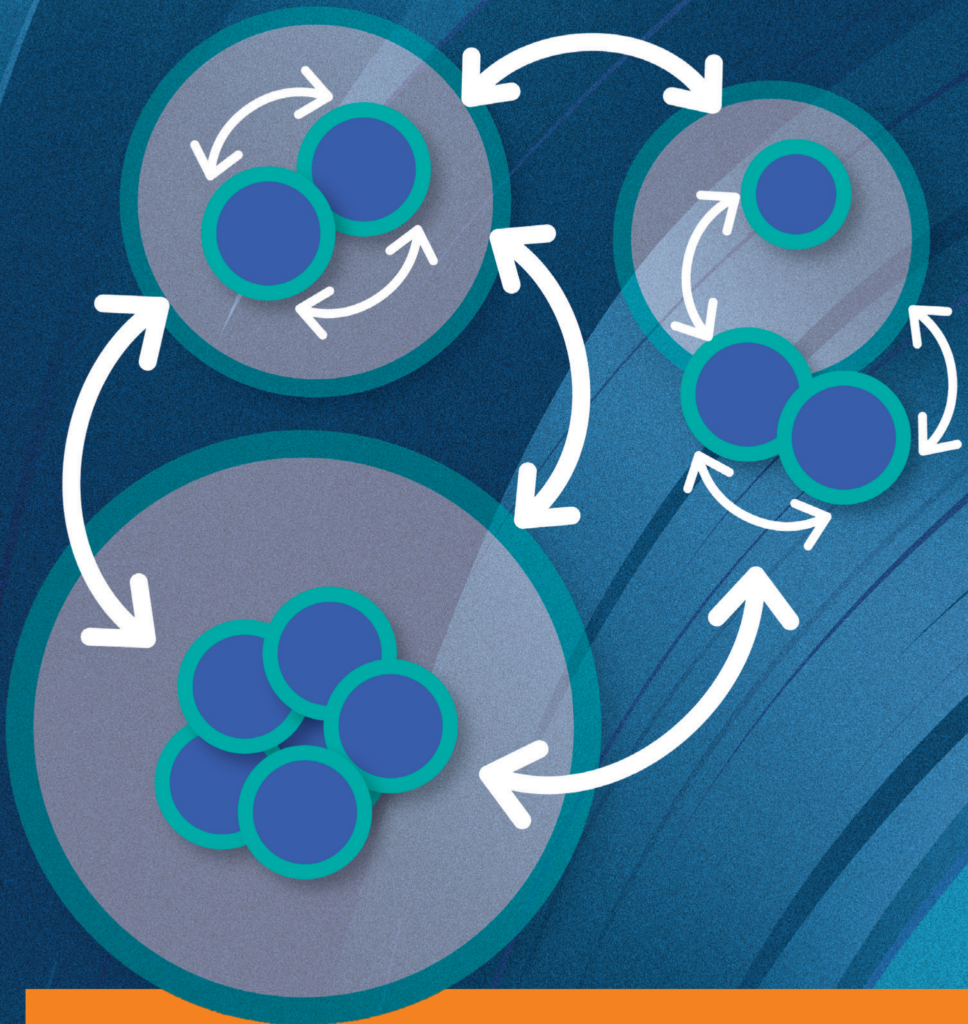
Hanze
Marian van Os
Centre for Entrepreneurship
University of Applied Sciences



# Future of Cluster Developments - Lessons from Energy Valley, The Netherlands

Anu R. S. Manickam

share your talent. move the world.

*This is a publication of Hanze University of Applied Sciences Groningen*
*Marian van Os Centre for Entrepreneurship*

## Research group
International Business
P.O. Box 70030
9704 AA Groningen
Netherlands

## Colophon
**Title** Future of Cluster Developments - Lessons from Energy Valley, The Netherlands
**Author** Anu R. S. Manickam
**Cover Design & Illustrations** Erik Eshuis Infographics
**Typesetting** Hester Slager-Nieuwsma
**Printing** Canon Business Services



**Commisioned by** Marian van Os Centre for Entrepreneurship
**ISBN** 9789053031292
**Edition** first edition, 75

# FUTURE OF CLUSTER DEVELOPMENTS –
# LESSONS FROM ENERGY VALLEY, THE NETHERLANDS

Anu Ratha Sivagengai Manickam

A thesis submitted in partial fulfilment of the
requirements of London South Bank University for the
degree of Doctor in Philosophy

November 2016
(Revised May 2017)

*On the far side of complexity lies profound simplicity*

*~ Karl Weick*

*For the family*

# *Abstract*

*The research explored how a Dutch energy cluster embedded within a larger context of European and global developments reflected complex dynamics due to changes in its context. The case study explored Energy Valley of the Netherlands, a peripheral region that meets the challenge of energy transition, regional development and national economic interests. The research engaged complex adaptive systems approach to gain insights into complex cluster dynamics to contribute to cluster study and policy.*

*The research captured insights into increased complexity of an energy cluster due to energy transition and other developments in the cluster context, exacerbated by differences in perceptions and responses of stakeholders to the new challenges. Findings on cluster developments included insights into cluster context, cluster condition, cluster dynamics and cluster transformations, and the interconnectedness of such developments based on Energy Valley and supplementary cases of Karlstad and Silicon Valley. The research findings led to insights into cluster systems developments and a model capturing cluster emergence.*

*The research contributed to cluster theory by developing a CAS approach for cluster study that developed a whole systems approach to understand cluster dynamics, offering to the field of cluster study a qualitative understanding of cluster systems developments. Insights into interconnected developments at the micro, macro and inter-systemic levels, and into energy clusters in the context of energy transition were results of the research. The broad scope and nature of the study meant limitations were inherent and therefore recommendations for future research were included. EU Cluster Policy motivated the research and hence recommendations for policy developments were also part of the research contribution.*

# *Executive summary*

The thesis intended to study cluster dynamics in a rapidly changing business environment marked by globalisation, accelerated technological advances and digital worlds that have been re-framing business and social landscapes. The financial crisis of 2008 epitomised the increased inter-connectedness and complexity of business environments.

European Union's decision to launch clusters as motors of innovation that would enhance Europe's competitive capacities was the prime motivator for the research. Implementation of such a policy to its diverse hinterland that included peripheral and lagging regions required insights and policy instruments that could serve as a guide. The challenge of implementing cluster policies in diverse settings was further complicated by rapidly changing economic, social and political landscapes of businesses. In order to support implementation of cluster policy in the EU, and elsewhere, understanding complexity of cluster development in their changing contexts would be desirable.

The energy sector, an enabler of other industries, is a key industry undergoing major transition processes due to pressures of climate change and resource depletion. The research chose to study an energy cluster as an extreme or critical case due to these complexities, strained by significant political and social pressures. The study of an energy cluster embedded in complex contextual developments could provide valuable insights on cluster practice. Energy Valley, the Dutch energy cluster of Northern Netherlands was chosen for the study. In this cluster, challenges of energy transition, rural and peripheral regional developments and national economic priorities converged, making it a complex cluster phenomenon.

The emergence of complex adaptive systems (CAS) in regional studies supported the choice of this approach for the study of complex cluster developments in its changing context. The application of complexity approaches, CAS in particular, in the fields of economics, ecology, innovation and transition management served as inspiration and guidance in developing a CAS approach for cluster study. A conceptual framework to guide analysis and strategy development in cluster policy to support European cluster policy implementations and contributions to theoretical developments in cluster studies were the focus of the research.

The research shows how the Dutch energy cluster was shaped by its existing and past traditions, structures and ambitions, its ability to respond to changing contexts, and how new patterns of collaborations and interactions resulted in systemic transformations in the cluster due to policy initiatives and self-organized developments.

CAS offered a 'lens' that facilitated the study of interactions and responses across players, levels and time. The research built on insights from evolutionary economics and regional innovation systems as these fields offered insights into evolutionary and systemic aspects of cluster development. Adopting CAS approaches for cluster study resulted in an analytical conceptual framework that provided guidance in the search of deeper insights into cluster developments. Insights into the complexity and dynamics of the energy cluster, enhanced by two supplementary cases, resulted in insights into cluster systems developments. The whole systems approach for cluster study based on CAS was new and added to on-going developments in cluster studies to understand complexity of cluster developments. Empirical study connecting micro interactions and 'sensemaking' of agents to macro level patterns development using complex adaptive systems approach was scarce in cluster studies. European energy policies impact Energy Valley's developments, specifically on energy transition developments, and at the same time, Energy Valley has been lobbying in the EU to advocate gas as fulfilling a systems function in balancing renewable energy fluctuations. The interconnectedness of interactions across systems levels and interrelated systems developments were made explicit in the study.

The research produced insights reflecting interconnected cluster systems developments for theory and translated these into recommendations for cluster policy and practice, with specific recommendations for Energy Valley. The research developed a complex adaptive approach for cluster studies, captured in the Cluster Emergence Model and thereby contributing to future cluster studies and policy developments.

## *Acknowledgements*

I would like to extend my gratitude to Hanze University of Applied Sciences, Groningen, and in particular, the International Business School (IBS) and its previous Deans Bram ten Kate and Paul Ganzeboom and the Centre of Expertise - Energy (CoE-E) and its Director, Jan-Jaap Aué for the opportunity and support provided during my doctoral programme.

I would like to express my deepest appreciation to my Director of Study, Professor Bruce Lloyd at London South Bank University (LSBU), who provided guidance, support and wisdom during the journey. Similarly, I appreciate and thank my supervisors, Professors Frank Jan de Graaf and Wim van Gemert for their generosity in offering academic, professional and personal support during the programme.

My appreciation goes to Energy Valley Foundation for providing consent and support in exploring the energy cluster, particularly, Owen Huisman. I thank all interviewees connected to Energy Valley for their time and input, including Professors at CoE-E for their invaluable insights on energy transition. My thanks also go to interviewees in Karlstad from the Paper Province, Karlstas Municipality and Karlstad University, who were generous in their time and information. My special thanks goes to Mats Williams for making the case study possible. My appreciation to those who supported the Malaysian case study: the late Anbalagan K. and Mohd Rosli bin Haji Abdullah, Ministry of KeTTha; Professor Dato' Kamaruzaman Sopian and Prof. Dr. Mohd Hafidz Ruslan and colleagues, Solar Energy Research Institute; Leong Yow Peng, UniTen; Manimohan M., Larry Law, TenderDirect, Baharum bin Ismail, SIRI; and all interviewees. My special thanks also goes to those who supported the national and EU level analyses: Hugo Brouwer, former Director Energy Transition; Herbert Krajenbrink, Secretary at Permanent Representation of the Netherlands to the EU, Dutch Energy Attaché; Nikos Pantalos, Policy Officer on Innovation and Clusters DG GROW, European Commission; and Mats Williams from the European Cluster Observatory.

The research programme EDGaR, the 'Big Picture' Project in collaboration with Hanze's CoE-E, provided additional resources that expanded the scope of the research to include energy transition developments. Professor Wim van Gemert, Wim Malon and Lies Oldenhof were instrumental in facilitating our participation. Colleagues, Karel van Berkel, Hein Mathee, Bart Ter Veer, Bert Kiewiet, Jeltje van der Sluis, contributed to the project and publication of ‘A New Take on Energy’. Research assistants were Dewi Eshuis, Negin Yarzadeh Dehkordi, Esme Lisanne and Ana Maria Lepan.

Appreciation and credits to Erik Eshuis (Infographics) for illustrations in the thesis and posters that enhanced the quality and aesthetics of the research. My gratitude also goes to Purushotman Mudaliar for proof-reading my manuscript and for his support. Credits to Eline Kos who assisted on the background report on Energy Valley, and Jacqueline Kruger in the review stage.

I wish to express my gratitude to Professor Ken d’Silva, Professor Shushma Patel, and Dilip Patel from LSBU for their roles in realizing and supporting collaborations with Hanze that resulted in my participation in the doctoral programme. Also, my thanks go to John Harper and Louise Thompson for their support in the different phases of my programme.

My colleagues contributed in different ways and therefore my gratitude to: Marjolein Annen, Jan Bekkering, Jeroen van den Berg, Professor Diederich Bakker, Jolande Donker, Austin D’Souza, Franz Josef Gellert, Candida Godefroy, Evert-Jan Hengeveld, Winny Hoogma-Dekker, Johan de Jong, Professor Bert de Jonge, Aline Kruisinga-de Boer, Jaan Kets, Ritva Laurila, Professor Koos Lok, Arnd Mehrtens, Joost Miedema, Professor Jan-Peter Nap, Lies Oldenhof, Frank Pierie, Louise Penton, Professor Rien Segers, Wim Timmerman, Margreet van der Velde, Professor Hugo Velthuijsen, Professor Martien Visser, and Ria Wiegman.

My appreciation to Karel van Berkel, who participated in the research as researcher and advisor on complexity management, contributed resources from We-Sense, but more importantly, offered invaluable support in my journey of learning and transformation.

Important sources of support, encouragement and inspiration throughout the years were my family and good friends: Ravi, Jyothi, Erik, Johan, Ans, Mena, Nagesh, Sharon, Margret, Tom, Kawther, Ria; but mostly importantly, my parents, and my children for their part in this journey, Dewi, Sidhya and Sangeetha.

# Table of Contents

# List of figures and tables

## Figures

## Tables

*Abbreviations*

| | |
|---|---|
| CAS | Complex Adaptive Systems |
| CEM | Cluster Emergence Model |
| DR | Province of Drenthe |
| EV | Energy Valley |
| EVF | Energy Valley Foundation (cluster organization) |
| ENSEA | European North Sea Energy Alliance |
| EDGaR | Energy Delta Gas Research programme |
| EEG | Evolutionary Economic Geography |
| FR | Province of Friesland |
| GR | Province of Groningen |
| LNG | Liquefied Natural Gas |
| MS | Member States of the EU |
| SWITCH | Northern Energy Agenda SWITCH |
| SME | Small and Medium Sized Enterprises |
| NGO | Non-governmental organizations |
| NHN | Noord-Holland Noord (Northern North Holland) |
| RDA | Regional Development Agency |
| RIS | Regional Innovation Systems |
| RS3 | Regional Smart Specialization Strategy |

# 1 Introduction

The chapter introduces the research motivation and purpose of the study and the theories, methodology and key issues related to the study. The chapter describes the main case study and concludes with an overview of the remaining chapters of the thesis.

## *1.1 Research motivation*

The main motivation of the research lay in implications of European Union's cluster policy given the purpose and the context in which it needed to be implemented. Smart Specialization Strategies of the Horizon 2020 programme of the EU embraced cluster policy as a key cornerstone to promote economic competitiveness. Diversity of regions in Europe and their particular 'smart specialisations' meant that successful cluster policy needed to meet the diversity challenge in its implementation strategies. EU policy makers were seeking ways to stimulate competitiveness of businesses, emerging industries and regeneration of existing industries and regions.

Existing policies and policy instruments did not provide the framework conditions for emerging industries to develop at the scales and speeds that were required to maintain and advance Europe as a region of innovation, jobs and wealth (European Forum for Clusters in Emerging Industries, 2013). Globalization, inter-connected social and business networks, user-led innovations, resource depletion, climate change agendas, emerging markets and shifting political powers were challenging traditional business and economic models and newer models able to deal with these complex landscapes were needed (Pralahad and Krishnan, 2008; Pecqueuer, 2008; Lorentzen, 2008; Wixted, 2006).

A systemic study of the increased complexity of business and cluster contexts would support cluster developments and enhance policy interventions. New approaches to understand new complexities and new strategies for cluster developments would contribute to both cluster theory and practice. An exploration of literature on cluster and related fields including complexity sciences would be carried out to understand current thinking and practice in cluster developments. An empirical study would be carried out to gain insights into complex developments of clusters in their changing contexts to gain insights into current practice. The use of complexity approaches in the research follows recent developments in regional studies (Martin & Sunley, 2003; Carbonara *et al*, 2010; Cooke, 2012; He *et al*, 2011). An extensive and exploratory study of cluster developments would offer insights into clusters dynamics and new approaches for cluster study and policy.

## *1.2 Introduction to cluster studies*

Clusters are defined as '*geographically proximate group of interconnected companies, suppliers, service providers and associated institutions in a particular field, linked by externalities of various types*' (Porter, 2003, p. 562). Cluster studies is an area of research characterised by diversity in focus, approaches and methodologies that in turn, reflected the diversity of the underlying theoretical disciplines. Henry *et al* (2006) indicated that whilst Martin and Sunley (2003) were right in their criticism of the lack of coherence and ambiguities that abounded in cluster studies, there was cause to value diversity of cluster studies. Their contention was that the discourse, namely, the 'theoretical conversations' in cluster research, and the existence of multiple theoretical bases of cluster research offered deeper understanding of cluster practice. Cluster theory was in their view 'emergent' and 'work in progress' (also, Cortright, 2006).

The broad range of fields supporting cluster study meant that there was a rich base of knowledge that could be combined to gain deeper and pluralistic insights into clusters that served the diversity of clusters. Emergence of new studies focusing on the increasing complexity of clusters was also acknowledged in the literature and is discussed in Chapter 2. Innovation systems studies and evolutionary economic geography are theoretical fields offering support to cluster policy developments.

Innovation studies and innovation policies embraced a 'systems of innovation' perspective, which rested on the assumption that innovation was an interactive process. Accordingly, this approach focused on the importance of linkages but acknowledged that effective links could not be a 'panacea' for all problems. European innovation policy embraced regional innovation perspectives. From the 2000s, industry and science linkages that focussed on interactions between the private and public sectors, creating networks of innovation in which transfer of knowledge was pivotal were prominent and there was a focus on 'more complex instruments such as cluster policies' (Izsák *et al*, 2013, p. 17). Izsák *et al* described a shift in focus to non-technological and systemic aspects, including more demand side public procurement of innovation as well as more traditional supply side policies. Cluster policy was recognized as a 'complex instrument' in innovation policy. Cooke (2012) also identified the need for facilitating transversality in complex adaptive innovation systems where policy interventions were needed next to more autonomous behaviours of firms and other stakeholders. He addressed emergent and adaptive nature of innovation systems, of which clusters were a part.

The research intended to explore clusters and their landscapes to understand how clusters develop. Existing fields of knowledge included evolutionary economic geography, regional innovation systems and complexity theories. These theories could support understanding emergent cluster dynamics in changing contexts as shown by Cooke in his exploration of complex adaptive innovation systems (2012).

In the tradition of using 'multiple theoretical bases' and multiple perspectives, evolutionary pathways, adaptive interactionists' perspectives and systemic studies would be embraced in investigating cluster developments. The research set out to explore broad questions related to cluster developments in order to determine the need for new approaches and new agenda in cluster study.

## *1.3 Important issues in cluster study*

Initial characterizations of innovative and competitive industrial districts are key features of current day cluster studies, and such studies included effects of agglomeration, value of proximity, specialized labour pool, networks and linkages, interactive knowledge flows, governance and organization of clusters, etc. (see Asheim *et al*, 2006; Belussi, 2006; Marlberg & Power, 2006). However, new developments showed that cluster theory was in need of enhancement and is described in this section.

The rise of internationalization and digitalization gave rise to questions on the significance of location and proximity in the literature (Langedijk & Boekema, 2008; Gertler & Wolfe, 2006). Developments resulting from globalization have included global production chains, global value chains and more recently, global innovation chains, and a need for new models that could support and transform current regional innovation systems (and clusters) to become globally more competitive (Viitanen *et al*, 2012).

A Canadian study of 26 clusters, across a wide of range of sectors, indicated 'that the key factors and processes which hold the elements of an individual cluster together are highly variable' (Wolfe, 2009, p. 182). Such variability in clusters reinforced the need for analytical frameworks that offered policy makers context specific analyses of cluster developments. Their research also indicated the significance of civic capital in cluster development. They explained that local leaders bridged the gap between local community and local government by leveraging solidarity and creating collaborative opportunities and development of goals amongst stakeholder groups who were not always included in formal strategy dialogues.

The need to modernize triple-helix model (policy, academia, industry linkages) was central to regional innovation systems and clusters (Etzkowitz, 2012; Etzkowitz *et al,* 2007; Farinha & Ferreira, 2013; Storper, 1997). Trends of changing business and consumer behaviours and relationships due to the rise of Internet and new technologies, and more empowered consumers in part due to an integrated European Union supported the need. These changing relationships and players in regional and cluster innovation systems meant new strategy and governance challenges prevailed. Ebbekink *et al* (2015) addressed the growth of 'associative governance' and the influence of civic society in cluster developments, resonating the findings of the Canadian study where civic leadership and civil associations were identified as being significant (Wolfe, 2009; Wolfe & Gertler, 2004).

Changes in cluster context were therefore a key concern in cluster developments and insights into broader issues of contextual changes and their implications for cluster practice would provide support in the design and execution of successful cluster policy. The research would therefore embark on understanding interconnected developments of clusters in their contexts. In order to do this, the research would turn to existing literature to explore theories and models that supported understanding of broader contextual and cluster developments.

## *1.4 Complex Adaptive Systems (CAS) and cluster study*

The financial crisis of 2008 reflected the interconnectedness of economic systems where financial sectors and disproportionate processes impacted global economics (Beinhocker, 2012, 2014; Chia, 2011). New complexities related to governance of economic structures beyond national borders resulted in increased interest in complexity studies. Complexity economics is one such development. CAS approaches have been applied to life sciences, ecology, management, economics, education, health care, etc.

A key characteristic of complex systems is the semi-autonomous behaviour of agents responding to changes to their environment, leading to changes of the system as a whole (Dooley, 1997).

A growing recognition amongst cluster scholars reflected the need to address complexity in regional studies and the potential value of complexity theories (Martin & Sunley 2007; Carbonara *et al*, 2010; He *et al*, 2011; Cooke, 2012) given that clusters were also affected by global and economic crises and developments.

Increasingly, CAS theories were applied to cluster study and some aspects of complex systems were explored. These included *self-organisation* and *emergence* (He *et al*, 2011), and *strange attractor*, *path dependency* and *emergence* (Cooke, 2012). Management studies focussed on firms, explored concepts of *variety*, *agents*, *attractor*, and *self-organization*, (Axelrod & Cohen, 2001), as well as *container*, *fitness to landscape*, *significant differences*, *transforming interactions*, and *emergence* (Olson & Eoyang, 2001).

Broadening the use of CAS in new fields of study as was the case in international aid and development studies (Ramalingen *et al*, 2008; Jones, 2011) guided and inspired the research to explore broader issues and design a CAS approach for cluster study. The CAS application to aid and development studies explored broad questions that included understanding eco-systems of natural and human environments, emergence of short and long -term cycles of developments, interaction patterns across levels, diversity, and connectedness of agents and institutions.

The application of CAS to cluster study was still in its infancy and additional research could support new approaches for policy and extend theoretical developments. The attractiveness of CAS lay in its whole systems approach and is increasingly applied to new fields of studies, including the social sciences.

## *1.5 Important issues related to CAS-driven research*

Existing cluster studies on complexity in clusters employed CAS and complexity approaches but were limited in their scope, often focussing on generic macro (emergent) developments, or, on specific aspects of cluster systems as described in the previous section. A comprehensive CAS model to support policy developments was lacking. A flexible and generic model capturing whole systems developments of clusters in their context using CAS principles would also serve theoretical developments. Nevertheless, a number of issues pertinent to CAS needed to be addressed.

The first issue is the epistemological issue associated with the transfer of complexity sciences rooted in life sciences to study of human systems. The differences between natural and human systems, specifically, intent and conscious behaviour in human systems are addressed in the literature. Clusters as complex adaptive systems would also be subject to these epistemological challenges. Different scholars in the social sciences, including Stacey and Eoyang, chose to address human dynamics and human responsiveness in their works in an attempt to make explicit the conscious decision making processes attributed to humans, which are absent in other living systems. These issues are discussed in the Methodology Chapter, but as indicated, CAS has been incorporated in social sciences and examples are provided to support the research in its epistemological stance.

A second issue in investigating deeper systemic interconnections, and a whole systems study of complex systems, is the interpretivist and subjective nature of the findings. 'Abduction' as postulated by Van de Ven (2007) in the study of complex phenomena, dominated the research for the same reason. Part of understanding abductive leaps in knowledge development could be understood by the notion of 'sensemaking' (Weick, 2001; Dervin, 1999). The concept of 'sensemaking' is significant to both the research process and in understanding behaviours of agents in complex systems. Agents respond semi-autonomously to local contextual changes by sensemaking processes. This process of sensemaking is addressed in CAS studies, although not always explicitly, and plays a central role in the research.

A third issue in CAS is the centrality of agents and agent perceptions as described above. This means that stakeholder perceptions would be leading in understanding cluster dynamics and developments. The convergence of multiple inputs would help create insights into cluster systems developments. Given that complex systems are never static and difficult to grasp due to the non-linearity and partiality of knowing, multiple analyses and inputs would help build a more complete picture of cluster developments rather than distinct analyses (see Chapter 3).

A fourth issue in CAS studies is that it provides a way of seeing the world, often compared to a 'lens' (Mitleton-Kelly, 2003). The use of metaphors to capture qualitative descriptions of complex systems developments is common in CAS studies. As such, the research uses the metaphor of the 'landscape' to describe contextual changes, including changes in energy landscapes. Complexity studies also use models as analytical and organizational tools to study evolutionary systems developments (Maguire *et al*, 2011). The research intends to develop a CAS framework to guide the exploration, analyses and description of cluster systems developments, and as such contribute to future cluster research and policy developments. The guidance feature of complexity theory to understand phenomena is in itself subject to evolution as 'neither the modeller nor the model are outside the system modelled' (Maguire *et al*, 2011, p. 3).

Finally, CAS theories embrace limitations of 'knowing' and therefore issues related to validity and generalizability arises. In addition, the principal of uniqueness of each system also meant that any study of cluster developments builds on the notion of plausibility rather than certainty. Nevertheless, a CAS framework could support exploration of unique features and potential developmental pathways of cluster systems. Any notion of 'managing' in the traditional sense needs to be adapted, in which interventions that could influence or support new path developments in cluster policy are sought.

## *1.6 CAS and the cluster study*

The research intended to explore whole systems development of a complex cluster through an extended case study. This would involve understanding agent behaviour responding to changes in the environments and discovering deeper insights into interconnected aspects of cluster systems. Complexity approaches building on systems thinking could map processes and patterns of interactions and feedback loops in interactions. A conceptual framework would be developed based on an extensive study of CAS and regional studies.

The research chose to investigate in depth a case study to gain insights into its specific system developments, contexts and their interrelatedness. Lessons from such a case study could provide understanding of cluster developments and responses at both the micro and the macro systems levels. These general patterns of interactions and system developments could offer insights that could contribute to theoretical discourse on clusters. In addition, policy implications could be captured as practical lessons. Complex Adaptive Systems (CAS) approaches and the conceptual framework to be developed would guide the research in its data collection, analysis and development of propositions and insights related to cluster systems developments.

## *1.7 Case study – energy cluster*

The energy sector had been facing unprecedented challenges due to resource depletion, explosive energy demands, sustainability, ecological challenges and social complexities

(Rifkin, 2004; Cherp *et al*, 2011; World Energy Council, 2013; IPPC; World Bank; Energy Environment Agency, 2013). A shift from a fossil-based to more sustainable energy systems is the energy transition. *'No one knows what the future of energy transition will be, and the consequences of collective decisions may have a big impact on the future and yet we need to act now as technology developments for energy transitions are expensive, long term strategies'* according to van Gemert, Professor of energy transition (interview, 15 July 2013). The transition meant that energy and energy sectors need to deal with determining, realizing and balancing different types of producers with different types of technologies (Kaloudis & Pedersen, 2008). The energy landscape is complex wherein interacting policy measures implemented in different sectors and government levels are needed to realize more energy efficient and low carbon economies. The Energy Environment Agency (2013, p. 13) emphasizes the significance of policy measures:

> *National policy frameworks are evolving across Europe. Debates on a national and European level are currently taking place about how to achieve the transition towards a low-carbon and energy-efficient future. Achieving optimal coherence between the various policy domains is crucial to maximise the co-benefits across sectors.*

Local energy sectors were therefore faced with complex challenges that included depletion of energy resources, emergence of renewable and other energy sources, need for more flexible infrastructure and need for new skills and knowledge for energy transition developments which were sensitive to global markets and developments.

Clusters included inter-firm dynamics that were both relational as well as spatial coming together to address common needs or issues through collaboration through iterative and dynamic processes of multiple self-organizing and unpredictable collaborative activities (Atherton and Johnston, 2008). According to Cherp *et al* (2011, p. 75), energy clusters faced 'multiple interconnected challenges' that demanded urgent and simultaneous strategies that drive collaborative processes. They also indicated that reductionists' approaches were failing, and that current policy was often fragmented, and that trust in institutions was weakening as they were part of 'complex and historically rooted 'arenas' co-evolving with the energy issues they address' (p. 75). The complexity of energy clusters was therefore tremendous and made them particularly suitable for a study of complex cluster developments faced with significant contextual changes.

Energy Valley, the energy cluster of the Netherlands, was chosen as the main case study for several reasons. The Dutch energy cluster was a local cluster that had an important position in European and global energy markets due the size of its gas resources (largest in Europe). In addition, the gas industry was critical to both the local and national economies. Energy Valley as a region had two major developmental strands. The first strand was the energy transition moving from a gas driven energy sector to a more sustainable and diverse energy market, and the second was the economic development of a peripheral region. The convergence of these developments in the energy cluster offered a case study that could provide deeper insights into cluster development where complexity was dominant. The cluster, situated in the region of the researcher, meant that direct observation and access to stakeholders and experts as well as added advantages of affinity and proximity were present.

The research would investigate additional supplementary cases of Karlstad and Silicon Valley to enhance the findings.

## *1.8 Research design*

The research intended to seek insights into cluster dynamics and developments to provide support to cluster policy and further theoretical discourse. Karlsson (2008a, 2008b) indicated that the case study method was ideal to understand internal dynamics of clusters and their future developments. He expressed that any exploration of clusters and clustering, and often only in retrospect, needed to be guided by theoretical analysis within such case study methodology. The outputs of case studies would add to the increasing wealth of knowledge. The research steps into the tradition of adding deeper insights into cluster development through case study guided by CAS and regional sciences.

The case study methodology also provided the study of phenomena in context, offered a robust but flexible approach (Eisenhardt, 1989; Eisenhardt & Graebner, 2007; Sanders *et al*, 2009; Yin, 2014) that suited the exploration of complex interactions of clusters with their environment within a whole systems approach of CAS. The research intended to use exploratory and revelatory case study methods to gain close-up view of a context-based study of Energy Valley cluster. In addition, exploring 'big' issues in practice of complex phenomena 'relies on a holistic understanding, obtained from engaging multiple stakeholders, of the problem itself, its history, the intentions of actors, and their evolving relationships in changing contexts' (Van de Ven, 2007, p. 287). The engaged scholarship practice advocated by Van de Ven overlaps the sensemaking essence of CAS approaches. The research would set out a qualitative research to gain richer perspectives through interactions with experts and stakeholders, with the core of the input from diverse agents related to Energy Valley cluster.

Related to the exploration of complex phenomena, Van de Ven (2007) advocated the need for ‘variations’ in thinking, drawing upon Karl Weick’s notion of ‘thought trails’, to explore phenomena from different categories to get better understanding, and eventually to build better theory. He also indicated that paradoxes, uncertainty and abductive leaps were part of this process. The research would engage multiple analyses and perspectives (categories) in the research, including micro - macro level perspectives and interactions; inputs from agents in different places in the cluster; multiple analyses to capture systems developments and interactions; and empirical and archival inputs on both past and current practice. The research consequently acknowledges the key role of sensemaking and interpretive ‘lenses’ of primary sources and analytical models as part the study (elaborated in Chapter 3). In investigating complex systemic developments, the research acknowledges the presence of paradoxes, uncertainty and abductive leaps but balances these subjective aspects with systematic mapping and analyses processes.

The research also includes two supplementary cases to verify and enhance findings of the main case study. Karlstad’s Paper Province and Silicon Valley are investigated and therefore strengthening outcomes of the research.

**Research Objectives**

The research intended to explore clusters in their changing contexts to gain insights into changes in the cluster environment, and how these affected cluster dynamics and cluster development through complexity approaches.

The main research question and its sub-questions described below would be answered to support the purpose of the research.

**Research Question**

*What drivers of change and cluster dynamics, in particular for energy clusters, are significant to cluster developments, and what revisions might be needed for cluster theory?*

**Research sub-questions**

1. What is changing in the context of clusters and influencing cluster development?
2. How are stakeholders and other factors at the micro-level influencing cluster development?
3. Can CAS approach be incorporated into cluster theory to support the future of cluster development?

## *1.9 Key concepts of the research*

Main concepts related to the research used in the research are described below.

**Clusters**

Clusters consist of interconnected companies, associated institutions and economic actors, in a geographical area and sharing a common field, that provide and share specialized expertise, services, suppliers and skills (adapted from European Communities, 2008 and Porter, 2003).

**Complex adaptive systems**

Complex adaptive systems are multi-agent systems in which agents constantly adapt to local challenges contributing to emergent, adaptive systems (adapted from Dooley, 1997; Heylighen *et al*, 2007).

## *1.10 Overview of chapters*

The thesis consists of five chapters including the present. This section provides an overview of the chapters.

Chapter 1 introduces the context and scope of study and addresses related theoretical and research challenges. The chapter describes issues in cluster practice and theories and the emergence of CAS approaches in cluster study. The chapter also addresses epistemological and ontological issues related to CAS approaches. The choice of case study and that of energy clusters to capture complex adaptive systems behaviour of clusters is explained. Finally, the research design, including considerations related to studying complex phenomena and complex adaptive systems studies, is linked to the research objectives and research questions.

Chapter 2, the literature review and policy chapter, is divided into two parts. Part 1 discusses literature related to cluster theory and related theories of agglomeration and regional studies in addition to complexity sciences and CAS approaches. Part 2 discusses

EU policy and reviews research focussed on cluster practice and innovation systems that are relevant to the research. The historical roots of cluster theory in agglomeration and regional innovation systems theories provide the context of cluster theory. More recent developments in regional studies, particularly, Regional Innovation Systems (RIS) and Evolutionary Economic Geography (ECG) fields are explored to understand key issues and approaches in these studies and their relevance to cluster policy given that recent developments included more systemic and, or evolutionary approaches. Next, complexity sciences and CAS are introduced to understand and define features of complex problems and the context of increased complexity in economic domains. This is followed by an extensive review of complexity and CAS approaches and their key concepts. At the end of the literature review, gaps and issues in cluster study are identified and a possible role for CAS in cluster theory acknowledged. Part 2 of the chapter introduces EU 2020 strategy, EU cluster policy, followed by models and approaches relevant to cluster developments and policy. These studies focussed on issues of complexity in clusters and innovation systems and, or encompassed holistic and systems approaches. The chapter affirms the need to understand new complexities in cluster developments, whilst EU's complex landscape of internal diversity and fragmentation and new challenges also acknowledge a need for new approaches in cluster policy.

Chapter 3 addresses methodological considerations in the research in Part 1 and describes the research carried out in Part 2. Part 1 describes the type, purpose and underlying philosophies framing the research, particularly those of complexity approaches. Next, the research strategy, which includes implications of the single case study method, is discussed. Details of the empirical study's research design, including inputs from the literature, field study procedure, ethical considerations and clearance, data analyses and presentation of the findings are described. This is followed by an explanation of how the design of the empirical study answers the research questions. Part 2 includes the research scope and an overview of the research, followed by a description of the CAS framework developments. The research design, including details of the Energy Valley case study and the supplementary cases, is also provided.

Chapter 4, the Research Findings and Discussion Chapter, is divided into two parts. Part 1 describes the research findings of Energy Valley as 'Lessons' of which Lesson 1 offers an overview of Energy Valley's 'Shifting Landscape'. Lessons 2 – 7 on different aspects of cluster developments, including those related to energy transition and related developments at the national and EU levels. The research findings are captured as 'insights into cluster developments' and a model that captures these insights. Part 3 discusses the research findings in the light of the literature review of Chapter 2.

Chapter 5 describes conclusions of the research in terms of the research questions and sub-questions, and thereby addressing the place of CAS approaches for cluster study. The second part of the chapter offers recommendations for cluster studies whereby recommendations for future research is included, as well as recommendations for EU Cluster Policy, cluster practice and Energy Valley. The chapter ends with a short personal reflection and topics for future cluster research.

### *1.11 Summary*

The chapter described the background and motivation of the research that set out to explore cluster systems developments in a changing landscape through the use of complexity approaches. The chapter introduced literature on clusters and complex adaptive systems to highlight key considerations and relevant issues related to the research. The study of energy cases and in particular, Energy Valley was introduced to explain main challenges present in energy clusters and its value as an illustrative case study. The chapter explained the research design, objectives and questions to be investigated.

The next chapter describes literature and policy developments, and key concerns in their respective domains in relation to cluster developments.

# 2 Literature Review

The chapter is divided into two parts: Part 1 focusses on cluster literature and Part 2 on EU cluster policy and cluster practice.

## *2.1 Part 1: Cluster theories*

## *2.2 Introduction*

Cluster study is not a clearly defined area of study. Often, cluster studies are part of larger areas of study, such as innovation systems, industrial and sectoral dynamics, competitiveness and production networks, urbanization and regional economies, evolutionary geography, etc. At times, clusters are the main focus of studies especially when policy needs are to be met. This rich arena of literature allows for selection of theories and insights that can support further development of clusters.

A common denominator of cluster studies is that of 'agglomeration' whereby geographical space determines a cluster and therefore 'space' is often one of the key aspects of clusters. In addition, it has been acknowledged that 'clustering phenomena are intrinsically complex, uncertain and very diversified regarding the emergence and evolution patterns they may display' (Hamdouch, 2011, p. 271). The literature review would help understand challenges facing cluster practice and identify gaps in cluster theories. The review provides a broad understanding of regional studies in relation to agglomeration literature and later, more specifically, clusters. This is followed by a review of complexity theories and specifically, Complex Adaptive Systems (CAS). The literature review helps understand theoretical discourse related to clusters and regional studies, the research context. The review of complexity literature helps identify principles and elements of CAS approaches to support development of a CAS framework for cluster study.

An overview of Part 1 follows. Section 2.3, a preface to cluster literature, explains the relationship between strategy development and cluster studies, and how success of clusters is tied to strategic policy development and implementation. The role of new approaches from complexity sciences to support such policy developments is also addressed.

Section 2.4 describes the 'cluster concept' and its roots in agglomeration studies that preceded cluster theory and practice. The consensus on what constitutes clusters, the success and types of agglomerations and studies on agglomerations are also discussed.

Section 2.5 explores Regional Innovation Systems (RIS) studies. RIS approaches, popular amongst policy makers, captures systemic and institutional roles supporting innovation processes. Key features and application of RIS, including limitations, are described.

Section 2.6 examines Evolutionary Economic Geography (ECG) including the place of EEG in regional studies and differences between evolutionary approaches and traditional economics.

Section 2.7 compares RIS and ECG and the convergence in regional studies in acknowledging increased complexity and the need to embrace complexity approaches.

Section 2.8 explores complexity theories more generally, including insights into the nature of 'wicked problems', differences in traditional and complexity approaches in economic realms, and key features of complexity approaches.

Section 2.9 focusses on Complex Adaptive Systems (CAS) and provides an overview of theoretical constructs used in applying CAS approaches. Differences and nuances in concepts are addressed to show the diversity amongst scholars and in applications of CAS.

Section 2.10 comprises concluding remarks on the literature review and of the possible exploration of CAS for cluster study.

## *2.3 Preface to Clusters and Strategy*

Lindqvist (2009) reviewed key strategy journals to ascertain the place of clusters in the study of strategy and found that in the period between 1990 and 2008 there were only eight references to 'the Porterian sense' of clusters. The significance of '1990' was the introduction of the cluster concept by Porter in his seminal work *The Comparative Advantage of Nations*. Although Paul Krugman brought geography back into economic studies as new economic geography and new trade theory, the study of clusters has remained primarily a focus of regional studies and economic geography. One of the reasons for this ‘disinterest of strategy' was explained by the rise of the resource-based view and focus on dynamic capabilities of firms. However, the emergence of network and relational studies of firms encompassed in the tradition of social network theories initiated interests in inter-firm relationships and their implications for strategy (Lindqvist, 2009).

Rehfeld and Terstriep (2013) explained how these trends, both in academia and practice, could be seen as new trends of the global economy that was coupled by shifts in political systems. These political shifts included those in Europe (due to EU structural policies) that saw the rise of decentralization, new public-private partnerships, all part of new policy strategies to deal with shifting contexts. The diagram below captures the economic and policy context within which clusters operate and how they are at the centre of meso-economic and spatial changes. Cluster policy was therefore at the heart of regional economic policy.

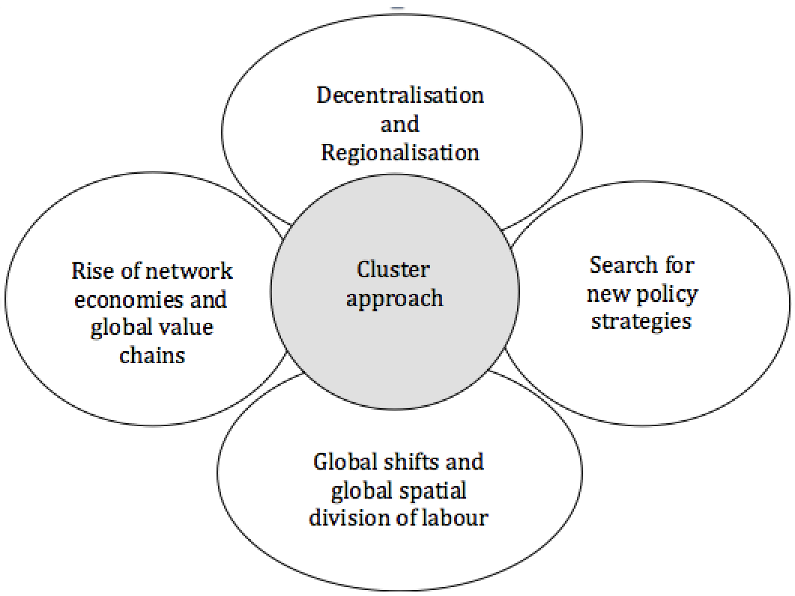



*Figure 1 Economic and political background of the cluster approach (adapted, Rehfeld & Terstriep, 2013, p. 280)*

The role of cluster policy and different cluster approaches are further examined in the second part of the chapter. First, theories on the cluster concept and its defining features in the literature are discussed.

## 2.4 *Cluster concept and theoretical diversity*

### 2.4.1 Cluster definitions

A cluster is a 'geographically proximate group of interconnected companies, suppliers, service providers and associated institutions in a particular field, linked by externalities of various types' (Porter, 2003, p. 562). In comparison, RIS defines clusters as 'geographically defined, administratively supported arrangement of innovative networks and institutions that interact regularly and strongly enhance the innovative outputs of firms in the region' (Cooke & Schienstock, 2000, pp. 273-274).

Cluster success lay in interactions and interdependencies of actors supported by local social conventions and institutions (Edquist, 1997, Storper, 1997). This view, in turn, has been underlined by claims that innovation processes were intangible, not captured in patents or tangible processes, but resulting from tacit knowledge exchanges across interactions and linkages (Asheim *et al*, 2006; Cooke, 2012; Cortright, 2006; Malmberg & Power, 2006; McCann, 2008).

According to these definitions, the core concept of clusters centred around close interactions of actors in a physical location sharing knowledge, norms and social institutions that often led to increased trust and collaborations that offered opportunities for greater specialization, innovation and flexibility to compete in global markets (Atherton & Johnston, 2008). The business and social environments feeding business interactions in clusters are therefore central to enhanced innovativeness of firms in clusters. Recent developments in practice have seen the emergence of 'hubs' particularly 'knowledge hubs' (Evers, 2008) and of 'innovation hubs' (Cisco, 2010) which can be attributed to the need for industrial transformation from production centres to 'hubs for knowledge creation and learning' (Tan & Thai, 2015, p. 131).

### 2.4.2 Historical roots and re-launch of clusters

'Clusters' and its predecessor 'industrial districts' as a concept capturing localization of industries and agglomeration effects can be traced back to academic research related to the industrial era of the nineteenth century and included scholars such as Thünen, Marshall, Weber, Ohlin, Hoover, Christaller, Palander, Lösch, Isard and Beckmann (Karlsson, 2008) and the later Italian industrial economic scholars such as Becattini, Brusco and Bagnasco (Asheim *et al*, 2006; Belussi, 2006). Empirical studies of small firms aggregated industries in Italy (Third Italy) by these scholars reflected the high degree of specialization of interdependent firms of related industries that shared strong social, cultural ties that underpinned their economic relations, and this resonated with Piore and Sabel's 'fusion' of society and economy (1984). The need to collaborate to reduce risks through cooperation based on mutual trust and social rules of governance underlined localization of industrial districts and spinoffs of externalities (Asheim, 2000; Asheim *et al*, 2006).

Rhefield and Terstriep (2013, pp. 274-294) offered an analysis of the economic and political backgrounds that saw the rise of clusters in the nineteenth century as described above and their return in the twentieth century when 'spatial divisions of labour' were prominent with the demise of mass standardization. They indicated how new developments of 'differentiated patterns of spatial developments' were responsible for the emergence of clusters as well as the rise of more flexible production systems through regional networking. Concurrently, the focus of regional studies on successful innovation systems, including the 'holy trinity' of Third Italy, Silicon Valley and Baden-Württemberg added to the revival of clusters and cluster studies. Rehfeld and Terstriep also concurred that the role of Porter in re-launching clusters to the forefront of policy and regional economic studies through his seminal work, *Comparative Advantage of Nations* in 1990, remained unchallenged. Agreement of Porter's role is resonated in cluster studies even as criticisms prevail and these issues are addressed in the next section that describes the 'core of clusters' and cluster studies.

### 2.4.3 Determining the core of clusters

The diffused nature of cluster studies meant that different approaches and defining features of clusters prevailed. This section explores cluster conceptualizations and approaches. Critical notes on various studies and methodologies are also included to reflect theoretical discourses on cluster study.

Porter's defining successful re-launch of clusters however also saw criticisms on his concept of clusters and clustering in particular in his aim to create a synthetic generalizable concept of clusters that was deemed to be static in comparison to works on industrial districts that explored social and cultural localization interdependencies (Asheim *et al*, 2006, p. 13). Similarly, Porter's methodology on cluster effects was also seen as being 'operational' since 'location quotients data and other aggregate measures of geographical localization and inferred inter-industry linkages' offered little more than generalizations about increased industrial agglomeration and (labour) market effects. Their critique also included Porter's assumption that clusters were always market driven and countered this with biotechnology clusters as example of research driven clusters. Porter's simplification of cluster formation and development processes did not do justice to cluster developments since, according to them, clusters were often framed by complex and long histories, and social and cultural processes of co-location. This simplification of cluster theory reduced to competitive advantage, claiming to explain cluster phenomenon in all their different dynamics and life-cycle phases remained a criticism in the literature (Asheim *et* al, 2006; Martin & Sunley, 2003). The consensus in the literature about clusters as being an umbrella concept and as 'work in progress' underlines the criticism that there can be no 'one size fits all' theory or concept of clusters (Hamdouch *et al*, 2009; Maskell & Kebir; 2006, McCann, 2008).

Another critic echoing the choice of cluster researchers and policy planners to use secondary macro and micro economic data to draw inferences on the relative success of clusters for benchmarking is Cortright (2006). He asserts that secondary data sets from established 'industrial, occupational or knowledge taxonomies' are used to determine proximity of firms, and also that 'indirect measures of affinity, such as inferences of connection from buyer-supplier relationships computed from national level input-output data' are used to determine proximity at regional levels (pp. 15-16). He acknowledges that there is value in specific quantitative cluster studies based on narrow structure and performance indicators but that these do not capture holistic cluster dynamics. The other practice in cluster studies, including case studies, offer context specific information that provides narratives that could generate insights into emerging patterns and processes specific to the case at hand. Capturing the cluster dynamics as a universal phenomenon, according to Cortright, may need more rigorous approaches. His conclusion on the study of clusters is that attempts made at 'characterizing the dimensions' or 'defining clusters' were 'not an exact science' and that this will still be the case till other correlations and insights into cluster dynamics that offer more powerful generation of outcomes are available (p. 5). He does concede that the diversity of theoretical bases in terms of perspectives, disciplines and use of data add rich insights into key cluster dimensions as being spatiality, life cycles, linkages and geographical scales.

McCann (2008) also raises the inherent challenges in measuring effects of agglomeration due to the fact that externalities often result from untraded inputs, pool and mobility of labour and knowledge sharing. Measurements of economic growth based on labour and sectoral aggregated data may not accurately capture externalities of agglomeration due to urbanization economies distortion; discrepancy in sectoral aggregation figures due to nature of sectors (example, service industry); the micro-level nature of agglomeration effects; and finally, the phenomenon of declining clusters (see McCann, 2008 for overview and details).

In another attempt to distil the core of clusters, Malmberg and Power (2006, pp. 56-57) in their analysis of 'true clusters', indicated that there were four criteria prevalent in determining clusters in the literature. The first criterion has to do with geography and related economic activity often leading to 'functional inter-linkage'. The second criterion was that clusters operated as 'functionally defined industrial systems' with diverse 'actors, resources and activities'. This criterion pre-empts the problem of defining the system border since, 'the spatial extension of most functional systems is much larger than what we normally think of as functional regions'. The third criterion has to do with policy and institutional aspects. This involved 'identity'; commonly, a cluster is explicitly named and has some policy programme attached to it. In the literature, it is also referred to as a 'policy construct' (Solvell *et al*, 2003). The fourth criterion relates to the 'competiveness' aspect ascribed to Porter. Malmberg and Power recommend that there be less focus on puritanical definitions of what 'true clusters' ought to be and instead, more focus on seeking ways to understanding knowledge creation and innovation. They assumed that this supports policy to create more supportive environments building on existing competitive strengths and leveraging local (and non-local) networks. Their advocacy for a more flexible approach towards defining clusters with a re-focus on knowledge creation, innovation and learning in local economies has struck a chord in more current studies where the focus has been to support policy understand cluster behaviour.

| Criterion of cluster | Characteristics | Advocates/domain |
|---|---|---|
| Geography and related economic activities | Functional inter-linkage | Closer to 'industrial districts' notion of cluster |
| Functionally defined industrial systems | Interrelations between actors, resources and activities | Systems approach to cluster |
| Policy and institutional aspects | Identity and label | 'Policy construct' often with policy programme |
| Competitiveness | Collaboration driven by competition goals | Porter on cluster |

*Table 1 Adaptation of Malmberg and Power's 'true cluster' analysis (pp. 56-57)*

To categorize cluster literature, Karlsson claimed that there were two traditional research perspectives relevant to regional economic development studies, namely, the resource-based and the scale-based functions of market potential. He indicated that newer traditions like evolutionary economic geography focussed on knowledge advances as a resource and skilled labour kept the study of spatial issues alive in economic development. The relevance of evolutionary economic geography to the study of regional economic developments was also addressed in terms of its contribution of temporal and contextual-sensitive aspects whereby agent behaviour could be understood as being tempered by historical path dependent contextual factors (Boschma, 2004). The focus on regional economic developmental studies was broached by different traditions of scholarship and each of these contributed specific insights into clusters and agglomeration effects that put localization at the core of their studies.

Asheim *et al* (2006) described five theoretical perspectives, namely, Neo-Marshallian Industrial Economics, New Trade Theory and Marshallian Localization Economics, New Endogenous Growth Theory, Economics of Firm Strategy and Marshallian Localization Economics, Neo-Schumpeterian and Evolutionary Economics, and how they captured changing socio-economic circumstances whilst describing convergence of returns of agglomeration and localization of businesses. They also described how localization and specialization contributed to entrepreneurial growth through inter-dependencies and collaborations whilst divergence and diversity were part of such developments.

In the evolutionary economic literature the notion of 'related variety' explains this phenomenon well and is included in the description of evolutionary economic traditions later in this chapter. The proximity of businesses and industrials to each other is a physical dimension that encompasses social and cultural proximities as addressed earlier. These different theoretical perspectives described in the table above also include proximities of a different kind, namely, technological, occupational and market proximity next to the physical and social (Cortright, 2006). The table below reflects proximities at the firm level.

| **Spatial** | **Technological** | **Skill/ Occupational** | **Market** | **Social** |
|---|---|---|---|---|
| Physical distance between firms | Similarities in technologies employed by firms | Similarities of workers in their skills | Similar or connected sets of customers | Levels and kinds of interactions between managers and workers |

*Table 2 Cortright's dimensions of proximity (tabulation by author)*

At the core of cluster and agglomeration literature, 'proximity' dominates and it has been shown that there are more dimensions to proximity beyond the physical and that these are linked to shared social and cultural ties embedded in institutions, conventions and governance structures (Boschma, 2004; Curry, 2006; Edquist, 1997; Storper, 1997) as well as related to businesses and trading as in markets, professions, technologies, and labour relations (Cortright, 2006; McCann, 2008), and as shown in the table above, the firm level manifestations.

On the industrial level, McCann (2008) captures the differences between pure agglomeration, industrial complexes and social networks. The first two types of agglomeration are often units of economic productivity and input-output analyses respectively. And whilst the first, pure agglomeration, captures transitory inter-firm relations that are co-located in the same space and often strongly competitive of market opportunities and found in urban spaces, the second captures the more traditional industrial production complexes such as those in the chemical and pharmaceutical industries where long-term relationships and oligopolistic positions are common. Production inter-dependencies are often part of the relationships that are secured in long-term partnerships and are therefore stable. And finally, the social network agglomerations based on Granovetter's work has a strong element of mutual trust often embedded in shared histories and experiences of players involved in decision-making whereby spatial proximity is not a necessary feature but often supports trust in relations (see McCann, 2008). The advantages of direct face to face contact where tacit knowledge is shared swiftly, known as knowledge spill-overs and untraded inputs due to the access to specialized knowledge and labour mobility of a local skilled labour pool represent the effect of agglomeration (see table below). In addition, co-located production saves transport costs, as do untraded inputs and knowledge diffusions.

| Characteristics | Pure agglomeration | Industrial complex | Social network |
|---|---|---|---|
| Firm size | atomistic | some firms are large | variable |
| Characteristics of relations | non-identifiable fragmented unstable | identifiable stable trading | trust loyalty joint lobbying joint ventures non-opportunistic |
| Membership | open | closed | partially open |
| Access to cluster | rental payments location necessary | internal investment location necessary | history experience location necessary but not sufficient |
| Space outcomes | rent appreciation | no effect on rents | partial rental capitalization |
| Notion of space | urban | local but not urban | local but not urban |
| Example of cluster | competitive urban economy | steel or chemicals production complex | new industrial areas |
| Analytical approaches | models of pure agglomeration | location–production theory input–output analysis | social network theory (Granovetter) |

*Table 3 Industrial clusters (McCann, 2008, p. 31)*

McCann (2008, p. 26) indicated that industrial cluster studies bring together 'location specific economies of scale' to innovation processes (knowledge generation and diffusion) and firm creation. Discussions of the polarity of growth theories dominated by key firms and the dependence of supply-buyer relationships in hub and spoke networked clusters, 'industrial complex', including those described through Porter's competitiveness model, are now being superseded by discussions that throw back to the Italian industrial districts dominated by small innovative and specialized firms accruing benefits from the social and cultural environments, also reflected in the innovative milieu school (for a description and overview of cluster literature, see also Bathelt, 2008).

In an attempt to understand how these different elements come together, the description of the evolutionary path of clusters by Belussi (2006) has been included below. The evolutionary path of industrial districts and clusters described by Belussi captures the localized formation, evolution and maturation of such phenomena. This model captures the significance of initial localized factors that explain the presence of firms in the local area and the possible emergence of clusters due to presence of externalities, technological developments and supportive institutional systems and the further 'cluster' developments emerging from collaborative production, marketing and knowledge development ventures that in turn initiate new infrastructure to support diffusion of knowledge as key resource. The final stage described in this evolution is the shifts to other locations due to cost benefits or proximity to market. The visualization of this process reflects how antecedents of localized economies could emerge depending on the socioeconomic and cultural frameworks present and the presence of external inputs such as technology, labour and knowledge inputs. Evolutionary economic regional studies offer more insights into the evolutionary processes involved in regional and cluster developments whilst innovation systems theories offer insights into the systemic interactions of clusters in terms of innovative processes and these are described later in the chapter.

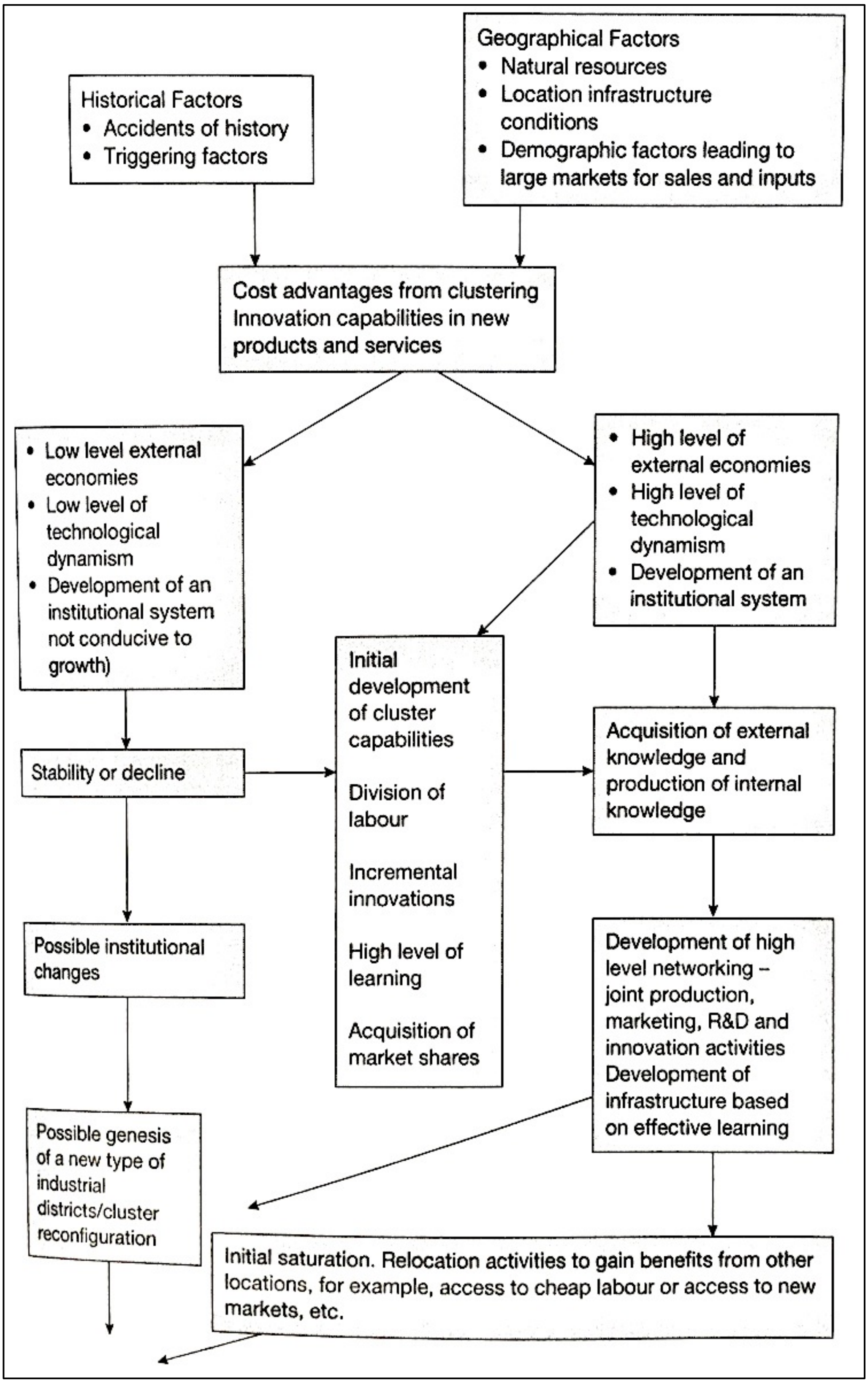



*Figure 2 Belussi's Evolution of industrial districts or clusters (2006, p. 83)*

To end the first part of the literature review, conclusions from Delgardo, Porter and Stern (*2013*) reflected the dilemmas of bringing together industrial specialization and the diversity of regions leaning on local socioeconomic and cultural strengths.

They concluded that the value of clusters is in its ability to facilitate ‘complementary activities’; these activities span across different economic activities (innovation, production, marketing, finance, etc.), different knowledge boundaries (scientific and tacit knowledge, innovation and entrepreneurship), and different regional and political boundaries (judiciary and regulatory differences, access to talent and knowledge pools, etc.). The horizontal and boundary spanning nature of clusters described as ‘transversality’ by Cooke (2012) is discussed in more detail in section 2.6.5. Similarly, Delgado *et al* (2014, p. 1797) concluded, ‘the presence of clusters, which foster multiple types of complementarities, seems to be a key driver of the emergence and growth of industries for all industry types’, and also, ‘that the growth and emergence of regional industries relate to the cluster composition in nearby regions’. They also indicated that future research needed to understand ‘drivers of the evolution of clusters’. They clearly advocated the need for understanding cluster developments and the broader contexts in which they operate. They also suggested that understanding roles of localized institutions was necessary as there was little theoretical and empirical research on these aspects.

Cluster theory therefore acknowledges the value and effects of agglomeration and proximity of firms supported by their specific shared socioeconomic and cultural contexts, accessibility to knowledge and markets, prevailing inter-dependencies in reaching global markets, and (risk sharing) innovations and production. The presence of complementary skills, resources, knowledge, etc. both within the region and outside available to firms in the clusters were also identified. These aspects of the literature review are also reflected in the table below, which summarizes issues related to cluster and agglomeration studies.

| | |
|---|---|
| Agglomeration impacts | Localization economies: specialization, common evolution of socioeconomic embedding, interdependent, complementary and flexible production based on trust and social governance structures, social and cultural interdependencies, skilled labour and knowledge pool – specialized clusters and sectors<br>Urbanization economies: diversity of knowledge pool, talent, creativity, (high) technology spillovers – high technology and creative clusters<br>Proximity sorts – spatial, technology/knowledge, skills, markets, social |
| Common goals | Competitiveness and market-driven – functional linkages in supply chain; collaborations for risk mitigation and assessing global markets; Realizing (multiple) complementarities for innovation and production – enhancing specialized local institutions to support complementarities |
| Knowledge bases | Interactions and tacit knowledge shared through close proximity and collective socioeconomic ties<br>Innovation as collective process where resources are brought together into networks hindered or supported by institutional roles and network ties |
| Cluster development | Life cycle of clusters/industrial districts – maturity of cluster phenomena<br>Drivers of evolution and change in cluster development |
| Methodology critique | Micro-level missed in macro-level aggregated data – untraded inputs, knowledge generation and sharing and mobility<br>Sectoral differences in use of aggregated data – services vs. production sectors<br>Overlap of urbanization economies and localization economies in cities not visible;<br>Agglomeration effects also for 'other' - transient and 'atomic firms'<br>Assumptions of inter-dependency in innovation: growth pole theory vs. urban diversity |

*Table 4 Key aspects addressed in agglomeration and cluster literature*

The literature review shifts to Regional Innovation Systems and Evolutionary Economic Geography theories as these fields of research provide insights into more dynamic aspects of cluster and regional developments (Martin, 2013; Martin & Sunley, 2007; Uyarra, 2010). The next section describes Regional Innovation studies with the focus on innovation systems whilst section 2.6 describes Evolutionary Economic Geography studies.

## 2.5 Regional Innovation Systems

National (NIS) and regional (RIS) innovation systems studies emerged in the 1980s as inter- and multidisciplinary areas of study, an offshoot of innovation studies (Fagerberg *et al*, 2012). The NIS and RIS studies support and inform policy practice, including the European Union, to the extent of becoming almost 'a normative concept' of policy makers (Uyarra & Flanagan, 2013). Sector and regional based studies support interventions designed to strengthen innovation capacities. The literature review focuses on regional innovation systems studies as being relevant to clusters and cluster developments. Related studies of national innovation systems (NIS), sectoral innovation systems (SIS) and technological innovation systems (TIS) share the systems approach of RIS but differ in their focus, the country level for NIS, industrial sectors for SIS and technology for TIS. The innovation studies literature explores how innovation processes are influenced by the interplay of institutions and actors in a system. Comprehensive overviews of the evolution of innovation systems studies and related policy developments are found in the literature (Fagerberg *et al*, 2012; Martin, 2013 & Uyarra and Flanagan, 2013) whilst this section focusses on RIS in relation to understanding innovation and systemic processes in cluster developments.

The study of Regional Innovation Systems also aims to capture differences in patterns of innovation in regions reflecting a region's own diversity. The region is seen as a complete system and interactions in the system are studied to identify possible causalities and related patterns (Lundvall, 2007). At the core of such regional innovation systems are interactive processes by its actors and these could be firms, universities, research institutions, organizations, governmental agencies, etc. (Andersson & Karlsson, 2004). Distinct system differences related to geographical proximity and tacit knowledge diffusion, due to local interaction processes, contribute to regional differences. RIS typologies depict such differences and are discussed in detail by Navarro and Gibaja (2012). Despite such differences, the literature describes 'an ideal-type' RIS (OECD, 2008) in which technology needs are key, captured in the illustration below.

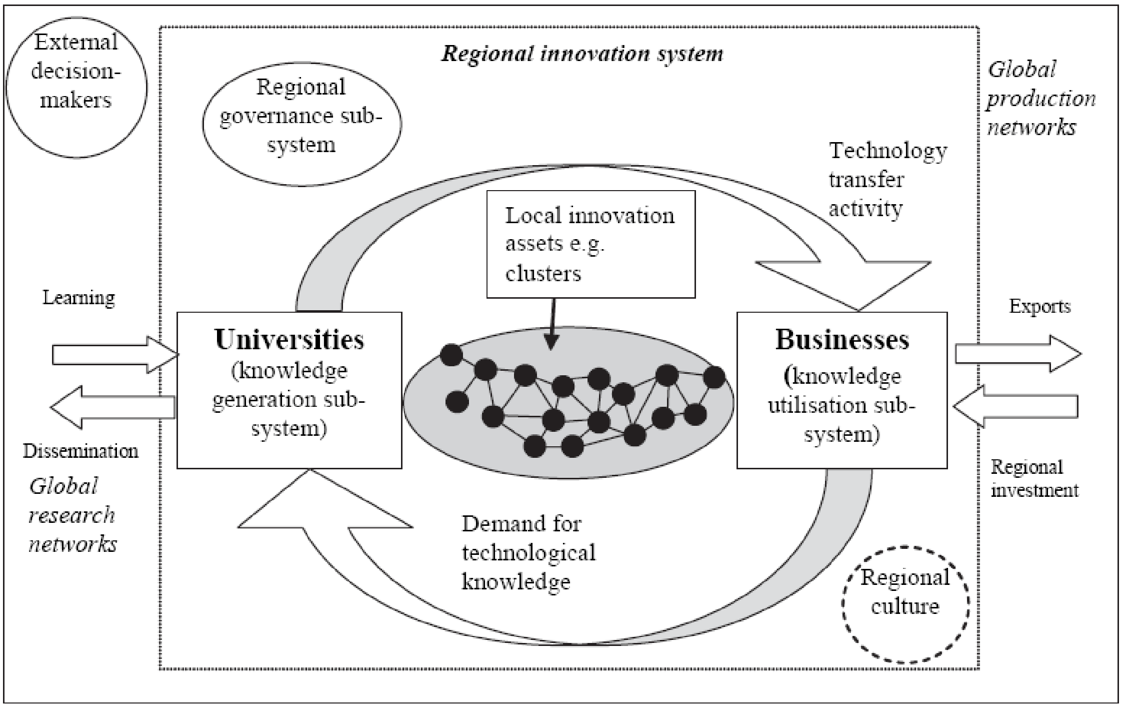



*Figure 3 An Ideal-type Regional Innovation System (OECD, 2008, p. 92)*

The RIS depicted above consists of a network of players in an inter-connected system where demand and transfer of knowledge and innovation take place between businesses (knowledge explorers and exploiters) and universities (knowledge generators). Knowledge creation and utilization amongst different actors is at the core of RIS. The diagram also illustrates how RIS is embedded in regional culture and governance sub-systems, and how RIS is connected to external linkages, activities and players. The simplification of businesses as utilizers of knowledge that all knowledge needs are necessarily technological is a limitation of the 'ideal type' RIS. These limitations are addressed below in the discussion of features of RIS and knowledge generation.

Andersson and Karlsson (2004) identified features of RIS that were necessary for successful regional innovation systems. In this overview, the significance of agents in RIS as opposed to institutions is highlighted, and it is not specific to technology driven innovation systems. The table below summarizes RIS features and conditions for their success.

| Features of RIS | Need for good functioning of RIS |
|---|---|
| Interactions between agents | Necessary condition |
| Clustering for agent interaction | Necessary condition for RIS – specific structures support production (and services) |
| Existence of knowledge-providers | Not a prerequisite |
| Actors produce and diffuse knowledge among each other | Necessary but not a sufficient condition – degree to which knowledge is produced and diffused is more relevant; minimum level needed for RIS to be realized |
| Different kinds of RIS | - How knowledge is produced;<br>- The kind of knowledge produced;<br>- How the interaction is organized;<br>- Boundaries of the system, i.e. how "regional"? |
| Different RIS produce different kinds of innovations | |

*Table 5 RIS features and conditions for successful RIS (adaptation based on Andersson & Karlsson, 2004, pp. 14-15)*

The table above shows that the role of agents and their interactions in producing and sharing knowledge is important to RIS and that formal knowledge-providers are not a necessary condition, but there is a pre-requisite that sufficient knowledge is produced and shared in the system. Regions endowed by innovating firms produce new knowledge and qualify as RIS if the generated knowledge is shared through interactions and collaborations. This view differs from the 'ideal-type RIS' where technology needs are assumed to be produced by research institutions. Differences in RIS are explained through types and ways of knowledge generation, organization of interactions and boundaries of the systems (Andersson & Karlsson, 2004). This differs from more traditional approaches whereby R&D spending and outputs are used as indicators of knowledge generation, reflected in the 'ideal-type RIS' where universities are central.

Asheim and Parrilli (2012) described the shift from traditional notions of R&D as indicators of innovation to new understanding of different knowledge bases supportive of different industries. They identified 'analytical (science-based), synthetic (engineering-based) and symbolic (arts-based)' knowledge bases (also, Asheim, 2007; Asheim *et al*, 2007) and described innovation as 'interactive learning' where different forms of innovation are combined. Lorenz and Lundvall (2006) first introduced the Doing-Using-Interacting (DUI) modes of innovation that expanded the discourse on what constituted knowledge, thereby acknowledging that innovation in some industries are less explicit and were part of continuous improvements in production processes. The shift in discourse offered a broader view of what constitutes knowledge and innovations in RIS and the co-existence of different types of innovation.

In addition, innovation policy needed to be wary of a narrow view of what constituted innovation as the success of such policies needed to acknowledge the significance of the societal context in which innovations took place, as captured in the quotation below.

> *'One of the most important issues of innovation policies in Europe is to connect the results of research carried out in universities and other research organizations with application-oriented activities of enterprises, whether these are SMEs or large, global corporations. This not only involves improving the functioning of the market mechanism but also a society-wide restructuring of laws and cultural attitudes. It is short-sighted to see innovation as only a matter of markets and firms.' (Lambooy, 2005, p. 1150)*

Given that innovation policies build on insights into innovation systems, there have been shifts in previous policy programme of EU and its member states from a dominance of Science and Technology (S&T) and Research and Development (R&D) focus to a 'broader and more comprehensive view of innovation has been applied to retain and develop competitiveness in the heterogeneity of Europe's regions' (Asheim & Parrilli, 2012, p. 2). According to Izsák *et al* (2013), 'A broader view emerged in the thinking about innovation with increasing attention being given to its non-technological aspects and its systemic nature being highlighted' (p. 17). Therefore RIS and innovation policies based on RIS saw a broadening in their scope and understanding of the mechanisms, constituents and realms of innovation.

Before moving onto discussing clusters as part of RIS, a brief note on methodology and RIS studies. A key point raised in typology and measurements of RIS studies is that whilst they generate a broad range of features to identify RIS typologies, they are limited to statistical and case studies RIS typologies (Navarro & Gibaja, 2012). Navarro and Gibaja (2012) also indicated that statistical analyses provide more comprehensive quantification of economic and innovation performance comparisons of EU regions whilst case studies provide deeper understanding of innovation processes related to governance structures, knowledge bases and interactions between actors in RIS. The popularity of statistical analysis and need for statistical data is clearly seen in the European Cluster Observatory, which provides fine-grained statistical information on EU regions to enable benchmarking. Policy makers can compare the relative performance of their region to other regions. At the same time, case studies and qualitative studies provide different typologies and insights. Both approaches are valid and offer complementary information in RIS scholarship.

### 2.5.1 Innovation clusters in RIS

In order to understand the overlap between cluster studies and innovation studies, Hamdouch (2007) reviewed clusters and clustering literature and described three main strands. These being,

- Studies with a geographical focus where scale-based studies included institutional roles and embedding of actors specific to geographical spaces;
- Studies on social and economic factors on network linkages and strength of ties;
- Studies on knowledge generation and diffusion, and learning processes where resources brought together in networks allow 'innovation as collective process'.

His attempt to build on these different strands has been captured on a renewed definition of innovation clusters (driven by technology and specialized knowledge).

> *'An innovation cluster comprises an ensemble of various organizations and institutions (a) that are defined by respective geographic localizations occurring at variable spatial scales and within specific institutional environments, (b) that interact formally and/or informally through inter-organizational and/or interpersonal regular or more occasional relationships and networks, (c) and that contribute collectively to the achievement of all kind of innovations within a given industry or domain of activity, i.e. within a domain defined by specific fields of knowledge, competences and technologies.' (Hamdouch, 2007, p. 18)*

This definition of innovation cluster captures the essence of RIS studies that brings into the systemic study of innovation processes and institutional arrangements of the related knowledge, social and geographical aspects of such systems contributing to successful innovation and competitiveness advantages for the firms and region.

Arikan (2009, p. 659) also advocated that clusters be recognized for their 'enhanced knowledge creation' capability tempered by antecedents such as geographical and industrial structures, degree and type of industrial knowledge base, cultural attitudes (towards co-operation), degree of codification of knowledge (tacit or codified), and firms' capabilities and strategic choices in knowledge exploration and exploitation. The role of the firms in knowledge exploration and exploitation was emphasized.

The emphasis on cross-fertilization of ideas and diffusion of learning as an important component of innovation system in successful clusters were captured by case studies, of which Silicon Valley and Route 128 were exemplary (Saxenian, 1994). Audretsch and Aldridge (2008, p. 75) similarly identified that high-tech innovative clusters like Silicon Valley and Route 128 were more important for innovative activity than 'footloose multinational corporations' in which the basin of innovativeness is embedded in geographical spaces and such that 'entrepreneurial activity is greater in locations with a greater investment in knowledge and new ideas'. The generation of entrepreneurship in a context of high knowledge investments were explained by the spin-off effect of knowledge workers seeking greater economic value for their knowledge products but remain in close proximity to the original knowledge sources to gain access to new knowledge and facilities. Location therefore was seen as the underlying organizational context of entrepreneurship and that entrepreneurship is an 'important conduit by which knowledge spills over' (p. 76) and that these two converge in entrepreneurial clusters. In addition, they argued that innovation was moved from being an endogenous resource to the regional level as innovation systems and innovative milieu. In the case of Silicon Valley, a culture of openness, flexibility of entrepreneurs, the mobility and intense interaction between agents contributed to an escalation of innovation and success that could be described as systemic. However, Hamdouch (2007) warned that knowledge diffusion could be burdened by 'structural holes' in their networks or, benefit from 'strength of weak ties' (pp. 22-24).

Further to the study of clusters as innovation systems is the role of businesses, universities and government. These three, initially described as the 'holy trinity' (Storper, 1997) and later as the 'triple-helix', contribute to innovation processes and play important roles in the formation and development of cluster. Triple helix studies focus on the role of universities and industries to generate and transfer knowledge and skills to entrepreneurial activities, and the supportive role of government.

Etzkowitz *et al* (2007, p. 15) describe changes needed in the triple-helix:

> *'A stable regulatory framework for knowledge-based societies is a necessary but not sufficient condition for organizational innovation. The transformation of the university, whether through internal or external impetuses from a teaching to a research and then to an entrepreneurial university is a key element in creating a viable triple helix.'*

This transformation of university needed to be part of effective policy as part of triple helix collaborations to support technology innovations (also, Martin, 2012). This in turn strengthens the high-tech and science-based notion of innovation and competitive growth of 'traditional' RIS and cluster studies.

An expansion of the initial concept of the 'triple-helix' to capture the increasing complexity of interactive processes and actors involved in innovation processes and of the influence of broader context in which innovation and clusters are embedded was needed to reflect diversity in triple helix developments (Etzkowitz *et al*, 2007; Farinha & Ferreira, 2013; Triple Helix Association's website). To this end, Farinha and Ferreira (2013, p. 21) developed a framework that 'reflects the interaction of relationships ongoing between three institutional spheres (university – industry – government) designed to secure regional competitive advantage within the framework of actions interrelated across a multi-level scenario'. Their framework captures deeper inter-connectedness of innovation actors and the contextual environment in which they operate. This shift in understanding triple helix interactions as being embedded in contextual factors and framing is also reflected in changing cluster studies and policy (diagram and discussion in section 2.7). In addition, they reflected how new social, environmental and economic framing and local economic, sociocultural, political and technology contexts influence the three spheres of academia, industry and government in supporting innovation and regional developments. Their framework also captures interdependencies of economic and regional developments in the local context.

The overlap between innovation clusters and RIS reflected the importance of high technology and research driven innovation clusters, strengthened by triple-helix models of collaborations as foundation for cluster and regional innovation systems. This supports the traditional R&D driven 'ideal-type RIS' described in the previous section. The acknowledgement of non-technology and distributed knowledge bases beyond universities contributing to successful RIS meant that the triple-helix model needed to be re-visited.

The next sub-section discusses limitations of RIS approaches.

### 2.5.2 Limitations of RIS

Criticisms on regional innovation studies resonate earlier acknowledgements on limitation in agglomeration and regional studies but there are specific issues concerning RIS and these are described in this section.

RIS approaches, as with NIS, SIS and TIS approaches, regard innovation systems as closed systems where firms and institutions are seen as actors in the system. This meant that individuals were not the focus of innovation processes whereas individual agents are part of the 'micro foundation' that partakes in innovation and learning processes (Bathelt, 2008).

The closed system assumption of RIS acknowledges but is not focussed on external networks in its system analysis, and as such, the 'global pipelines' (Bathelt, 2008; Langedijk, 2002) and clusters as 'local nodes in global networks' (Gertler, 2005; Wixted, 2006) are not at the core of RIS. With increasing developments of global value chains and global innovation chains, a closed system analysis implies insights into cross-border linkages are limited or missing whilst knowledge bases and knowledge diffusion cross borders (Cooke, 2012; Pecqueur, 2008; Smith, 2008). The Canadian NRC study clearly identified the need to include non- local linkages to better explain the success and dynamics of clusters in 'open' economies such as theirs (Gertler & Wolf, 2006), reinforcing the need to redefine RIS boundaries. In addition, cross-industrial opportunities also evident in Canadian clusters (Wolf, 2013) and in the health and energy clusters leveraging 'transversality' for innovation supported the need to extend RIS approaches (Cooke, 2012; Cooke, 2013). Furthermore, RIS studied the role of institutions and formal institutional contexts in understanding innovation systems, ignoring the role of civic leaders and associations in leading cluster formation and developments, whilst the shift to acknowledge the role of civic and associative governance was growing (Wolf & Jelles, 2008; Ebbekink *et al*, 2015).

Similarly, dismissing or not acknowledging distributed knowledge bases and a tendency to focus on technology driven innovation, the 'ideal type RIS', and a focus on narrow views of knowledge as being scientific, as discussed in previous section, are also limitations of RIS studies where these practices prevail. In addition, this connects to the triple-helix model that forms the basis of RIS studies and its assumptions as discussed in the last section.

The dependence on statistical analyses in quantitative RIS studies is related to definition and measurement of knowledge when categorizing and defining economic and innovation success. In addition, limitations of data sets available to explore interactions at the regional level remain an issue in statistical analyses of RIS at the EU level, as discussed in the previous section. Despite these issues, policy and scholarship continue to rely on such statistical analyses (Cortright, 2006).

Another criticism of RIS was its inability to study multi-level and dynamic processes in innovation systems as well as agency, which made RIS approaches inadequate in explaining cluster developments, and as such evolutionary and complexity approaches were preferred even as limitations in these fields were also acknowledged (Martin, 2012; Martin & Sunley, 2006; Uyarra, 2010).

RIS' focus on establishing comparative advantage was critiqued in preference of building on existing local socioeconomic advantages in the face of globalization (Pecquer, 2008). EU policies on Regional Smart Specialisation Strategies reflected also the focus on building on regional strengths (EU Horizon 2020 programme).

RIS assumes that clusters as innovation systems, were responsible for innovation successes as opposed to the possibility that innovation processes were responsible for the success of RIS and clusters (Simmie, 2006). Simmie acknowledges connectivity as key in local innovation systems but warns that connectivity and linkages are not necessarily guarantees of successful clusters (RIS). He also took issue with assumptions of co-locations as being evidence of inter-linkages, which is often the case in studies of innovation systems as well. Simmie also addressed criticisms of defining boundaries of RIS and clusters, which made comparative study difficult and therefore benchmarking RIS and innovation clusters would be questionable if no clear delineation exists.

RIS studies' limitations addressed in this section included issues related to the role of agency in innovation processes, external and other linkages in innovation processes, the primacy of institutions and policy support, types and sources of knowledge within RIS, reliance on statistical and limited data sets, multi-layered and dynamic processes, focus of RIS on competitive advantages as opposed to building on strengths, and causality of innovation and innovation systems as well as assumptions of co-location and linkages. These criticisms reinforced the need for complementary or extended approaches in cluster study.

### 2.5.3 Summary of RIS in relation to cluster study

The table below captures key aspects of RIS and innovation clusters as presented in the preceding sections.

| | |
|---|---|
| **RIS** | System boundary, networks, nodes and interactions in system<br>Knowledge, cultural and governance sub-systems<br>Institutional conventions in relation to knowledge/innovation capabilities<br>Understanding causality and related patterns<br>Competitiveness goal<br>Knowledge generation and diffusion (research institutes not only actor) |
| **Knowledge in RIS** | Traditional view vs. broader view:<br>R&D, S&T vs. distributed knowledge base<br>Types of knowledge and innovation modes<br>Analytical, synthetic, symbolic/ DUI modes<br>Knowledge beyond markets and firms<br>Also laws and cultural attitudes |
| **Types of RIS** | System differences related to spatial proximity and knowledge diffusion<br>Clusters as innovation system – enhanced knowledge generation capacity inherent |
| **Clusters and Innovation** | Underlying geographical and industrial structures and knowledge bases<br>Strategic knowledge exploration and exploitation, and collaboration behaviours<br>Institutional environments, role of universities, and technology developments<br>Triple-helix parties operating in three different spheres<br>Variable scales and multiple levels; individual and firm levels<br>Collective nature of innovation |
| **Methodology – different approaches** | Case studies – innovation processes and governance structures, knowledge bases, interactions between actors<br>Statistical analysis – economic and innovation performance |
| **Criticisms** | 'Closed systems' focussed on 'local linkages'<br>Extended 'triple helix' concept – civic society and leaders<br>Causality and effect between clusters and innovation processes unclear<br>Multi-level dynamism not included<br>Missing analysis of 'adjacent possible' (of related industries) in innovation<br>Narrow knowledge base definitions (broader distributed knowledge base suggested)<br>Micro-learning processes not included |

*Table 6 Key aspects of RIS and innovation clusters*

Criticisms of regional policies and innovation systems is summarized in the following extract:

*'.... first, the lack of adequate understanding of meso or even micro specific configurations characterizing RSIs [regional systems of innovation] and differentiating them from National Systems of innovation. This 'Listian' view often leads to regional policies being national policies writ small. Second, there is a lack of understanding of the multi-level dynamics of the governance of innovation (of markets, knowledge, and policy decision-making), thus leading regions to act as 'islands' in their policy articulation and focus on internal connectivity, ignoring the multiple geographies of knowledge networks. Third, a neglect of the diversity and context specificity of regions translates into a tendency to draw policy advice from ex-post generalizations of a limited catalogue of successful cases. Fourth, a static bias present in most analyses prevents a proper understanding of the dynamics of change and adaptation of regions, and the need to adapt policies accordingly.' (Uyarra, 2010, pp. 132-133)*

RIS approaches, whilst offering systemic analyses were also limited in capturing the complexity and dynamics of innovation systems. The focus on network formation and role of institutions, 'static' approaches, with limited institutional focus and scope could not cater for regional diversity and cluster types, inter-connectivity across institutional arena and levels and agency as described by Uyarra above but it also meant that 'spatial evolution of innovation networks' was not explained satisfactorily (Balland *et al*, 2013). The next section on evolutionary approaches describes how this approach captures spatial evolution.

## *2.6 Evolutionary Approaches in Regional Studies*

This section explores how evolutionary approaches offer additional facets to the study of clusters that supports understanding cluster developments. Evolutionary economic geography has its roots in evolutionary approaches from economics, sociology and a wide range of other disciplines although originally from Darwin and life sciences (see Martin, 2013 for an overview). Comparison between RIS and innovation systems and that of evolutionary economic approaches in regional studies is prevalent due to the overlap and continuing development of these approaches (Cruz & Teixeira, 2009; Uyarra, 2010).

The next sub-section highlights key aspects of evolutionary economic geography.

### 2.6.1 Evolutionary Economic Geography (EEG)

*'.... the value of an evolutionary perspective is as a way of thinking, in our case about the unfolding and transformation of economic landscapes over time.' (Martin & Sunley, 2015, pp. 716-717)*

Through evolutionary principles with its spatial and temporal dimensions, regional studies have been able to understand how transformations in the economic landscapes take place (Martin & Sunley, 2015). EEG offers 'a broad, yet evolving framework that has at its core the production and destruction of novelty in space and the links between novelty and regional economic fortunes' and this includes 'creation of technology, its movement and recombination within different regional ensembles of economic agents and institutions' (Kogler, 2015, p. 705). EEG offers a framework to understand evolution of regions in their ability to leverage innovative technology and knowledge developments.

### 2.6.2 Evolutionary economics

Key features of evolutionary economics are based on Neo-Darwinism principles, namely, that of 'variety', 'selection' and 'retention' (Martin & Sunley, 2015). Darwinism, embedded in life sciences, developed into evolutionary approaches applied to economics, sociology and other disciplines, and it is from these disciplines that regional studies gained their roots of evolutionary approaches (Martin, 2013). The works of Nelson, Winter and Freeman were important in establishing evolutionary economics within mainstream economics whilst scholars such as Metcalfe, Boschma and Frenken, Martin and Sunley were important for their contribution to EEG (see Boschma, 2004 for historical developments; Martin & Sunley, 2015). The significance of evolutionary approaches in economics are captured in the comparison with traditional economics in the table below.

Evolutionary economics approaches differ from traditional economics in various ways. The assumptions of equilibrium and market optimization through rational behaviour marks traditional economy. Evolutionary economics embraces assumptions of non-equilibrium, need for variety and related diversity to support adaptability to market and technology, but understanding the influence of institutional environments. The evolutionary process is significant to the latter's approach as opposed to traditional economics where history is not considered. The table below summarizes the key differences of these two approaches with more details.

| (Neo) Classical economics | Evolutionary economics |
|---|---|
| Equilibrium | Non-equilibrium |
| Optimality | Variety and (related) diversity |
| Costs and factors of production as comparative advantage – market optimization focus | Innovation as competitive advantage – creativity and adaptation to market and technology (disruptive and cumulative change) |
| Unbounded rationality – ability to maximise production with no historical constraints | Bounded rationality – routine behaviour embedded in institutional environment; influences on innovation and collaboration behaviour |
| History not considered | History matters – process approach to change |
| Reductionist – rational individual | Interactionist – actor–structure interactions including layers of institutional environments (sub-systems); and 'holistic' |

*Table 7 Traditional versus evolutionary economics (compilation based on Van der Steen, 1999; Steiner, 2006; Boschma, 2004; Cooke, 2013)*

Another difference in evolutionary studies lies in its methodologies. Krugman (1991) introduced into mainstream economics the notion of an evolutionary economic landscape that brought geography back into economics, also known as new economic geography. However, Martin and Sunley (2006), prominent in the discourse of evolutionary approaches in geography, were critical of scholars, Krugman included, who utilized abstract modelling and scientific analyses to understand human interactions and economic developments.

> *However, it is our view that a formal (mathematical) modelling methodology is neither necessary nor of itself sufficient for understanding the complex behaviour of economic landscape; evolutionary processes in the social-economic sphere are not easily reduced to, nor rarely can be adequately represented by, formal models. (Martin & Sunley, 2007, p. 4)*

Alternative schools of evolutionary economics focus on qualitative variation in economic development rather than quantitative growth and these studies attempt to capture dynamic processes whereby processes of selection and evolution of innovative agents (firms) and the embedded nature of decision-making are explained (Atzema *et al*, 1997). Concepts of path dependency (explained in next sub-section) and bounded rationality in evolutionary approaches support more qualitative understanding of institutional roles in regional differences. Differences in evolutionary traditions within regional studies reflect developments in the scholarship fed by different theoretical fields. Section 2.7 describes developments in regional studies. The research focusses on evolutionary approaches in regional studies, EEG. The next sub-section thus describes key features of EEG.

### 2.6.3 Key features and concepts of EEG

In EEG 'related variety', also referred to as 'relatedness' (of industries) explains how related industries in a region could support economic growth due to innovation and new economic activities through transfer of knowledge between firms. The innovation framing of EEG is reflected in its understanding of relatedness in terms of knowledge exploration and exploitation activities. The notion of relatedness also overlaps the concept of agglomeration and proximity, addressed in earlier sections. However, relatedness and related variety in EEG include not only industrial or sectoral variety but also technological relatedness. The relatedness concept explains shifts and adaptations in industrial evolution linked to localization and urbanization externalities, where localization is connected to specialization and urbanization to diversification, whereby both these externalities have different dynamics of development.

Cooke (2013) states that EEG moved away from static understandings of externalities and instead turned to more dynamic notions of path creation where relatedness between industries could result in new industrial pathways. The notion of path creation as a result of relatedness brought with it issues regarding (radical) innovation and the process of new path developments. Cooke also points to the short and long term effects of new path creation due to relatedness and claims that major shifts in regional developments were often subject to 'multi level interactions' influenced by existing 'industrial legacy' of that region. Such a legacy could include 'entrepreneurship, merger and acquisitions, and exploitation of industrial density' that shape path developments. In the more traditional view of agglomeration of industrial districts, there was 'a notion of an industrial ecosystem, which means complementarities foster growth while unrelatedness destroys it' based on the assumption that complementary specialization offered flexibility and risk mitigation, and therefore enhanced economic growth potential (p. 103).

However, a 'closely tied core in the local network' has both the advantages of efficiency and flexible complementarity (localization effect) and the disadvantages of hindering innovation (urbanization effect). The controlling and coordinated behaviours in such networks suffer from a lack of recombination possibilities in favour of control and efficiency and lower risks of opportunistic behaviour at the expense of adaptability. This makes them vulnerable to shocks (Boschma, 2015, p. 739).

Similarly, 'path dependency' is a concept that captures how regions' adaptation and change of pathways are constrained by their history (Cooke, 2013). Studying path dependency helps understand how regional and cluster developments occur. Exploring industrial antecedents could illustrate how these could influence future technological changes, which also includes the risk of a 'lock-in'. 'Lock-in' is a term that describes how institutional and spatial factors and existing knowledge capabilities can act as constraints in knowledge diffusion and generation (Cooke, 2013; Kogler, 2015).

The prevalence of conventions and their effect on behaviour in terms of 'rules' is an important feature of EEG. Rules and conventions govern behaviour and interactions at different levels, and impact innovation developments. The 'rule-based' behaviour of regional and agglomeration actors in EEG is acted out at different levels. At the meso level, rules are generated, diffused, adapted, retained and replicated; on a micro level, individual's uses of rules are enacted; and at the macro level, deep structures of meso-rules determine how rules interplay and work together (Martin & Sunley, 2004). The notion of governance rules in transition processes (Geels, 2004, 2010) also reflects EEG's perspectives to include multi-level segmentations to understand regional and technological transitions (see Cooke, 2012, 2013 for a discussion of EEG and transition management scholarship). The interaction of governance 'rules' at the different levels in a region is also reflecting institutional evolution of governance.

Another feature related to multi-level perspectives in EEG is that of 'agency'. The rule-based approach of EEG is tempered by individual agency (Martin & Sunley, 2007). This development, reflecting complexity approaches, is also explained below:

> *'An evolutionary economic geography approach aims to understand actions of economic actors and paths of change in a context of time and space. It explains how the behaviour of agents is situated and conditioned, but not determined, by structures accumulated at the level of the organization (e.g. routines) and the environment (e.g. social networks, institutions). In other words, these surrounding structures enable and constrain, but do not determine actions of agents: chance*

*events and human agency, often in combination with increasing returns, may result in unforeseeable changes.' (Boschma, 2004, p. 1002)*

Agency in EEG approaches therefore reflects interactionists' perspectives whilst acknowledging influences of institutional (sub-) systems. In order to appreciate how evolutionary economic geography adds to extant cluster studies, comparison to innovation studies is included in the next sub-section.

### 2.6.4 RIS and EEG

Innovation studies focus on how institutional settings influence actors and networks engaged in innovation processes in a region, whilst evolutionary approaches take as units of analysis networks and sectors and explore what specific features and evolutions are involved in their developments. The focus of evolutionary approaches, therefore, is on evolution of the broader sectoral context. This includes 'the coevolution of economic, institutional, and technological forces, and this in turn will shape knowledge sharing processes (whether in geographical proximity or at a distance), industrial dynamics and supporting structures' (Uyarra, 2010, p. 119).

Another criticism of innovation studies is that it focuses on top-down and structural elements supporting innovation in regional systems rather than insights into micro-level activities of firms. Moreover, innovation systems approach is deemed to be more a conceptual than an operational approach that makes application difficult (Uyarra, 2010; see also sub-section 2.5.2), whilst evolutionary approaches help understand regional differences based on micro-level firm histories and spatial specific evolution of industries and networks at the regional level, offering both top-down and bottom-up aspects and therefore a more holistic approach.

Another dimension of evolutionary approaches in regional developments is the attraction and selection of economic activities through 'connectivity, receptivity and variety' processes tempered by institutional preferences of intensity and nature of relations, which result in interactive learning (Boschma, 2004, pg. 1005). Boschma stressed that regions were subject to changes depending on their ability to 'upgrade, transform or restructure specific organizations and institutions required for the development of new economic activities' (p. 1008).

Evolutionary economic geography is multi-layered and holistic in its approach and includes the historical and socio-technical context to explain the changes in regions and clusters. The firm level decisions in seeking competitive advantage are also starting points of study. Innovation studies' focus on innovation process with policy and knowledge developments at centre stage brings different insights to understanding economic growth in spatial dynamics. There is overlap in their approaches but more importantly, there is a trend of convergence in regional studies and this is described in the next sub-section.

### 2.6.5 EEG and developments in regional studies

Regional studies from the evolutionary perspectives focused on understanding path developments and path creations, the evolution of regions, and how existing structures shape a region's future developments. Recent discussions in the literature focus on adaptation and adaptability capacities of regions in their search for how regions respond to external shocks. These more recent developments focus on understanding the 'resilience' of regions and the ability to absorb shocks and adapt to changes in the environments (Boschma, 2014; Cooke, 2012, 2013; Martin, 2012; Martin & Sunley, 2012).

The shift in focus on effects of 'shocks' to regions and the ability to adapt to such contextual changes reflects recognition of the unpredictable nature of changes that regions have to face. Martin and Sunley (2007) acknowledged the value of complexity sciences in understanding regional evolutions in its increasing contextual complexity and this led to an increased discussion and introduction of such concepts in the EEG scholarship and to some extent also in RIS (Cooke, 2012, 2013; Martin & Sunley, 2013).

Martin and Sunley explored complex adaptive systems approach for understanding regional and cluster evolutionary processes by re-visiting Krugman and his emphasis on emergent properties and structures and self-organizing principles of geographical space.

Similarly, Cooke (2012) introduced the notion of 'transversality' to understand 'complex innovative adaptive systems' to gain insights into more horizontal 'knowledge-flow dynamics' and 'platform policies' that could offer interventions to support knowledge asymmetries. Knowledge initiatives such as 'living labs' to support learning and knowledge diffusion were part of his exploration of embracing more horizontal linkages beyond 'ideal type' RIS, reflecting the parallel developments to regional studies as a whole that was dealing with the need to extend extant theories to deal with the need for resilience (see *Regional Studies,* Resilience Re-visited (2016)).

Martin and Sunley (2015) explained that EEG included increasingly complex adaptive systems concepts to explain evolution of regions in search of more 'more holistic and deeply contextualized accounts' (p. 728) that recognize interrelatedness of evolutionary pathways have resulted in including concepts of 'self-organization and emergence' as well as 'robustness, plasticity, niche construction and evolvability' (p. 712). Complexity economics therefore was informing EEG and these developments are captured in the overview of EEG's features in the next sub-section.

### 2.6.6 Evolution of EEG and key features

To conclude, the field of evolutionary economic geography extended its initial Darwinist roots applied to technology and spatial economic developments to include inputs from resilience theory and complex adaptive systems theory, and in doing so strengthened the contextual and systems perspectives in regional studies on evolutionary developments.

> *'Evolutionary economic geographers have tended to adopt the same strategy: in their work, too, the notions of variety (and more recently 'related variety'), selection and retention have been used to construct an evolutionary perspective on the spatial economy, including studies of how industries emerge and develop across space, how regional economies function as 'selection' environments, how far and in what ways various 'retention' mechanisms lead to the 'lock-in' of particular regional patterns of economic activity, and how spatial networks of economic relations and forms of spatial economic agglomeration (from clusters to cities) evolve through time, to name but some of the topics of interest.' (Martin & Sunley, 2015, p. 713)*

The description of evolutionary economics above reflects how parallel developments in this field were evolving to deal with broader developments using principles of evolutionary approaches. The descriptions of complexity economics informing EEG addressed earlier reflect the evolution of EEG to deal with changing contexts of spatial developments be it regions, cities or clusters (Martin and Sunley, 2015). The table below captures features of EEG summarizing the literature review.

| | |
|---|---|
| Core of EEG | - Evolution over time and space<br>- Emergence through variety, selection and retention<br>- Potential for adaptation |
| Rule-based and bounded rationality | - Micro- level – firm and enactment of rules<br>- Meso-level – rule generation, diffusion, adaptation<br>- Macro-level – deep structures that determine rules interplay |
| Evolution of path ways | - Interrelated structures and pathways<br>- Related variety and path dependence |
| Approach | - Holistic and multi-layered<br>- Assumes top-down and bottom-up developments |
| Resilience focus | - Adaptation and adaptability to external shocks |
| Complexity focus | - Assumes emergence and self-organization in systems |

*Table 8 Key features of Evolutionary Economic Geography*

The next section brings the review on regional studies to a closure by highlighting the diversity of the scholarship, the embedded nature of cluster studies in regional studies, and challenges of clusters.

## 2.7 Regional studies and clusters

The discussions on EEG above and in the earlier sections on RIS and predecessors to cluster studies have shown how regional studies, as a field, is diverse and still emerging to deal with the growing complexities of regional development. These approaches from different theoretical traditions offer rich ground to support policy strategies and interventions from industrial districts and agglomerations studies, to RIS and EEG whereby parallel developments were seen in regional studies. Porter's re-launch of clusters despite critique has been lauded for bringing clusters into the foreground. His later works with colleagues broadened the scope of cluster studies to include understanding industrial sectors and their evolutions through macro data to foresee emergence of new cluster and industrial formations.

The cluster challenge can be best viewed as being embedded in a broader regional challenge whereby a culture of 'competitive innovation' thrives in a localized system of interdependencies and interactions as captured below by the analysis of the Bay Area's economic success.

> *'The larger economic lesson to be learned from the success of the Bay Area experience is that the ability to innovate is a competitive advantage not just for companies but for entire nations. Nurturing and developing innovative companies is a product not just of proximity to excellent universities and government research*

*facilities, modern physical infrastructure, or access to capital, as important as they may be. Just as we have seen in private companies, it stems from a culture that values openness to new ideas, and a networked environment in which ideas and people can flow back and forth, interacting fluidly. And it stems from finding and developing people who themselves understand the value of low barriers to the open exchange of technology and people between universities, government, and business, a premium on entrepreneurship, openness to talent from any source, and rewards commensurate with people's willingness to assume risk. While any one element in isolation can produce positive results in terms of growth and economic development, it is their combination and interaction that is critical to truly competitive innovation and a self-sustaining cycle of economic success.' (Jaruzelski et al, 2012, p. 25)*

The example of the Bay Area reflects the broadening of regional studies literature from understanding fragmented slices of economic and innovation successes to more integrated and holistic approaches of interconnected developments, path inter-dependencies (Martin & Sunley, 2006), notion of transversality (Cooke, 2012), resilient regions (Martin, 2012; Wolfe, 2013), and, complex adaptive (innovation) systems (Cooke, 2012; Martin & Sunley, 2007, 2012). There is recognition that regional studies, RIS and EEG, are emergent studies. EEG has been acknowledged as being in its infancy; these fields of studies encompass concepts and approaches from various relevant disciplines. The overlap and convergence of multiple disciplines in regional studies contribute to the emergent nature of the scholarship. The study of clusters, in turn, also reflects similar developments and is described in the next sub-section.

### 2.7.1 Cluster studies as 'work in progress'

Cluster studies as an area of research is characterized by the diversity in focus, approaches and methodologies approaches reflecting the diversity of the underlying theoretical disciplines. Henry *et al* (2006) expressed that whilst Martin and Sunley were right in their criticism of the lack of coherence and ambiguities that abound in cluster studies but also indicated that cluster studies have value and need to be assumed as 'work in progress' (also, Cortright, 2010). They found that 'theoretical conversations' in cluster research and the existence of multiple theoretical bases of cluster research offered a potential for deeper understanding of cluster practice.

In addition, the nature of clusters, multi-facetted, diverse in its manifest given its varying geographical and socio-economic scale and locations; target of political, industrial and increasingly academic construct as a means to an end, whereby these goals may not always coincide, attracts and offers room in cluster study for new insights and developments. This reinforcing relationship between an evolving field of study rich in theoretical foundations, and a phenomenon complex and subject to demands and changes in policy and in its context as described earlier, allows room for further exploration of complexity approaches in support of understanding cluster practice.

The diagram below captures key features of RIS, EEG and clusters in support of policy needs as a summary of the literature on regional studies.

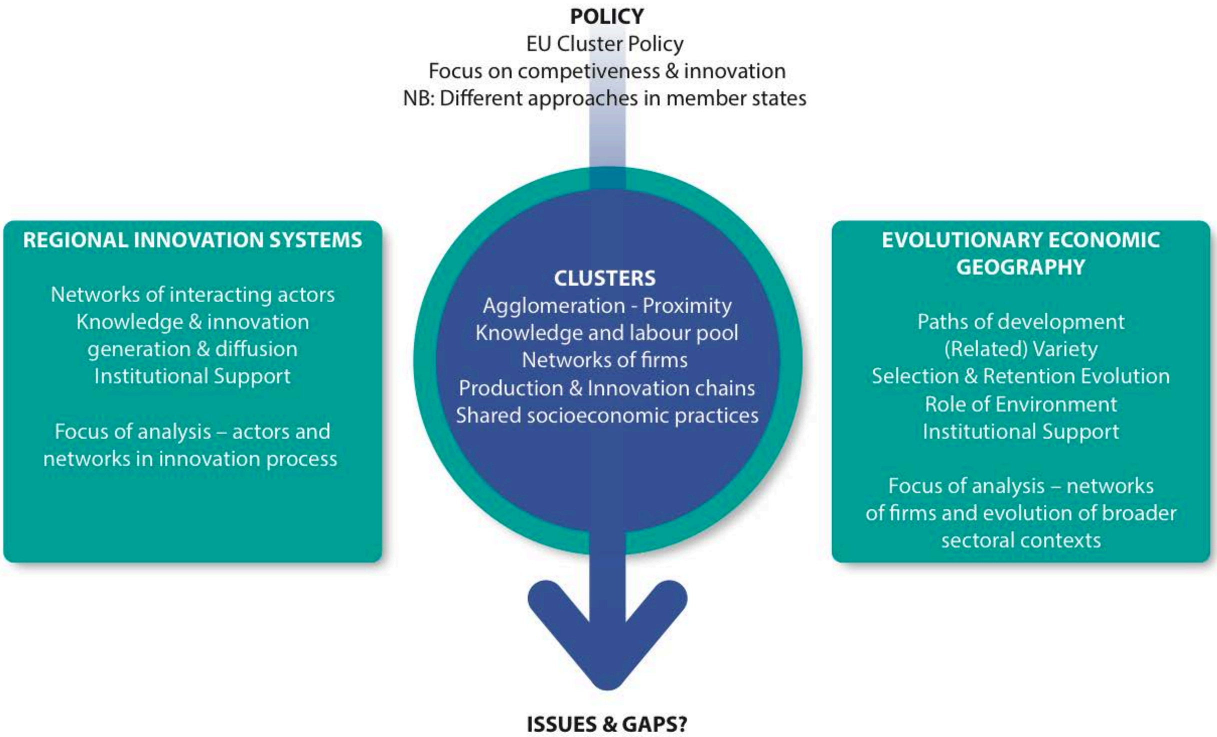



*Figure 4 Key features and focus in literature and policy*

The next section describes complexity theory and approaches.

## *2.8 Complexity Theory*

The emergence of complexity approaches in regional studies supported exploration of complexities approaches, and in particular that of complex adaptive systems, to understand how these approaches could provide better understanding of cluster developments. The literature review begins with understanding how complex problems and phenomena can be identified. The concept of 'wicked problems' and the application of this concept are described in first part of the review.

The section begins with ‘wicked problems’ as a concept to understand and define complex phenomenon before proceeding to the theoretical framework of complexity approaches for managing cluster developments.

### 2.8.1 Wicked Problems

Urban planners, Rittel and Webber, introduced the concept ‘wicked problems’ to describe complex social processes that needed a different approach compared to normal ‘tame’ problems (1973). They stressed that complex processes cannot be solved by linear, traditional analytical approaches. They distinguished ‘wicked’ from ‘tame’ problems and defined the nature and scope of ‘wicked’ problems: complex, unpredictable in solution outcomes, messy in definition, divergent interests and perceptions of the problems and solutions by stakeholders, and each case is unique with no definite measure of success. The identification (diagnosis) of complex situations through the concept of ‘wicked’ helps policy makers and others involved in social and economic change to engage in different solution paradigms as opposed to dealing with more ‘tame’ or normal challenges. Ritchey (2005) indicated that Rittel and Weber’s ten characteristics defining wicked problems (see table below) was more than a diagnostic tool but that these should be treated as ten heuristic perspectives that offered deeper understanding of the nature of complex social planning challenges.

| Features | Wicked problems |
|---|---|
| Definition | **There is no definite formulation of a wicked problem** |
| Rules | **Wicked problems have no stopping rules.** |
| Solution | **Solutions to wicked problems are not true-or-false, but good- or-bad.** |
| | **There is no immediate and no ultimate test of a solution to a wicked problem.** |
| | **Every solution to a wicked problem is a "one-shot operation"; because there is no opportunity to learn by trial-and-error, every attempt counts significantly.** |
| | **Wicked problems do not have an enumerable (or an exhaustively describable) set of potential solutions, nor is there a well-described set of permissible operations that may be incorporated into the plan.** |
| Problem identity and resolution | **Every wicked problem is essentially unique.** |
| | **Every wicked problem can be considered to be a symptom of another [wicked] problem.** |
| | **The existence of a discrepancy representing a wicked problem can be explained in numerous ways. The choice of explanation determines the nature of the problem's resolution.** |
| | **[With wicked problems] the planner has no right to be wrong.** |

*Table 9 Properties of 'wicked' problems (adapted from Rittel and Webber, 1973)*

Batie (2008) discussed 'wicked problems' in seeking new non-linear approaches to social and economic challenges in her review of applied economics. She advocated the need for new 'postnormal science' in the light of 'wicked problems' that included engagement and dialogue with stakeholders. She indicated that 'normal science assumptions and approaches were inadequate for addressing the complexities of wicked problems in a policy context' (p. 1176). She identified ecological economics, complexity economics and sustainability science as examples of 'postnormal science' that attempted to analyse and understand inter-connected behaviours at different scales in systems. She also recognized the need for multi-disciplinary, integrated scientific approaches that included different worldviews, knowledge (including tacit knowledge), conflicting values and participation of stakeholders. Batie suggested that adaptive management approaches were an example of dealing with wicked problems where experiments were part of policy development processes. Batie

(2008) provided a categorization of types of problems and approaches to understanding them and seeking solutions, see the illustration below.

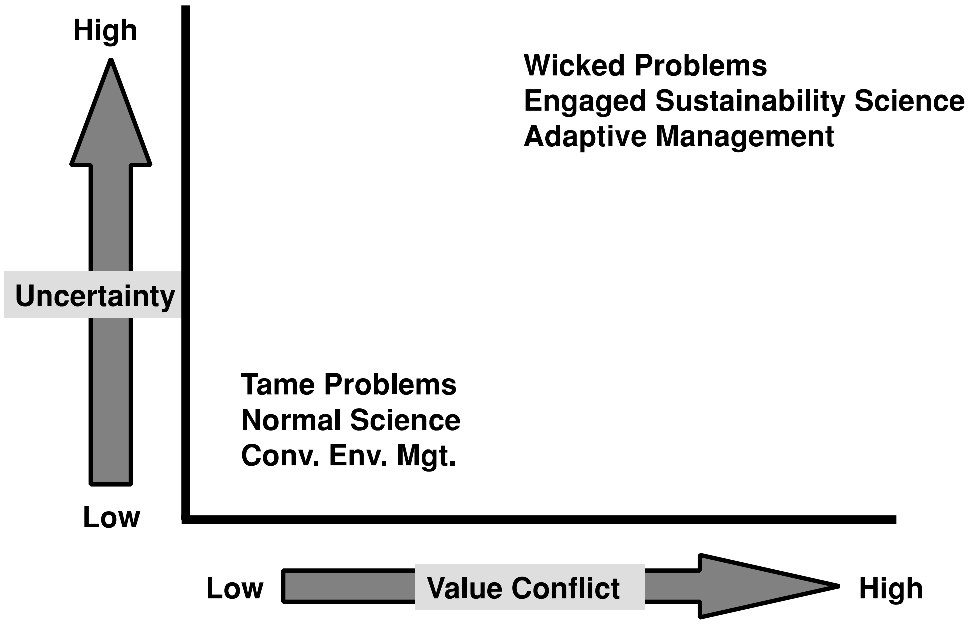



*Figure 5 Wicked versus tame problems (Batie, 2008, p. 1185)*

The diagram shows the role of uncertainty and value conflict in problems in identifying ‘tame’ and ‘wicked’ problems and roles of ‘normal’ and alternative science. Complex approaches that include stakeholder participation and adaptive or flexible management practices are cited as examples for wicked problems in this diagram.

Adaptive management in systems development processes is at the core of complexity approaches. Complex Adaptive Systems (CAS) approach, a branch of complexity sciences, applied to organizational and management studies, embraces ‘non-linearity, edge of chaos, self organization, emergence and co-evolution’ (Ramalingam *et al*, 2008, p. vii).

Batie’s model is similar to the Ralph Stacey’s matrix commonly used in management sciences (in Zimmerman, 2001; Cooke, 2012).

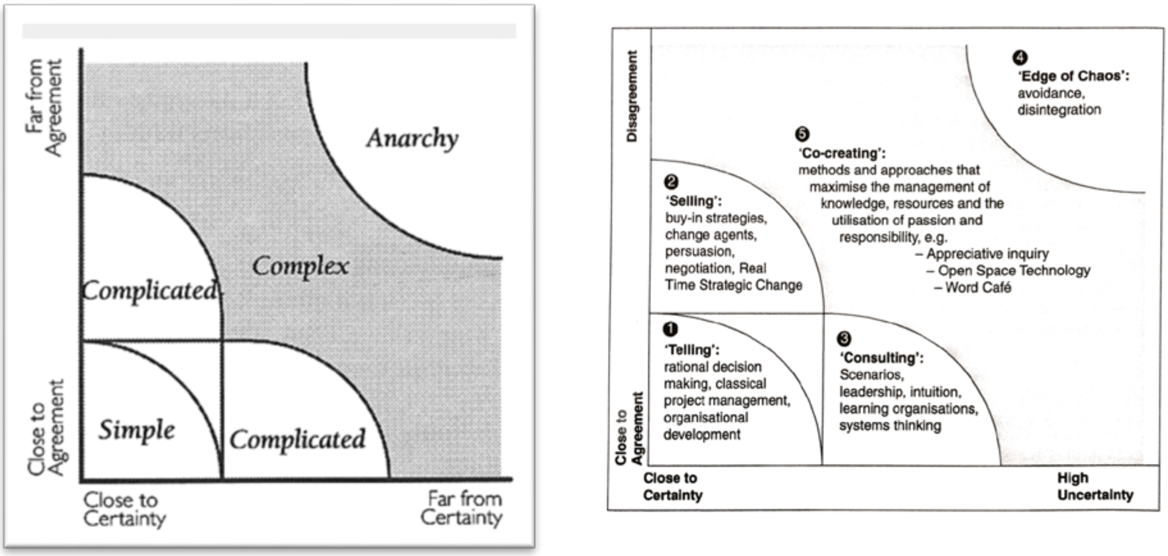



*Figure 6 Stacey's Matrix (adapted from Zimmerman, 2001 & Cooke, 2012)*

Stacey's matrix offered appropriate strategies for organizations for the different categories identified. (See section 3.4 on Stacey's later stance on complexity theories and management sciences).

In policy implementation, the Australian government embraced Rittel and Webber's concept of 'wicked problems' to develop a policy perspective that has its roots in academic discourse and policy studies and developments (Commonwealth of Australia, 2007). They described a need for more 'adaptability in the public sector' (p. 14) that allowed convergence and connection across boundaries in policy, public service agencies and users. The underlying need for innovative, adaptive approaches based on reiterative models to tackle complex problems is a shift from traditional policy studies that focused on more linear and mechanistic models to solve social economic challenges.

Ramalingam *et al* (2008) in their exploration of complexity science for development and humanitarian efforts concluded that 'the concepts of complexity science provide a basis for understanding different aspects of 'messy realities' – aspects which may not otherwise be well understood or systematically investigated' (p. 62). The search for answers for 'wicked' or complex phenomena in the realm of complexity sciences and the advocacy for more non-linear, non-traditional approaches to investigating these 'messy' or 'wicked' challenges underlies the choice of the complexity approach for this research.

Developments in EEG and RIS incorporating CAS approaches confirm the initial choice of the research to base its cluster study on CAS's value to cluster developments. Martin and Sunley (2007) addressed the growing attraction and emergence of complexity theory in economics as being 'a novel and powerful framework of thought capable of challenging the fundamental principles of the mainstream economic canon' (p. 8), and shared Batie's concern of challenges in applied economics. As mentioned earlier, their discourse on complexity approach launched theoretical discourse within economic geography scholarships.

In order to understand and identify when 'normal' science or linear approaches were suitable and when complexity approaches were needed, a classification of phenomena is needed.

| Rittel and Webber, 1973 | Grint, 2005 | Snowden and Boone, 2007 |
|---|---|---|
| Tame | | Simple |
| | Complicated | Complicated |
| Wicked | Complex | Complex |
| | Critical/Crisis | Chaotic |

*Table 10 Classifications of Problems (from Venton, 2011, p. 3)*

Venton (2011) expanded Rittel and Webber's 'tame' and 'wicked' problems by including classifications from Grint and Snowden and Boone. The categories included 'simple', 'complicated', 'critical', 'chaotic' and 'complex'. Venton indicated that 'wicked' excluded simple, complicated and chaotic as phenomena that demanded complexity approaches. He explained that non-wicked problems would be for the domain of 'normal' science investigations.

In the next sub-section, distinctions between wicked and non-wicked problems, and the need for appropriate types of investigations are explored in terms of traditional economics and complexity approaches in economics. This exploration has been included to further appreciate perspectives and methods adopted by complexity sciences as opposed to more traditional economic and scientific theories.

### 2.8.2 Complexity and traditional economic approaches

Traditional notions of the economy being 'mechanistic', efficient and self-regulating meant that policy interventions were justified in the case of market failures, and policy measures were evaluated 'through the lens of cost-benefit analysis' (Beinhocker, 2014). However, there is a 'turn' in economic thinking that is reflected in the quote below.

> *A capitalist economy is best understood as an evolutionary system, constantly creating and trying out new solutions to problems in a similar way to how evolution works in nature. Some solutions are "fitter" than others. The fittest survive and propagate. The unfit die. The great economist Joseph Schumpeter called this evolutionary process "creative destruction." And he highlighted the importance of risk-taking entrepreneurs to make it work.*
>
> *Thus, the entrepreneur's principal contribution to the prosperity of a society is an idea that solves a problem. These ideas are then turned into the products and services that we consume, and the sum of those solutions ultimately represents the prosperity of that society" (Hanauer and Beinhocker, 2014, para. 26 & 27)*

The shift in economic thinking is captured in 'complexity economics' that expresses the 'streams of theoretical and empirical work that can be directly or indirectly linked to 'complexity thinking' where five key dimensions distinguish 'complexity economics' from traditional economics (Beinhocker, 2006, 2012). The move away from the 'rational' behaviour of individuals and efficiency notions of markets to include networks and innovations where problem-solving entrepreneurial and knowledge developments take place in dynamic, unpredictable markets, are shaping macro-level economic patterns of development. The table below captures key differences.

| | Traditional economics | Complexity (new) economics |
|---|---|---|
| Individuals (agents) | Homogeneous: rational beings, use of deduction, access to perfect information, no bias | Heterogeneous: both inductive and deductive reasoning, assess to local, incomplete information, use rule of thumb, subject to errors learn from mistakes |
| Networks and institutions | Market mechanisms determine interactions, networks not relevant | Networks are important, social relationships, trust, reciprocity play a part |
| Dynamics | Economies as static and closed linear systems in equilibrium | Economies as highly dynamic, open and non-linear, shifts from equilibrium to sub-optimal states plausible |
| Innovation (evolution) | Mysteries and unpredictable, subject to external forces | Technology and social innovation as evolutionary processes critical to economic growth and change |
| Emergence | Macro economic activity extrapolated from linear summation of individual (homogeneous) decisions | Macro patterns emerge from non-linear dynamics of interactions at micro levels by heterogeneous actors, small changes can have big effects and big changes can have small effects |

*Table 11 Traditional economics and new complexity economics (adapted from Beinhocker, 2006, 2012)*

The 'shift in paradigm' (Beinhocker, 2014) that acknowledged the need for more dynamic approaches in economics supports exploration of complexity approaches for cluster study. Complexity approaches in economics conveyed the role of agency, significance of networks and local social capital, the non-linearity of systems, role of technology and social innovation and the interactions of micro and macro level activities supporting a whole systems approach to understand the interconnectedness of systems developments. The next sub-section offers insights into these defining features in complexity approaches.

### 2.8.3 Defining features and value of Complexity Approaches

Complexity science is distinguished in its 'unified focus, it is to be found in its way of thinking, which is intrinsically different from the one of traditional science' (Heylighen *et al* 2007, p. 2) whilst Maguire *et al* (2011, p. 2) claimed that 'complexity science challenges not only the foundations of our knowledge – our philosophy and our science – but also the economic, political and social institutions we build upon that knowledge'. The significance of complexity in challenging traditional science and notions of knowledge makes any study of complex systems, including cluster systems, different from traditional approaches.

To understand how complexity approaches differ, this sub-section describes their defining features, including assumptions about complex adaptive systems and about 'knowing'.

Complex adaptive systems are 'composed of a diversity of agents that interact with each other, mutually affect each other, and in so doing generate novel behaviour for the systems as a whole…when a system's environment changes, so does the behaviour of its agents, and, as a result, so does the behaviour of the system as a whole' (Lewin & Regine, 1999, p. 6).

In the following quotation, the centrality of agency in the evolution of complex adaptive systems and the interconnected nature of micro and macro processes, express how such features are inherent to both natural and human systems.

> *The study of complex adaptive systems, from cells to societies, is a study of the interplay among processes operating at diverse scales of space, time and organizational complexity. The key to such a study is an understanding of the interrelationships between microscopic processes and macroscopic patterns, and the evolutionary forces that shape systems. In particular, for ecosystems and socioeconomic systems, much interest is focused on broad scale features such as diversity and resiliency, while evolution operates most powerfully at the level of individual agents. Understanding the evolution and development of complex adaptive systems thus involves understanding how cooperation, coalitions and networks of interaction emerge from individual behaviors and feedback to influence those behaviors. (Levin, 2002, p. 3)*

Another feature of complex adaptive systems is the presence of 'deep rules' or mechanisms that govern emergent order in complex systems and interactions of these mechanisms result in new emergent systems (Lewin & Regine, 1999). They explained how Brian Goodwin (deep rules) and John Holland (interacting mechanisms) contributed to such insights, and that complexity study focussed on uncovering features of what they called 'the emergent whole'. In addition, they also explained how new emergent systems could be part of mechanisms of the next level of emergence.

The concept of multi-layered, interacting systems in complexity science makes complexity theory also a powerful tool of analysis. There is a growing body of research bringing complexity approaches to understand interconnected, multi-level social challenges (Ramalingam *et al*, 2008). The need for new policy approaches with such prowess is reflected in the fact that policy makers 'increasingly encounter a daunting class of problems that involve systems composed of very large numbers of diverse interacting parts. These systems are prone to surprising, large-scale, seemingly uncontrollable, behaviours. These traits are the hallmarks of what scientists call complex systems', and such systems display 'non-linearities and discontinuities; aggregate macroscopic patterns rather than causal microscopic events; probabilistic rather than deterministic outcomes and prediction; change rather than statis' (OECD 2009, p. 2). Mitleton-Kelly (2003, p. 4)) explains that '**theories of complexity** provide a conceptual framework, **a way of thinking**, and **a way of seeing the world**' such that these theories offer methodologies and tools to gain a deeper understanding of 'the nature of the world – and the organizations – we live in'.

Complexity theories are not one field of theory but rather encompassing different strands with different approaches and assumptions. Dominant strands include those with more objectivist perspective that emphasizes modular and computational approaches from the 'outside'; and those with interpretivist perspectives emphasizing perceptions of agents from within the system 'through meanings', and often though not always, through metaphors (Maguire, 2011). Another manifestation of different strands is seen in the European School focussed on self-organization, assumptions of 'far from equilibrium' conditions in which order emerges from disorder through small deviations, with or without mathematical models, exploring interactions of systems with their environment; and the North American School using computational approaches drawing on life sciences to generate agent-based modelling to simulate pattern formation and causality, focussing more on intra-system processes (Maguire, 2011).

Limits to knowing, central to complexity approaches, also saw pluralistic epistemological positions (Maguire, 2011; Maguire *et al*, 2011). Advocacy for a 'scientific realist epistemology' (McKelvey, 2011), for 'complex realism' (Byrne, 2011), post structuralism (Cilliers, 2011) existed but collectively, complexity sciences question assumptions of causality and what constitutes 'explanation' in scientific scholarship (Juarrero, 2011; Maguire *et al*, 2011). The relevance of determining causality in the Aristotelian tradition was seen less important. Chia (2011) summarizes how ‘complexity thinking’ supports the need to ‘appreciate and discern the seemingly inconspicuous, the peripheral and the as-yet disclosed’ and that ‘managing complexity entails the art of seeking out the obscured, the hidden and the implicit and dealing with them before they manifest themselves explicitly’ (p. 197). In addition, Chia indicated that studies of complex systems needed to be understood through ‘oblique’ or indirect means. The focus on creating more resilient organizations and systems able to deal with changes in the environment was seen to be more important in policy and therefore, in scholarship.

The table below provides an overview of key concepts and developments in complexity sciences in management. More details of complexity sciences, its developments, different streams, methodologies, application and scholarship are documented in the literature (Allen, *et al*, 2011).

| | |
|---|---|
| Assumptions about 'informed' and predictable strategies | **Limitations of informed action and policy**<br>Management (and organizational) knowledge in evolving social systems is limited and incomplete<br>- As opposed to: notion of 'objective truth about natural laws governing unchanging systems'<br><br>**Limitations of analyses**<br>Descriptions and analysis of organizational systems dynamics limited<br>- Agent's reality includes interactions with other agents and this includes different perspectives and views on reality<br>- Values, aims and goals of different actors not always coinciding and therefore, system development will reflect reinforcing and conflicting interactions<br>- Agents, in response to outcomes due to their beliefs and actions, may strengthen their current beliefs and actions when outcomes reinforce them, or, may change over time if their expectations are not confirmed, thus leading to new system behaviour and response<br><br>**Limitations of predictability**<br>Some system features can be predicted in some circumstances, but predictability is difficult as 'seemingly small and inconsequential local events in a system can be amplified to cause global change'<br>- Paradoxical forms of wisdom: *'Individuals can change their worlds through interventions, but their agency must be reflexive and respectful of the system in which they are embedded'* |
| Assumptions about knowing and reality | **Implications of complexity for management** due to ontological, epistemological and axiological differences - responsibility, accountability and governance re-considered<br>- Ontology of connected entities: networks with changing links, nodes that change internally, capabilities that develop and change over time<br>- Opposes traditional notions of objectivist epistemologies of organizations, instead 'open systems' interacting with their environments, operating as 'interpretation systems'<br>- Modeller and models are part of the system, and therefore influenced by the interactions: the model, modeller and system evolving through the interactions<br>- Actor's interpretation of situation as part of the system<br>- 'Learning by doing' in resources management recognizing limits to knowledge, later in broader management |
| Key management concepts of complexity (Since 1980s) | **'Soft science' concepts**<br>- Interpreting, sense-making and constructing meanings<br><br>**New management notions**<br>- Decentralization of decision-making, autonomy and empowerment of workers<br>- 'Coping with uncertainty' |
| 'Complexity Thinking' | **Embraces methodological pluralism:**<br>- 'Interpretivist' - narrative and metaphorical<br>- 'Objectivist' - reductionist and modular traditions<br>**Acknowledges limits to knowledge about complex phenomena**<br>**Includes different types of studies**<br>- Philosophy-driven<br>- Phenomenon-driven applications<br>- 'Interfaces' studies - theoretical developments of management and 'other' fields<br>**Offers flexible concepts and robust methods**<br>**Beyond fixed rules dynamical systems**<br>- System plasticity – addition and disappearance of qualitative features<br>- Evolution – emergence and qualitative development of structure and organization<br>**Analytical scope of complexity**<br>- As an organizing tool<br>- Metaphorical applications |

*Table 12 Summary of key complexity features and developments in management sciences since the 80's (adapted from Maguire et al, 2011)*

Complexity science offers dynamic whole systems investigations, to explore less defined behaviour and phenomena at multiple levels that are constantly changing.

Within this field, Complex Adaptive Systems (CAS) approach has been applied in social sciences, ecology, organizations, policy studies, health care, education, etc., also referred to as 'interface' studies (Axelrod & Cohen, 2001; Mitlteton-Kelly, 2003; Olson & Eoyang, 2001; Ramalingam *et al*, 2008; The Health Foundation, 2010; Van der Steen *et al*, 2013). CAS has also been incorporated into regional studies and in particular cluster studies as clusters exhibit many of the traits of multi-scalar, multi-agent systems that are hard to predict and understand and qualify as complex adaptive systems (Carbonara *et al*, 2010; Cooke, 2012, 2013; He *et al*, 2011; Martin & Sunley, 2007, 2015).

The application of CAS to cluster (case) studies is still limited: in numbers, in addressing whole systems analyses, in theoretical and policy developments, and is also still 'work in progress' offering room for new investigations. The table above offers signposts for such a study: focus on qualitative systems changes; focus on 'open systems' interacting with the environments acting as 'interpretation systems'; use of 'soft science' concepts of sensemaking; identify self-organizing behaviours of agents dealing with uncertainty; explore agent perceptions and interactions and reinforcing patterns of behaviour and system shifts; use of complexity as analytical tool to organize investigations as well as to explore metaphorical applications; and finally, understand the limitations of knowing. The search for 'deep rules' and interrelated mechanisms of embedded systems, by focussing on peripheral, hidden and insignificant aspects in complex systems developments, key features and guidelines for understanding complex systems are also inputs for the research.

The initial introduction of complexity sciences has set the stage for a more specific focus on CAS. The next section describes and explores key features and concepts with the view of developing a CAS approach for cluster study.

**Complex Adaptive Systems**

John Holland (1992, p. 18) introduced the concept complex adaptive systems (CAS) and he describes that systems 'change and reorganize their component parts to adapt themselves to the problems posed by their surroundings. This is the main reason the systems are difficult to understand and control - they constitute a "moving target." We are learning, however, that the mechanisms that mediate these systems are much more alike than surface observations would suggest. These mechanisms and the deeper similarities are important enough that the systems are now grouped under a common name, complex adaptive systems'. Holland also identified that CAS 'represents the kernel of some of our most difficult problems, ranging from trade balances to control of the AIDS epidemic' (p. 29). The ubiquitous nature of complex adaptive systems across disciplines and situations is reflected in the application of CAS to diverse settings and knowledge fields. An overview of characteristics of complex systems is provided in the table below.

| **Complex Systems** | **Comments/Qualifications** |
|---|---|
| Open | - Boundaries vary, often vague, but 'known' to agents |
| Non-equilibrium conditions | - Constantly changing and adapting |
| Multiple components (agents) | - Can be simple or regarded as simple |
| Output of components (agents) | - Function of inputs<br>- Some outputs are non-linear (unpredictable) |
| State of system | - Determined by values of inputs and outputs |
| Interactions | - Determined by actual inputs-outputs relations and dynamic, and, they usually change over time<br>- Multiple interactions by each component (agent)<br>- Multiple routes possible for interaction choice and behaviour<br>- Feedback loops may prevail to affect further interaction behaviour, may be immediate or delayed feedback loops |
| System behaviour (emergence) | - Determined by interaction of components rather than inherent properties of components |
| System structure | - Is asymmetrical and is developed, maintained and adapted through internal dynamics of system<br>- Structure is maintained even as components change |
| System changes | - System changes are diverse and occur over range of time scales<br>- Dynamics of change in different parts of the systems are often different<br>- Some parts respond rapidly to environmental changes but this is only possible when other parts of the system changes slowly - important to sustain the system |
| System description | - Divergent descriptions of a complex system is possible<br>- No description will be complete<br>- Different description capture different degrees of complexity |

*Table 13 Nature of Complex Systems (adapted from Cilliers, 2005)*

CAS as a 'multi-agent system' that involves autonomous agents that interact locally to produce a 'global order' in which agents are 'intrinsically subjective and uncertain about the consequences of their actions, yet they generally manage to self-organize into an emergent, adaptive system' (Heylighen *et al*, 2007, p. 19) reflects the significance of local interactions leading to systems changes. The local-systems paradigm of CAS provides a means of studying local interactions in response to contextual changes and the influence of such interactions on systems developments. Key concepts in CAS are described next to understand and afterwards select relevant concepts for cluster study.

#### 2.8.4 Concepts in CAS

This sub-section provides highlights of key concepts of CAS. Appendix 4 provides more details (with overlaps). Concepts and features of CAS are categorized into three parts: micro systems, systems features and systems responses.

##### *2.8.4.1 Micro systems*

The main concept of CAS is 'agents' (Axelrod and Cohen, 2001). Agents are 'semi-autonomous' and 'seek to maximize some measure of goodness, or fitness, by evolving over time' (Dooley, 1997, p. 85). The notion of 'fitness with the environment' diverts from traditional notions of strategy where the aim is fitness to the objectives and goals set out by the individual agent or organization.

Micro systems include '*bounded rationality*', '*sensemaking'* and '*schema'* that influence behaviour of agents responsible for micro level dynamics.

**Bounded rationality**

Bounded rationality expresses the fact that agents have limited information, assumptions, expectation, values and habits that form their perception of the context and that in turn, determine their actions. This concept is also used in evolutionary economics.

**Sensemaking and complexity**

Agents' behaviours are determined by 'sensemaking' of changes in the environments to be able make 'meanings' to 'inform and constrain identity and action' (Weick *et al*, 2005, p. 409) as seen in the illustration below.

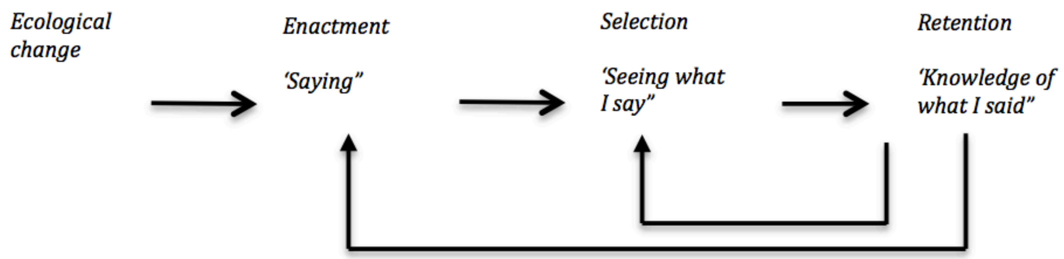



*Figure 7 Weick's notion of sensemaking (adapted from Weick, 1979, p. 132-134)*

'Sensemaking is about the interplay of action and interpretation rather than the influence of evaluation on choice' (Weick *et al*, 2005, p. 409). Sensemaking is context-bound, always in retrospect and in connection to others. In addition, sensemaking facilitates 'common language and conceptual categories, define group boundaries and criteria for inclusion and exclusion, distribute power and status' (Dooley, 1997, p. 86). Strategies used by agents (and influenced by their understanding of their environment) can influence future strategies (Axelrod & Cohen, 2001). In addition, sensemaking processes can facilitate consensus on strategy, resources, vision, goals and how to reach these, indicators of success, etc. (Axelrod & Cohen, 2001).

Sensemaking is assumed in CAS, but not identified as a key concept. 'Schema' in CAS has overlaps with 'sensemaking'.

**Schema**

Schein (1992, in Dooley, 1997) described that shared schema defined culture in organizations that could support shared schema among stakeholders, be it in organizations or in collective initiatives (clusters). This concept is similar to institutional contexts of regional studies.

#### 2.8.4.1.1 Summary of micro systems

The sub-section on micro systems described how agents with their bounded rationality, sensemaking strategies and shared schema form the system and how their actions and strategies influence the system. The additional concept of 'sensemaking' helps understand more precisely how agents 'understand', namely, through shared discourse, values, and vision of future.

### *2.8.4.2 Systems features*

Complex adaptive systems display systems patterns and have interacting mechanisms across systems, and micro level interactions are connecting to systems developments. These features include *systems patterns*, boundary and identity (*container*), context (*sensitive to initial context*), shape (*phase space*) and underlying constraints (*attractors)*.

**Systems patterns**

Complex systems display patterns that occur across various levels and events occurring in one part of the system can also have an effect in a different part of the system.

- *Self-Similarity*

Simple rules (similar to Goodwin's 'deep rules') present in complex adaptive systems create similar patterns within the system at different levels, known as *self-similarity* in systems. Patterns of behaviour and interactions in multi-level systems (such as clusters) could reveal underlying self-similarity in systems at different levels. (See *simple rules* and *self-organizations* below).

- *Embedded and overlapping systems*

The nature of complex systems is such that they are often embedded in another (higher) level of systems. The behaviour of one system is often input for the next level system. In complexity, there is a notion of upward and downward causality (Maguire, 2011).

- *Local behaviour and macro-level effects*

Systems display changing and unpredictable behaviour due to agents' behaviour and decisions to seek 'fitness' with their environment are based on their local situation, their goals, etc. They are often unaware of the effects of their behaviour in remote parts of the system. This is known as the 'principle of locality' (Heylighen *et al*, 2007). Local behaviours of agents will cumulatively and spontaneously affect the global level of a system in non-linear ways.

**Systems boundary and identity – 'container'**

Systems are demarcated from their environment and this demarcation allows a system to have an identity [Eoyang & Olsen, 2001]. System boundaries or containers can be geographical, organizational, behavioural, conceptual or institutional.

The notion of container differs from traditional notions of systems as in economics and geography, where such systems do not cross boundaries or levels but operates in distinct levels or areas. Changing system boundaries changes the dynamics of system (Olson & Eoyang, 2001).

**Sensitivity to initial conditions**

Another salient feature of complex systems, according to Prigogine (1985) is that they tend to be sensitive to local environments in which the interaction takes place, the notion of 'sensitive to initial conditions'. The notion of sensitivity to initial condition overlaps with concepts of history (in sensemaking) and path dependence (in evolutionary economics).

In the literature, sensitivity to initial conditions is often linked to the notion of amplifying effects and therefore explaining non-linearity in systems, whilst path dependency is more often associated with the risk of lock-in. Both these concepts point to the effects of actions in the system, underlining the need to explore history and contexts of local (initial) conditions for both *ex ante* and *ex post* systems studies.

**Phase space**

The possibility spaces of a complex system, due to interactions of its agents and critical values present in the system, have a maximum space within which a systems' patterns of emergence can be found (see *attractor* for constraining forces) even as there is no way of knowing where patterns of emergence will be found within this phase space.

In order to identify this 'space of the possible' (Cohen and Stewart, 1995, in Ramalingam *et al*, 2008), critical values of the key dimensions are mapped to identify possible spaces.

**Attractor**

The concept of attractor refers to the underlying pattern of order originating from mathematics (nonlinear dynamical system theory) where different phases with corresponding attractors determine behaviours (patterns) in the system. Strange attractors have patterns of trajectories that can result in system change when critical values exceed certain thresholds:

*'This strange attractor shows that complexity – although seemingly completely disordered, actually displays order at the level of its trajectory, and that although it may be unpredictable in its detail, it always moves around the same attractor shape. This 'narrowness of repertoire' is at the heart of the order hidden in complexity.' (Ramalingam et al, 2008, p. 38)*

According to Goldstein (2008), when critical threshold levels are crossed, a system transformation takes place, known as 'bifurcation':

*'A system may undergo a much more significant type of change, a phase transition into a new phase dominated by different attractors. This kind of system transformation….is termed "bifurcation"….Bifurcations result when there is a change in certain critical parameter values toward a threshold.' (Goldstein, 2008, p. 12)*

Understanding that complex systems have internal attractors constraining and shaping possible behaviour of its constituents including bifurcations that transform systems could support new discoveries about cluster developments and possibilities for new policy interventions.

##### 2.8.4.2.1 Summary of systems features

Understanding that complex systems offered new ways of understanding cluster systems and their developments. Such developments are underpinned by dynamics of interactions; constrained by 'simple rules' or mechanisms; reflected self-similarity of underlying patterns of developments; but displayed interacting and overlapping systems of interconnected developments of micro-macro levels; were sensitive to initial conditions, in which history matters; and where boundaries and identities of systems influence their developments even as their 'phase space' is constrained by attractors, and where strange attractors are capable of systems transformations when critical thresholds are reached. Mapping clusters to uncover systems features could provide useful inputs for policy and cluster study.

#### *2.8.4.3 Systems responses*

Complex adaptive systems respond to changes to their environments and these changes can be described in terms of strategies or goal matching (*fitness and adaptation*), the ability to deal with complexity, often reflected in variety (*significant differences*), the 'rules', dynamics and results of *interactions* and the resulting *emergent system*.

**Fitness and adaptation**

There are two notions relevant to adaptation in complexity, one of *fitness* and *fitness landscape*. Both concepts are present in complexity approaches.

- *Fitness and fitness landscape*

The notion of 'fitness' in complexity theories reflects the need to deal with complexity resonant of evolutionary theory's 'survival of the fittest', dealing with changing, complex environments. Complexity of its environment needs to be matched by the systems internal variety (McKelvey, 1999; Merali & Allen, 2011), and in organizations, variety is recommended (Axelrood & Cohen, 2001). This is further discussed in describing the concept of *significant differences*.

The concept fitness landscape advocated by Kaufman is explained by Cooke (2012) as the landscape of complex systems as 'topography of hills and valleys' in which interactions and recombination of knowledge may be hindered or unobstructed and that diversity is important to economic growth. The popularity of fitness landscape in complexity sciences has its limitations when applied to social sciences (Ramalinam *et al*, 2008). Ramalingam *et al* suggest that a broader concept of 'fitness' could support understanding co-evolutionary nature of agents in interaction with the environment by adopting the notion of 'optimal trade-offs' instead of Kaufman's fitness 'peaks'.

The 'fitness' seeking behaviour of agents and interdependent adaptations of local agents could help understand systems developments in cluster studies.

**Significant differences**

*Significant difference* is a concept that is approached differently by various scholars in complexity science.

- *Variation and diversity*

Axelrod and Cohen (2001) address variation as a key concept essential to innovation and a source of potential success for existing problems.

Diversity is recognized as an important element of renewal in urban studies and innovation in general (Johnson, 2012). Evolutionary economic geography also addresses diversity in the literature related to regional and urban development (Boschma, 2004) and the term 'related variety' is used (sub-section 2.6.3).

- *Significant differences and transformation*

In CAS, Olson and Eoyang (2001) explained that significant differences may be physical, mental, ideological, perceptual, experiential, social, political, etc. depending on the system. Goldstein (2008) explains that a significant difference is 'a difference that makes a difference' (Bateson, 2000, in Goldstein, 2008, p. 7)

Identifying 'significant differences' in complex systems offer insights into innovation potential, similar to the 'adjacent possible' in Kaufmann's terms (Cooke, 2012), which could perhaps support new path creations in cluster developments.

**Interactions**

Dynamic interactions of agent behaviours as part of systems responses are described through *feedback loops*, *transforming interactions* and *simple rules*.

- *Feedback loops*

Adaptive behaviour of agents is triggered where mismatch occurs between agent and environment to seek fitness to the local environments. Unlike normal scientific paradigms, connections in CAS are often non-linear and tend to have amplifying effects (positive feedback) or regulating effects (negative feedback (see Merali & Allen, 2011; Ramalingam *et al*, 2008).

- *Transforming interactions*

Olson and Eoyang (2001) described how significant differences could transform interactions. They used the term *transformational exchanges* to capture this effect.

Recognizing opportunities for transforming interactions and identifying significant differences to facilitate and broaden potential path creations can be important inputs for cluster policy.

- *Simple rules*

Complex systems are often governed by simple rules as illustrated by flocking birds or ant colonies, or military strategy in unpredictable, complex combat settings and the term 'semi-autonomous agents' is used to describe local rule governance and freedom of action.

To manage complex systems and problems, understanding local dynamics of actors and their environment is necessary in order to enhance and, or enable adaptability of local actors in their local contexts, also relevant to cluster policy.

**Emergent systems**

To understand how patterns emerge in systems, concepts of *self-organization* and *emergence* are described.

- *Self-organization*

Self-organization captures how 'new emergent structures, patterns, and properties arise without being externally imposed on the system' (Goldstein, 2008, p. 9). The behaviour of diverse agents, locally tapping into creative and novel behaviour, to adapt themselves to seek 'fitness' (Kaufman's 'fitness landscape') and maintain system structures without external design refers to the self organization property of complex systems (Heylighen, 2002; Heylighen *et al*, 2007). Change in CAS emerges from interactions of agents in the system whereby diversity and autonomy exists (see *transforming interactions*) with the understanding that self-organization in itself is not a sufficient condition to initiate emergence. 'Constraining' (*attractors*) and 'constructional operations' (systems boundaries and identities, diversity of fitness strategies, interactions leveraging diversity, etc.) are often needed to support emergent systems (Goldstein, 2008; Maguire, 2011).

- *Emergence*

The concept of 'emergence' is critical to CAS. Holland (1992, p. 20) explains how 'individual parts of a complex adaptive system are continually revising their ('conditioned') rules for interaction, each part is embedded in perpetually novel surroundings (the changing behaviour of the other parts)'.

> *'the arising of new, unexpected structure, patterns or processes in a complex system…Emergent phenomena are understood on a "macro"-level which is considered a "higher" level in respect to the "lower" or "micro"-level components from which the emergent emerge'*

and,

> *'Emergent phenomena seem to have a "life of their own" with their own rules, laws, and possibilities which are radically novel with respect to the lower level components'. (Goldstein, 2008, p. 9)*

*Emergence* is how 'properties of a complex system emerge from interconnections and interaction' with no clear relationship between the emergent properties and the contributing factors (Ramalingam *et al*, 2008, p. 21).

Focus on interconnections and interactions, and mapping the resulting changes in structures, processes, visions, creativity, meaning, forms of collaborations, etc. would capture emergent behaviour of cluster systems as qualitative shifts in systems.

##### 2.8.4.3.1 Summary of systems responses

Systems responses to changes in context as interconnected and distributed responses of agents can be understood through exploration of fitness and adaptation behaviours, significant differences potential, interaction patterns, and emergent systems behaviours, and their respective concepts. The emphasis on relevance and need for diversity to deal with complex changes, significance of focus on interactions and interconnections in systems developments were essential to CAS approaches. The emergent changes also reflect qualitative systems changes in its structures, visions, meaning, behaviours, responses as seen in interactions and collaborations.

### 2.8.5 Overview of CAS concepts

The table below offers an overview of the CAS concepts.

| | |
|---|---|
| **Micro systems** | **Agents**<br>- Bounded rationality<br>- Sensemaking and complexity<br>- Schema |
| **Systems features** | **Systems patterns**<br>- Self-Similarity<br>- Embedded and overlapping systems<br>- Local behaviour and macro-level effects<br><br>**Systems boundary and identity**<br>- Container<br><br>**Sensitive to initial conditions**<br><br>**Phase Space**<br><br>**Attractor** |
| **Systems responses** | **Fitness and adaptation**<br>- Fitness and fitness landscape<br><br>**Significant differences**<br>- Variation and diversity<br>- Significant differences and transformation<br><br>**Interactions**<br>- Feedback loops<br>- Transforming interactions<br>- Simple rules<br><br>**Emergent systems**<br>- Self-organization<br>- Emergence |

*Table 14 Overview of key concepts of CAS*

In order to support the choice of concepts relevant for cluster study, applications of CAS in other fields were explored and are presented in the next sub-section.

### 2.8.6 Complexity studies and choice of concepts

Insights from other complexity studies are presented to understand choice of concepts used to capture key elements. The table below captures studies in the areas of organizations, health care, international aid, management and peace-building studies. The main complexity concepts are shown.

| **Organizations** | **Health Care** | **International Aid** | **Management** | **Peace building** |
|---|---|---|---|---|
| *Miltleton-Kelly (2003)* | *The Health Foundation (2010) Zimmerman (2011)* | *Ramalingam et al, (2008)* | *Richardson (2011)* | *Walter C. Clemens, Jr, (2002)* |
| Emergence | Emergence | Emergence | Emergence | Emergence |
| Self-organization | Self- organizing<br><br>Simple rules<br><br>Distributed control | Self-organization | Self-organization | Self-organization<br><br>Self-organized criticality |
| Space of possibilities | | Adaptive agents | Adaptation<br><br>Learning | Fitness<br><br>Fitness landscapes |
| Far from equilibrium Feedback | Feedback | Non-linear<br><br>Feedback processes | Non-linear feedback | Agent-based (feedback) systems |
| | Edge of chaos | Chaos/edge of chaos | | |
| Historicity & time<br><br>Path-dependence | Sensitivity to initial conditions | Sensitivity to initial conditions | Local memory<br><br>Limits to knowledge | |
| Connectivity<br><br>Interdependence | Connectivity<br><br>Iteration | Interconnected and interdependent elements and dimensions | Microscopic behaviour – macroscopic effects | |
| | Embedded/Nested systems<br><br>Fractals | | Sub-systems CASs<br><br>Downward causation | |
| Creation of new order | Co-evolution of meaning | | | Coevolution |
| | Sub-optimal | Phase space | | Punctuated equilibrium |
| | Requisite variety | | | |

*Table 15 Application of CAS concepts in different fields of studies*

The table shows that there are broad overlaps in key concepts but that choices varied. To account for this, one could turn to Mitleton-Kelly (2003, p. 23) who claimed that 'there is no single unified Theory of Complexity' and that this led to differences in what constitutes 'key concepts' and features of complex adaptive systems. Some overlap in the studies included concepts of emergence, self-organization, feedback processes and adaptive agency, non-linearity and sensitivity to initial conditions and, or path dependence, interconnectedness, co-evaluation of order, and space of possibilities. Other aspects featured in the studies included embedded systems, assumptions of limited knowledge, variety, learning, edge of chaos, and fractals. There was room for variation and the next sub-section explores CAS approaches and view on its applications.

### 2.8.7 CAS approach – differing views

The attractiveness of CAS approach lies in its ability to analyse complex systems as a whole system through different concepts, features and related processes that offer deeper insights into self-organizing and emergent behaviours of their agents and systems. The previous sub-sections explained key concepts, features, approach and processes that commonly recur in the literature. The range of disciplines and phenomena to which it has been applied reflects both its versatility and robustness (Maguire, 2011). Below is a diagram that captures the whole systems approach of CAS.

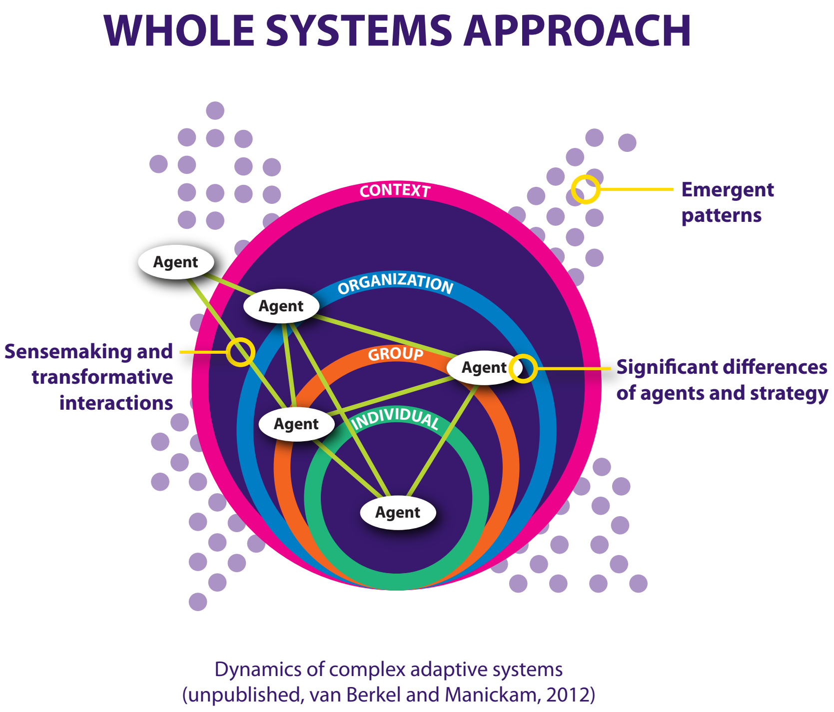



*Figure 8 CAS as whole systems approach (unpublished, van Berkel & Manickam, 2012)*

The diagram shows embedded systems with distributed agents interacting within and across systems, engaged in sensemaking and transformative interaction processes resulting in emergent macro-level patterns. The primacy of agency and interactions with local and broader contexts and other agents capture the dynamics of emergent systems:

> *'Complex adaptive systems (CAS) are a basic unit of analysis in complexity science. CAS are networks of interacting, interdependent agents who are bonded in a coöperative dynamic by common goal, outlook, need, etc. They are changeable structures with multiple, overlapping hierarchies, and like the individuals that comprise them, CAS are linked with one another in a dynamic, interactive network.' (Uhl-Bien et al, 2007, p. 299)*

Important criticisms on complexity approaches were that the theory uses concepts that are not really new. However, Ramalingam *et al* (2008) explained that although (systems) concepts were used in other fields, specifically systems theory, when incorporated in complexity these had different or broader features focussing on the centrality of interconnectedness, interdependence, non-linearity, role of agency and emergence. Therefore, complexity approaches offer new insights and ideas that allow more holistic and realistic views of complex and 'messy' problems that help to understand interconnected nature of systems that cross boundaries and levels. CAS approaches provide such insights through a common 'lens' and that 'its nature as a meta-theory of change' offered investigations that were trans-disciplinary and able to cover multi arena issues (p. 61). In addition, CAS supports both *ex ante* and *ex post* analyses. CAS can be used as an analytical tool to design programmes or strategies for complex systems, and it can be used to understand change processes of such systems retrospectively.

Another criticism is that complexity approaches is not a solid theory but 'more like a loose network of interconnected and interdependent ideas' that display 'conceptual linkages and interconnections between the different ideas' (Ramalingam *et al, 2008,* p. 59) but this too is refuted by explaining that there are different strands within complexity sciences with different approaches in methodologies, epistemologies, choice of concepts and focus, but with shared epistemology of limitations of knowing, definition of CAS, key concepts like agency, interconnectivity, non-linearity, emergence and self-organization (sub-section 2.8.3 and fig. 10 earlier). There are therefore varying perceptions to complexity approaches amongst scholars, captured in the table below.

| Perspective | Summary of approach and attitude towards complexity |
|---|---|
| Champions | • Complexity is a new paradigm of science, thought and action for social thinking and action.<br>• Direct application of mathematical approaches found in the natural sciences to social phenomena; calling for time series data which are analysed to identify the existence of the key concepts of complexity; demanding evidence comparable with that found in the natural sciences; facing methodological issues.<br>• Those who suggest that the lack of data and other issues facing quantitative applications of complexity in social sciences should not deprive social analysts of a set of useful insights and metaphors – complexity is a metaphor or a conceptual toolkit for clarifying problems and suggesting solutions. |
| Pragmatists | • Exploring relevance of complexity to assess practical benefits from applications outside natural sciences.<br>• Complexity can aid insights and help to guide thinking and, therefore, action.<br>• Complexity as a 'lens', providing important concepts and tools, but not the only way to look at and do things. |
| Critics | • Dismiss the relevance of complexity science beyond the natural sciences.<br>• More work to demonstrate specific applicability required.<br>• Criticise fad-driven 'complexologists' selling their services in the realm of organisational management.<br>• Complexity sciences adds nothing to existing approaches to understand social phenomena and only offers recommendations already reached elsewhere. |

*Table 16 Perspectives towards complexity (Ramalingam et al, 2008, p. 64)*

Complexity approaches are contested and criticized by different scholars, but there is also a growing acknowledgement of the need to deal with complex challenges and recognition that complex systems have advantages that make them attractive:

> *'....open systems that interact with their environment exhibiting the highest degree of resilience.... the more diverse the component types and the greater the variety and number of internal couplings the higher a system's resilience will be' (Juarrero, 2011, p. 163).*

CAS offers a different way of thinking in policy and management to deal with complexity challenges that seek to strengthen resilience rather than seek stability and optimization and therefore offer new approaches for resilient clusters in the face of complex global business contexts.

## *2.9 Conclusion of Part 1*

The literature review explored cluster theory and developments to understand key issues and approaches in regional and cluster studies. Cluster theories offered insights and support to clusters but were limited in their approaches and acknowledged the increasing complexity and interconnectedness of cluster developments to their contextual developments. Developments in RIS but more so in EEG acknowledged and incorporated CAS concepts and approaches in their fields. The gap in the literature indicates that an operational and comprehensive CAS approach for cluster study need to be developed.

The ability of CAS approaches to help understand systems dynamics and their complex contexts, role of agency, self-organization, micro and macro interconnections, interrelations across embedded systems, and emergence of systems, could possibly contribute to cluster study. A CAS-based conceptual framework for cluster studies could support on-going theoretical developments.

A review of applying complexity approaches in 'interface studies', reflected diversity and flexibility with no rigid template. The rich palette of concepts and metaphors and examples from other fields support adaptation of CAS approaches for cluster study.

Part 2 of the chapter describes European policy and approaches to understand the context of clusters, and to explore studies supporting cluster policy implementation.

## Part 2: EU Cluster Policy and Approaches

### *2.10 Introduction*

The second part of the literature review covers four aspects. The first aspect is on European strategies, the second on EU cluster policy, the third on EU policy trends and the fourth on cluster approaches. This review helps understand EU cluster policy and the challenges it faces and the various studies supporting implementation of effective cluster policy.

### *2.11 European Strategy*

European Union's strategy for the future, Europe 2020, forms the context within which EU cluster policy takes place and the essence of the strategy is captured below:

> *'In a changing world, we want the EU to become a smart, sustainable and inclusive economy. These three mutually reinforcing priorities should help the EU and the Member States deliver high levels of employment, productivity and social cohesion…. the Union has set five ambitious objectives - on employment, innovation, education, social inclusion and climate/energy - to be reached by 2020. Each Member State has adopted its own national targets in each of these areas.' (Website Europe 2020)*

The need to meet economic, social and ecological goals was underlined by challenges of structural weaknesses exacerbated by the financial crisis that had wiped out economic progress and the well being of its people (EC, 2010b). The need to re-structure its industries and strengthen its internal markets through coordinated efforts was at the core of these strategies in order to maintain EU global leadership and to ensure the well being of its population. This meant a further integration of its internal market, consolidating resources and capabilities across nations and regions, focussing on knowledge-driven innovation and competitiveness strategies to solve ‘grand social challenges’. Europe’s vision and strategy for the 21st Century, ‘a strategy for smart, sustainable and inclusive growth’ (EC, 2010b, p. 5) takes place in a complex landscape of structural weaknesses and great diversity amongst member states.

The regions in turn focussed on regional Research and Innovation Strategies for Smart Specializations (RIS3) and clusters were important in realizing this. The RIS3 policies were place-based innovation strategies that embraced broader innovation approaches and stakeholder engagement to include more demand-side perspectives to stimulate open and user-driven innovation and self-organized collaborative practices in an effort to create new ‘connections and conversations’ (EU, 2012a, p. 40). More details on the EU context, Europe 2020 and RIS3 have been included in Appendix 5.

The next section looks at EU Cluster Policy, its developments and role in supporting Europe 2020 Strategy.

## *2.12 EU Cluster Policy*

Clusters have been part of EU’s landscape and focus of policy since the 1980s and were identified as part of a broad-based innovation strategy in 2006 and 2008 by the Commission (EC, 2008). There was a consolidated programme of policy development to leverage the potential of clusters in recognition of clusters’ role in facilitating innovative firms and the ambition to develop ‘world class clusters’ by the Commission.

In the Europe 2020 Strategy, cluster policy was identified as one of the horizontal policy approaches that could support ‘industrial competitiveness and innovation by bringing together resources and expertise, and promoting cooperation among businesses, public authorities and universities…’ and, together with regional and national policies, EU cluster policy was expected to ‘overcome existing market failures and funding gaps, and especially to supply the bridge between companies and research institutions' (EC 2010, p. 14). There was a shift from a national and regional policy to a more coordinated EU level policy approach for cluster development, reflecting the growing significance of clusters.

## 2.13 Cluster policy - nature and role

EU policy defines clusters as 'a group of firms, related economic actors, and institutions that are located near each other and have reached a sufficient scale to develop specialised expertise, services resources, suppliers, and skills' (European Communities, 2008, p. 10) and cluster policies as 'specific government efforts to support clusters' (p. 73). Similarly, the significance of clusters as key drivers of 'competitiveness, economic growth, productivity, innovation and employment' (European Communities, p. 21) is also captured in the following excerpts from the EU's Cluster Portal:

> *'Clusters operate together in regional markets. 38% of European jobs are based in such regional strongholds and SME participation in clusters leads to more innovation and growth.*
> *There are about 2000 statistical clusters in Europe, of which 150 are considered to be world-class in terms of employment, size, focus and specialisation.*
>
> *According to the European Cluster Excellence Scoreboard, for a number of selected emerging industries and regions in the period 2010-2013, 33.3 % of firms in clusters showed employment growth superior to 10%, as opposed to only 18.2% of firms outside clusters.*
>
> *The Commission Communication For a European Industrial Renaissance (COM (2014) 14) highlighted clusters as being able to facilitate cross-sectoral and cross-border collaboration, helping SMEs to grow and internationalise.' (EU Cluster Portal)*

Clusters therefore held promise of enhanced innovation and growth when they excelled as 'world-class' and were successful in supporting cross-sectoral and cross-border collaborations, often in emerging industries. However, the European Commission acknowledged the difficulty of designing and implementing effective cluster policy due to challenges faced in finding a good 'policy mix' and in dealing with the different framework conditions present in different regions, the lack of advanced evaluation measures and tools, and the need to align and integrate priorities of different funding sources present with the need to improve sustainable economic performance of the region (EC, 2013).

## 2.14 Cluster policy strategies

EU cluster policy focussed on three aspects, namely, 'cluster excellence', 'internationalization' and 'emerging industries'. Cluster excellence refers to the quality of clusters with 'world-class' clusters as being the gold standard. The need of firms, especially SMEs to participate in European (and global) value chains through 'cross-sectoral and cross-border collaborations' (EC, 2014, p. 18) meant that cluster policy promoted 'internationalization' of clusters and their firms. The focus on 'emerging industries' is related to Europe 2020 Strategy in which emerging industries showed a higher than average growth numbers (see Appendix 5).

The implementation of EU cluster policy included establishment of the Cluster Observatory and the European Cluster Collaboration Platform, which have been merged into the Cluster Portal. These initiatives aimed to provide benchmarking information for regions (similar to Cluster Mapping initiative in US) and to foster collaborations between businesses and clusters. The EU facilitated research projects, training activities (for cluster managers), conferences, matchmaking initiatives, etc. and these were communicated through the websites. More information on these websites is included in Appendix 5. In addition, information and interactions on EU policies and funding opportunities were spread via groups on social media platforms like LinkedIn. Interestingly, self-organized groups were also participating in such platforms on social media (also described in Appendix 5). In addition, more recent developments in EU cluster policy included formation of European strategic cluster partnerships to support joint internationalization strategies (also in Appendix 5).

An initiative of EU cluster policy is its annual conferences where new developments in policy, academia and cluster practice are discussed. At the 4th European Cluster Conference, 300 participants (national and regional policy makers, cluster managers, academics and industrial and SME participants) collectively identified challenges, issues and recommendations for cluster future through Open Space Technology methodology. This resulted in a declaration captured in the table below.

| | |
|---|---|
| Challenges of EU Cluster Policy (CP) | - **Support for practice: for transformation of existing industrial value chains; creation of new value chains in emerging cross-sectoral industries; and for 'world class cluster' developments**<br>- **Support for RIS3 developments: facilitating cross-sectoral, cross-border collaborations and synergies, and collaborations with regions with same specialization priorities**<br>- **Support for lagging regions: twinning programmes with more advanced regions** |
| CP and EU strategies | - **Provide excellent business environments aligned to Europe 2020 priorities** |
| Key focus areas | - **Bottom-up approaches to innovate value chains**<br>- **Facilitating and accessing new sources of finance**<br>- **Creating and facilitating open spaces and cross-sectoral collaborations** |
| New CP developments needed | - **Cluster internationalization through Meta-clusters and European strategic clusters**<br>- **Both top-down facilitation and bottom-up initiatives** |
| Cluster excellence | - **Training and customized support rather than general benchmarking and 'cluster label' initiatives**<br>- **Statistical measurements of job creation, innovation and turnover increases as effective measures** |

*Table 17 Key Challenges, issues and recommendations for Cluster Policy (adapted from Fourth European Cluster Conference 2014 Declaration, 2014)*

The 2014 Declaration resonated issues and challenges addressed in EU policy and strategies and recommendations focussed on expanding current cluster policy thinking. These included enlarging the scope of clusters to support RIS3 developments and making new connections with different regions including lagging regions, with bottom-up approaches, with new financial sources, with new perceptions like 'meta-clusters' and 'European strategic clusters' and with a focus on competence building as policy intervention instead of only benchmarking. The declaration also embraced current policy thinking focussed on creating new value chains crossing sectors and borders, improving business environments and creating 'world-class clusters'. The move away from more traditional notions of place-based, sector-based clusters focussed on local network linkages was emphasized. EU cluster policy was in evolution in an attempt to keep pace with the changing context of clusters.

## *2.15 Summary and discussion of EU Cluster Policy*

Extant EU Cluster Policy emphasises

- Creating 'world class clusters' and cluster excellence
- Cluster internationalization for firms and clusters

- Emerging industries for new growth areas
- RIS3 priorities, opportunities for collaborations, development of niche markets and supporting RIS3 developments
- Providing information, mapping, tools and analysis of EU clusters (through the European Cluster Observatory)

Also, the official website, The Cluster Portal, provides information, tools and web links for EU policy and related areas, including those mentioned above.

The description of EU Cluster Policy showed how clusters have grown from a regional and national policy instrument to one that is coordinated and facilitated by the Commission and its agencies. The significance of clusters is not disputed but policy implementation (at the local and EU levels) and optimizing cluster performance is. In the 2014 EU Cluster conference declaration, concern for lagging regions was signalled due to neglect or absence of developments in these regions and in EU cluster policy. The discussion on the significance of lagging regions for cluster policy reflected that issues such as critical mass, fragmentation, out-dated industrial and knowledge bases, diversity of values and interests at all levels, etc. converged in lagging regions and posed multiple challenges in implementing and re-generating regional growth (Conference discussions, 4th European Cluster Conference). The challenge remained for EU cluster policy to cater for different types of cluster developments and the need to develop policy instruments that provide insights into context-specificities and support interventions.

The next section describes cluster context and trends, and selected models and approaches supportive of cluster practice and related policy.

## *2.16 EU Policy Trends*

### 2.16.1 Policy perspectives

The roadmap from the European Forum for Clusters in Emerging Industries (EFCEI, 2013) provides insights into developments in cluster practice as input for policy. It identified challenges facing EU clusters and most importantly indicated that 'old growth paths' like investments in knowledge were not sufficient and that new thinking and solutions were needed. A key recommendation was supporting development of 'emerging industries' whereby 'new industrial value chain' where deemed necessary which included the need for 'radical reconfiguration of existing one' whereby 'disruptive' ideas or 'convergence of ideas' were seen to be the purveying higher value added products and services (p. 4). Their main criticism of existing policy was that existing framework conditions were sectoral and fragmented and hampered new developments for new value chains and transforming existing ones. They indicated that clusters could play an important role in support of emerging industries and economic transformations, and that interaction between sophisticated demand, cross-cutting technologies and service innovation and innovation processes were needed to create new industrial pathways (diagram below).

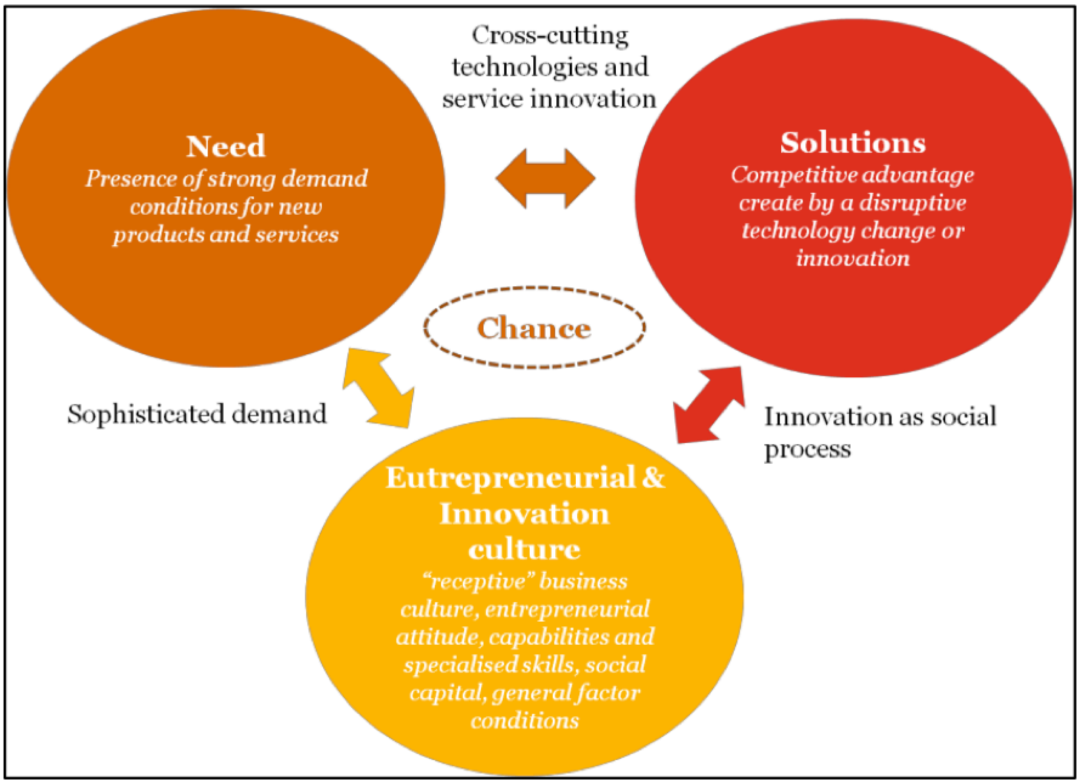



*Figure 9 Key drivers behind emerging industries (EFCEI, 2013, p. 11)*

Issue-driven value chains that leverage innovative capacities from different industries and knowledge bases are deemed important foci for cluster policy.

Hence new competences and framework conditions were needed with policy being alert to shifts in value chains. There was a plea to move towards cross-sectoral cluster initiatives focussed on 'thematic strategy, market or concept' (EFCEI, 2013, p. 16) with government facilitating new value chain creation, new skills developments including entrepreneurial skills, internationalization and future-oriented strategies.

Clusters in turn needed to deal with more complex and broader scope of activities to support new value chain creations.

In order to explore alignment of cluster policy implementation to that of practice, the EU commissioned study, *'Where the cluster winds are blowing in Europe?'* (Tactics, 2012). The table below captures the key findings.

| | |
|---|---|
| Evolution of cluster concept as policy tool | - More focus on clusters' relation to innovation<br>- A broadened view of the drivers of innovation<br>- A changed logic and scope of cluster initiatives |
| Enhancement of innovation processes through clusters | - Inclusion of various innovators, including users<br>- Internationalisation of cluster initiatives and cluster branding<br>- Cross-cluster/cross-sectoral cooperation as a way to increase innovation capacity |
| Implementation and integration of cluster-related policies | - Smart Specialisation – balancing support to existing and emerging clusters<br>- Funding of cluster initiatives<br>- Coordination across policy levels<br>- Integration across policy areas |
| Strengthening cluster effectinitiatives | - Increased participation of SMEs<br>- Strengthening the knowledge dimension – increased collaboration science and cluster initiatives<br>- Skills supply – attraction of talent and skills' development<br>- Use of design skills as a driver for innovation<br>- Service innovation as a way to strengthen innovation capacity in clusters<br>- More professional management and process support<br>- Focus on performance |

*Table 18 Trends in the use of clusters as a policy tool (Tactics, 2012, pp. 11-19)*

In EU 2020 strategies resolution of 'grand social challenges' was a key focus. In cluster policy a focus on new value chain creations, cross-sectoral developments, internationalization and emerging industries is present reflecting alignment to the Roadmap recommendations. However, the resolution of 'grand social challenges' is not explicit.

This section looked at policy perspectives on cluster developments and in the use of cluster policies to understand trends in cluster practice. More details on EU Cluster Policy, developments and context are given in Appendix 5. The next section looks at cluster models and approaches supporting policy development.

## 2.17 Cluster Approaches

This section explores models, frameworks and approaches that are relevant to cluster and policy developments. The selection reflects studies exploring interconnected systems developments related to clusters and economic transitions to understand existing tools available for study of interconnected systems developments in clusters.

### 2.17.1 The Principal Dynamic Loops – Scottish enterprise

The Scottish Enterprise developed a cluster model using a systems approach and it illustrates key feedback loops in cluster systems. The feedback loops included processes of inter-firm co-operation and rivalry, responses to external influences such as global competition and markets, common collaboration incentives and threats, influence of the cultural contexts, attractiveness of capital and investments in knowledge. The systemic analysis is shown below.

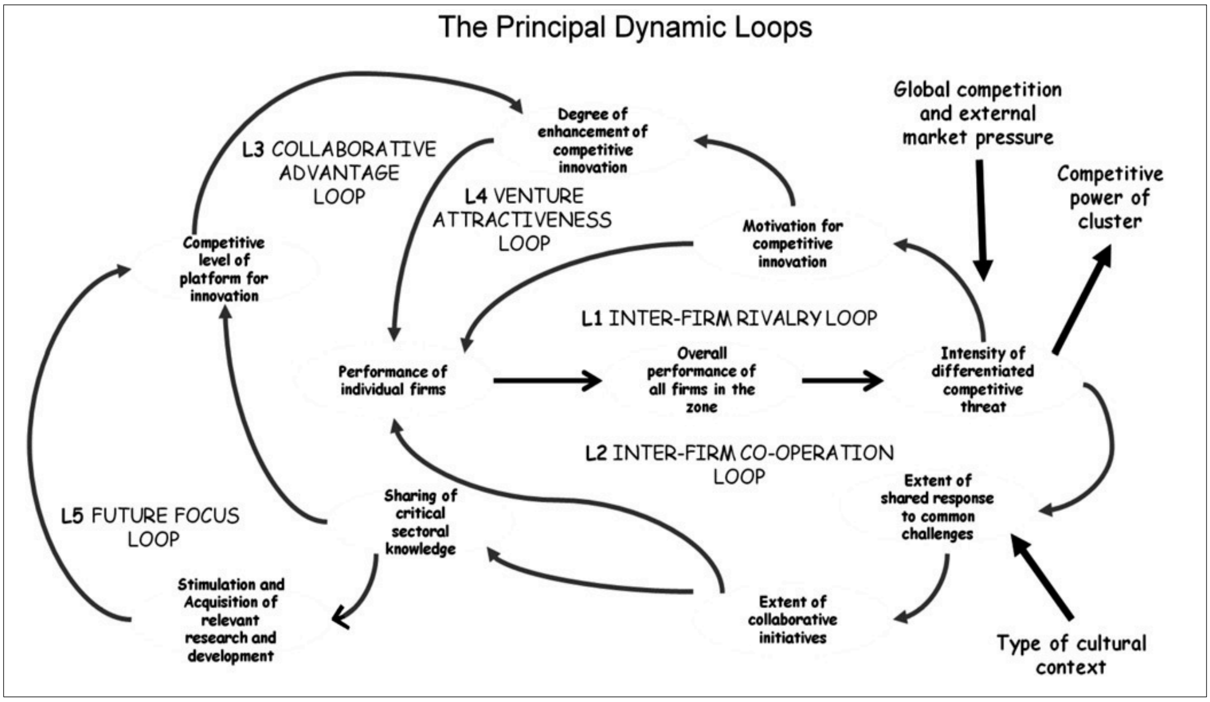


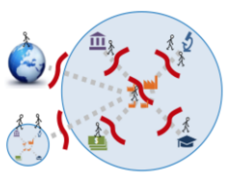

*Figure 10 Principal dynamic loops from the Scottish Enterprise (in Smith and Brown, 2009, p. 290)*

This model captures interconnections of clusters and the external and internal factors affecting cluster dynamics. The mapping captures cluster dynamics based on centrality of firms and their interactions and takes into account contextual factors. The systems approach illustrates its ability to capture dynamic interactions in clusters.

### 2.17.2 Building the Cluster Commons

The EU Cluster Observatory acknowledged the seven innovation gaps faced by firms and the role of clusters to bridge these gaps through the notion of *Building the Cluster Commons* (Sölvell & Williams, 2013). Potential 'gaps' or weak interactions in clusters include triple-helix linkages between firms, academia and policy but in the 'commons' they are extended to include linkages between firms and educational and financial institutions, inter-firm linkages, inter-cluster linkages and linkages to global markets.

The diagram below shows various stages of building the cluster commons whereby a dynamic cluster with strong interactions is seen as a successful cluster. Details of the seven gaps and distinctions of weak and strong interactions are also identified in this approach.

| 1. Dynamic cluster with intense interaction across actors | 2. Cluster with innovation gaps | 3. Clusters bridging innovation gaps |
|---|---|---|
|  |  |  |

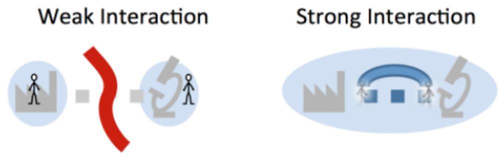
| 7 'Gaps' often prevalent in clusters | Weak and strong linkages in diagrams |
|---|---|
| 1. **The research gap barring interaction between firms and research organizations**<br>2. **The education gap barring interaction between firms and education organizations**<br>3. **The capital gap barring interaction between firms and education organizations**<br>4. **The government gap barring interaction between firms and public bodies**<br>5. **The firm-to-firm gap barring interaction among firms in the cluster**<br>6. **The cross-cluster gap barring interaction with firms in other clusters**<br>7. **The global market gap barring interaction with global markets** | <br>Poor knowledge<br>Weak networks<br>Different "languages"<br>Different norms and attitudes<br>Different vision<br>Low trust<br>Negative incentives to collborate<br><br>Good knowledge<br>Dense networks<br>Common "language"<br>Similar norms and attitudes<br>Shared vision<br>High trust<br>Positive incentives to collborate |

*Figure 11 Dynamic Clusters Commons (own tabulation based on C, Sölvell & Williams, 2013; author presentations; Ketels et al, 2012)*

'The commons' focusses on interactions and linkages beyond traditional notions of clusters (financial institutions, educational institutions, global markets and inter-cluster) and therefore reflects shifts in cluster practice. This approach is also focussed on supporting policy interventions. EU cluster policy emphasis on 'world-class' clusters, cross-cluster and international linkages are reflected in this approach. Centrality of businesses and clusters is also prominent in this 'model' in supporting policy actions even as it resonates innovation systems approaches with its focus on linkages and systems archetypes in building the 'commons'.

### 2.17.3 The NRC cluster framework

National Research Council (NRC) of Canada commissioned the development of a model to allow policy to support successful cluster developments. The framework was built on Porter's work and empirical research on Canadian clusters carried out by the Innovation Systems Research Networks (ISRN), which was extensive covering twenty-six clusters. In order to support technology based cluster initiatives and development, NRC designed the NRC cluster framework that had six constructs and thirty-four indicators that included quantitative firm-based surveys and qualitative interviews and sessions with stakeholders and experts. The expert and stakeholder inputs validated outputs of the quantitative data and added insights into qualitative developments. They also distinguished four stages in cluster developments, namely, latent, developing, established and transformational to acknowledge life cycle of clusters. The literature review discussed this study (sub-section 2.5.2). It is also included here as one of the models supporting cluster practice. The NRC cluster framework is shown here.

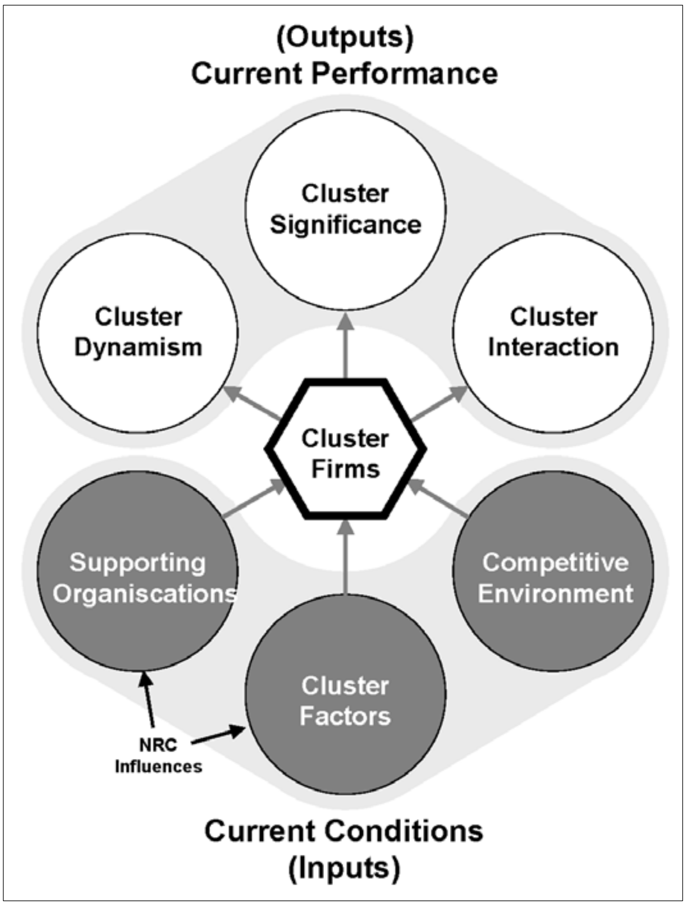



*Figure 12 NRC cluster framework (Arthurs et al, 2009, p. 269)*

The NRC framework distinguishes 'current conditions' as 'inputs' and 'current performance' as 'outputs'. These in turn are divided into indicators describing cluster characteristics and its environment. The approach held firms central to cluster conditions and acknowledged the systemic and evolutionary nature of cluster developments: 'current conditions impact future performance, and current performance is the result of past conditions' (Arthurs *et al*, 2009, p. 269).

Key lessons from the study are highlighted in the table below for cluster study and policy developments.

| | |
|---|---|
| Developing cluster framework and indicators | - Interactions between theory and practice essential<br>- Development of framework interactions enhances policy and management practice<br>- Understanding of innovation pathways and cluster dynamics improves policy interventions |
| Clusters indicators and policy | - Supports social knowledge management in cluster environment<br>- Supports governance processes and mechanisms |
| | - Accurate indicators needed for all clusters; support from senior policy makers needed |

*Table 19 Lessons from NRC Canadian cluster research (adapted from Arthurs et al, 2009)*

The NRC framework captures cluster developments that extend to social capital and contextual factors, and demonstrate the significance of non-local interactions. The cluster framework offers insights into different aspects of cluster developments and is relatively comprehensive in its scope but limitations lie in the centrality of firms and exclusion of broader developments, which limits its ability to explain complex systems developments.

### 2.17.4 Triple-helix triangulation 'model'

Cluster developments focus on 'triple-helix' linkages and the triangulated triple-helix was already discussed in the literature review (section 2.5.1) but is included here as one of the cluster practice supportive models.

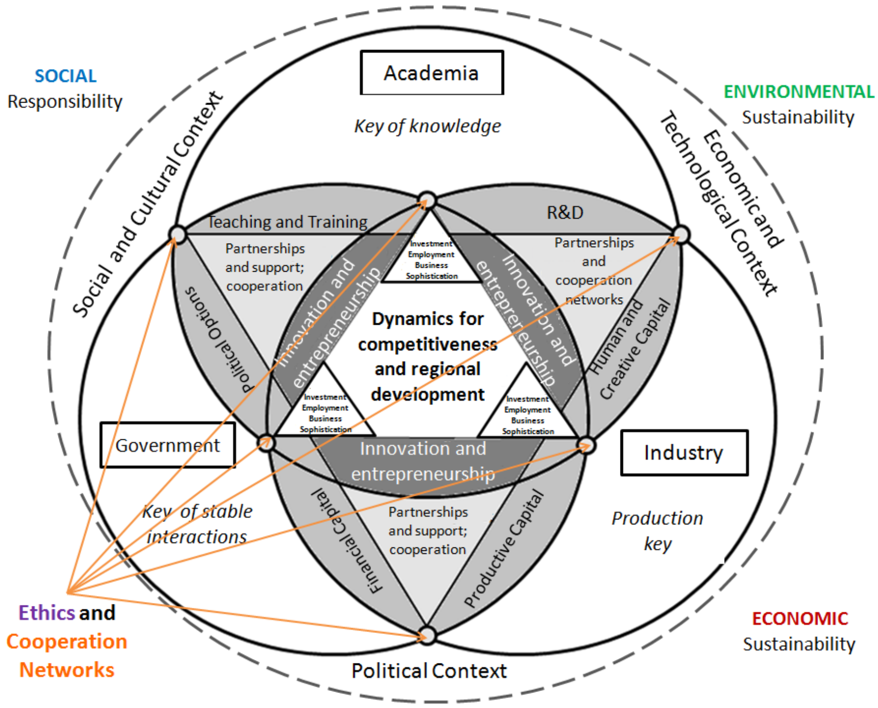



*Figure 13 Triangulating the Triple-Helix (Farinha & Ferreira, 2013, p. 20)*

The illustration shows that interaction between academia-industry-government in facilitating innovative and competitive capacities and resources are subject to ethical norms and behaviour of cooperation networks. The overarching governance practices impact in turn social accountability and environmental and economic sustainability. Triple-helix linkages, at the core of cluster approaches, were broadened to include contextual dynamics and constraints. This meant that competitiveness and regional developments needed to be understood as being part of ecosystems. This approach emphasized the interconnectedness of systems and the significance of 'ecosystems' thinking in regional and cluster developments. Focus on local interconnectedness and that from an institutional perspective meant that the extend triple-helix model brings the local complexity into to the forefront but how the interconnectedness evolves and how global developments and interactions influence the local dynamics have not been explicitly addressed.

#### 2.17.5 Associative governance in cluster practice

Cluster governance and practice exposes gaps in policy development and implementation from an 'associative governance' perspective. The assigned roles of government and cluster stakeholders support or deter such practice. This perspective sheds light on the significance of personal and collaborative cluster practices based on Dutch clusters. The associative governance perspective and key lessons from the report *Cluster Governance, Lessen voor clusters in Nederland* (Ebbekink *el al*, 2015) have been translated and summarized in the following tables.

| | **'Associative governance'** | **The practice** |
|---|---|---|
| Cluster policy | Sum of individual and collective policy actions of all cluster stakeholders – co-creation | Policy actions of government combined with organized cluster input – consultancy |
| Ownership/accountability | Everyone – public, private, all levels | Not specified |
| Policy development | Ramified co-evolutionary process in continuous development | Centrally led and programme design – policy circle model |
| Policy review | Collective learning throughout | Based on evaluations |
| Role of government | Partner | Facilitator |

*Table 20 Cluster Policy development based on associative governance principles (translated, Ebbekink et al, 2015, p. 20)*

The following table contains ‘seven lessons’ as key aspects of cluster developments aimed at Dutch policy makers.

| | |
|---|---|
| ‘Civic entrepreneurs’ | Recognized, accepted, with influence, collective leadership |
| Personal proximity and (non-) ‘clicks’ | Impact of proximity and social processes |
| Cluster identity | Alliance formation – personal motivations, shared identity and goals |
| Strategic intelligence | Personal radar, market trends, local buzz and global pipelines, etc. |
| Institutional entrepreneurship | Institutional playing field as dynamic anchors, subject to tinkering, moulding, system changes (by collective/civic entrepreneurs) |
| Policy leverages | Eco-system facilitation – conducive start-up climate, short and long-term regulation/administration and public procurement measures, R&I subsidies |
| Strategic connections | Focus on knowledge exchanges – within niche specializations connecting globally and in global value chains, transparent and shared strategies, cluster branding, |

*Table 21 Key aspects of Clusters (adapted from Ebbekink et al, 2015)*

The associative governance perspective used by the Dutch Research group resonate findings from the Canadian study and NRC framework that was reviewed in sub-sections 2.5.2 and 2.19.3 respectively, in particular, the role of civic leaders and civil society.

The associative governance, role of civic society and eco-systems also resonated the research’s choice of developing whole systems approach and extending the scope of cluster developments. The associative governance approach offered insights into more complex cluster development processes and the principles of associative governance signposted the relevant developments often ‘hidden’ or not recognized as relevant in traditional cluster analyses. It seemed unlikely that the principles of associative governance were sufficient to support complex cluster developments, although they added valuable insights and aspects to cluster study.

### 2.17.6 Transition Management Model

This model was developed by Dutch scholars and is the Transition Management model:

> *‘Transition Management (TM) aims to deal with persistent societal problems by exploring and furthering more sustainable systems. It is an innovative governance concept based on complexity theory, social theories and insights from the field of governance. TM is a process-oriented and participatory steering philosophy that enables social learning through iterations between collective problem structuring,*

*vision development, coalition building, experimenting and monitoring.' (Website Drift)*

The reiterative learning process is captured in their model below:

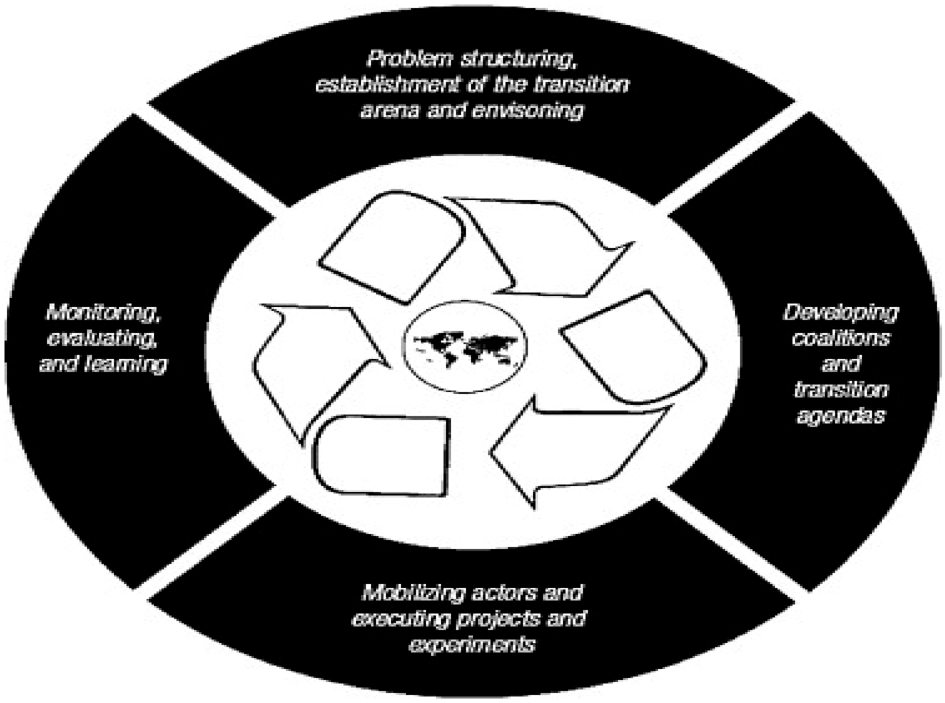



*Figure 14 The Transition Model (Transition Management, website Drift)*

Transition management approaches were discussed in the review of EEG and RIS studies as these latter studies also built on transition management perspectives. The transition model supports policy development and includes co-evolutionary developments addressing social and economic transitions. The approach overlaps that of the research in its focus on transitions as part of local economic developments and the interconnectedness of these processes. However, the transition management model being a broad process-oriented policy instrument translated complexity approaches into a plan-check-do-evaluate model common to policy instruments. Potential interventions in systems developments have not been made visible or explicit due to the choice of the transition management as a 'governance concept' that supported 'participatory steering' and learning at its core. However, transition management theories are relatively new and evolving (see sub-section 2.6.3) and are not specific to cluster developments.

### 2.17.7 Complex Adaptive Innovation Systems Model

The need for policies that support 'transversality' and leverage 'related variety' in terms of the 'adjacent possible' form the basis of Cooke's (2012) model of Complex Adaptive Innovation Systems (CAIS). He addressed path-interdependencies through the example of intersecting path dependencies of the elderly healthcare and housing pathways resulting in a new provision of services and design of elderly housing and health care based on a case study from Cardiff University's Centre for Advanced Studies (2012, pp. 229-231). The landscape of complex adaptive systems, based on Kaufman's fitness landscape, was used in the example and served as a model for extending insights into regional systems developments as shown below.

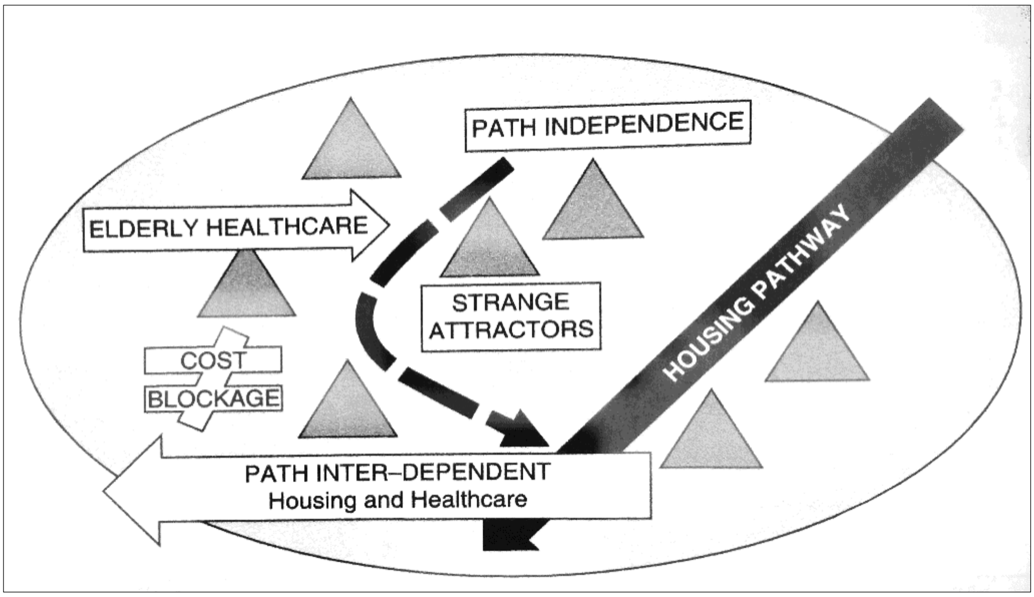



*Figure 15 Path interdependence in societal innovation - system optimisation in health care (Cooke, 2013, p. 110; also Cooke, 2013, p. 229)*

In addition, Cooke (2012, 2013) uses Stacey's Matrix to explain how policy design needs to be appropriate to the types of challenges faced. Problems and challenges with high degree of disagreements and uncertainties found in the zone closest to the edge of chaos (6) needed policies that explore and describe system patterns, as these are often complex systems. Other zones with lesser degrees of disagreement and uncertainty need policy to either direct and, or convene and intervene as these types of problems are relatively simple to address (see sub-section 2.8.1).

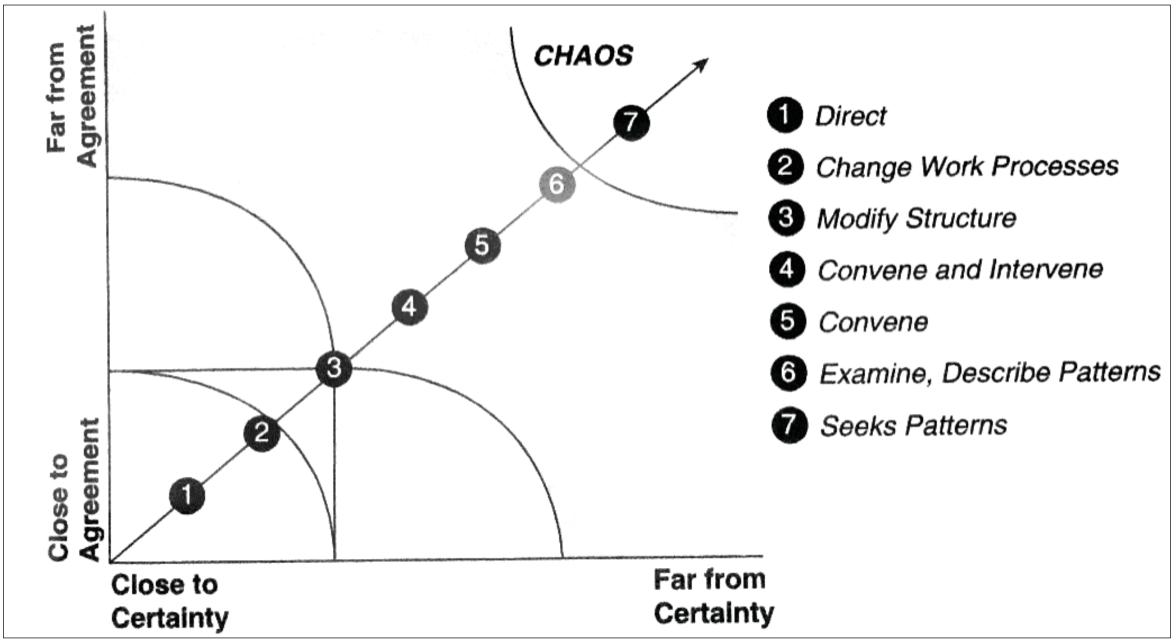



*Figure 16 Policy design using the Stacey Matrix (Cooke, 2013, p. 109; also, Cooke, 2012, p. 228)*

The CAIS model by Cooke served to confirm the value of Complex Adaptive Systems approach in understanding regional and cluster developments, and served to affirm the direction and developments of the research undertaken, including its conceptual model. CAIS offered a translation of CAS to regional innovation systems at a higher level of analysis resonating RIS approaches. The institutional and sectoral levels are in the foreground even as firms are central to the RIS approach (see section 2.5). Policy interventions at the systems development levels are described but operationalization is limited to general policy directions.

### 2.17.8 The systems innovator

Systems are part of modern life and Leadbeater contends that 'systems innovation will become the most important focus for companies and government, cities and entire societies' (Leadbeater, 2013, p. 28). Leadbeater explains how systems are focussed on achieving 'a purpose' through collaboration and how orchestration is necessary:

> *'Systems innovation is a highly–collaborative endeavour. It involves bringing together many actors to make complementary investments. Orchestrating this is necessarily a highly–political process to determine how revenues and risks are shared between different players in the system, how standards are established and who controls knowledge and intellectual property.' (Leadbeater, 2013, p. 36)*

The 'New Rules of Innovation' in the table below offers insights into supporting systems innovations.

| | |
|---|---|
| **Innovation and systems** | – Supporting and enabling systems crucial – great product alone is no guarantee of success |
| **Systems approaches** | – Different systems need different approaches |
| **Systems innovation** | – Systems innovation needs<br>- Alliances as co-innovators of systems<br>- Needs behaviour change - new consumer behaviours, etc.<br>- A mix of leadership styles – more interactive and distributed leadership<br>- Right timing is vital |
| **Value creation** | – No value will be created unless shared – social contracts, economic and technical |
| **Interventions in systems** | – Intervene at the right point (from Donella Meadows)<br>- Parameters of a system (buffers and stock as critical parameters)<br>- Physical features (difficult to change but does not deal with behaviour change)<br>- Information flows (feedback loops can affect behaviour but limited)<br>- Rules and goals of governance (potential impact is huge)<br>- Framework and purpose (most impact on behaviour) |
| **New and old systems** | – New systems develop out of old systems<br>- All new systems incorporate parts of old systems<br>- Learning to leapfrog instead of reforming old systems |

*Table 22 New Rules of Innovation (adapted, Leadbeater, 2013, pp. 49-53)*

The new rules of innovation and systems innovator approach emphasized the need to innovate whole systems and to understand the interconnected nature of complex systems developments. This approach supported the research in its choice of 'whole systems' approach for clusters.

## *2.18 Summary of Part 2*

This part of the chapter reviewed European Strategies, EU cluster policy, and cluster approaches. The first three aspects gave insights into EU policies and therefore the policy context of cluster developments. The fourth aspect provided insights into cluster approaches that supported understanding systemic developments and acknowledged the complexity of clusters due to contextual interconnectedness.

The goals and perspectives of EU policy were important as the research intended to support cluster policy implementation. In addition, reviewing existing cluster approaches helped understand developments in cluster study. The selected approaches revealed features that included systems thinking focus on innovation and contextual factors, governance issues and social processes and transitions. Furthermore, CAIS model demonstrates how CAS approach is relevant to understanding regional innovation systems development. The need to focus on 'grand social challenges', acknowledgement of various aspects being relevant, such as history, stakeholders interactions, governance, context, etc., and the significance of systemic interconnectedness were made explicit. The necessity of systems innovation and a whole systems approach for understanding complexity of social and economic developments were evident. The approaches reviewed addressed one or more of these aspects or offered higher-level perspectives that made operationalizing policy interventions difficult or unclear. The direction of cluster approaches and policy developments reflected the need for more systemic and broader scopes.

Part 3 offers a summary of the chapter and implications for the research.

## *2.19 Part 3: Summary of literature review and implications*

Part 1 of the chapter, the literature review on theory discussed how agglomeration literature was diverse and emerging, but that there was consensus on the value of spatial agglomerations. There was also consensus on the need for more integrated approaches that could study regions and clusters in their interconnected developments. Complex Adaptive Systems approaches were reviewed and deemed to be a 'holistic and realistic' meta theory of change able to support understanding of complex systems in which 'neural-like networks of interacting, interdependent agents' were united to achieve common goals through collaborations (Uhl-Bien *et al*, 2007, p. 299). CAS offered a 'lens' to uncover underlying patterns of order in otherwise 'messy' or 'wicked' phenomena. CAS connected micro dynamics to emergent macro-level systems developments and recognized interconnectedness of contextual and embedded systems developments. CAS therefore offered whole systems approaches that could enhance cluster theory.

Part 2 of the chapter reviewed EU policy and cluster approaches. EU strategies emphasized the need for integrating policy initiatives to deal with 'grand social challenges' and structural economic weaknesses. EU cluster policy focussed on excellence, internationalization and emerging industries through EU coordinated cluster support. However, it was seen that cluster policy was focussed on innovation and economic developments rather than dealing with 'grand social developments' and societal transitions. The review of cluster approaches supporting policy implementation offered understanding of systemic and complexity aspects but were limited to specific aspects or were of a higher level making policy interventions difficult. Therefore, there was a need for comprehensive approaches in cluster study that was suitable for clusters of diverse nature but transferable into actionable policy interventions. The cluster approaches contributed and validated choices made in the research and in turn, the research could contribute to furthering these developments.

The review of cluster literature, policy and cluster approaches highlighted the gaps and issues present in understanding and supporting cluster developments in its changing context. The key features in EU policy, RIS and EEG disciplines, and CAS, the focus of their intervention strategies and gaps and issues in cluster developments are captured in the diagram below. Similarly, key features and interventions of CAS are included with a question mark to indicate a possible contribution to meet gaps and issues of cluster study and practice. The research sets out to explore complex adaptive systems developments of clusters and the contribution of CAS towards this end in order to support both cluster study and policy developments.

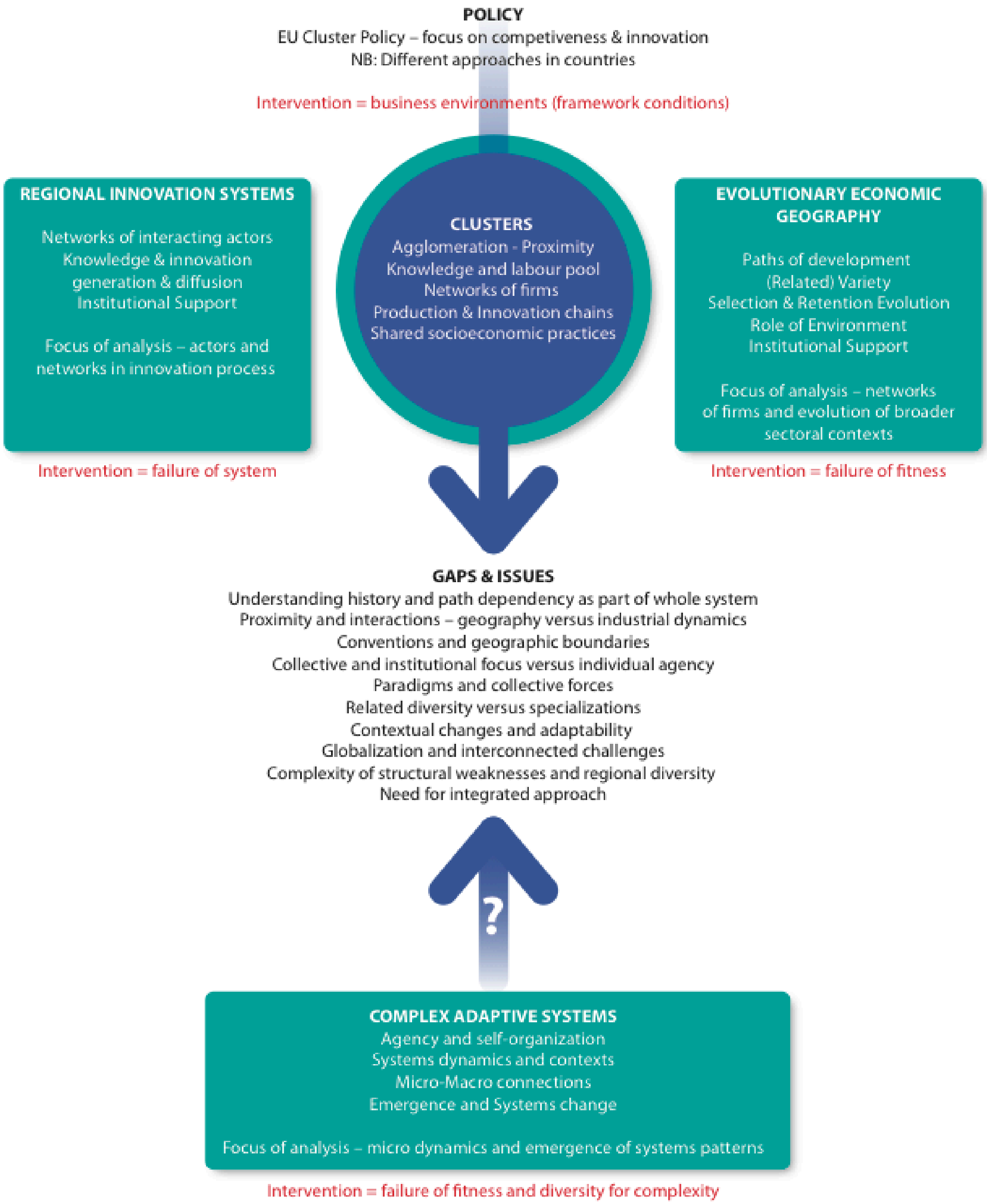



*Figure 17 Overview of cluster literature, EU policy and cluster approaches and gaps in cluster developments*

Strategy development and implementation of cluster policy in diverse and complex landscapes of the EU meant that sound, holistic approaches with cluster specific insights drawn from local knowledge of unique factors and agent behaviours embedded in local contexts were needed. In addition, insights into interconnected contextual factors driving change and multi-level interactions and governance practice as systems developments stemming from diversity of stakeholders, interests, capabilities, resources, etc. were also essential. CAS offered robust whole systems approaches for application in interface studies including cluster study albeit in its infancy. This research builds on these emergent developments to design a comprehensive CAS approach to gain deeper insights into cluster developments faced with complex challenges.

In conclusion, the research intends to address the gaps and issues identified above in the illustration by developing a CAS approach for cluster study.

# 3 Methodology

## 3.1 Introduction

This chapter has 2 parts. Part 1 describes the research method and methodological issues related to the choices made in setting up the research. Mode 2-type research that frames the study is explained, followed by reiterating the purpose of the research. The philosophical position underlining the research including that of CAS approaches are addressed Afterwards, the research strategy and methodological issues related to the chosen case study strategy are described. The research design with details of the field study and ethical issues are also addressed. Finally, data analyses justifications and linkages between the empirical study and research sub-questions are provided.

Part 2 describes the research and includes scope, process (including development of CAS framework), design and implementation details.

## 3.2 Part 1 Research Methodology

## 3.3 Mode 2 type research

In the previous chapter, the complexity of EU clusters policy implementation and limitations of extant cluster literature to understand and support clusters were addressed. The complexity of clusters and the need in policy to deal with this was the starting point of the research in the tradition of Mode 2-type research (MacLean *et al*, 2002).

Development of a cluster approach supporting complexity in clusters and policy implementations and gaining insights from a close study of complex cluster developments would in addition contribute to theoretical discourses on clusters.

The European Union's cluster policy initiative, in its effort to strengthen European competitiveness due to global competition and structural weaknesses (Appendix 5) was therefore the impetus for the study. More details follow in the next section.

## 3.4 Purpose of the study

The research aimed to explore how clusters developed in the rapidly changing economic and social contexts in which they operated and to draw lessons for policy, particularly, EU's cluster policy. Increasing complexity of clusters was addressed in cluster theory and complexity approaches and was acknowledged as being valuable for studying such phenomena. The research therefore intends to develop a complex adaptive systems (CAS) approach to explore cluster developments in their changing contexts. This includes examining micro-level stakeholder perceptions and behaviours and how these connect to cluster systems developments. The implication of using CAS approaches for the chosen research strategy and design, including qualitative research methodology are discussed in more detail below.

The need for an exploratory orientation was underpinned by the limited empirical evidence and theoretical developments on cluster theory based on complexity approaches for a whole systems approach as described in the earlier chapter on literature. Eisenhardt (1989) found exploratory case studies 'well suited to new research areas or research areas for which existing theory seems inadequate' and 'when a fresh perspective is needed' (pp. 548-549). Additionally, the exploratory case study allows for in-depth and flexible investigation with multiple data inputs. The nature of the research required such a flexible and in-depth approach to uncover the underlying, deeper aspects of cluster dynamics and to capture the diversity of agent interactions in clusters.

The research therefore intended to support emergent theory on cluster dynamics in complex contexts by providing insights from practice. Complexity approach informed by selected cluster theories would underpin the research.

The following section explains firstly the underlying philosophical assumptions framing the research, and secondly, what factors were considered in the research strategy, design and implementation.

## *3.5 Underlying philosophy of research*

The research had chosen complexity approaches and specifically CAS. Therefore, the first part of the chapter explains assumptions made about 'reality' and knowledge development in these areas of study.

> *'Complexity thinking is about limits and, specifically, about limits to what we can know about our organizations and the environment in which they operate.' (Richardson, 2011, p. 366)*

*'The new vision afforded by the development of complexity science forces us to confront the idea that managerial and organizational knowledge pertaining to actions and policies in evolved - and evolving - social systems is necessarily limited and incomplete instead of being based on objective truth about eternal natural laws governing unchanging systems. We may be able to describe and analyse organizational dynamics within natural and social systems, but this description will have to reflect the facts that part of the experience of any agent is the interaction with others and that these agents will in general have different perspectives and views on reality.' (Maguire et al, 2011, p. 2)*

The two quotations above reflect the nature of 'complexity thinking' with an emphasis on limits to knowing, the nature of agency, interactions and pluralism in emerging systems and therefore limitations to knowledge of social systems.

Relativism and interpretive aspects of knowing as described above formed the basis of this research. Although the quotations above refer to organizations, the underlying assumption in complexity approaches was the 'agent-based model-centred epistemology' (McKelvey, 2011). The socially embedded nature of systems meant that meaning was subjective and that agents in the system created meanings through their interactions. Agents were key to 'knowing' the system and differences in perceptions of different agents were part of the meaning creation process. Interactionism contributing to non-linear dynamics is characteristic of complex adaptive systems. Nevertheless, even as pathways were not predictable, potential developmental pathways could be captured. Ciliers (2011) reinforced the notion that complexity cannot be known completely and that interpretation and judgement were part of any attempt to study complex systems, which in turn, demanded reflexive and critical attitudes. He stressed the need to understand the temporal and spatial aspects of knowledge of complex phenomenon.

The research embraced the limitations to knowledge, the role of agents in creating meaning in interactions, the changing spatial and temporal meanings that reflected the nature of complex systems and their structures that are constantly transforming. The research therefore assumed that investigation into complex cluster developments could reveal plausible patterns of developments through convergence and mapping of stakeholder perspectives. The research expected that the findings could be 'messy' and partial but that insights into cluster developments would be useful even with these limitations. The research intended to develop a framework that would help capture insights through systematic mapping of cluster development aspects using stakeholder inputs based on an in-depth exploration of clusters through a single case study, with supplementary cases to enhance the findings.

Another philosophical aspect relevant to CAS was explained by Ramalingam *et al* (2008) who indicated that complexity approaches appealed to pragmatists who were intent on exploring its relevance to social systems and organizations in the search of practical benefits. The pragmatic stance was described as one that accepted the 'work in progress' nature of complexity theories' developments in its application to social sciences and other human based systems. The value of complexity was seen to lie at a meta-level where complexity approaches offered a way of looking at reality, a 'lens' that helped to understand how things were being viewed, 'new ways to think about problems and new questions that should be posed and answered, rather than specific concrete steps that should be taken as a result' (p. 65). The approach of complexity anchored phenomena in context and highlighted the interconnectedness of phenomena. This interconnectedness of things and systems demanded a different approach to knowing. The research therefore embraced a pragmatic position and acknowledged the need for deepening theoretical developments in cluster research in order to capture interconnections and systemic developments.

Differences in underlying assumptions about systems between complexity and first and second order systems theory were present. One such difference was that the latter assumed rule based developments of systems and existence of clear delineation of system boundaries (Heylighen *et al*, 2007). Complex systems as applied to social systems (non natural systems) assumed interconnectedness of agents, systems and boundaries between system and environment and that these were not clearly defined as opposed to natural systems (first and second order systems theory). The notion of intentionality of agents in systems that was at the core of complex adaptive systems, 'multi-agent based systems' (Holland, 1996), meant that agents in the system responded to environmental changes in order to increase their 'fitness' based on limited perceptions of the immediate environment (and other agents). And that co-evolution through agent interactions led to adaptation of the larger system. The non-linear development of systems due to this notion of multi-agency interactions described as self-organization processes in complex systems underlined the philosophical position that no pre-determined order nor rational, linear developments were inherent. Intrinsic uncertainty and emergence were thus assumptions of complex adaptive systems.

Related to the notion of emergence and non-linearity, is the notion of systems in systems, or 'supersystems' (Heylighen *et al*, 2007). Heylighen *et al* explained the existence of hierarchy of systems that are interconnected and interacting to emerge as complex adaptive supersystems indicated that the nature of complexity whether explored locally or as part of larger supersystems remained the same, that of non-linearity, adaptation and emergence. CAS therefore embraces a broader definition of systems than the first and second-order systems theories in this respect.

Heylighen *et al* (2007) also made a distinction between 'hard' complexity sciences as represented by the Sante Fe school and 'soft' complexity sciences as applied to social sciences: the former were modernist and the latter post-modernist (p. 16). In the 'softer' version of complexity, individual perceptions and 'framing' became relevant and philosophical issues related to relativism and incomplete knowledge underlined the challenges faced by complexity approaches in social sciences. The research acknowledged these philosophical challenges are being unresolved but also acknowledged that more work and application of complexity sciences to realms beyond natural systems would add knowledge to help develop deeper insights into the nature and evolution of complex adaptive systems. The research hoped to contribute to this end indirectly as it was beyond the scope of the research to do so directly.

Important to the discussion on human intentionality was Stacey (2007) who rejected the application of natural science systems theories to human systems. He did however acknowledge the need to understand the value and contribution of complexity sciences and particularly complex adaptive systems approaches for organizational strategic management issues that grappled with complexity. He acknowledged that there were realists' positions as well as interactionists' positions within systems theory that focused on interactions and learning as part of the co-evolutionary pathways within systems. Notions of intentionality and emergence were significant to human systems as opposed to natural systems. Stacey underlined the notion of human responsiveness in systemic interactions where intentionality was an explicit part of the interactions. Systems theory assumed more rational behaviour and natural selection as the basis of emergence as described in the discussion earlier. Stacey was focused on organization level strategy approaches and the application of complexity sciences to these issues. Stacey indicated that complexity theories offered more comprehensive and coherent strategy development perspectives than traditional ones (Stacey, 1995, p. 480).

Moving on to ontologies and epistemologies directly concerned with regions and clusters, Cooke (2012) described clusters and regions as complex adaptive innovation systems building on 'relatedness and transversality' that take place in collective spaces. Cooke acknowledged that the 'lens' of complexity allowed studying changes in innovation and regional systems as emergent processes triggered by self-organization and used the metaphor of 'landscape' to describe how 'attractors' and 'strange attractors' influenced path interdependencies towards emergence and novelty. Cooke also stressed the non-predictability of path developments of systems and that any knowledge of such developments could only be *ex post*.

The 'knowing' (sensemaking) in complex adaptive systems through individual agents making sense of in response to changes in the environment is aligned to social constructionist's notion of sensemaking. Similarly, the centrality of sensemaking with its social constructionist position was adopted in the study of clusters. Stakeholder perspectives were central to 'knowing' how clusters developed.

In line with complex adaptive systems approach, the research therefore embraced relativist and social constructionist traditions, which assume that knowledge about reality was subjective and that meanings were socially constructed, and interactionists and interpretivist positions explain distributed and culminating systems developments. The interpretivist paradigm of complexity (Maguire *et* al, 2006) overlaps the relativist and social constructionists traditions. The interpretivist tradition assumes that actors and their institutions are interpretive, sensemaking systems.

Beyond the epistemological and ontological traditions of complexity sciences, the research also embraced reflexive methodologies, hermeneutical traditions, critical theories and pragmatist stands that supported investigating complex social phenomena. These approaches are described in the following four paragraphs.

Data and insight driven approaches allowed deeper search for meaning that was coupled with wider critical reflection of the social institutions and ideologies related to the research context of which the research was a part. Alvesson and Sköldberg (2009) described reflexive methodology as data, insight and critical emancipation driven. This methodology assumed the uncovering of deeper meanings of phenomena through ‘construction of empirical conditions’ rather than collection of raw data, and leaned on interpretivism to assess meaning that included a wider critical interpretation of the social context in which it takes place. Critical reflection of emancipatory issues is included in the critical theory discussion below.

The research drew on hermeneutical traditions (also critical to reflexive methodology). This tradition acknowledged that the researcher was a participant in the discovery of ‘real-world phenomenon’ through engagement, learning and acceptance of multiple viewpoints and representations that existed as postulated by Hendrickx’s as the ‘participant frame of reference’ (1999, in Van de Ven, 2007). The research chose an exploratory study that engaged hermeneutical discovery as part of the investigation on cluster development through collecting information (various viewpoints) from stakeholders and experts. The knowledge gained in the process of the research, beginning with orientation in literature and practice, followed by desk research, and finally with field research, was constantly reflected upon and built on in the successive steps. And often, earlier knowledge was revisited with new understanding and this process was on-going throughout the research.

The warning of critical theorists of the dangers of power relations impinging on the ‘purity’ of the research and the need for awareness of interests, biases and values both of the researcher and those contributing to the research as advocated by postmodernists (Van de Ven, 2007) were important inputs for the research, and reflexivity formed an important part of the research process. The research chose to include a variety of inputs and methods, also for purposes of convergence of evidence, to help increase validity of outputs. The inclusion of research literature and perspectives from different areas of study and the broad orientation to clusters as a phenomenon was part of the effort to include multiple views and potential models for analyses. Collaboration in the research was sought where possible by engaging others from practice and scholars from different backgrounds to increase multiple perspectives and analyses. The engagement of different scholars and practioners was important to the research to ensure that no ‘lock-in’ effect took

place in knowledge development whilst self-reflection and being open to feedback were important to limit researcher bias.
The research also embraced a pragmatist approach in accepting that knowledge could be useful to serve as guidance for action through better understanding of reality through models and constructs. The mode two-type research paradigm, the starting point of this research, assumed that some gap in knowledge in practice could be addressed by research and that recommendations based on such practice-oriented research could clarify and offer wisdom for action. These insights could serve policy and other stakeholders and contribute to existing knowledge. The research leaned on the principles of 'engaged scholarship', 'a participative form of research for obtaining the different perspectives of key stakeholders (researchers, users, clients, sponsors, and participants) in studying complex problems' (Van de Ven, 2007,) evident in the discourse above, in order to be aligned to practice. Input from stakeholders meant that distributed knowledge of the system informed the research, reflecting CAS' agent-based model-centred approach. Moreover, an engaged scholarship approach of including multiple perspectives offered a more robust view of reality in capturing complex social phenomena and a better grounding of the problem definition, and therefore the research design.

Another aspect of the research is the place of 'abduction' and 'plausibility' in seeking answers to anomalies. Through abduction, the creative leap in formulating a conjecture is considered the first step in creating a theory that advances a new but not yet tested explanation (Yin, 2014; Van de Ven, 2007). In creating theory about complex social phenomena, 'abduction' and the notion of 'plausibility rather than validity' were important in framing conjectures to help solve an anomaly (Weick, 1989, p. 525; Van de Ven, 2007, p. 110). The research developed a conceptual framework to gain deeper insights into cluster systems development through abduction. Study of complex systems lends itself to appreciate and conceptualize complexity with the understanding that knowledge cannot by completely captured and is 'provisional and contingent' (Maguire, 2011). The research therefore explores underlying interconnected patterns of developments rather than fixed truths about clusters and their developments. Metaphors and systems mapping are examples of conceptualizations used in the research.

This section described epistemological and ontological positions and related issues that framed the research.

The next section describes the research strategy adopted for the research.

## *3.6 Research strategy*

The research stance described above includes interpretive, sensemaking traditions and the need to uncover deeper processes and patterns of interactions and systems developments. The research strategy therefore adopted exploratory case study methods and a single case study. The rest of the section addresses these choices as well as issues of validity, generalizability, rigour and relevance.

### 3.6.1 Exploratory case study method

The research intended to seek insights into cluster dynamics and drivers of change to provide knowledge that could help policy makers and practitioners to implement cluster theory in practice. Exploring complex interaction of clusters with their environment and influence of internal interactions on the environment as whole systems needed research strategies that would provide flexibility and close-up view of context-based study. Van de Ven explained that engagement of different stakeholders and using 'arbitrage as a strategy of explaining differences by seeing interdependencies and webs of entanglements between different and divergent dimensions of a problem, its boundaries, and context' would support investigations of complex phenomena (2007, p. 15). Similarly, exploratory case study method offered the flexibility, study in context, multiple data collection and analyses that were needed (Yin, 2014).

In addition, Van de Ven discussed Weick's notion of 'thought trails' and the need for variations in these thought trails by exploring phenomena from different categories to have better understanding and eventually build better theory (Van de Ven, 2007, pp. 107-109). Engaging different stakeholders involved in cluster development from their different perspectives, exploring clusters at both the micro and macro levels and, using literature and field study and therefore reflecting past and current practice, were all attempts by this research to explore cluster dynamics and its context as a phenomenon from a variety of perspectives. This included the understanding that paradoxes, uncertainty and shifting realities were part of the nature of clusters and their natural landscapes in the spirit of abductive investigation. An extended exploratory case study in this case serves as a 'revelatory case study' in that theoretical inference and construct validity are sought. A detailed case study also helps ground development of theory.

The research therefore chose an exploratory, revelatory single case study to allow deeper investigations and illustration of cluster development in its context. Such a case study also allowed closer examination of systems dynamics at different levels, and the different agents, and their perceptions and responses of changes in the environment as part of developing a CAS approach for cluster study. The selection and justification of the main case study is described in the next sub-section.

### 3.6.2 Single case study – choice and methodological issues

The research pioneered in capturing whole systems developments in clusters through CAS approach in the case study of Energy Valley cluster. It also embraced the inherent flexibility of exploratory case study methods and determined what further analyses were needed, including additional minor case studies to validate and enhance the findings of the main case study. More details of these additional analyses and extended cases are provided in section 3.16.

The research chose Energy Valley, energy cluster of Northern Netherlands, as its main case study. Energy Valley was chosen because of the complexity of issues facing the cluster due to contextual changes, and these conditions were ideal for a revelatory case study. In addition, proximity and accessibility to the cluster were also pragmatic considerations. The next sub-section offers insights into the complexity of Energy Valley cluster. The sub-sections that follow address validity, generalizability, rigour and relevance issues related to a single case study strategy.

#### *3.6.2.1 Choice of Energy Valley case study*

Energy clusters are faced with transitions in the energy landscape, moving from fossil based energy sources and infrastructure to decentralized renewable energy sources. Energy Valley is interesting due to its scope and scale of operations (one third of the Netherlands, covering 3 ½ provinces in the northern parts of the country). It bears with it the paradox of rich gas resources and relative poverty of a lagged region. The discovery of gas and its dominance in the cluster, region and the country is typical of clusters with dominant industries or sectors.

Energy Valley cluster and region faced complex challenges that included the significant contribution of gas revenues to the Dutch economy (12% GDP in 2013), depletion of its gas resources, European liberalization and internal energy market developments, security of supply issues both at the Dutch and EU levels, climate change agenda and growth of renewable energy markets, etc. (details in Appendix 1).

In addition, Energy Valley was a peripheral region beset with regional economic growth issues, the 'lagged regions' challenges (Cluster Conference, 2014). More general changes facing all businesses and clusters, globalization, Internet, new technologies and changing business models were also part of the complexity of the Dutch energy cluster.

Energy Valley, which faced multiple challenges due to contextual changes, was a suitable candidate for the case study on complex cluster developments.

#### *3.6.2.2 Issues of validity and generalizability*

The meta-level 'lens' of complexity offered new ways of looking at existing phenomena. The main objective was re-thinking current approaches to cluster study. Whilst there had been studies on clusters using complexity sciences, a whole system approach using CAS for clusters was absent. The research initiated the developing of theory to redress this imbalance.

The single case study of Energy Valley offered scope for exploring 'big' issues related to cluster dynamics and system adaptations to its changing environments, characteristic of revelatory cases. The complexity of energy cluster may not be necessarily replicated elsewhere but the workings of such a cluster could provide useful lessons for other clusters.

The research acknowledges that complex systems are unique in their development but underlying cluster systems developments of interconnected patterns may be relevant for other clusters. Propositions based on the findings of Energy Valley will be formulated, and then verified and enhanced through supplementary cases. Hence, external validity of the findings is included through the supplementary cases. Underlying patterns of cluster developments captured in the study, guided by the initial conceptual framework, would be presented. This input could support development of a model of cluster systems developments. Using an extremely complex energy cluster to gain insights into complex cluster systems developments would warrant adequate dimensions of complexity supporting development of a CAS approach able to investigate complex cluster systems.

Transferability of insights and conceptualization of systems developments and the CAS approach to other cluster studies were the aim of the research as opposed to generalizability. The uniqueness of each cluster systems supports notions of plausibility (Van de Ven, 2007) rather than generalization. Conceptualizations of cluster systems developments contribute to emergent theories on clusters for further study (sub-section 5.5.1).

#### *3.6.2.3 Issues of relevance and rigour*

The research was led by the EU cluster policy initiatives to support competitiveness in its regions. The research intended to study cluster practice to inform cluster policy developments. The relevance of the study of cluster dynamics and developments in its changing business contexts is directly related to the desire to gain insights from practice for policy. The research intended to develop a framework to guide exploring cluster developments using CAS and this instrument could be a viable policy instrument to analyse clusters for their specific context and dynamics, and thereby support policy interventions and developments.

The rigour of the study lay in the research design, specifically dealing with data collection, data integrity, and analysis, which were guided by the case study protocol, and through reiterative processes with inputs from practice and theory. Rigour in the study, captured in systematic collection and analysis of the data and limiting bias, are addressed in more detail in the research process (section 3.14).

Research that is interpretive, subjective and partial in knowledge capture, demands rigorous norms that are in part captured in critical and reflexive attitudes. As mentioned earlier, the research was data, insight and emancipatory driven that meant that a balance between flexibility and rigour was observed through informed and critical reflection, ethical considerations and engaged scholarship.

Rigour is taken in its broadest sense due to the meta-level systems approach focussed on agent-based model-centred nature of complexity theory supporting the research that acknowledged the limits of knowing (Ciliers, 2011; McKelvey, 2011; Ramalingam *et al*, 2008).

The next section addresses the research design that includes tactical choices to ensure validity and rigour.

## 3.7 Research design

The research design describes what inputs and choices were made in realizing the research objectives. This is described in terms of inputs from theory and practice; inputs for development of the conceptual framework; field study procedures and related issues; and how data collection relates to answering the research sub-questions.

### 3.7.1 Guidance from theory and practice

The literature review on clusters supported identifying theories included more dynamic approaches to clusters and regional development. Insights from evolutionary economics and regional innovation systems approaches were chosen for their approaches to spatial and innovation systems. The review of complexity and complex adaptive systems theories in support of developing a whole systems approach for clusters included exploring applications of CAS to ecology and organizational sciences (Carbonara *et al*, 2010; Cooke, 2012; He *et al* 2011; Jones, 2011; Ramalingam *et al*, 2008). In addition, EU policy was explored to understand theoretical and practical considerations framing cluster policy. Also, consultations with energy and cluster experts and a complexity consultant and review of cluster case studies informed the research. These various inputs supported development of a conceptual framework that also guided the research in data collection, analysis and reporting. The next sub-section describes the conceptual framework and steps taken to support and justify its developments.

### 3.7.2 The conceptual framework for cluster study

The research was grounded and supported by inputs from literature to capture various aspects of cluster developments. The Canadian cluster study from NRC was particularly relevant and as such is described in the next sub-section for its contribution to the research. Details of the conceptual framework in terms of concept construct and inputs for these are provided in the research process (section 3.13).

The conceptual framework and the interview schedule were then ‘tested’ in pilot studies to ensure that concepts and related questions in the interview were well formulated. The first pilot was a new cluster initiative within Energy Valley. EnTranCe was an ideal choice for the pilot as collaborations between energy businesses, researchers and local policy initiated an open innovation facility for energy transition challenges. This overlapped cluster stakeholders involved and issues facing Energy Valley. The second pilot on Paper Province supported review of the research and the conceptual framework since it was a mature cluster with a dominant industry and facing challenges of peripheral regions, similar to Energy Valley.

The conceptual framework was therefore grounded in theory and practice and refined through pilot studies. The next sub-section describes inputs from the Canadian study in support of the research methodology.

#### *3.7.2.1 Learning from NRC Canadian study*

A key cluster study relevant to the research was the Canadian study commissioned by the National Research Council (Arthurs *et al*, 2009; ISRN, 2002; Wolfe, 2009; Wolfe & Gertler, 2004; Wolfe & Lucas, 2005). The study provided various inputs for the research. Description of the study is found in sub-section 2.19.3.

The Canadian study supported the initial thinking and development of the conceptual framework. The research was inspired and supported by the Canadian study by its conceptual model, design and approach.

Firstly, the Canadian model categorized various elements of cluster development into a simplified model with inputs as current conditions and outputs as current performance and each of these aspects were sub-divided into relevant elements.

Secondly, the Canadian study used evolutionary approaches, which included contextual and historical aspects in the study of cluster developments.

Thirdly, the Canadian economy was similar to the open economy of the Netherlands and therefore, global linkages were included as part of cluster systems.

Fourthly, the study had interviews with experts and stakeholders to understand contextual factors and cluster developments. The Canadian study however included extensive quantitative data on the 26 clusters.

Departing from the Canadian study, the research limited itself to qualitative research methods and an in-depth case study constrained by considerations of time and resources. The research also differs in its use of CAS to develop the conceptual framework that also guided data collection, analysis and reporting.

On a broader note, the research design was informed and inspired by existing knowledge in cluster and complexity theories and cluster case studies in a search for solutions for policy development. The research area spanned different areas of knowledge and policy fields to synergize learning from these different but related fields of studies. The almost opportunistic endeavour to gather useful knowledge to construct a viable research framework for the study of clusters in changing contexts could be criticized by more conservative traditions of scholarship. The research explored these various fields of study even as complexity remained at the core of the research developments reflecting the nature of clusters, both in practice and fields of study.

The next and following sub-sections describe field study issues including ethical considerations.

### 3.7.3 Field study procedures

This sub-section elaborates the field study and related issues of data integrity and ethics.

The conceptual framework guided data collection, analysis, and provided structure and coherence to the research whilst the case study protocol provided an overview of key aspects of the research procedure.

#### *3.7.3.1 Case study protocol*

The case study methodology required a case study protocol (Appendix 6) to increase reliability and guide the research (Yin, 2014). The exploratory nature of the research meant that flexibility was important and this was incorporated in the protocol.

The protocol included:

- Background and design including scope, research question, cases and themes
- Data collection procedures including number and type of interviewees, planning and storage of data
- Data capture including interview schedule, data overview and verification

- Guidance of report including guidance, convergence and expansion of findings and alternative explanations
- Limitations

The research included a second researcher whose main role was to assist in the administration of the research, specifically to ensure data integrity in the research since the original data was in Dutch and steeped in Dutch cultural perspectives.

#### *3.7.3.2 Data integrity*

At the level of data collection, measures to ensure data integrity were included in collecting stakeholder and expert inputs as main sources of information. The main measure to ensure data integrity was through engaging a Dutch researcher as part of a two-researcher team. This ensured that interviewer bias was minimized; proximity to Dutch informants was maximized; mistakes in translation, errors in data processing and analyses reduced. In addition, transcriptions by student assistants would be revisited if needed during the research for accuracy. The reiterative nature of the research processes would include re-visiting data and initial analyses in subsequent analyses.

A parallel project, 'The Big Picture' on the future of energy transition, made this possible. The overlap in energy transition issues and the use of the framework to uncover energy systems developments offered convergence of findings that went beyond the cluster study. A copy of the report is included in Appendix 10.

#### *3.7.3.3 Proximity to energy cluster*

A close understanding of energy transitions and the energy cluster was needed to enhance the investigation given the on-going nature of the cluster's developments.

The research team lived and worked in the region and were witness to, and sometimes party to, many of the developments of the energy cluster through work, personal networks, participation in energy transition debates and events, including Energy Valley's network events, and media coverage and analyses. Proximity to the networks and accessibility to new developments through these networks enhanced understanding of interconnected challenges and developments in Energy Valley. This in turn, enhanced the abductive and interpretivist foundations of the study.

#### *3.7.3.4 Additional information and convergence of inputs*

The research explored relevant policy documents and reports to corroborate and supplement the findings even as the main source of information were experts and stakeholders. Study of the national and EU policies depended on both interviews and secondary sources.

The extensive data collected from different stakeholder groups, from different regions and levels in the cluster meant that the convergence of these inputs strengthened the reliability of the data on the cluster system as a whole. This in turn, supported the research's aim to understand and identify system patterns and systems developments. Overview of research process shows the convergence of inputs (section 3.17)

The next sub-section looks at the ethical aspects.

#### *3.7.3.5 Ethics – relevance, support and access to data*

The grounding of the field study in the cluster included ethical and legitimacy grounding and this was sought through proper governance and support from the stakeholders involved.

One of the first steps taken was to ensure that the object of the study, cluster development of Energy Valley was relevant and supported policy development. The consent and support of the cluster organization, Energy Valley Foundation, as well as key academics in energy transition involved in Energy Valley developments contributed to this end.

The next part of ensuring relevance and grounding the research in practice was the degree of stakeholder involvement and inputs for the research. Interviewees were selected mainly through references (snowball method). References were requested with considerations of representation of different regions and levels of the cluster in mind. Interviews of key stakeholder meant that the findings of the research would be directly available to those responsible for the cluster developments through a planned expert panel session on the initial findings of the research and the cluster organization.

At the level of data collection, ethical guidelines were followed in accordance with the university's requirements. The research provided information to interviewees including explanations on the relevance of the research, right of withdrawal from the study and details for more information or complaints, and adhered to rules of consent and participation based on the Social Research Association's Ethics Guidelines and the University's Guidelines for Ethical and Research Governance Clearance. Ethical clearance was obtained in March 2011 from the University Research Ethics Committee prior to the field study in accordance with University regulations.

Explicit consent from interviewees was also requested for additional investigations into Energy Valley in the parallel project, 'The Big Picture' focussed on energy transition developments. Similarly, interviewees from Karlstad were also informed that the investigations covered both the 'Opening Up' Project and the main research and consent was obtained.

#### 3.7.4 Data Analyses

CAS and evolutionary theories would frame the conceptual constructs of the framework that would guide the search within these constructs in understanding the data. This would be carried out by means of systematic study of data to identify key points and themes within and across different stakeholder groups, and from related secondary data. This process of distilling key themes and points on each of cluster development aspects would be mapped to identify patterns. These patterns would be identified based on the conceptual framework and this would include patterns related to path dependent factors, cluster identities, definitions, vision and strategies, stakeholder participation, interests, roles, motives, identification of urgent challenges and solution resolution, interactions and collaborations, and of changes envisaged and identified due to changing contexts, etc. The initial data analysis would be verified and enhanced by an expert panel session and other experts.

In the second phase of data analysis, reiterative processes of additional analyses would be carried out, including systems level mapping of findings. Given the data driven nature of the investigation, analyses would 'follow' leads arising from data and initial findings. In order to capture whole systems development, multiple analyses and different perspectives may be added in keeping with the exploratory nature of the research. These analyses would undergo various levels of abstractions and result in cumulative findings. Sections 3.14-3.17 and Appendix 7 describe these processes.

#### *3.7.4.1 Insights into cluster developments for future study and practice*

The research would develop insights into cluster systems developments. The insights into patterns of cluster developments based on Energy Valley reflect CAS assumptions of unique systems developments. Underlying patterns of developments captured in propositions would be compared to supplementary cases to strengthen the validity of these insights. Chapter 5 addresses implications of such insights for theory and policy.

#### *3.7.4.2 Case study report: format for narrative*

The case study of Energy Valley would be captured as a narrative (Yin, 2014; Eisenhardt and Graebner, 2007) structured by the conceptual framework. Aspects of cluster developments would be described individually and as part of interrelated systems analyses in this narrative.

The case study description would offer deeper insights into the story of Energy Valley's cluster dynamics and contextual changes, to be verified and enhanced by analyses of supplementary cases.

## *3.8 Linking research questions to field study*

The research and its data collection were set up to answer the main research question and sub-questions. The main research question was

- What drivers of change and cluster dynamics, in particular for energy clusters, are significant to cluster development and what revision might be needed for cluster theory?

In order to answer this, three sub-questions were formulated. The first two sub-questions would be answered through the data collected on Energy Valley.

The first sub-question to be answered by stakeholders would be:

- What is changing in the context of clusters and influencing cluster development?

Stakeholder perceptions and understanding of changing contexts and their expectations of impacts of such changes was sought rather than 'facts' due to the CAS approach underpinning the research. The contextual setting of the cluster would be defined and framed by stakeholder and expert inputs. Similarly, the second sub-question would also be answered through information from experts and stakeholders.

The second sub-question focussed on 'micro-level' activities of cluster developments:

- How are stakeholders and other factors at the micro-level influencing cluster development?

The case study protocol and interview schedules would guide the data collection to gain insights into these micro-level developments. The information sought would include perceptions and actions of stakeholders in response to contextual changes including policy and other agents; to underlying forces and processes affecting cluster change including historical, geographical and cultural aspects; and examples of new solutions, initiatives, competence and knowledge developments, changing interactions and collaboration patterns, changes in scope and scale of activities, trust issues, etc. Inputs from stakeholders and experts would be mapped, analysed and verified and further analyses carried out as described in the previous sections. Details of the interview schedule and the protocol are provided in Appendix 7 and also in sub-sections 3.14-3.16.

The third research sub-question was not directly linked to the field study but was linked to the development of a CAS approach for cluster study, which frames and supports the field study. The third sub-question was:

- Can CAS approach be incorporated into cluster theory to support the future of cluster development?

The development of the conceptual framework, the resulting findings and the conceptualization of cluster systems developments would collectively provide insights that would answer the question. The discussions of the findings in section 4.15 and the conclusions in sub-section 5.2.3 focus on this question.

### *3.9 Conclusion of Part 1*

Part 1 described the methodological considerations and position taken by the research, namely, to explore cluster development with the aid of Complex Adaptive Systems approach through the case study of Energy Valley cluster. The research intended to exploit the scope of exploratory research whilst using a framework based on CAS literature to structure the research. The chapter also described how information from different stakeholders (agents) in the system would offer collective perceived meanings and insights into cluster developments in line with CAS principles. The role of agency responding to changes in the environment and the resulting macro level system changes meant that stakeholder interviews and data were central to the chosen research methods and analysis. Significance of proximity to the cluster including immersion in the cluster environment to support deeper understanding of whole systems developments was also discussed. The attention to ethical issues, integrity of data and on field studies procedures as part of the overarching case study protocol was described.

The exploratory nature of the research and limitations of 'knowing' of complex systems were balanced with systematic analysis and a two-team research set-up to strengthen the collection of empirical evidence.

## *3.10 Part 2 The Research*

## *3.11 Research scope*

Cluster and agglomeration theories were explored to establish the direction and scope of the research. Strategy development and implementation of cluster policy in a changing and globalized world within the complex landscape of the European Union was the impetus for initiating the research. The research intended to understand broader issues and management implications for cluster developments. The research sought to incorporate complex adaptive systems approach in cluster analysis and strategy development.

The field research on the main case of Energy Valley took place in 2013 and 2014. Preliminary research, including pilots and development of the conceptual framework preceded this. Research analyses, supplementary case studies, further improvements to the conceptual framework, and subsequently, design of the cluster model, and development of theoretical and policy insights continued into 2016.

## *3.12 Research overview*

The research developed a conceptual framework based on inputs from literature and cluster policy and practice. The research had two pilot studies, an emerging cluster initiative, EnTranCe, and a mature cluster, Paper Province. The first pilot served to refine the conceptual framework and interview schedule, whilst the second offered insights into developments in cluster practice and policy, and strengthened the research approach. The second pilot was re-visited later in the research to broaden the research findings of the main case study. An additional case study was also included to this end, the case of Silicon Valley.

The main case study of Energy Valley included interviews with stakeholders and experts on the cluster, energy transition and policy. The interviewees (25) were recommended (snowball-method) and were selected from different levels of the cluster and policy. Policy documents and reports recommended by experts and stakeholders as well as literature research were important inputs on energy transition and policy. Media coverage, websites and newsletters from government and energy agencies, sessions with experts, and other energy related events in the region also provided valuable insights. The cluster organization, Energy Valley Foundation, and Hanze University's energy research centre were important sources of information and access to stakeholders.

Expert meetings and conferences on EU cluster development and policy were visited on average twice a year from 2009 till 2014 and these provided information on latest developments and lessons on EU cluster policy developments, practice and studies. High-level policy makers, academics, cluster consultants, researchers and managers from across EU and the Commission were present. These events were an important part of understanding the scope and complexity of cluster challenges and of cluster policy in the EU. Two experts, one from DG Enterprise and Industry and the other from the Cluster Observatory, were interviewed as part of the field study on EU policy and developments of clusters and were used as background information inputs.

To reiterate, the research was set-up as an exploratory study based on complex adaptive systems approaches to understand broader issues related to cluster developments, cluster context and dynamics, and the implications of such findings for policy. Details of the research process are described in the next sections. Development of a CAS approach for cluster study was the first step in the research process.

## *3.13 CAS approach for cluster study*

The research incorporated insights and inputs from the literature to develop a complex adaptive systems (CAS) approach for the study and development of clusters.

Scholars from Evolutionary Economic Geography (EEG) and Regional Innovation Systems (RIS) discussed the value of CAS approaches (see Chapter 2). EEG incorporated CAS in its approach whereas RIS explored transition and complexity approaches. CAS applications to other realms, and the extensive literature study of regional and cluster developments were instrumental in guiding design of the framework. Inputs from theory, policy studies and practice led to identifying different aspects of cluster development and the related concepts.

Four diagrams are included to illustrate linkages between theories and inputs for the framework, CAS conceptualizations of cluster systems interactions with context, aspects of cluster developments and the CAS conceptualization of cluster developments in context. Each of these diagrams are discussed below.

The first diagram illustrates how concepts from CAS, RIS and EEG led to a selection of concepts for the conceptual framework. These being, path dependency, container, stakeholders, attractor, fitness to landscape, significant differences, transforming interactions, emerging patterns, self-organizing, drivers of change and complex problems.

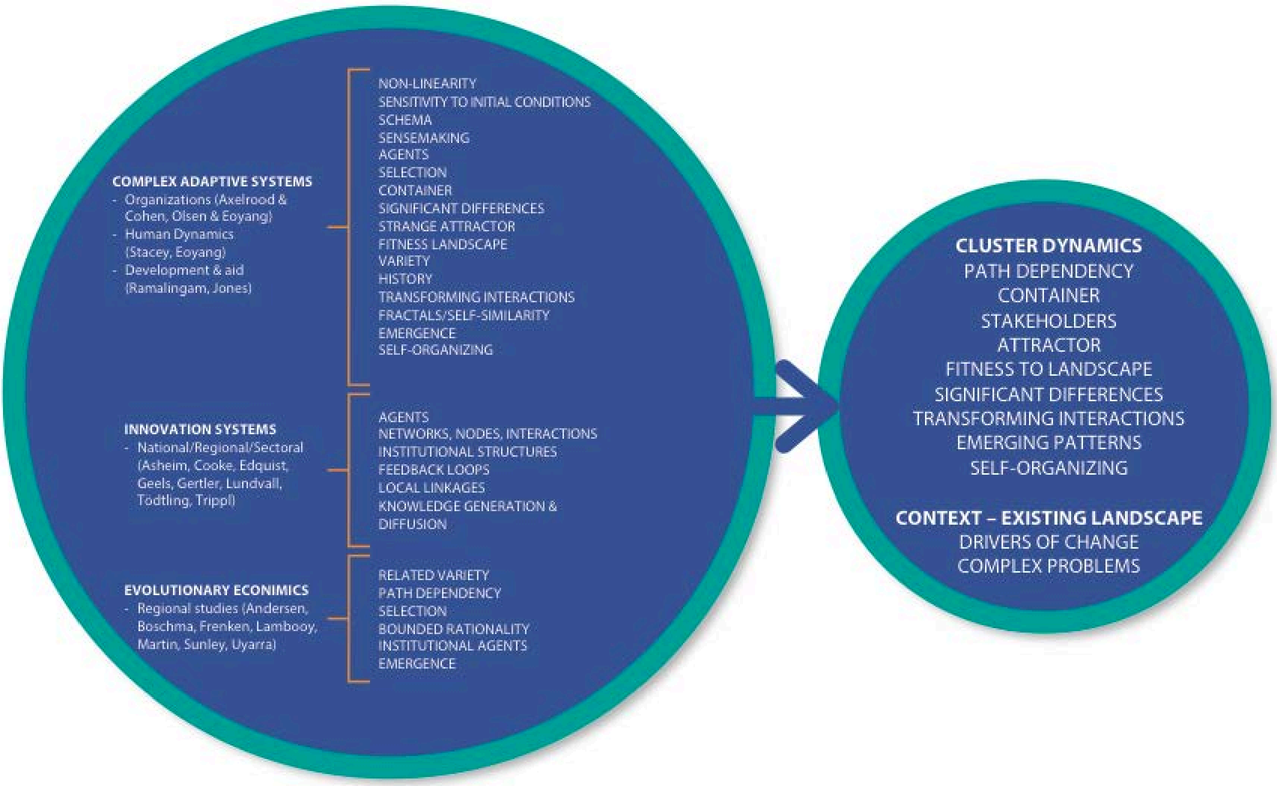



*Figure 18 Theories, concepts and conceptual framework*

To appreciate the relation of the selected concepts (in italics) to complex adaptive systems developments, a brief description follows.

A key understanding in complex adaptive systems is the self-organizing process of agents at the micro-level and systems dynamics. Agents (*stakeholders*) act and react to changes in the environment (*complex problems*, *drivers of change*) such that behavioural changes and interaction patterns (*transforming interactions*) are visible and change the macro level systems patterns (*emerging patterns*). The systems dynamics can be understood as changes in systems definition and boundaries (*container*) steered by underlying factors (*path dependency)* of patterns, responses and capacity for new developments (*attractors, fitness to landscape, significant differences*).

The next diagram illustrates changing contexts affecting cluster dynamics and developments in complex systems.

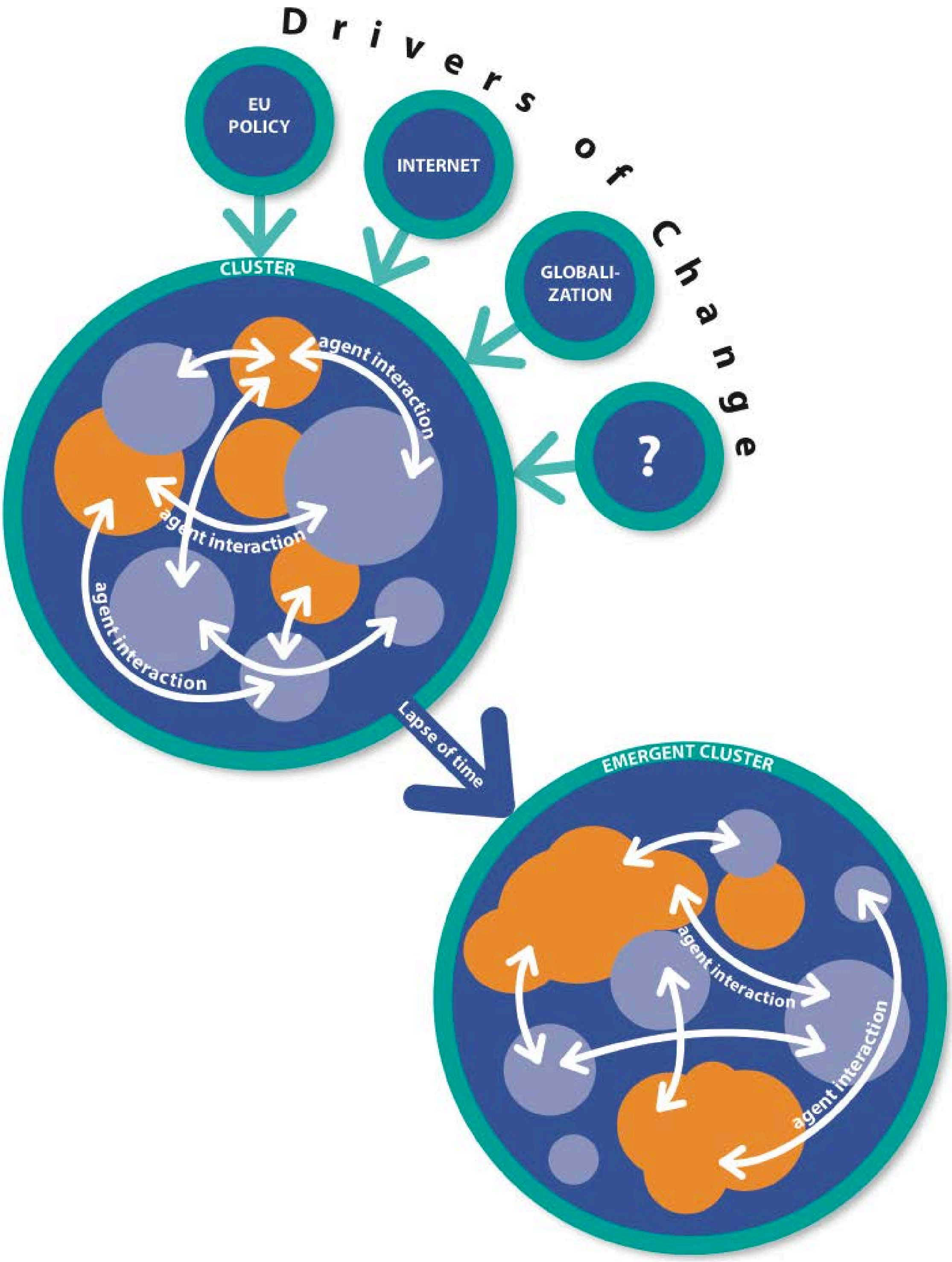



*Figure 19 Drivers of change, cluster dynamics and emergence*

The diagram above shows how external drivers of change influence agents and their interaction patterns. Over time, transforms are visible in the cluster.

Key aspects of cluster systems were identified that helped categorize the selected concepts. The next two paragraphs and the next diagram describe this aspect of the framework.
CAS identified micro-level interactions, system dynamics, as responses to contextual changes. Therefore, 'cluster dynamics' and 'cluster context' were included in the conceptual framework. In addition, CAS regarded sensitivity to initial conditions as important to systems development. Therefore 'cluster conditions' was included to the framework. Emergent interactions and macro-level shifts in patterns were captured as 'cluster performance'. The Canadian National Research Council's (NRC) study identified 'current conditions' and 'current performance' in their model of cluster developments. These two categories overlap the research framework's 'cluster condition' and 'cluster performance' whilst the other categories reflected additional CAS features.

The diagram below captures these interrelated aspects of cluster developments. It reflected how **cluster context** acts on the cluster framed by its **cluster condition** of path dependent factors and stakeholders, and how **cluster dynamics**, the responses, then lead to **cluster performance** of emergent interactions and systems developments.

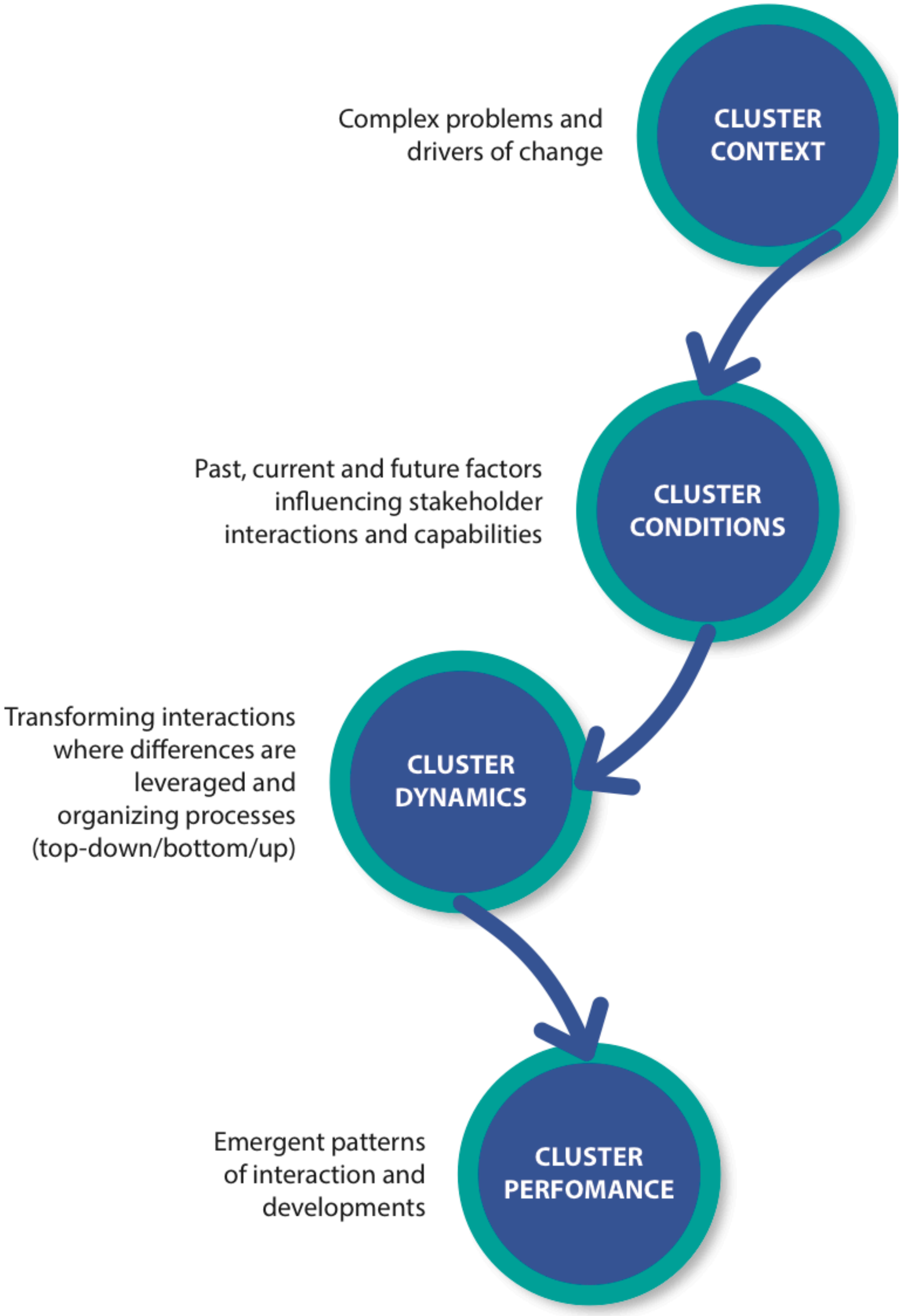



*Figure 20 Four aspects of cluster developments*

The next diagram, developed early in the research, reflects cluster developments with the selected concepts incorporated into the conceptual framework. The four aspects are not captured in the framework but help structure the framework in narratives on cluster developments. The CAS approach for cluster study was therefore conceptualized as follows.

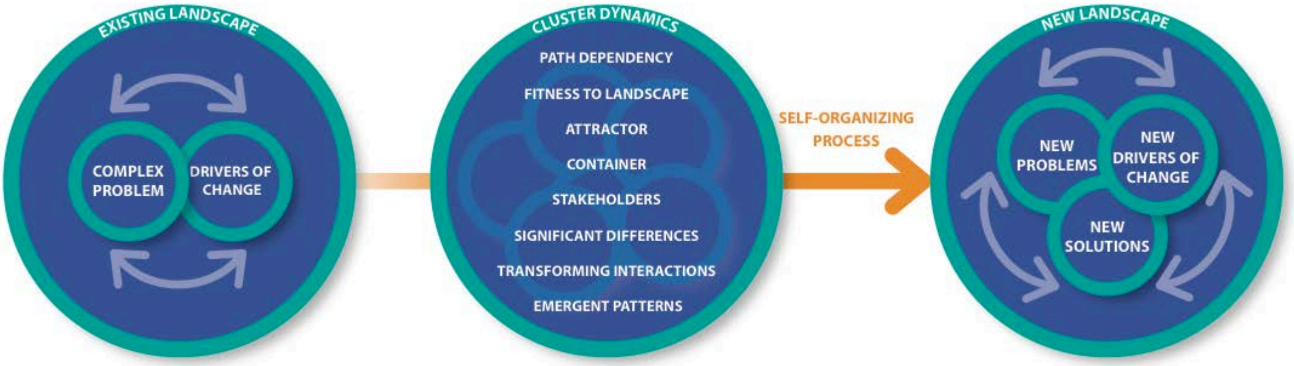



*Figure 21 Visualization of cluster dynamics and developments based on CAS approach*

The first circle captures 'existing landscape' where complex problems arise due to drivers of change. 'Existing landscape' resonates geographical as well as metaphorical landscapes, such as, social, political, economical, technological, and ecological landscapes.

The middle circle captures 'cluster dynamics', responses of the cluster and the resulting changes. The third circle captures the 'new landscape' in which the cluster, emerging from its own dynamics, has a new context where new solutions (to previous complex problems) contribute to new problems and drivers of change.

This third circle captures how 'wicked problems' are never solved but create new problems in need of new solutions, and generate new dynamics of change. Central to the cluster dynamics and developments are 'self-organizing processes' captured by the arrow.

The next sub-section provides detailed description of the conceptual framework that guided the research.

### 3.13.1 Conceptual framework and concept definitions

The framework and its four aspects of cluster context, condition, dynamics and transformations (replaces performance), and related concepts, are described in terms of their relevance and use in supporting cluster study and developments.

**Cluster context**

Urgent challenges faced by clusters (energy transition in energy clusters) were often perceived and identified differently by stakeholders; problem definition and resolution often reflected diversity of stakeholders and complexity of issues in clusters. Chapter 2 addressed changing contexts of clusters that included globalization, digitalization, consumer demands, climate change, and economic crises as drivers of change. Identifying 'wicked' problems (Rittel and Weber, 1973), characterized by high levels of uncertainty and disagreements amongst stakeholders, and factors exacerbating them, the drivers of change, would make explicit any diversity in stakeholders perceptions and behaviour towards such challenges.

'Cluster context' maps stakeholder perspectives of complex problems and drivers of change.

**Cluster condition**

'Cluster condition' captures initial conditions in terms of 'path dependency', 'stakeholders' and 'container'.

The concept of 'path dependency' is important to CAS and evolutionary scholarship. In the framework, it captures historical, geographical and socio-economic aspects significant to a cluster's formation and later developments. Path dependent factors influence cluster developments and include lock-in risks.

The second concept of cluster condition is 'stakeholders'. The concept of 'agents' in CAS is captured as 'stakeholders' to reflect cluster policy and management terms. 'Stakeholders' could be both individuals as well as categories of stakeholders (policy, industry, etc.). Dooley (1997, p. 85) explains that 'agents are semi-autonomous units which seek to maximize some measure of goodness, or fitness, by evolving over time'. Experts and key stakeholders in the cluster would be asked to identify significant stakeholders including gatekeepers and 'missing stakeholders'. The latter are often not part of strategic dialogues and considerations but important to cluster developments. The NRC study showed that civil leadership needed to be included in cluster studies whilst Ebbekink *et al* (2015) stressed the significance of 'civic entrepreneurs' on Dutch cluster developments.

The third concept of cluster condition is ‘container’ which identifies defining features of complex systems. This includes physical space (geographical territory), organizational structures (cluster or platforms) and conceptual boundaries (identity, purpose, boundaries, governance). This notion of ‘container’ has been adapted from Olsen and Eoyang (2001). They also describe the ‘container’ as the playing field and ‘rules of the game’ of complex systems (pp. 11-12). Understanding a cluster’s container offers insights into stakeholder perceptions of its boundaries, identity and purpose, features, rules of engagement and interaction and vision of its future. These insights would reflect coherence or divergence in clusters.

Collectively, path dependency, stakeholders and container reflect a cluster’s initial conditions. These three aspects are interrelated since clusters’ stakeholders often assign or assume its vision, identity, governance and norms; at the same time defining features of clusters determine choice of stakeholders; and, path dependent factors of history, geography and other relevant social and economic factors define the cluster, its identity and scope, and its stakeholders. The interconnected nature of a cluster’s initial condition and later conditions has been acknowledged in agglomeration and cluster literatures on the path dependent nature of regional and cluster developments although CAS literature acknowledges that not only ‘history matters’ but makes explicit and studies the interconnectedness of systems.

‘Cluster condition’ maps path dependent factors, stakeholders and container and through this helps understand cluster dynamics.

**Cluster dynamics**

'Cluster dynamics' captures responses of cluster systems to contextual changes. The concepts of 'attractor', 'fitness to landscape' and 'significant differences' help understand how clusters could respond to contextual changes.

Attractors are significant as they are constraining and shaping forces in systems (sub-section 2.9.1.2). In complex and unpredictable systems, strange attractors hold together a 'narrowness of repertoire' (Ramalingam *et al*, 2008) that provide the hidden order in complexity. Attractors and strange attractors are systems' constraints displaying discernible patterns of 'possible landing' points in systems development. When critical values or thresholds are exceeded, a transformation takes place, bifurcation, resulting in transformed systems with new attractors. Not all attractors lead to bifurcations nor are all attractors necessarily strange attractors. Consequently, 'attractors' was the preferred concept for the cluster study framework. In addition, this concept could help uncover 'attractiveness' or 'stickiness' of locations, which is at the core of spatial geography studies (Asheim & Parrilli, 2012). By identifying and understanding attractors, underlying patterns of attraction, development and constraints at the systems level, future cluster developments could be anticipated and policy interventions developed.

'Fitness to landscape' is the second concept of cluster dynamics. Fitness to landscape captures cluster capabilities needed to deal with changing environments, the fit to changing landscapes. The notion of fitness has been preferred to Kaufman's concept of 'fitness landscape'. Co-evolutionary change of mutual adaptations in interactions with other agents and the environment described by Ramalingam *et al* (2008; sub-section 2.9.1.3) resonates with Dooley's notion of 'fitness' to 'landscape' whereby agents seek to achieve their goals in interaction with their environments (Dooley, 1997, sub-section 2.9.1.1).

The fitness to landscape concept identifies future capabilities of clusters (competences, knowledge base, behaviour and interactions) needed to transform them in the face of changing contexts. Stakeholders could be asked to identify what was needed to 'fit' changing contexts, that is, strategies in terms of new competences and capabilities needed to be resilient to changing contexts.

In addition, exploring stakeholders' perceptions of what is needed to make the cluster 'future proof', capable of facing complex problems, gives insights into stakeholders' future vision, scope, scale and identity of the cluster, and re-affirming insights into these aspects. In addition, insights into shared notions of current developments and a sense of urgency in the cluster could offer insights into common grounds for change and intervention opportunities.

The third concept in understanding cluster dynamics is 'significant differences'. This concept captures 'differences that make a difference' that offer potential system transformations if leveraged (Olson and Eoyang, 2001; sub-section 2.9.1.3). Significant differences could be different at different levels in systems and could be physical, mental, ideological, perceptual, social, political, etc. Significant differences could offer new interactions that lead to transformations needed to enhance 'fitness'. In a cluster analysis, identifying significant differences offer opportunities for new path creation.

Different stakeholders in the cluster, including 'missing' and new stakeholders, have different interests, resources, strategies, capabilities, etc. Focussing and making explicit differences, recognizing the need for 'differences that matter' and their potential value for new value creation is at the core of the concept of 'significant differences'.

**Cluster transformations**

'Cluster transformations' captures insights into new connections, collaborations and cluster level patterns through the concepts of 'transforming interactions' and 'emerging patterns'.

'Transforming interactions' is a variation of the term coined by Olson and Eoyang (2001) and Eoyang and Yellowthunder (2011). They used the term 'transforming exchanges' to explain connections between system agents where exchange of resources (information, physical resources, etc.) take place. These exchanges result in some 'transformation', filter into the system, evoke responses from neighbouring agents and thereby set off changes in the local environment (sub-section 2.9.1.3). The exchanges take place in interactions and hence the term, 'transforming interactions' in the framework. Such transformations are visible changes in the system at the micro-level and display 'new' or 'innovative' features.

In addition, transforming interactions often reflect connections of significant differences that cause transformations or changes in agents, and subsequently in the system. This was illustrated in the Kosovo study. The study showed how understanding significant differences and transforming interactions offered insights into possible intervention points to influence macro-level systems patterns (Eoyang & Yellowthunder, 2011; sub-section 2.9.1.3). In cluster study, stakeholders and analyses could identify transforming interactions in different parts of the cluster, which in turn, could help identify emerging macro-level systems patterns.

The second concept in cluster transformations is 'emerging patterns' (sub-section 2.9.1.3). Micro-level components and dynamics, including interaction patterns and feedback loops, collectively generate 'new, unexpected structure, patterns or processes in a complex system', the emerging patterns, 'with a life of their own' that are 'radically novel with respect to the lower level components' (Goldstein, 2008, p. 9). 'Emerging patterns' and 'emergence' are concepts used to show how 'properties of a complex system emerge from interconnectedness and interaction', and, emerging properties can be in the form of 'structure, processes, functions, memory, measurement, creativity, novelty and meaning' (Ramalingam *et al*, 2008, p. 21). The emergence process is subject to 'rules' that are local and different in different parts of the systems. There is no single overarching systems rule. Hence, unpredictability and non-linearity prevails in systems developments.

The concept of 'emerging patterns' in cluster developments captures shifting systems patterns, structure, processes, etc., by focussing on novel interactions and collaborations and related issues of trust and commitment, new partnerships and collaborations, scope, new communications, new knowledge sources, new ways of sharing, innovation processes, solutions orientations, etc. 'Trust' is key to cluster developments and needs prominence in any study of clusters (see Chapter 2 on agglomeration and cluster literature).

Related to emergence and cluster developments are self-organizing processes that capture local agent behaviours that are central to all processes in complex adaptive systems. Agents in systems 'seek to make sense of their environment including the behaviour of other agents' that reflect self-organized interactions (sub-section 2.9.1.1). Sensemaking and seeking novel responses to meet challenges in local environment as 'fitness-seeking' without any 'external design' (Heylighen, 2002;

Heylighen *et al*, 2007; sub-section 2.9.1.3) describe motivation and behaviour of agents. The space to behave 'autonomously' is however constrained by other factors including container (system boundaries), attractors and other agents.

Therefore, the concept of self-organizing processes was included in the framework to capture insights into autonomous stakeholder behaviours in the cluster. Insights into 'bottom-up' as opposed to policy or 'top-down' initiatives capture reflect degree and visibility of self-organizing processes in clusters, therefore their potential adaptation capacities (sub-section 2.9.1.3).

To recapitulate, the proposed framework for cluster study was designed to explore cluster context, cluster condition, cluster dynamics and cluster transformations with related concepts as described in this sub-section. An overview of the concepts is included in the next sub-section. The proposed framework guides the research in its exploration of cluster developments in its changing contexts from a whole systems, CAS based 'meta theory of change'. In keeping with this approach, stakeholders, their perceptions and behaviours, are central to the study.

Insights into cluster study using the framework will help answer the third research sub-question, '*Can CAS approach be incorporated into cluster theory to support the future of cluster development?'*

The next sub-section provides an overview of concepts and aspects used in the framework that guided the empirical study.

#### *3.13.1.1 Overview of concepts of CAS framework*

The table below captures the concepts used in the CAS framework.

| | |
|---|---|
| **Cluster context**<br>*Complex problems*<br>'Wicked problems' often paired with high levels of uncertainty and disagreements<br><br>*Drivers of change*<br>Factors affecting change in cluster context | **Cluster condition**<br>*Path dependency*<br>Factors such as history, geography, cultural, etc. defining existing conditions<br><br>*Stakeholders*<br>Key actors including gatekeepers and stakeholder groups in cluster systems<br><br>*Container*<br>Defining features of systems including scope, boundary, vision, governance structures, etc. |
| **Cluster dynamics**<br>*Attractor*<br>Constraining forces as underlying patterns of order reflecting direction of cluster developments<br><br>*Fitness to landscape*<br>Ability to co-evolve or transform to 'fit' changing contexts and need for (new) competences<br><br>*Significant differences*<br>Differences that could make a difference and contribute to 'transforming interactions' | **Cluster transformations**<br>*Transforming interactions*<br>Exchange of resources, knowledge, ideas, goods, etc. that transforms (agents, activities, policy, etc.)<br><br>*Emerging patterns*<br>Systems level patterns emerging from interconnectedness and interactions of micro-level activities |
| *Self-organizing process*<br>Autonomous agent behaviours responding to changes; bottom-up initiatives versus top-down initiatives | |

*Table 23 Definitions of concepts in CAS approach*

This sub-section described the CAS approach to clusters and the development of the framework and the concepts. Details of the conceptual framework and different evolutions of it have been included in Appendix 8.

The next section describes research design and process.

## *3.14 Research design and process*

The research design was guided by Yin's case study methodology (2014) supported by the theoretical and conceptual framework and models as described in the preceding sections. The following sub-sections describe case study protocol, interviewee selection and questions and the pilot study to test the design of the field study. The guiding principles of 'close to practice' as advocated by an 'engaged scholarship' approach is briefly described before details of the fieldwork of Energy Valley and the analysis phase is described. The case study of Energy Valley also explored the context in which it operated to understand what 'frames' the cluster's development and this is covered in the sub-section 3.15.1.3, 'Energy Valley – framing the context'.

#### *3.14.1.1 Case study protocol and interview schedules*

The research developed a case study protocol according to the principles of case study research as prescribed by Yin (2009, 2014) and as described in the Methodology Chapter. The protocol described the scope, process and developments of the case study to be carried out (Appendix 6). The nature of the case study was exploratory and guidelines were set up to ensure validity and reliability even as flexibility was inherent to the research. The CAS approach was an overarching influence in the design of the case study protocol, the framework and interview schedules. The exploratory nature of the research allowed customization of the interviews whilst adhering to the framework. For example, adaptations of interview schedules served the three key stakeholder groups whilst key aspects of cluster developments of the framework were always addressed in order to gain inputs from all interviewees to have reliable mapping of cluster systems developments (interview schedules in Appendix 6). Questions of the interview schedule were 'open' to accommodate room for deeper exploration if needed, and also to build on knowledge gained as the interviews progressed. The need for exploration and 'rigidity' of inputs were carefully balanced.

#### *3.14.1.2 Data collection and research sub-questions*

The insights derived from the CAS approach and framework in the research would answer the third sub-question (sub-section 3.13.1). The other two sub-questions would be answered through data collection.

The interview schedule was guided by the remaining sub-questions of the research:

- What is changing in the context of clusters and influencing cluster development?
- How are stakeholders and other factors at the micro-level influencing cluster development?

The concepts of drivers of change and complex problems of the framework helped gain insights that could answer the first sub-question. Individual stakeholders and experts were asked to identify 'what is driving change' and 'how this is influencing cluster development'. They were also asked what 'urgent challenges are faced by the cluster' in order to identify the complex problems needed to be addressed that reflected contextual changes. Inputs from the various stakeholders and experts offered insights into contextual changes that in turn, were mapped; supplementary documentation was included to verify or validate information particularly on policy matters where needed. The contextual changes and challenges faced by clusters and regional economic developments had been addressed in the literature and particularly with regard to policy and practice. Outcomes of the research are discussed in the light of this literature at the end of the chapter.

The second question on 'micro-level' activities has been explored through information on cluster conditions, cluster dynamics and cluster transformations that were addressed in the interviews. The questions addressed different aspects of stakeholder interactions that included their perceptions and reactions in relation to: changes in the cluster including policy, other agents' behaviours and challenges faced; drivers of change; underlying forces and processes; influence of historical, geographical, socio-economic and cultural aspects; search for solutions and need for new competences; changing interactions, and emergent patterns; scope and management of such processes, etc. These aspects reflect concepts in the framework and guided the field study in an effort to explore the second sub-question of the research.

A copy of the case study protocol and a sample copy of interview schedules have been included in Appendix 6. Interview schedules were adapted for different stakeholder groups.

#### *3.14.1.3 Interview selection and overview*

There were three stakeholder groups identified in the literature on clusters and industrial districts, also known as the 'triple-helix' (Etzkowitz, 2012). These included policy, industry and research institutions and universities. The research adopted the triple helix stakeholder groups and added consumers and civil associations as 'civil society' in the research. The inclusion of civil associations in cluster studies reflected outcomes of the Canadian studies (sub-sections 2.5.2 and 2.19.3).

In this research a number of adaptations to the original triple-helix categories of stakeholders were made. In the category ‘industry’ all private enterprise was included. However, a distinction between large industrial stakeholders and Small and Medium-sized Enterprises (SME) was made since large energy corporations dominated the energy sectors whilst newcomers to the cluster were often SME. Such a distinction allowed the research to understand particularly what ‘urgent issues’ in energy clusters were from the perspectives of large and small corporations. Similarly, in the category ‘policy’ stakeholders a distinction was made between regional and local (city council) policy stakeholders and regional development agency (RDA) that included the cluster organization. The latter category had a different role as they served the energy cluster as a whole whilst the regional and local policy stakeholders represented only their respective geographical territories. A note on Energy Valley Foundation, the cluster organization, as it was an atypical of cluster organizations in that it had a double mandate; it served its cluster members (platform members) and also served the ‘energy cluster’, which was a policy entity, extending across the Northern Netherlands. The inclusion of ‘civil society’ as a stakeholder group has been mentioned and therefore the research interviewed organized consumer co-operatives and non-governmental organizations (NGOs). Inputs from Energy Valley experts reinforced the growing significance of this stakeholder group in energy transition. To summarize, ‘civil society’, ‘’regional development agency’ and ‘SME’ as separate groups were added to triple-helix’s ‘policy’, ‘industry’ and ‘academia’ stakeholder groups in the research. These groups were particularly relevant in understanding complex, urgent issues faced by the energy cluster and the implications for cluster developments.

The research used the ‘snowball method’ to identify relevant stakeholders for interviews as well as information provided during the interviews. This second source of information helped identify ‘missing’ stakeholders, specifically the ‘civil society’ group. Another consideration in interview selection was the geographical spread to cover all four Provinces of the cluster. Finally, interviews of experts from national and EU levels were included in order to gain insights into the broader context and drivers of change from outside of the cluster. The table below gives an overview of the stakeholder groups and sub-groups used for the case study of Energy Valley.

| Energy Valley interviews | |
|---|---|
| Stakeholders | Sub-groups |
| Policy | Regional and local policy |
| | Regional development agency and cluster organization |
| Industry | Large (energy) corporations |
| | Small and Medium-sized Enterprises |
| Academia | Universities and research centres |
| Civil Society | Organized Consumer initiatives and NGOs |
| Additional interviews | |
| Policy | Netherlands and EU levels |
| Industry | EU lobbyist |
| Academia | Consultant/Researcher on EU clusters |

*Table 24 Stakeholder categories in cluster analysis*

The stakeholder categories identified above were also used for the pilot studies although in the first pilot only industry and academia were involved in the cluster initiative. In the second pilot, all groups of the triple-helix were represented. 'Civil society' was not relevant to the pilot studies and therefore omitted.

### *3.14.1.4 Pilot studies*

A pilot study was carried out on EnTranCe, a cluster that was being formed at that moment. The purpose of the pilot was to finalize the interview schedule for the main study and to explore use of the CAS framework for cluster study.

EnTranCe was accessible to the researchers, its initial formation stage allowed exploration of commonality in stakeholder's expectations and mission, and the limited scale of the cluster made it possible to do a comprehensive study with four interviews covering all key stakeholders. Findings of the pilot were presented to two members of the committee who indicated that the findings were surprising and contributed to their work supporting the cluster development. Specifically, differences in expectations, a lack of clarity on the exact mission of the cluster for some partners resulted in an increased urgency to address these issues. The findings offered input for their next steps.

The pilot contributed to finalizing the interview schedule for the research as planned, strengthened the research in its chosen direction, and offered insights into mapping and presenting the data to stakeholders. In addition, feedbacks on the interviews were positive and respondents indicated that they had not considered some of the aspects included pointing to the potential value of CAS in cluster studies (similar responses in the study of Energy Valley).

The second pilot took place in Karlstad, Sweden where an interview was scheduled on European cluster policy and the work of the (European) Cluster Observatory. This included the opportunity to study Paper Province, the paper and pulp cluster of Karlstad. This is a mature cluster and interviews with key stakeholders from the cluster organization, city council and the university were organized. This pilot served to understand issues facing older industrial based cluster developments and the direction of cluster policy and practice in Sweden. Sweden has a long history of cluster practice and policy and has been important to European cluster policy developments.

Paper Province is a cluster dominated by the paper industry in Karlstad and the Region Värmland. The pilot was focused on understanding issues of cluster developments and the 'new phase' of cluster policy that the Swedish clusters were moving into. The pilot had a more open interview structure given the aim of the study. There were four interviews and they provided extensive information such that these findings were re-visited later in the research and a more detailed analysis was carried out. The findings were presented to and validated by one of the stakeholders who had a long history in the cluster's development. The Karlstad pilot therefore served the research in two ways: initially to gain deeper insights into cluster developments, and helped consolidate the interview schedule and research focus; and secondly, the extended analysis of the study helped broaden the findings of the Energy Valley case.

#### *3.14.1.5 Proximity to 'Practice'*

In order to ensure that practice and developments in practice are followed closely, the research was informed through continual engagement with experts (particularly on energy transition and local developments). In addition, inclusion of a local consultant in the field study increased understanding of local practice and bridged cultural and language gaps, and immersion in the region allowed close rapport with developments in the cluster.

The need for proximity to practice was necessitated by the speed of change and developments in the local energy cluster, which in turn, reflected challenges and responses in the energy sector as a result of climate change agenda, EU policy, economic crisis, etc. (see Literature Chapter). In addition, challenges of being a 'lagged' region exacerbated by the economic crisis, and new developments resulting from gas exploration were specific to the region and necessitated inputs and engagement with key stakeholders in Energy Valley. The support of the following partners offered such inputs:

- Cluster organization – Energy Valley
- Centre of Expertise – Energy, Hanze University of Applied Sciences Groningen
- EU Cluster policy experts
- Local consultant in research team

Engagement with these stakeholders offered insights into deeper issues related to cluster and regional developments and helped frame the research and supported more informed analyses of clusters and their changing contexts.

## *3.15 Energy Valley field study*

The research focused on the energy cluster, Energy Valley, of the Netherlands that covered all of northern Netherlands (general map on cover of Appendices; background information in Appendix 1). The cluster was initiated in 2003 and was in its tenth year when the field research took place in 2013.

#### ***3.15.1.1 Interviews – considerations and overview***

The field study of Energy Valley involved 25 interviewees across stakeholder groups of policy, academia (knowledge and research institutions), businesses and civil society. These stakeholders were spread across the four provinces that the cluster spanned. The range and choice of stakeholders for the field study were based both on literature review, including case studies on cluster, and the snowball method. In addition, experts and stakeholders outside of Energy Valley were interviewed at the national and European levels to gain insights into the broader context of Energy Valley.

The research intended to carry out a 'whole systems' approach and therefore sought to have stakeholders in different parts of the cluster system. The cluster organization, Energy Valley Foundation, was a focal point in the cluster and therefore information on key participants, stakeholders and recommendations for interviewees were derived from their management. The list of recommendations was then compared to that from an expert in the field of energy transition in Energy Valley. Both lists served as starting points and these names were checked for their geographical and stakeholder group representation. Interviewees were also asked for recommendations (snowball method), and decisions were based on the relevance and considerations of spread in cluster and quality (strategic level) of input. 'Missing stakeholders' were also included based on recommendations of interviewees. The spread across provinces and stakeholder groups of those interviewed is captured below.

Details of interviewees have not been included beyond generic description of stakeholder type to ensure confidentiality. The Director of Study was provided details of interviewees to ensure transparency.

| Stakeholder type | Provinces | Total EV | NL energy rep. | EU Dutch energy rep. | Total |
|---|---|---|---|---|---|
| Policy | Dr (1) Fr (1) Gr (1) NHN (1) | 4 (1) | 1 | 1 | 6 |
| Regional Development Agency (RDA)/Cluster Organization | Gr (2) | 2 (1) | | | 2 |
| Academia/Research Centres | Gr (4), NHN (1) | 5 | | | 5 |
| Industry | Gr (3) | 3 | | 1 | 3 |
| SME | Dr (2), Fr (1), Gr (1) | 4 | | | 4 |
| Civil Society | Dr (2) | 2 | | | 2 |
| **Total** | | **20** | **1** | **2** | **22** |

*Table 25 Overview of stakeholder interviews on Energy Valley*

There were twenty-two interviews included for the study of Energy Valley, of which twenty were inputs on Energy Valley cluster, and two on the broader context. The latter interviews focused on energy transition and energy policy at national and EU levels. Both interviewees were Dutch officials with energy dossiers at their respective levels. As with all interviewees, these officials were recommended by Energy Valley stakeholders. Two interviews (indicated with parenthesis in the table) were not included in the analysis as they offered operational and general information rather than strategic insights, which did not serve to understand Energy Valley's developments.

In addition, in order to understand Energy Valley's context, information was gained not only through interviews at national and EU levels, but also through policy documents, reports and relevant websites. Recommendations for information sources were provided by experts and interviewees and sourced from official EU and national government's websites. The main purpose of the additional sources of information was to validate and, or broaden the empirical findings. Similarly, Energy Valley studies, reports, policy documents and information from relevant websites validated the research findings on cluster developments.

The installation ceremony of new professorships (chairs) in October 2013 at what is now the Centre of Expertise - Energy provided further understanding of energy transition challenges faced by Energy Valley. The team of Professors were from different fields of scholarship and therefore a multidisciplinary view of the challenges was provided. Key insights into energy transition in Energy Valley was analysed and validated by two of the aforementioned professors. This and other inputs from the Expertise Centre, policy documents and energy related reports provided additional information that extended the findings from the field study on Energy Valley. On-going discussions and events on energy transition in the region increased knowledge and understanding of key issues in energy transition throughout the research period that supported informed analyses on the energy sector and energy cluster. A separate section, Lesson 7, addresses insights into energy transition in Energy Valley.

To summarize, the main source of data for the research was from stakeholders. As explained in the Literature and Methodology Chapters, in Complex Adaptive Systems, agents at the micro-level perceive, make sense and respond to changes in their environment and therefore stakeholders' inputs were primary in understanding changing systems. Convergence of information from different stakeholders and experts in the cluster formed the main validation of insights into systems developments in accordance with the interactionists' philosophy of CAS. Other sources of information provided background information and served to validate research findings; these included information from media, special reports and government publications.

Data collected from the field study of Energy Valley generated extensive information on different aspects of cluster development as designed by the framework. Data was collated, analysed and presented to different stakeholders in two separate sessions whereby inputs from the first session were included in the second presentation. Both these sessions served to validate the information gained from the field study and the initial analysis. The steps and details of research activities are described in the table below. More details and discussion of the research follow in the next session on data analysis.

| Activities | Energy Valley – analysis process | Additional information |
|---|---|---|
| Raw data recovery | Transcripts | Interviews in Dutch |
| Verification, categorization & summary of raw data using framework | - Data placed into analysis format<br>- Verifying transcripts<br>- Summary of key points | Dutch inputs retained; summaries of key points into English<br><br>*Appendix 6 – Formats; Sample 2* |
| Verification of summary | Verification of key points | Dutch researcher verifies translations; validates key points extracted |
| Database creation | Key points into database tagged for relevant details | Data inputs (summaries) tagged to interviewee, region, stakeholder group, framework cluster aspects<br><br>*Appendix 6 – Sample 7* |
| Summaries of key points & recognition of patterns | - Analysis of cluster development patterns<br>- Summaries by stakeholders<br>- Summaries by framework cluster aspects<br>- Search for patterns in responses of stakeholders<br>- Search for patterns in changing processes | CAS theory and framework support analyses<br><br>*Appendix 6 – Sample 1, 2, 3, 4, 7* |
| Validation & enhancement of analysis | - Initial findings presentation<br>- Expert meeting<br>- Stakeholder consultations<br>- Expert engagement/input | Validation and enhancement by experts and stakeholders<br><br>*Appendix 6 – Sample 6* |
| Revision & enhanced analyses for further validation and additional input | - Revised findings presentation<br>- Summary of key points per cluster development aspect<br>- Overview 'Energy Valley Cluster Development – Shifting Landscapes' | Cluster organization validation and enhancement<br><br>*Appendix 6 – Sample 7*<br>*Lesson 1* |
| Final analyses of processes & patterns - feedback loops, context & systems analyses | - Revised Energy Valley analyses<br>- (Lessons learnt)<br>- 'Shifting landscapes of Energy Valley'<br>- Energy Valley's feedback loops in cluster elements and developments<br>- Systems view of cluster development<br>- Energy transition & Energy Valley cluster development<br>- Comparison of national and EU level systems dynamics<br>- Karlstad and Silicon Valley analyses | Reiterative processes through various analyses:<br>- Contextual analysis of cluster changes 'Shifting Landscapes'<br>- Complexity – mapping of issues by stakeholders and regions<br>- Systems dynamics and developments in cluster<br>- Energy transition analysis as systems developments<br>- Systems-in-systems analysis<br>- Re-visiting Karlstad case using CAS framework<br>- Exploration of Silicon Valley case using CAS framework<br>- Analyses of all cases<br><br>*Lessons 1- 7*<br>*Appendix 6 – Sample 5*<br>*Appendix 11, 12, 13, 14* |

*Table 26 Research process of Energy Valley case study analysis*

#### *3.15.1.2 Data analysis – considerations and overview*

There were three steps involved from transcript data to summary of key insights. The first was placing the interview data into a template that categorized the transcripts based on the conceptual framework and summarizing key points of the interviews (in English). The second step was placing the summaries in a format on cluster development based on the framework. The summaries were placed in a database (tagged to interviewee number, stakeholder type and region) to facilitate analyses and searching through the data. The third step involved analysing and synthesizing the information to generate insights into the different aspects of cluster development. Systematically summarizing themes and identifying underlying patterns were repeated with each of the stakeholders, and convergence of themes and patterns were identified in the various analyses described below. Appendix 6 provides samples of the various formats and summaries as described in this paragraph.

Measures taken to ensure data integrity and to minimise bias in extracting and analysing key insights from the interviews included engagement of a second researcher. Additional measures included validations from expert/stakeholder panel session, extra input from panel members after the session, and consultation and feedback from Energy Valley Foundation. Corroboration from policy documents and other reports also provided convergent evidence as part of the case study approach (Yin, 2014).

Insights into Energy Valley's cluster context were categorized and analysed in terms of the different stakeholder groups. The aspects complex issues and drivers of change formed cluster context and as such answers from the different stakeholder groups were mapped to explore the degree of coherence in the cluster. All other aspects of cluster development were analysed based on information collected from all stakeholders. The need to understand stakeholder's perspectives on cluster context relates to Complex Adaptive Systems' focus on agency. Problem definition, solution resolution and perceptions of drivers of change of urgent issues by stakeholders groups were therefore mapped and analysed. These insights on cluster context supported understanding and analysis of cluster dynamics and cluster transformations. The next stage of analysis was therefore focussed on these aspects and the initial cluster condition of Energy Valley.

The research conducted various reiterations of analyses of the data collected to recognize and 'make sense' of the information. These included exercises to capture feedback loops in the system, seeking interconnections between cluster aspects, feedback loops of systems and its context, etc. Inputs from the national and EU level interviews, and that of energy transition developments contributed to understanding the various interlocking and nested systems in the Energy Valley cluster. The study of Energy Valley cluster was therefore extended to include the energy transition system dimension and the larger national and EU level systems developments against that of Energy Valley's systems development (see next sub-section).

In the analyses, underlying feedback processes and interconnectedness were sought, through abductive processes, building on knowledge, insights and reflection gained in the research process and professional discretion. The analysis phase therefore included reiterative processes as described by the Engaged Scholarship method (Van de Ven, 2007); a journey of discovery similar to Weick's notion of 'thought trails' (1989; also, Van de Ven, 2007); and, sensemaking (Weick, 2001; Dervin, 1999) processes culminated in inference and abductive leaps resulting in pattern recognition, including interconnections and system processes, and systems-in-systems relations (see Methodology Chapter). Discussions with the expert panel, with individual experts and stakeholders, reflection and synthesis of developments that continued after the field study, commentary by journalists and experts in the field in the media, and own reflection contributed to and reinforced the process of discerning interconnected patterns and whole systems developments.

The next sub-section describes the research inputs and considerations in the study focussed on Energy Valley's larger context in an exploration of related developments.

#### *3.15.1.3 Energy Valley – framing the context*

The cluster context of Energy Valley was framed by national, European Union and global developments. The national and EU developments were most important as they determined the framework conditions of Energy Valley and therefore the spatial, juridical and innovative aspects of its development. The research explored policy related to energy and cluster developments for this purpose. In addition, EU structural and cohesion policy frameworks, the general backdrop to all EU member state context, were included where it supported describing Energy Valley's context. The second part of the Literature Chapter on EU Policy discussed the relationship between clusters, member states and global developments supporting the search for interconnectedness in cluster development and its larger context. This analysis has also been described as a 'systems-in-systems' analysis.

#### *3.15.1.4 Data used in systems-in-systems analysis*

Global drivers of change and globalization as a general context were included as part of national and European policy considerations. OECD, UN agencies, EU documents, commissioned reports from consultancy firms and independent research appraisals were studied to frame general drivers of change in energy and economic developments. Convergence of data and trends analysis was the aim rather than a systematic search.

Specific energy contexts from a global perspective were included from data from energy and global trends institutions, in particular the International Energy Agency and World Energy Council. For the Dutch context, specifically the technology and forecasting report from ECN, the main Energy Research Centre of the Netherlands, and DNVGL (was KEMA), a key player in gas related research, provided information on technology trends for 2020.
(http://issuu.com/dnv.com/docs/technology_outlook_2020_lowres).

European and Dutch energy policy inputs were also included for relevant policy directives and frameworks. The findings of this aspect of the research are found in Lesson 6.

## *3.16 Extended Studies*

The research included two supplementary cases to enhance the findings of the Energy Valley cluster study. The next section explains the motives and choice of these cases.

### 3.16.1 Value of extended research

The research's objectives were to explore deeper understanding of cluster developments engaging more holistic approaches and particularly embracing complexity approaches. The main case study on the energy cluster of the Netherlands offered an opportunity to explore deeper patterns of interactions and emergence from a systems perspective. The main study offered an in-depth study into cluster developments whilst the additional cases, although limited in scope, added to cluster development insights by broadening the findings to more mature clusters, and to clusters in different regions and sectors. The additional value of the extended studies was included even as the opportunity presented itself for such investigations in the case of Karlstad. A planned case study of an energy cluster in Malaysia did not take place due to an unexpected turn in the national elections at the time of the field study. The case of Silicon Valley was instead included as it offered detailed contextual and historical developments of the cluster. The two different sectors and countries made it possible to broaden the findings and validate the initial findings.

#### *3.16.1.1 Extended study 1 – Karlstad, Sweden*

The research also chose to further its investigations by re-visiting the pilot study of Paper Province, Karlstad to explore of a mature European cluster. The analysis and findings of this case was written up and sent to one of the interviewees, an expert on cluster policy, cluster practice and Paper Province (previously known as 'The Paper Province' up to 2014). The analysis of this case was validated for insights and details. The case is described in the light of Energy Valley's findings and qualifications on propositions on cluster developments were made (Appendix 13). In addition, the Karlstad case was written up as a Policy Brief (Appendix 11) for a European Project that overlapped the research using the CAS framework. Background information is found in Appendix 2.

#### *3.16.1.2 Extended study 2 – Silicon Valley, USA*

A second case of Silicon Valley cluster as described by Ekzkowitz (2012) was analysed using the CAS framework. The iconic status and the long history on cluster developments provided by this case supported the choice of the case. The analysis of Silicon Valley offered insights that verified and qualified propositions on cluster developments through its different phases. Details on Silicon Valley are provided in Appendices 3 (background), CAS analysis notes (12) and verification and enhancement of propositions (13).

## *3.17 Overview of research process*

The exploratory nature of the research with its case study design using qualitative research methods based on interpretative principles and interactionists approach demanded multiple sources of inputs and convergence of findings and validation. The figure below captures the research process.

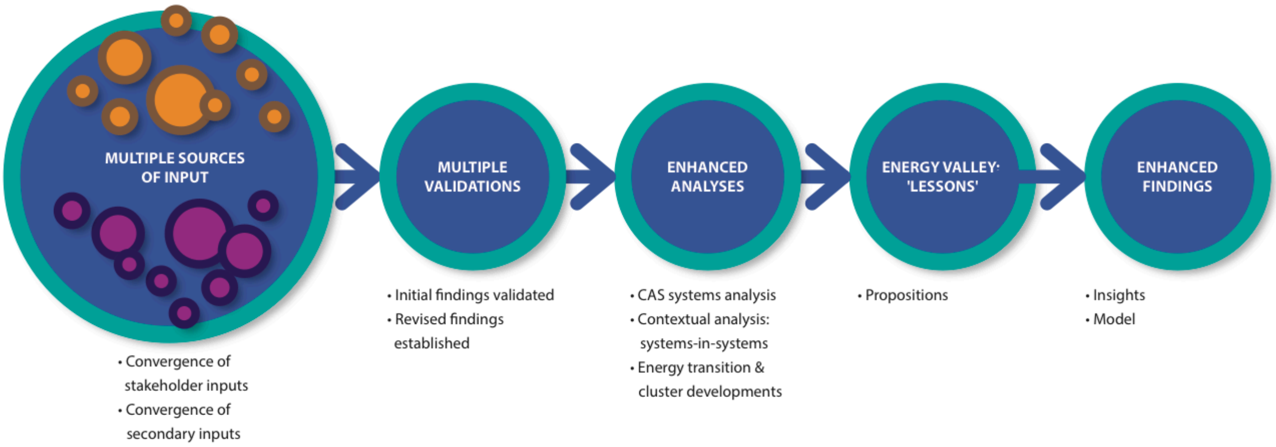



*Figure 22 Research process of Energy Valley and extended studies*

## *3.18 Conclusion of Part 2*

Part 2 described the research process and issues related to various steps of the research. To summarize, the research set out to explore and understand systemic developments in clusters through stakeholder perceptions and behaviours in accordance with CAS approaches. A conceptual framework based on CAS and regional studies literature was designed tempered by insights from pilot studies and current developments. The framework structured data collection and presentation of the outcomes. Close interaction with practice, developments in cluster practice and regional and policy studies related to clusters, and further analyses of related clusters provided the research with a broad and engaged perspective. The research, inspired by the principles of 'engaged scholarship' (Van de Ven, 2007), built on abduction processes through close proximity and involvement of practice and professional discretion. Stakeholder and expert information as main inputs to capture deeper interconnections of systems also contributed to the close proximity to practice. In addition, an investigation of clusters in context in both Energy Valley and Karlstad cases offered a systems-in-systems view of cluster developments through expert and policy inputs. Validation of the outcomes were described and explained within the perspective of complexity's notion of partial knowledge and specificity of each context and phases of systems development.

The next chapter describes and discusses the research findings and its implications for cluster theory and policy developments.

# 4 Research Findings and Discussion

## 4.1 Introduction

This chapter has two parts. Part 1 describes the research findings whilst Part 2 is a discussion of 'lessons learnt' in the light of the theoretical and policy developments discussed in Chapter 2.

## 4.2 Part 1 Research Findings

This part of the chapter describes the main findings of Energy Valley, initial propositions, 'insights into cluster developments' and the resulting model capturing the insights.

## 4.3 Energy Valley cluster

The Energy Valley case study findings form the main part of the findings that answers the research question, '*What drivers of change and cluster dynamics, in particular for energy clusters, are significant to cluster developments and what revisions might be needed for cluster theory and practice?*'

The research findings show how Energy Valley cluster responds to drivers of change and contextual change through its dynamics, and what the effect of such responses are in terms of the cluster's systems developments. The insights are presented as Lessons. Lesson 1 provides an overview of the contextual changes of Energy Valley and includes comprehensive quotations from the interviews to illustrate insights gained into different aspects changes in the cluster that overlaps with other Lessons and therefore references to Lesson 1 occur.

Lessons 2-5 provide details of specific aspects of initial cluster condition, changes in the context, cluster dynamics and cluster transformations whilst Lessons 6-7 describe broader interrelated systems developments.

## 4.4 Lesson 1: 'Shifting Landscape' of Energy Valley – overview contextual changes

The interviewees reported that there were major changes in the context of Energy Valley and that they needed to reconcile with many more factors in their strategy development and decision-making processes. Different aspects of contextual changes in the landscape of Energy Valley are described below with relevant quotations.

Firstly, Energy Valley was a region that was dominated by the largest natural gas reserves of Europe that was discovered in the 1950s and developing the gas industry for the Netherlands and Europe was a primary goal. The concerted effort to build up this industry meant that there were a few players, including the national government, who were dominant in these developments.

### 4.4.1 Energy Valley's gas dominated landscape illustrated by quotations

> *'The gas region, and to a lesser extent also oil which is on the rise again, but we have been a gas region for years in the first place.' [RDA Stakeholder, EV11]*
>
> *'The discovery of Groningen gas fields meant that there would have been no GasTerra and NAM would have been doing a little work in the North Sea… how can you say that the Netherlands is not a gas country. But I believe that the leading position that the Netherlands has taken in the out roll of gas grids, in introducing the HR boiler (high capacity boiler) which had not been deemed plausible, and with the start of developments of the micro Combined Heat and Power (CHP) boilers, and now with the smart grids….' [Industry Stakeholder, EV10]*
>
> *'The Netherlands is unique in the world with 97% of buildings connected to the gas grid.' [Industry Stakeholder, EV16]*
>
> *….the big pitfall is that we are very focussed on the role of gas…. Groningen has evidently interest in the role the larger [energy] corporations and the harbour for their position in Europe and the hub function in the European system.*
> *[RDA Stakeholder, EV1]*
>
> *The historical position is that of a gas position and before that perhaps a harbour position…but for now we are talking about the gas position and the core expertise that we have in the region is due to the fact that we developed the gas infrastructure for Europe and this may be our only expertise we have that distinguishes us from the rest of Europe. And that this expertise includes dealing with decentralized balancing close to consumers, matching the difference between supply and demand, and this expertise of balancing, often not recognized, has always been the most important function of natural gas. [Academic Stakeholder, EV24]*

One of the most important changes mentioned by the interviewees was the shift from a dominant gas driven context to one of multi-energy and more complex context.

> *'Everyone is calling for sustainable, and I understand this, but this can only be achieved when there is sufficient conventional [energy] offered to offset this, whilst I see that conventional is being increasingly dismantled and sustainable [energy] is being increasingly employed, and there is no balance between the two and a risk of security of supply in the Netherlands will continue to increase.*

*I think that sustainability will become the norm in the Netherlands…. Technology is the game changer, look at Shale gas, which happened because we could suddenly drill vertically which was not possible before. Also, solar panels broke through [markets] because of lower production costs, partly because of China but also [technology] happened…Also in upstream technology, we can now exploit gas from deep waters because new technology can take the pressure…. electricity storage will happen and that will be a game changer…fuel cells bring a whole different [energy] market in the near future….' [Industry Stakeholder, EV10]*

*'It is difficult to see what exactly it [the trend] is and that is why we choose different directions. What we do see is that fortunately some aspects of sustainability are maintained due to a EU push. What we also see is that some technology is becoming cheaper…. but also allowing [decentralization], smaller scales'*
*[SME Stakeholder, EV23]*

The quotations above reflect the changing energy landscape and the unpredictability of change and particularly change coming from 'outside'. Examples mentioned were technology and the related developments in different energy sources and sectors, often in the global context. The switch from fossil fuels to renewable energy sources cited in the first quotation point to the challenge of 'balancing' arising from this new context. Many renewable sources such as solar and wind energy are intermittent and unpredictable and require alternative solutions to meet energy demands, also referred to as the 'security of supply' challenge or issue.

The second aspect of this changing energy landscape, and in particular in Energy Valley, brings with it new challenges that involve the physical landscape, the social constraints, technological developments, and policy planning. Implicit in the new energy landscape are issues of energy security and sustainability coupled with a diversity of stakeholders and interests. The quotations below capture some of these facets of a changing energy 'landscape' in Energy Valley.

*'Look at the Veen colonies, why do they look the way they do…. that is energy driven. And the same is also for gas…. and we find it difficult, as energy in the future needs more space than fossil energy. It is an advantage that we have a tradition, a tradition of energy shaping our landscape. Energy is landscape. And the chance that this will happen again in the future is considerable…. and that is tough.'*
*[Policy Stakeholder, EV8]*

*'There was a study on wind energy earlier and everyone wants wind energy but not [in my backyard]…. the plans for [a wind park] are constrained by the Province, as this is not a designated area although we have ensured that it is in the infrastructure vision [strategic infrastructure of the city council]. And that it is clear that we should choose to be energy neutral that wind energy needs to take a*

*prominent role and that it is financially viable at this moment. [Policy Stakeholder, EV20]*

*[On citizens' acceptance of wind energy]*
*'There needs to be good communication strategy and that is what we want, to bring wind energy here and so citizens need to have ownership…. not just a few shareholders....' [Policy Stakeholder, EV20]*

*'There is a difference…. fossil versus not fossil; large-scale versus small-scale or decentralized if you wish…gas versus electricity…. national versus Europe, and then there is national versus regional versus Europe…..' [RDA Stakeholder, EV1]*

*'Therefore the more important themes [in Energy Valley] are the gas roundabout and the greening of, bio-based energy in a broader sense of the word, decentralized energy systems particularly Smart Grids, and small-scale initiatives and local renewable energy businesses and such, and of course the main story as far as we are concerned is large scale production and balancing, the balancing issue.' [Policy Stakeholder, EV8]*

*'On natural gas, our vision is that natural gas is not a transition fuel but it is a destination fuel because natural gas offers the flexibility needed for the implementation of sustainability.' [Industry Stakeholder, EV10]*

*'For us it's all set out – what is important for everyone is also important to us. Looking at the Frisians, they say that they have no interest nor connection to the Gas roundabout., but they are keen on 'greening' gas. They are not interested in the large-scale production and balancing, it's 'Gronings feestje' [Groningen's party]. Bio-based energy they are naturally interested in and decentralization is completely up their street. So they identify themselves in this quarter [of the strategy vision] and for them this quarter is the Frisian vision. Research and education, 'Gronings feestje'… of course we have Hanze University… ECN is important and that is North Holland…for Drenthe its bio-based energy…and the energy transition park at Wijster is very important for them, as well as Avebe with Potato Power, a big project. But they have difficulties with wind on land…but these are not on a scale that we are talking about in Groningen. So there are issues, but they [Drenthe] are including production of geothermal energy in their vision on infrastructure and therefore further than where Friesland and we [Groningen] are.' [Policy Stakeholder, EV8]*

*'Bio-LNG can be produced locally and therefore avoiding transport costs and fuel loss, which makes it easier to compete, compared to LNG…. also, you can mix bio-LNG with LNG…. because of EU requirements to include biofuels…. both biogas and bio-LNG…. are cheaper than bio-ethanol and bio-diesel.*

*If I look at national and international scenes, you can see that there is much more [effort] aiming towards small-scale. Perhaps the Netherlands is not the best example but even here you see the trends in other countries, the less populated the region, the more attractive it is, plus that the more southern you go, the more likely decentralization through use of certain technologies.' [SME Stakeholder, EV23]*

*'It requires a whole lot of mental flexibility in the situation that in The Hague they are advocating top sector policy and that in Europe, it is the stimulation [facilitation] of lagging regions and these are opposing developments' [RDA Stakeholder, EV11]*

*'What I find difficult is that there are a few players, the State, the traditional/fossil producers…. and the sustainability movement and then a few international parties in this area…. that is how it ought to be and these are important opinion leaders' [Policy Stakeholder, EV14]*

The quotations above illustrate how cluster stakeholders were faced with a new energy cluster landscape whereby there were more sources of energy, more stakeholders, more open borders that included a more European and global focus, and there was a need for new infrastructure to meet the new energy landscape. The key points raised in this first change in the landscape can be summarized as follows:

Initially, the landscape was relatively 'simple and complicated' and included technology, economics and policy that

- Focussed on gas
- Had few stakeholders
- Had a regional and national scope
- Had mainly centralized grid and power

This landscape changed to become more complex and included 'many', reflecting distributed agency that had

- Many energy sources
- Many new stakeholders
- Global and EU interests and focus
- Centralized and decentralized grid and power structures and therefore a need for new infrastructure

The second shift in the landscape was in paradigms, power structures and influences, arising from the shift of a few gatekeepers and stakeholders to many and diverse stakeholders that included a change from centralized organization and strategy structures to one that was more diffuse as described in the paragraphs above. The presence and increase of grassroots movements and developments at the local level was also paralleled by the increased significance and impact of EU and its policies. The shift therefore was seen in the dominant frames in Energy Valley. The following stakeholder quotations reflect these shifts in both stakeholder and policy perceptions and developments in Energy Valley.

*'In the Netherlands, and in whole Europe, due to Napoleon's instigation, everything below 100 meters in the ground belongs to the State. Therefore, all resources are owned by the State and all profits also go to the State unlike in the US…here we have NIMBY when it comes to gas exploitation, shale gas exploitation, there they have CIMBY…. and so you have different dynamics….' [Industry Stakeholder, EV16]*

*‘We have enough [gas] till 2025 in any case for our own use and the discussion now is if we should develop exploration of Shale gas, we do not know how much there is…. I am not sure but the question is whether we can afford the luxury not to?*

*The gas price in America is one third of that here and that is why the coal is priced as it is and a declining price and this is why all the old coal power plants in Europe are running and the more modern gas-powered plants are almost at a standstill, and all that $CO_2$….’ [Industry Stakeholder, EV9]*

*‘Look, Europe is important in terms of making obligatory or determining percentage of renewable energy production, and then at some point we have to meet those demands, regardless of what you think about it. The State operationalizes this; it has its own instruments.’ [Policy Stakeholder, EV14]*

*‘Energy Valley is different things to different people… on the one hand you have the [local] governments that are focussed on keeping employment in the region. The same for the Hanze and the university as well and other higher education institutions and that is to attract students and to keep the students in the region….’ [Academic Stakeholder, EV6]*

*‘You have Grunneger Power and there are a whole lot of [local] initiatives like this and from this it is evident that people want to have control of their lives again. The same applies to the food chain to name another example - you see it everywhere. People want to know what is on their plate, we had the recent meat scandal, the bank [financial crisis]. I am convinced that there will be a turning point that involves a different way of organizing things.’ [Policy Stakeholder, EV20]*

*‘We attach great value to our social environment…. whilst there are many organizations in Energy Valley that are only interested in profits…. and the question is, on the longer term whether we need those giant power plants that are being built, particularly the coal power plants, no one is waiting for them to come…. we were naïve about a new solar park initiative that seemed to be a good idea, but someone made it clear to us that there were different interests: the interest of energy corporations are purely profits and shareholders and that our interest is one of ideology, how you want it for yourself and your children, to make it up to them [for damages of the past].’ [Civil Society Stakeholder, EV21]*

*I have a feeling that things are shifting, for example in Energy Academy…. there are attempts to ‘shake up’ discussions by bringing in good speakers and connecting them to young people…. But this does not mean that everyone is leading the discussions, you see that the big energy corporations are busy with this discussion [energy transition] and this is logical as it is their core business. But you also see that local provinces and city councils are also getting involved. It would be good to have citizens get into the discussions….’ [SME Stakeholder, EV4]*

*‘Of course in a number of other dossiers you see also resistance because of the large economic interests and you have there is the status quo that has views on topics such as green gas…. it is all difficult and it all takes a lot of time and money…it is the changing the mind-set that takes time….’ [RDA Stakeholder, EV1]*

*‘In politics we have seen in Drenthe, that the energy savings is on top of the list on paper but when it comes to action, it is more about the realization of large scale production, or about investigating a hydro-powered plants in the main waterways*

*of Drenthe of 1 megawatt or investigating solar panels or biomass or this or that. It was too little focussed on behaviour, on savings by industry, [energy] savings and really not concerned about these important issues…also, there are differences in emphasis on how you define sustainability and sustainable energy provisions, and that is defined by big corporations and also by the government as burning biomass in coal-fired power plants… thus the local concept of sustainability, thinking in terms of re-cycling that is where the differences in emphasis is and that idea of local sustainable production cycles is more logical. Large corporations also think that global production cycles will become smaller. I think that this is a logical development and we think in terms of regional scaled cycles.' [Civil Society Stakeholder, EV19]*

*'Energy Valley, is within the Netherlands and our lobby, our region has succeeded fairly in gaining recognition as an energy region. Although not quite in important dossiers in The Hague always…. often not quite the same financial significance as Brainport, Mainport.' [Policy Stakeholder, EV8]*

*'On the other hand, I feel that also with sustainable energy that, as with other developments, at some point we have to do something. We can in the Netherlands make a whole 'soup-bath' of procedures and zoning policies and more…at some point we need to realize this [renewable energy targets] and then we have to just push it through.' [Policy Stakeholder, EV20]*

*'I do not know if there is a big divergence but in the end everyone has more or less the same point in the horizon, we want to move towards sustainable energy provisions in two thousand something, even as that date moves every year.'*
*[Civil Society Stakeholder, EV19]*

The quotations above are a selection to illustrate the second shift in Energy Valley, from a few dominant 'frames' namely, the national and economic interests and to a lesser extent the regional growth, to include the energy transition and sustainability agenda influenced by global developments and political pressure both locally and at EU/global levels, and partly due to the growth of grassroots movements and consumer demands. The rise of new agendas and new stakeholders and the urgent need to meet challenges of the energy transition meant that there was a search for meaning and new strategies.

To reiterate, initially, one or two frames of reference were driving policy and strategy in the energy landscape; these being

- Economic interests including gas and energy politics
- Dominant national policy rather than EU dominance

Changes in Energy Valley included

- Multiple frames: Economics, energy transition and regional politics frames
- Climate change and sustainability agenda dominant in policy
- Increase in consumer and grassroots movements

- EU policy dominance in energy and its focus on regions
- Increased decentralization agenda in policy and energy transition trends

The increased number of stakeholders, the resulting diversity and uncertainty of energy transition meant that an increasing need for dialogues and sensemaking'.

Another aspect of the shift in Energy Valley's landscape was a shift in the nature of future scenarios for the region and energy transition. The previous scenario was one that was more 'homogeneous' and of relatively slow change where there was a centralized planned strategy with the role of large corporations and national government being prominent and there seemed to be more convergence amongst these stakeholders in terms of future strategies and scenarios. The increased numbers of stakeholders and their divergence in interests, scope, competences and resources meant that the landscape of the future was more diffuse and unpredictable in its nature. Below are quotations to capture changes and the nature of change itself in Energy Valley.

> *'The national government demands a lot more from provincial, regional, governments than they can realize. At the same time it is more efficient, as proximity to citizens means that their sentiments are felt immediately here in the region, much more than in The Hague…. windmills, $CO_2$ storage, drilling in the Wadden Sea and such issues.' [RDA Stakeholder, EV11]*
>
> *'Too much from the 'top', too little from below…yes, it is still too much steering from above, not that there should be less incentives as this could be more but more the feeling that there is help available when needed. But perhaps the 'bottom' also needs to be more competent and take more initiative….*
>
> *'I think that the sector, referring to the gas industry, earned its money quite easily in the past, it did not need to do much for it, of course it has made decisions and only afterwards were the effects of such decisions felt, and often long after it vacated its position of making decisions. I think that the cycles are becoming shorter, and thus the impact will come sooner. One has to look beyond one's own borders and not only decide what is good on their own which was common to monopolies in the past. They determined what was good for the market whilst now they have to listen to what the market wants and think about what is needed and how do go about this and therefore the risks are higher for corporations. Thus you need to have people that dare to have a broader orientation, and people who have a vision and who can connect to others and this connection to others is really critical…also, management needs to be open, transparent, show authentic leadership, no longer top-down but bottom-up is just as important….*
>
> *I think that we need to have a [energy] mix and I think that we should not choose one or two but that there a mix exists and that in the end the market determines in which proportions the mix will takes on.*

*There is also the diversity of supply [needed], should the Russian gas not materialize, than it needs to come from LNG [liquefied natural gas] or from underground storage and through the existence of such diversity we will be less vulnerable.'*
*[Industry Stakeholder, EV10]*

*'Yes the thinking is pretty much top-down. But it is well supplemented by input. We wrote up the story [of Energy Valley] but we did not do this from behind our desks as provinces. There were round table discussions with all stakeholders in the platform as well as the big stakeholders such as institutions of higher education in Energy Valley. We got the city councils and provinces organized and that is once more taken through the workings of SER north [coalition of social partners] where social organizations, employers, employees, etc. are represented. That is the foundation of our story. It is not only top-down. In projects, for example, the Green Gas story, there is contact with farmers, with LTO [Association for agriculture and horticulture] but in these initiatives we have challenges resulting from inconsistent [national] policy… the current SDE [subsidy programme] is better than the older MEP…. however, we had very successful projects where digesters were running based on the MEP. But because the MEP ends these digesters will also fall and the State does not do anything [to intervene]. Talking about consistent policy… "They never miss a chance to miss a chance."' [Policy Stakeholder, EV8]*

*'What I see mostly is that it [energy transition shifts] is coming from below…I do not see much stimulation from above and there is a need for more [stimulation from above] to make it easier… It is possible but it costs money and the Dutch government is restricted in its budget and if you do implement a package with less energy tax then it will become difficult [budget-wise]. One possibility with the energy tax is, heavy users pay almost nothing, less than one cent in tax and private users including VAT pay thirteen cents. If you shift this tax structure than you will come far. However, there will be protests that the Dutch industry will leave the Netherlands because energy becomes too expensive. In an ideal situation, there can be more top-down initiatives, for example, to make alternatives more expensive compared to renewable energy instead of subsidizing renewables. In this way, the gap between the two will be less but to achieve this you need regulations….we were asked by the city council of Tynaarlo to convert an empty industrial lot into a sustainable [energy] project. This was a large field and this was technically not a problem, various alternatives could have been developed. However, regulations got in the way such that it was financially not viable to do this.' [SME Stakeholder, EV15]*

*'What I see now is that there is knowledge [expertise] but that it is not used and I see that this is now becoming diluted, that the whole market for green gas is slowly diminishing… that it is cumbersome, difficult, it is easier to produce electricity than to facilitate [green gas into gas grid] as you need to meet strict requirements and that producers begin to add impurities such that everything needs to be documented and that is to be expected and because of this the grid companies become more concerned…. if we do not intercede then all of this will be stopped and then there will be no green gas afterwards whilst the sector has such a good reputation…. I do not see a platform or entity says that we need to discuss these issues.'*
*[Industry Stakeholder, EV10]*

*'The whole earthquake issue, you cannot ignore it. Something has to be done about it. Yes there are the historical developments, the exploitation of gas, but it can also*

*become an stimulus [for the region]…the gas exploitation here of course means… how do we compensate the people [for the earthquake damage and loss]…. There needs to be an end to the idiotic frugality.' [Academic Stakeholder, EV3]*

*'I have the impression that the pressure from below will be big and that this has to be acknowledged and that things will have to be done, like balancing [energy usage and production], but these are minimal steps…. I cannot judge whether it is the balance of power related to economic interests, given the gas and with Shell that has large investments here or the lobby, but perhaps they all play a role, economic powers and the gas grids here… what I do see is that there is a difference, you have businesses, you have city councils and before it was [separate] and now, and that is really good about the crisis, what you see now is that everyone is connecting with each other, because they need each other….*

*At one point, there was a decision about how to go about this [energy transition process] and it was clear to everyone. But it is one big pot of frogs, jumping in different directions and then once in a while something interesting comes out of it…. the development of electric mobility which is already on the way, but the question is will be hydrogen driven or will there be a completely different system that will come….*

*Yes it is clear that it can take another ten, twenty years, thirty years and that is what is special about this period. What will emerge and what will not, what structures and what and how will Europe be on a global level, will we have the Euro, what is going to happen….? In this sense, it is a time of innovation…. And developments will be known when it has arrived and not before….' [Policy Stakeholder, EV20]*

The various viewpoints of interviewees above illustrate different aspects of change in the landscape of Energy Valley and these different viewpoints also highlight how dominant frames in Energy Valley, from the 'old' landscape, that of the gas industry still prevails and how they are grappling with the need to adapt to changes, both locally and globally. The changing roles and nature of collaboration and strategy developments, the uncertainty about the future, the different new players have all been illustrated in the different quotations. The next paragraphs offer a summary of the third aspect of change in Energy Valley's landscape.

There was originally, a more 'homogeneous' future scenarios shared by different stakeholders who dominated the energy sector, energy corporations and national government, and this way of organization and strategy development saw a predominance of 'top-down' approach. This landscape could be described as one that projected slow change and convergent future scenarios in a relatively stable context:

- More top-down than bottom-up
- Change through blue-print strategy
- Focus on large corporation and national government linkage
- Convergent future scenarios
- Slow change and stability

The developments in Energy Valley described unpredictable future scenarios involving the changing landscape. The increased bottom-up movements and pressure from citizens and the complexity of energy transition meant that there was a mix of both top-down and bottom-up strategies and organization. There were more interactions and connections between the increasing number of stakeholders and the need to seek and facilitate more collective change processes in energy transition. The process of change became more complex due to these new stakeholder groups given their diversity that included their perceptions of the future. A key aspect of the change was the degree of unpredictability and impact of events from outside the region as summarized:

- Both top-down and bottom-up
- Change through interactions
- Presence of multiple and new players and linkages
- Divergent and unpredictable future scenarios
- Change characterized by uncertainty, and turbulence – earthquake, geo-politics, shale, etc.

The fourth aspect of the 'Shifting Landscape' of Energy Valley was related to notions of 'trust'. There is an overlap of this aspect of the shift in landscape with those aspects mentioned above. This has to do with the acceptance of top-down structures and decision-making in the region and an assumption that national government and energy corporations guaranteed the safety and interest of the general public. There was in the past deference to authority and specialists inherent in this 'trust'. The interviewees mentioned a change in what was a relatively 'harmonious' landscape of goodwill and trust. Trust was no longer carte blanche; stakeholders differed in their acceptance of government and specialists in their decisions and plans related to the energy transition and related dossiers. There was a shift in the 'trust' facet of the landscape. Quotations below illustrate varying levels of acceptance and distrust in policies and developments in Energy Valley (some repetition due to overlap elsewhere).

> *'In this region there is, in my view, and it may sound cynical but the earthquake problem is also an opportunity…. The director of NAM has been visiting residents in*

*the area and you could say that he should have been doing this for years now…. But the point is that this has been done in the past. Look at the sport halls, swimming pools and other facilities in the Netherlands where the NAM has contributed in the past. We will set up [drilling] installations in your village but we will also do something for the community. There was always a dialogue, agreements about the plans….both NAM and Gasunie managed to gain local support for their activities in Groningen. Now you see how fast this [relationships] is changing…. now with the earthquakes it is clear that this [relationships] needs to be much stronger…. they [residents] still want to live there, but they want to be acknowledged, they want these risks of building collapse acknowledged….' [Industry Stakeholder, EV16]*

*'We think that there is some degree of dissatisfaction, let us say that the fact is there is a latent distrust of the government, as it is not fulfilling its role. The government is no longer the sustainability partner…. That used to be the domain of the government. You went to the government, and it sets out a law [regulation], provided subsidies and it was purely a domain of government. Businesses were not in the picture as they were the enemy, but the government did everything to ensure sustainability. This role is now completely gone.... it is not clear where the money [environment tax, energy tax] is going to and what you are getting for it. It's going to Vattenval, to RWE…. its all getting more international and 'bigger'.*

*….energy is essential for living and people see rising prices, people get uneasy, and all of this comes together in the drive from below creating energy groups, sustainability groups…and it is more than only energy….communal care, neighbourhood services and neighbourliness 'noaberschappen'….' [Civil Society Stakeholder, EV19]*

*'Now if there is one thing that everyone is calling for is, that consistent policy is important, thus not switching between subsidies and no subsidies for solar panels, stop adapting your subsidy instrument and your tax laws [incentives]. We are doing this way and like Germany then go full speed ahead…. I am curious about the developments now that the energy accord is coming, whether it will provide guidelines sufficient for a number of cabinets [periods]….' [Policy Stakeholder EV14]*

*'The trust in the national government has decreased in the last years because of the changing policies, because of less money made available for these [sustainability] issues. Civil servants do not get time, tasks, the notion that the government knows where we need to go, that notion is not prevalent with many people I think. I hear in any case more often that people do not have much trust in how things are going and therefore the trust in government is waning. For us, trust is depending on the role we take, we used to be, like the government, custodians of knowledge and expertise and this is how we were seen. In the last years, through the internet democracy, that is disappearing. We are not the only supplier of knowledge….'*
*[Civil Society Stakeholder, EV19]*

*'I can explain the frustration. This has to do with policy that is framed in terms of targets and not in terms of creating support. We are constantly victims of our own desire to demonstrate results and to gain credit. And this is why in the new cabinet's accord a new approach sets out high levels….' [Industry Stakeholder, EV16]*

*'…There are different interests, and these interests need to find each other in Energy Valley. And it is true that there are people who would rather have more invested in traditional energy and others who say that if you need to curtail $CO_2$ levels then nuclear energy is the choice. The discussion about $CO_2$ storage in empty gas caverns, there are those who are only for off-shore wind energy and another for both on- and off-shore…so there are differences but there are no conflicts that stop discussions…. I mean, there are a lot of people who are very critical about new coal plants being built still…. and yes, you can be critical about this and about it being located here…but without this [coal power plant] there was no critical mass, and we would have been not visible…. so you need to be a bit pragmatic in this and realize that if the market wants this plant…. and if it is built here then I have control of it and perhaps I can try to do something positive with it…. current developments show that there are different pathways in the [energy] transition, sustainable but also traditional.'*
*[Academic Stakeholder, EV3]*

*'There was resistance especially against windmills…. you come across these groups, mostly emerging from dissatisfaction…. We are different; we wanted to offer a positive signal and started to think about energy production…. to make it more amiable to live… a better world begins here in…. we thought about it, we can point to others but we can also take action ourselves….there [village climate feast] it became clear that if we do not do something, and the world around us is going to change any way, we may end up not being able to do anything about it because farmers disappear because they are not able financially which means that our landscape will change….and so you can think of different solutions and about the whole energy challenge….*

*It seemed that the energy issue was relevant for more people and so we took organized a brainstorm session where 45 families from this village took part, 116 residents, 5 working groups…. wood from pruning to wood fired heaters, LED public lighting…. the aim was not even energy savings but more that things can be changed…. we showed that we had influence on our environment and that was really important for our sustainable village initiative.' [Civil Society Stakeholder, EV21]*

*'There has been research and everyone wants wind energy but without [negative effects]…. there are examples of how to do it [social acceptance]. That means a very good communication strategy needs to be developed…. want to bring the energy here and therefore the energy needs to be also from the citizens and not how it generally is that yes we bring the wind turbines here and that the money goes to a few shareholders…. I know of a Frisian village, one that is shrinking, there, the wind turbines are secured for the whole community. There is a committee that determines how the money is spent, be it for the community centre or…. You see how this is a different experience and this too, is a solution.' [Policy Stakeholder, EV20]*

*'I think that the trust in businesses is growing because there have been successes in other businesses and there has been evidence that if you want to be leading, you need to invest [in sustainability]…. I think that the one accelerating the transition is in general are the large corporations, DSM for example….they have an economic perspective….but they have a vision about how to deal with resources and energy and are designing charters such that this dictates that their suppliers will have to comply with this vision …. and these are substantial forces to be reckoned with….these leading players are part of networks that have reasonable impact….it*

*is good that these corporations even as they are not consistent, are more consistent than the Dutch government.' [Civil Society Stakeholder, EV19]*

To summarize, Energy Valley was previously a landscape of 'trust' reflected in the acceptance of authority and specialists:

- Top-down approaches in energy policies and solutions;
- Gas exploration for 50 years.

The shift in this landscape was that trust became more conditional; there was more criticism of national and corporate policies and approaches. The degree of trust in decision-making and futures then varied from tolerance and engagement to parties that felt alienated and there were more initiatives to seek own solutions. The reliance on government for energy solutions saw different movements and these included:

- Protests from citizens regarding wind farms, carbon capture and storage, shale gas and gas exploitation;
- Increase in local energy co-operations, shares in wind farms, solar panels on roofs, demand for green energy, etc.;
- Corporations pushing for sustainable production and energy.

The next aspect of the changing landscape lay in the nature of knowledge development. Previously, energy knowledge development was left to specialists and experts and often within institutions and university departments and very fragmented and focussed on internal needs and policies. The shift towards more 'open' forms of learning and knowledge development was a result of the urgent and complex challenges brought about by the energy transition. The interview excerpts below illustrate some of these changes.

*'We have a lot of knowledge available, for example at Zernike, we have knowledge but is labelled differently which results in not directly being visible to the energy world…. In North Netherlands, here in Zernike, all the knowledge needed for this development is available here. All faculties, chemical, physical, technical…. everything is available here but it is not visible as 'energy'. If you gave me the space in a green open space, and I can do what I want, I would bring all this available expertise and put them in a row and than I could have put a signature on a new MIT.'*
*[Academic Stakeholder, EV24]*

*'Energy Academy is to us an instrument to bring about structural knowledge sharing between the knowledge and business pillars…and that will be translated and focussed into lessons, in education and in research programmes…. but an instrument like EnTranCe is naturally an ideal instrument to bring more industrial knowledge and academic knowledge together.' [RDA Stakeholder, EV1]*

*'….Besides the level of knowledge, in applied sciences university, there is more of the transverse [horizontal] part of 'T' whilst in fundamental knowledge development is per definition in the vertical part and this is why there is in terms of contents divided segments and you cannot blame people…. the Hanze has a different role in the game and they should take on this role but you can say, for example, when a new director is chosen for Energy Academy, that is the precise moment to choose someone who is above all parties, and all interests….you can in any case say that Hanze has an important task…. to ensure that the various disciplines of knowledge is channelled to create value….you need to do two things, you need to bring the different segments together and get people to work together and Hanze needs to be made accountable for its responsibility to make this happen.' [Academic Stakeholder, EV24]*

*'It is about systems both local with houses and of larger systems regarding cohesion between gas and electricity, developments on LNG, wind, it is the totality of the system in terms of underground positions, knowledge that is present here but also of the physical characteristic of projects present here, and we achieved this thus far.'*
*[RDA Stakeholder, EV1]*

*'Previously, we were considered the stakeholder who was an authority on environmental and landscape issues…. but this is changing and we have become a stakeholder focussed on being a process manager. We steer, we help people come into contact, that processes are taking shape, and that we try to keep the process going. I think that our role and others too take on this role; the government takes such a role; it is more a coordinating role as it is called. Energy Valley has this role for years now, not executing but more facilitating and there is so much energy in businesses and business alliances, and in local working groups of businesses, foundations, in villages…and that is a good role. It is good that Energy Valley focuses on the 'big' corporations….' [Civil Society Stakeholder, EV19]*

The domain of knowledge and how this has been developed and organized has already been addressed in earlier aspects of 'Shifting Landscape' [on gas dominant landscape, trust, etc.] where it was shown how reliance on experts and institutional research was commonplace previously and that in Energy Valley more traditional knowledge development patterns were present. The types of knowledge development included:

- Specialists, experts, disciplines, institutions, specific energy types, public and private research, fundamental and applied research, sector-based, etc. and often in 'silos'.

The quotations above show a shift in the landscape of knowledge development that included more experimental and knowledge sharing practices where new players and combinations of players were brought together. This was motivated by a need to meet challenges of energy transition at different levels. To summarize, 'learning' and 'being open' were becoming the norm as was being more inclusive and more space for experimentation:

- Shifts in Energy Valley towards ‘open innovation’ and connected research development, both horizontal and vertical integration and public-private collaborations. Examples were EnTranCe, Energy Academy Europe and Energy Valley Foundation.

Another aspect of the changing landscape in Energy Valley relates to types and nature of collaborations. There was a strong gas-centric landscape as described in the earlier parts of this section that meant that a few players were dominant and authorities had their say. There was a certain ‘in-crowd’, the ‘happy few’, as mentioned by one of the stakeholders and there was acceptance of the status quo as also described in the first part of this section on ‘gas dominance’. This landscape therefore was also characterized by fragmentation and segmentation where knowledge development elsewhere in higher institutions of education for example, were not connected to energy developments and therefore fragmented and faculties were focussed on their own disciplines and organizations were also mono-sector in their orientation and focus. The key driver of businesses was competition rather than collaboration in this previous landscape. The provinces too had their share of differences as reflected below.

> *‘Here in the North, there is willingness to collaborate, there is an amicable atmosphere, people wish others well…. maybe Energy Valley has something to do with this, since the ambition is to make the North the centre of energy.’*
> *[SME Stakeholder, EV15]*

> *‘What we are seeing is that especially since the funds in the Netherlands, we were always dependent on State and Provincial subsidy funding, is drying up at a fast rate we are particularly focussing on European subsidies….this means you need to have a broader scope, provincial or larger, as you need this scope to get the money and thus, you have to work together….’ [Policy Stakeholder, EV20]*

> *‘The provinces acknowledge the need [to collaborate] and that is what we need to do this….but we know that there is a lot to be done. It is not easy, collaborations, it is about getting to know each other, on getting misunderstandings out of the way, try to organize projects together which makes these collaborations complicated already in the Netherlands…. it take a lot of effort and time….’ [Policy Stakeholder, EV8]*

> *‘We try to bring stress that it is about optimization of production and utilization and not about the cheapest possible capacity system, which seems to be more the inclination of the minister. This is really a substantial approach, optimization of production and utilization is also about influencing demand and thus also about energy efficiency/savings but it is also about behaviour of businesses…. this is why the Power Matching City in Hoogkerk is so important.*

*The project that we are doing with Niedersachsen….Dass hätte kein Niederlande kein Deutschland….one example of one this is in Oldenburg focussed on cold stores, which are well insulated… and they are only cooled when price is low of when power is abundant and not when it is expensive. Thus, not a standard electricity flow but a management system designed for this purpose. This is the way to go for all of us. It is also, besides being a good project, it is a metaphor for the whole [transition] on which direction we all need to go with this.' [Policy Stakeholder, EV8]*

*'There are examples of cross-overs….for example, between sustainable energy and the agro sector where they are exploring how you can deal with residue heat, solar, heat and cold storage, those types of issues, and yes, collaborations are sought…it is not always easy [to find the partners] and it has been difficult to form clusters….*

*Another cross-over…. is sustainable energy and the Marine…. Maritime and Off-shore sector. That is a cluster to be found around Den Helder…. exploring testing location and facilities….' [Policy Stakeholder, EV14]*

*'The first five, six years of its existence [Energy Valley Foundation] it was explicitly forbidden to have activities internationally….that has changed and as we have it now, it is as one of the key themes. In particular, we have built up relations with Niedersachsen, and actually in the larger North Sea region, as this is a relevant playing field for us. Only Niedersachsen is too limited, partly because of Brussels' norms…. The key coalition agreement with Niedersachsen that has just been realized…. has two key words with regards to energy….they find it important to collaborate with the Netherlands for storage and [systems] integration, these are the key words…. this is the story.' [Policy Stakeholder, EV8]*
*'The Energy Academy…. is a good example and Energy College….the whole 'column' [of education] MBO, HBO, WO, research and applied research….Grunneger Power is another nice development….this is the new energy users.' [Academic Stakeholder, EV3]*

*[on solar panels] 'Because you of course will have competition where they look at you and say if you can do it then I can too and, cheaper…. Yes, and the price, and particularly in China, they have gone large scale and they are at almost half the cost price of German producers…. you also have the US where they are good at product development and improving the efficiency so that the cost price is reduced…. that is technology development and that is important and we are also very good in this in the Netherlands. If you look back 15 to 20 years ago, the Netherlands was leading in Europe in solar energy…. but this is changed, there is little government support via subsidies at present.' [SME Stakeholder, EV15]*

*'I agree with the initiative of Energy Academy…. to ensure that we have an advantage above Eindhoven, they have only a university, but we also have a university of applied sciences and therefore we have applied research and also we have a lot more disciplines, we have psychologists, economists, lawyers, sociologists…. what our ambition is, to have what they in Stanford call the T-shaped education where our students are have a specialisation in certain areas but that they also have a connection to the broader energy theme. Because energy is not only technical but also politics, economics, law, power….it is something that changes the world.*

*It is really important to connect the economic activities to universities and universities of applied sciences so that you can take it to what for me is an excellent example, how Wageningen is organized around food. You have a university and a research centre and all of that is in one organization with one board, a lot of businesses aligned to it, a lot of patents being registered there and that is the opportunity that Groningen also has. Not only Groningen, but also with collaborations with ECN as a minimum, but also Delft and Eindhoven. The Netherlands is too small…. Energy Academy Europe it is called but we are also talking to the Russians, the Saudis, the English…. it is our intention to make it an international hotspot for this type of education and research.*

*The nexus energy and water…. there are [opportunities] there are tremendous overlap and synergies and therefore these need to be connected and we will do this. But it is challenging in the phase where we are now and where we do not have much success yet to share. There needs to be good things happening at some point so that also the people in Drenthe and North-Holland will also be saying, yes that is also ours….' [Industry Stakeholder, EV16]*

*'A quarterly newsletter, that has more 'popular' content but we have abundance of sessions where you can go deeper [into topics] with experts and this is one way to stimulate knowledge sharing…. and we are busy with on-line community developments. We are relentless about developing knowledge content that we sometimes forget to communicate….' [RDA Stakeholder, EV1]*

To summarize, Energy Valley moved from a fragmented landscape where collaborations were segmented due to the nature of the landscape itself. Previously, collaborations were limited to specific domains due to:

- 'Silos' dominating scientific disciplines and the mono-sectoral organization
- Competition as main driver of companies rather than collaborations
- 'Authority' of government, big companies and experts
- 'In-crowd' dominance being common and accepted

Most of these points have already been addressed in earlier parts of this section as well in the quotations presented. Similarly, new contexts in Energy Valley, the energy transition being an important one, meant that sharing, connecting and crossing borders were part of the changing nature of collaborations. To summarize, changes in collaborations included:

- Cross sector value chain creation
- Multi disciplinary approach that went beyond technology
- Cross regional and international collaborations
- Open innovation platforms and partnerships such as in EnTranCe and Energy Academy Europe
- Self-organization and on-line communities
- New impetus such as sustainability and autonomy as drivers pushing collaborations

A number of these points have been mentioned in quotations in earlier sections and in the quotations above. This overlap is inevitable as many of the aspects described in the 'Shifting Landscape' are interrelated and overlapping.

The next aspect of change in the landscape of Energy Valley is the shift from more centralized decision-making structures to more diffused structures of governance that included new stakeholders and norms; this shift also reflects the new diversity and complexity of the changing cluster. There is also recognition of the need for both the top-down and bottom-up approaches as well as more horizontal structures.

> *'It is an interaction and I hope that it is not only centrally steered, as this will not work but also not …[only decentralized]…. we shall see…. as this too will not work…. but you need the interaction of both [approaches].' [Academic Stakeholder, EV3]*

> *'We have our opinions about these [wind farms in the North Sea], but our role as province is not very significant because we do not have a say about things in the sea and we have limited say on coastal areas but of course you can offer input, but it is limited. And you can react to plans presented but legal and regulatory aspects are anchored in these, but of course you can offer incentives to stimulate such developments. In our case, in NHN we have construction capacity at Den Helder and Ijmuiden, and also good access to these wind farms, there is a lot of knowledge and developers and research institutes that are available in NHN…yes, ECN naturally…We have chosen for North Holland, through the coalition's programme and accepted by the Provincial Executives, that there will be wind at sea, biomass, solar and energy efficiency in built environments. These are our strategic focal points. And wind at sea is very important for us and we need to see how much say we have in this, and the State's say.' [Policy Stakeholder, EV14]*
>
> *'But we have an excellent position when it comes to offshore construction, we are the only sustainable energy sector in the top three in the world…but where we have an issue in that we need to have a good domestic market, and that is not yet realized. We also have excellent positioning for the North Sea with the locations of Eems Harbour, Den Helder, and Harlingen to some extent…. more so than most German harbours. And there is a lot of jobs, a lot more than in on-shore and also a lot more than in the power plants…. and if we want to maintain our position as an innovative region where new developments are taking shape, we can only do this if we have a very strong knowledge base and otherwise we will loose it… it can be better…. there is a lot – Edgar, Flexi-programmes, RenQi, EDI…. collaborations in EnTranCe obviously. All of this is good….but it needs to be more coherent and there needs to be more… more researchers with global fame in the energy transition field. And not only hard core technic…. we have these in Delft, Eindhoven and Twente, better than us…. but we have organic solar panels here…. we need system integration, social acceptance, business economy, legal aspects, etc.' [Policy Stakeholder, EV8]*

> *'There is a different and more simpler and more horizontal [role]…. What can a club like Energy Valley do for the 'big boys' in their regular work….? These 'big boys', the NAM, GasTerra, the Gasunie, TAQA…. they do not need Energy Valley Foundation for their core business…. But there are however issues between these businesses, interfaces that need to be developed and designed and this role of*

*bringing parties together and the different ideas together, this is where Energy Valley could play a significant role.' [Policy Stakeholder, EV8]*

*'We are not able to make a business case [for sustainable energy]. In the Spring Accord in the Netherlands, we had a coal tax implemented as a sympathetic gesture but it was a completely wrong instrument. You do not need a coal tax but a $CO_2$ pricing [instrument] and that at the EU level and although even this scale is [too] small….but we work on an EU scale….when we are working with these [sustainable energy] projects and want it launch it, we need to have a good business case in which case, the $CO_2$ pricing mechanism is needed….the EU needs to be more fanatic in this. And they know this.' [Policy Stakeholder, EV8]*

*'We all set agendas [on sustainable energy]…. who doesn't? Everyone….and in The Hague, every decision is a plausible story but the total picture is dramatic…. that is the problem…..Yes we have to have 9% in 2010 and when we finally seem to be reaching our target, it is suddenly stopped…what? What will happen to the world after 2010…. these investment decisions are about long term [plans]? …. My take on Europe, my feeling is, that they…. at some time in the future… will make big progress on energy efficiency, although, there could be more pressure in this….but I think that the car lobby and other lobbies are preventing this. The $CO_2$ pricing mechanism has been the biggest failure of policy, let us be clear about this…. the ETS theory is faulty….'*
*[Policy Stakeholder, EV8]*

*'You can see how also in energy, the large-scale nature is something that people do not feel connected to, like the banks…. I see a trend and we need to be smarter about how we do this…. also with industry. Look at wood [waste] for wood-fired heaters, being exported to Germany in the past…. we could use it here too….there is a shift in the thinking….there are initiatives, neighbourhood teams, for example in Eems delta I believe, where cooperatives emerged and you see these developments….'*
*[Policy Stakeholder, EV20]*

*'Harbour and location, and the presence of power plants, that is a nice picture we have made…. seen in the energy atlas. This is a logical place. In fact, we are similar to Niedersachsen, they also have a similar role, production and a throughput station for sustainable energy for southern Germany, where they need it. We are the same…. it is not a coincidence that Google is located here with the power plants next door. But the gross of it goes to the 'Randstad' [metropolitan area of the Netherlands] or to the Ruhr region.' [Policy Stakeholder, EV8]*

*'Historically, we were a rich region and had much influence 100 years ago but this [standing] has dramatically fallen within the Netherlands. It has to do with the fact that we are far away from The Hague and we are thinly populated with only 10% of the total population. But the biggest problem is that this is an agricultural region, and agriculture has become less important due to its value creation capacity…. so we had become a quiet 'suburb of the Netherlands' but this is changing.'*
*[Academic Stakeholder, EV7]*

The changing landscape of Energy Valley saw that the previously centralized decision-making structures of national policy, government and large corporations were being challenged. The 'old' landscape was characterized therefore by:

- National dominance, top-down, planned and large scale dominance;
- Centre-periphery relations.

The new landscape of Energy Valley included 'multi' governance structures that were not necessarily formalized but with the growing collaborations across sectors, levels and borders, new governance norms were needed whereby new players and new ways of organizing were emerging. This new landscape of decision-making was characterized by

- Multi-layered and multi-scale structures;
- Top-down and bottom-up approaches;
- Planned and self-organized groups;
- Nodes and networks.

The landscape of the energy cluster and the region of Energy Valley moved from one that was linear in its approach, using more traditional ways to plan the future, to one that was more systems-oriented and context-sensitive in its approaches. This shift in approaches was due to the shifts in its landscape. Most of the past approaches have already been addressed in the descriptions earlier on centralized and dominant governance and organization structures where top-down approaches were prevalent. In the shift, there is an awareness and change in behaviour to more collaborative strategies and an expansion of scope whereby learning and knowledge development became more important. The notion of clustering and specialization were also part of this new landscape. The quotations below and those cited previously illustrate these shifts in strategic approaches and the role of the changing contexts in this.

> *'If I look back at 10 years of energy in North Netherlands…. when Energy Valley was set-up….in our organization, there were 2 energy boys and 'half' of someone in Spatial Planning and someone from economy. In the first years we did projects, later we implemented themes be set in 4-year programmes. At some point, these themes needed to be justified and where the Provincial role could add value. This is around 2007 when the first big energy accord North Netherlands was realized, with thanks to Ed Nijpels for a large part, the former Queens's Commissioner from Friesland. This brought a lot of connectedness. We began working programmatically and this phase is now two and half years…and this was outside of Energy Valley [Foundation]…. but since about two and a half years now, we decided that we need to bring this to a higher level and we need to have more focus*

*and this is when the ‘vizier’ [energy programme] emerged.’ [Policy Stakeholder, EV8]*

*‘The metaphor of a pie, and it is not about dividing the pie but it is about making the pie bigger, and this is what they want in energy, in general terms, and of which sustainable energy is a part of, but also in terms of employment, investments….economic targets, but also in terms of energy, traditional and sustainable.’ [Policy Stakeholder, EV14]*

*‘You have in north Netherlands…. a whole lot of local initiatives in municipalities, neighbourhoods, cooperatives and such…. important and ideologically driven. These decentralized systems are important…. these local initiatives are everywhere, in the Netherlands, North West Europe…. it is the prevailing spirit. It is a movement…. but the problem is that there is no back-up if there is no wind or the sun does not shine…. and it is cold and we need heat….but you cannot say that the power plants are closed as there is no business. That is the problem.’ [Academic Stakeholder, EV7]*

*‘We have tried together with Niedersachsen and a number of partners from around the North Sea as core region in Europe to position ourselves in energy and energy developments in a number of subjects, including production thanks to off-shore wind and this will become big and where we are now involved in is gas and the balancing [of energy] for Northwest Europe.’ [Policy Stakeholder, EV8]*

*‘In the last three years in North Holland North (NHN), we have made a conscious strategic choice for the cluster approach…. driven by Europe of course to allow regions to focus on your key areas and to bundle your resources in what you are good in [smart specializations]. Running through these clusters are a number of goals, education and labour market is one such, sustainability and spatial quality [is another]…. these clusters are steered by a Board….The NHN Energy Board clustered all sustainable energy initiatives in the region of NHN; and Energy Valley does the same for the whole region [of Energy Valley].’ [Policy Stakeholder, EV14]*

*‘Government is concerned with the supply side of things whereas governments should be focussed on the demand side. We are good in demand-side modelling, but then we need to have the opportunity to do it. And in fact, smart grids are manifestations of demand-side modelling.’ [Academic Stakeholder, EV6]*

*‘It is not only to keep the university and university of applied sciences here but also need to bring a few substantial research institutes here. ECN could play a significant role in this but with teleworking and Internet and so…but with technic it is different. EnTranCe can become something like this but is still small in scope….that we have a few large scale, regionally anchored [programmes], that go beyond regional interests [compare to ‘Lifelines’ for Healthy Aging]. Philips [in Drachten] is intensely involved in robotics but you do not hear their names in Energy Valley… get them involved…have a huge private stake…. cluster them….the region is large, it is one quarter of the Netherlands. This needs to be a buzzing hub where everyone can walk into each other’s place….’ [Academic Stakeholder, EV6]*

*‘We have a Drents Energy and Climate Consultation where the Province is developing a new policy and I think that this needs to at the provincial level and that decisions are made about the focal points and that in three years all municipalities have to realize them…. it offers scale advantages and perhaps advantages for European subsidies, and to avoid duplication…. and also not to*

*have to deal with internal objections at the local municipalities where there are often a lot of resistance…it is better to determine our goals and to move ahead….yes there are inter-municipality consultations on energy and energy transition…the province has its inter-provincial consultations, IPO. And Energy Valley Foundation and the Province have consultations about what needs to be realized in The Hague, that is another [consultation].' [Policy Stakeholder, EV20]*

*'If you develop knowledge to capture $CO_2$, get industrial about it, then we can continue to burn fossil fuels without large-scale environmental effects and then you can build the chemical industry with this. You can make polymers and offer carbon dioxide to glasshouses instead of letting it escape which is the case now. The Eems harbour power plant will produce three million tonnes per year…. if you can capture it and do useful things with it then you have double advantages….continue with the coal fuelled plants that generate more $CO_2$ and in more concentrated form than gas powered plants. If you can capture $CO_2$ and do useful things….' [Academic Stakeholder, EV6]*

To summarize, Energy Valley saw a shift from more traditional problem and solution approaches (linear thinking, modelling and scenarios) whereby they were

- Non-contextualized, cause-effect analysis and problem solving strategies

The shift saw that the focus on systems and context included what was labelled by the cluster organization as 'ecosystems thinking'. This included

- Shifts to more ecosystems approach by linking learning and innovation, production and consumption, consumer and local citizens' initiatives, regional and cross-border, local and global
- Creating cross sector visions and approach such as bio-based economy, systems integration, smart grids, water-energy-agro programmes
- Enlarging the system included examples such as the North Sea connections, (ENSEA), NW German linkages (HEC) and EU linkages
- Cluster as geographic and intellectual concept and challenge

This documentation illustrated in detail how the context of Energy Valley cluster changed and how this influenced its landscape. Various quotations from stakeholders were included to show different aspects of the change. The table below is an overview of the 'Shifting Landscape' of Energy Valley that summarizes insights into changing contexts of energy clusters, a summary of Lesson 1.

| Existing landscape | New landscape |
|---|---|
| **'Simple & complicated' – technology, economics, policy** | **The 'many' & the 'complexity' – distributed agency** |
| - Focus on gas<br>- Few stakeholders<br>- Regional and national<br>- Centralized grid and power | - Many energy sources<br>- Many new stakeholders<br>- Global and EU interests (focus)<br>- Centralized and Decentralized grid and power – need for new infra |
| **One or two frames of reference in policy/strateg** | **Multiple frames & sensemaking – new 'voices' and dialogue** |
| - Economics and gas/energy politics<br>- National policy dominant<br>- EU less dominant | - Economics, energy transition and regional politics frames<br>- Climate change and sustainability agenda<br>- Consumer and grassroots movements<br>- EU policy dominance in energy and focus on regions<br>- Increased decentralization agenda |
| **Slow change – 'homogeneous' future scenarios** | **Uncertainty and change – unpredictable future scenarios** |
| - More top-down than bottom-up<br>- Change through blue-print strategy<br>- Focus on large corporation and national government linkage<br>- Convergent future scenarios<br>- Slow change and stability | - Both top-down and bottom-up<br>- Change through interactions<br>- Presence of multiple and new players and linkages<br>- Divergent and unpredictable future scenarios<br>- Change characterized by uncertainty, and turbulence – earthquake, geo-politics, shale, etc. |
| **Latent trust in authorities and specialists** | **Trust is conditional – varying (tolerance, engagement, alienation)** |
| - Top-down approach, energy policies and solutions accepted<br>- Gas exploration was accepted for 50 years | - Wind farms, Carbon capture and storage, shale gas and gas exploitation generated protests from citizens<br>- Local energy co-operations, shares in wind farms, solar panels on roofs, demand for green energy embraced by citizens/consumers<br>- Corporations pushing for sustainable production and energy |
| **Knowledge development - exclusive & internally organized (traditional)** | **'Learning' & 'being open' as norm (inclusive, experimentation)** |
| - Specialists, experts, disciplines, institutions, energy types, public and private, fundamental and applied, sector based, etc. | - Shifts in Energy Valley towards 'open innovation' and connected research development, both horizontal and vertical integration and public-private – examples, EnTranCe and Energy Academy Europe |
| **Collaboration – fragmented & segmentations** | **Different collaborations needed (sharing & cross-border)** |
| - 'Silos' dominating scientific disciplines, mono-sector organization dominant<br>- Competition as main driver of companies<br>- 'Authority' of government, big companies, exper<br>- 'In-crowd' dominance common and often accepted | - Cross sector value chain creation<br>- Multi disciplinary approach beyond technology<br>- Cross regional and international collaborations<br>- Open innovation platforms and partnerships<br>- Self-organization and on-line communities<br>- New impetus – sustainability and autonomy – pushing collaborations |
| **Decision-making – centralized** | **'Multi' governance – new players & new norms** |
| - National dominance, top-down, planned and large scale dominance<br>- Centre-periphery relations | - Multi-layered and multi-scale<br>- Top-down and bottom-up<br>- Planned and self-organized<br>- Nodes and networks |
| **Problems & solutions – linear thinking (modelling & scenarios)** | **System & context – ecosystems thinking** |
| - Non-contextualized, cause-effect analysis and problem solving strategies | - Shifts to more ecosystems approach by linking learning and innovation, production and consumption, consumer and local citizens' initiatives, regional and cross-border, local and global,<br>- Creating cross sector visions and approach – bio-based, systems integration, smart grids, water-energy-agro programmes<br>- Enlarging the system – North Sea connections, (ENSEA), NW German linkages (HEC), EU linkages<br>- Cluster as geographic and intellectual concept and challenge |

*Table 27 'Shifting Landscape' of Energy Valley*

The landscape of Energy Valley and its context became more complex due to energy transition and related developments. In order to better understand the increased complexity, details of Energy Valley's cluster condition, context, dynamics and performance and their interrelated nature are described in Lessons 2-5.

### *4.5 Lesson 2: Cluster condition – interrelatedness of local conditions*

Stakeholders identified Energy Valley's path dependency, stakeholders and container that formed its cluster condition. The next sub-section describes how the dominance of gas in Energy Valley cluster condition's path dependency also affects who its key stakeholders are and how the container is shaped by both these factors. The key outcome of this lesson is the interconnectedness of cluster conditions.

The discovery of gas in the late 1950s in the Northern part of the Netherlands resulted in a strong gas related economy and expertise. Gas exploration and the resulting revenues were important contributions to Dutch national development and to the treasury. Gas earnings contributed between 5-10% of the GDP and with an accumulated total of 265 billion euros since its discovery. In 2013, earnings of 15 billion euros were recorded and the gas (80 BCM) served domestic energy needs and exports including long term contracts (*http://aardgas-in-nederland.nl, retrieved April 2014*). The following quotation from Energy Valley Foundation's brochure also describes the significance of gas.

> *'The Netherlands is a true gas country. The country sits on top of the largest gas field in North-Western Europe, has a central position in the European gas grid and benefits from a wealth of business and knowledge regarding gas. The Netherlands forms the logistical hub – or gas roundabout – for the extraction, transport, storage and trade in gas throughout Europe. Energy Valley is focussed on utilising this unique gas position in the transition towards a sustainable energy supply. Gas is the cleanest fossil fuel, easy to store and can be used as a back-up if there isn't enough wind or sun to produce sufficient energy. It is also possible to produce green gas from biomass. The North of the Netherlands is the Dutch principal green gas region; a region that has made considerable investments into Green Gas Hubs, infrastructure, fermentation installations and the acquisition of knowledge.'*
> *(Digital brochure Energy Valley Works, 2014 Edition)*

The gas history shaped the formation and development of the cluster. In defining the cluster, retaining gas in the energy mix was important to uphold the gas industry. Requirements of the European Commission to split national energy companies into trading and infrastructure entities triggered the formation of Energy Valley. The

Dutch government set up separate companies for exploration and trading of gas, and one for managing the gas infrastructure. These gas corporations and the Dutch government were in turn, its key stakeholders. Some of these aspects are captured below:

> *'Energy Valley was created because of opportunities but also because of threats. The threat was the enforced splitting of energy companies which meant that a possible departure of the gas headquarters and therefore a huge loss of jobs. This was 60% of the reason to initiate Energy Valley Foundation; 40% was to develop our region as an energy region and sustainability was a key theme from the start, 1 of the 3 pillars, a sustainable energy transition.' [Policy Stakeholder, EV8]*

> *'In the first place, in the history of Energy Valley that the gas reserves are under the ground here provides a strong base…. then there is the European [policy]…. the [splitting] of energy companies, thus transport and trade were divided which brought about a huge change in the market, privatization…regions being more focussed on asset management, and not only physical [assets] but also human capital…. the third success factor…. if I may say so is the increasing focus on not so much on sustainable energy, as on phasing out of fossil energy…. again, an important success factor from the point of view of our regional interests.' [Policy Stakeholder, EV1]*

> *'Of course in a number of dossiers there is resistance as you are dealing with huge economic interests and you have the vested order to deal with in subjects as green gas…. it is difficult and it costs a lot of time and money…. changing mind-set costs time…' [Policy Stakeholder, EV1]*

[On stakeholders]

> *'Energy [industry] is an important group, politics and education, I think. But too little of businesses – even as energy is about businesses…. [SME Stakeholder, EV4]*

> *.... actually, the province of Groningen is among the regional [governments] I guess leading in the theme…. [also] Gasunie and GasTerra' [Policy Stakeholder, EV1]*

The deep concerns that the region would lose its key sector, jobs and its distinct comparative advantage as a gas region due to EU driven energy developments were important factors such that Energy Valley Foundation, the cluster organization, was set up to support economic growth and job creation whilst pursing sustainable energy transition goals. Energy transition was an important part of the cluster's focus. Regional (provincial) governments, responsible for economic growth, were therefore also key stakeholders in Energy Valley. However, the resistance of vested interests and the need for change have also been raised in these quotations. Whilst research centres and educational institutes were also identified, other stakeholders were deemed to be more important.

The need to protect economic interests, jobs and income, by focusing on gas, both at the national and regional levels was evident. The focus on economics and regional development in the cluster was dominant and has been translated as ‘economic’ and ‘regional development’ frames. The third dominant frame in Energy Valley was that of ‘energy transition’. In Energy Valley, this meant the focus on moving from natural gas dominated energy systems to one that was more diverse including renewable or sustainable energy sources as described in Lesson 1 (pp. 172-175).

The illustration below captures interrelatedness of Energy Valley ‘s cluster conditions based on its gas history, which shows how this path dependent factor influenced its initial stakeholders and container (also discussed in Lesson 1).

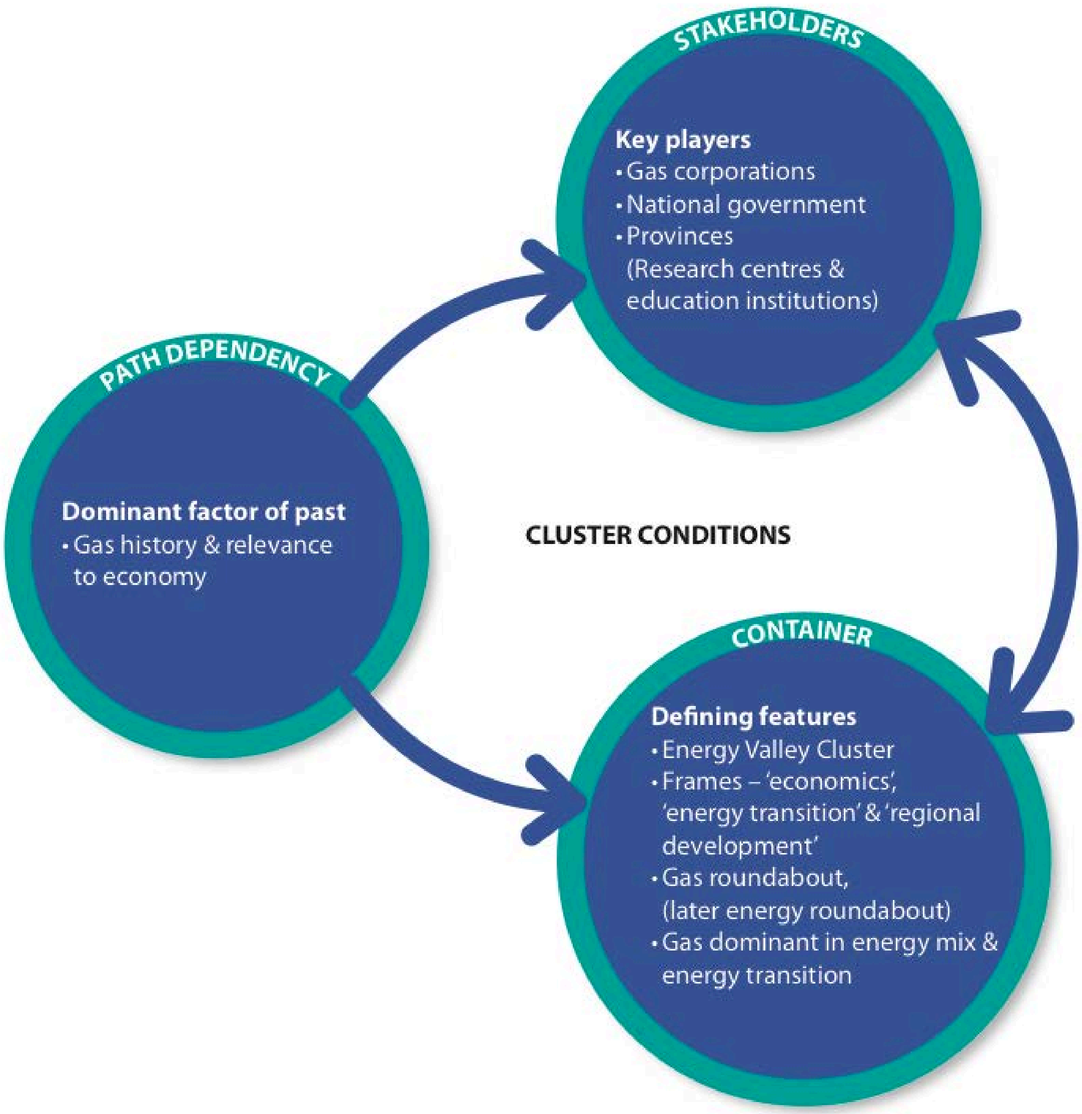



*Figure 23 Energy Valley’s gas history, stakeholders and container*

Lesson 1 described the increase in sustainable and renewal energy developments, and that of increased and diverse stakeholders where previously it was a few gas related stakeholders (pp. 172-175). Stakeholders focussed on sustainable energy had different interests and therefore affected the cluster's container. The following quotations reflect conflicts of interests and shifts in energy developments and the added complexity:

> *'A major criticism of the State [national government] is also that when it comes to subsidies for energy, money going to the fossil industry is billions more than money for the sustainable industry…. I do also understand that a lot of income is generated for the State as well.' [Policy Stakeholder, EV13]*

> *'In the past, it was relatively simple but large power plants at the outer borders of the country, near the sea for cooling water and with a fine grid network and it was not visible but it was well organized. There is a whole complex system emerging with solar-panelled houses and wind turbines and bio-digesters and what else you can add to the list, this complexity of course also makes the added value of Energy Valley [Foundation] greater.' [RDA Stakeholder, EV1]*

Changes to Energy Valley's developments captured in their initial and changing cluster conditions were illustrated with the 'gas dominance' aspect. The table below captures Energy Valley's cluster condition that includes all aspects. More information on these is found in Appendix 9.

| | |
|---|---|
| **Container** | There were<br>– **Three main 'frames'** – 'economic', 'energy transition' and 'regional development' – defined strategy and behavior of stakeholder groups<br>    - Lack of common frame or explicit framing positions risked sub-optimal dialogues and results<br>    - **Provincial differences** in local contexts and agendas present (see path dependency)<br>– EV foundation's vision/mission framed by key triple-helix stakeholders, the 'founding fathers', public funding agency (SNN) and members of the cluster – **complex collaboration**<br>    - Collaboration and formation of EV cluster was a joint initiative by the 'founding fathers' in response to gas reserves depletion and dispersion of gas expertise<br>    - Collaboration despite (regional) stakeholders differences reflected urgent need to face energy transition and regional economic challenges<br>– The cluster organization was commissioned to serve local energy businesses, broader energy transition developments, and regional economic developments – **complex and sometimes conflicting agendas**<br>    - Large-scale developments in the Eems harbor region served national and strategic interests rather than job creation, decentralization and sustainability goals<br>    - Limited capacity of cluster organization meant iconic (political and large) projects superseded local business support and job creation goals<br>– **Initial regional focus and scope** |
| **Path Dependency** | – **Gas reserves created new industry and expertise since 1950s**, whilst energy market liberalization threatened loss of energy expertise and jobs through M&A and HQ re-location<br>– **Dominance of 'gas' in the history, energy infrastructure and energy system** in the Netherlands determined Energy Valley's initial cluster condition – **lock-in** risk and power imbalance<br>– **Dominance of national economic interests** (BV NL) – power imbalance<br>– **Peripheral position** of North Netherlands reinforced need to collaborate to develop future strategies jointly<br>– **Focus of Energy Valley** cluster reflected factors related to path dependency: gas, biogas (agriculture), wind, water, NW Germany and North Sea Region<br>– **Knowledge base of Energy Valley limited and fragmented – 'cluster drain' and divergence risk**<br>    - Lack of major corporations and R&D capacity outside of 'gas'<br>    - Fragmented public research capacities and disciplines<br>    - Dispersed innovative SMEs<br>– **Path dependence differences of socio-economic structures of provinces**: large gas corporations, autarchy, food and agro-based industry, recreational and tourism industry, horticulture industry, SME dominant, 'Veen' colony, hinterland of Amsterdam Metropolis |
| **Stakeholders** | **Energy** stakeholders related to and representing<br>    - Policy<br>    - Energy industry<br>    - Academia & research<br>    - Regional development agency<br>    - Cluster organization (EVF)<br>– Key gatekeepers - visible champions of Energy Valley (as identified by stakeholders)<br>– 'Missing' stakeholders - not involved in strategy dialogues<br>    - Financial institutions (not part of cluster)<br>    - Broad SME representation (diffused group)<br>    - Civil society representation (diffused group)<br>        o **Decentralization of energy supply - new players** including citizen initiatives and new SME energy services<br>        o **Local municipalities and some NGOs** had closer links to citizens and SMEs but were not engaged in cluster strategy<br>        o **Energy transition decisions** impact local communities and businesses as evident in protests related to wind park development, CO2 storage, gas-related earthquakes, etc.<br>– **Groningen was identified as a gravitational point** of cluster<br>    - Dominant (gas) incumbents<br>    - Province of Groningen<br>    - Cluster organization |

*Table 28 Insights into cluster conditions*

Insights into Energy Valley's cluster conditions were developed into a proposition on this aspect of cluster development. Below is the proposition on cluster condition with supporting insights based on Energy Valley findings.

| | |
|---|---|
| *Cluster developments are connected to their initial conditions of container, stakeholders and path dependent factors.* | - Path dependency was an important aspect of cluster developments.<br>- Path dependent factors influenced container and stakeholders; container and stakeholders were also connected to each other.<br>- Cluster's stakeholders were based on past economic and political structures; they initiated and defined cluster boundary and identity, which influenced cluster developments.<br>- Stakeholders had different frames in defining key issues in clusters; dominant frames (economic, regional, energy transition) were present in the cluster.<br>- Lock-in risks and path creation potential were present in cluster.<br>- Cluster's container included physical and non-physical boundary (scope, orientation, identity) that affected cluster developments and strategies; changes in container changed cluster's stakeholders and developments.<br>- Cluster organization served diverse stakeholders with different agendas, had different roles and was accountable for complex processes.<br>- Gatekeepers and stakeholders were diverse and some stakeholders were 'missing'. |

*Table 29 Proposition on cluster conditions*

The proposition on cluster condition is discussed in more detail in the discussion of the cases in Appendix 14.

The next section describes Energy Valley's cluster context.

## *4.6 Lesson 3: Cluster context – complexity and drivers of change*

Insights into Energy Valley's cluster context are based on stakeholder perceptions of contextual changes and drivers of change and reflect the level of coherence in the cluster and common themes or categories of the challenges and drivers. The Lesson describes urgent challenges and drivers of change as perceived by the main stakeholder groups (4.6.1 and 4.6.3) and the prevalent themes of these challenges and drivers (4.6.2 and 4.6.4) to understand the complexity of the cluster. In addition, regional differences in Energy Valley are also described, which brings added complexity to the cluster (4.6.5).

Energy Valley was initially an inward focussed regional cluster supporting linkages between local energy businesses, between businesses and academia to meet challenges of energy market developments. The cluster was mandated to focus on regional issues and to avoid transnational and international collaborations up until 2010 (Energy Valley 4, Strategy Plan 2012-2015) even as it needed to deal with changes in its context, related to energy transition, globalization, technological advances and socio-economic changes. The following sub-sections captured these drivers and challenges.

### 4.6.1 Stakeholder perceptions of contextual changes – urgent challenges faced

Stakeholders and experts were asked by way of interviews to identify three urgent challenges facing Energy Valley. The 20 interviewees identified more than 60 urgent issues. These issues were not distinct issues. Although there were overlaps, there were also significant differences in focus, priority, concerns and solutions amongst the various stakeholder groups. The stakeholder groups were Policy, Academia, Industry, SMEs, Regional Development Agencies (RDA) and Civil Society. Other differences within the groups reflected an overall diversity of priorities, interests, goals and strategies in the cluster.

In the diagram below, urgent issues identified by the four main stakeholder groups were mapped to demonstrate overlaps and differences amongst them. Views of industry and SMEs are presented separately as different issues and priorities were identified; RDAs were included in the policy group as there was considerable overlap; and finally, 'Civil Society' was not included as they were not part of the cluster. The mapping therefore includes four quadrants capturing the main stakeholder groups. Overlaps between adjacent quadrants are captured in boxes between the quadrants; overlaps of three quadrants are captured in the middle with colour coded text boxes; and common challenges identified by all stakeholders are found in the core.

The illustration demonstrates the diversity of stakeholder perceptions and interests related to urgent challenges in Energy Valley.

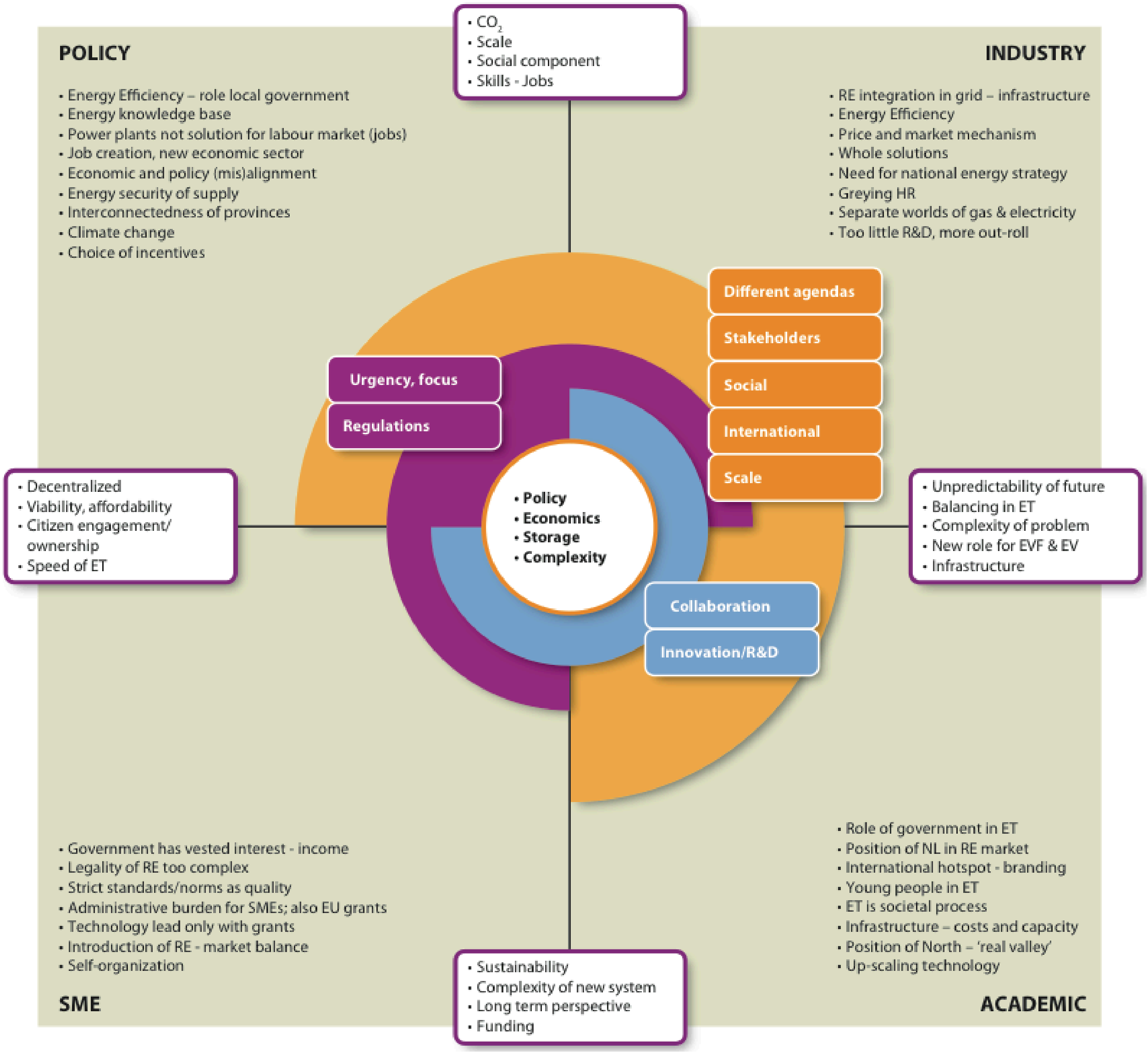



*Figure 24 Mapping urgent, complex issues by stakeholder groups*

Common areas shown in the illustration were 'policy', 'economics', (energy) 'storage' and 'complexity'. Within these common areas, differences also prevailed, congruent to the overall picture of urgent challenges facing Energy Valley. For example, 'policy' as an issue for SMEs concerned regulation and inconsistency of policy and subsidies whilst larger industrial corporations were concerned with inconsistency of policy in relation to large and long-term investments; regional policy stakeholders were concerned with 'policy' that influenced regional economic growth and job creation, and that supported sustainable energy solutions rather than dependence on external sources.

Various quotations have been included to illustrate these common issues and other challenges, in which differences and nuances in stakeholder perceptions are captured.

Stakeholder quotations are related to policy, including regulations, economic interests and inconsistency of policy:

> *'There has been a whole process underway in the Netherlands to reach a national energy agreement that is not only politically based but much broader and in particular for the consistency of policy since it is a lot to ask corporations to invest in things that have to work for 20 to 25 years whilst policy changes course every 2 years, wind energy being important and then it is solar energy, it is killing…. industrial politics under one cabinet to be spread to regions and then under another cabinet it is more focussed on sector politics and now, it is in-between.' [RDA Stakeholder, EV1]*

> *'…. Our polder culture…. we keep trying to find consensus, but there are as many for as against and if we keep talking till we agree, than we will be 10 years down the road and all independently going on…in Germany, there were very clear directions and one vision…with the right funding, good communication, you will get the public moving…. carrots and sticks…. and there is movement…. but here, we are still bubbling along….' [Academic Stakeholder, EV24]*

> *'But I feel that with renewable energy, like other developments, you must get through all the procedures and location planning barriers and…. at some point, just do what needs to be done.' [Policy Stakeholder, EV20]*

> *'…. take for example the MEP [energy subsidy] that was taking off finally and it was removed on a Sunday afternoon…Why was Biovalue launched in the Eems Harbour and why was the Bio-ethanol factory at Suikerunie not realized? This was an important criticism by the Auditor ['rekenkamer'] on our realization of energy targets two weeks ago. It was due to this. We need to meet the targets of bio-fuel production as a region, which was an important target due to decisions outside our influence. The reason that we did not succeed was that the State lowered the targets. Our business partners agreed to invest as there was a 6% target to be reached by 2010…but then the State changed this to 2% and then the business case fell through, and we could not do anything about this.' [Policy stakeholder, EV8]*

> *'The bottlenecks and barriers, that is in particular in the production [of RE], getting mileage, not so much in energy efficiency in the built area. The legal framework, both financial and judiciary…as you have to deal with fiscal challenges. Energy is pure income and as long as the State [national] does not…[have other options].'*
> *[Policy Stakeholder, EV14]*

> *'There are a lot of legal issues, the law and regulations are for small business like ours a barrier…. we have good contact with xx [name of utilities company] and the universities but even the utilities company in a meeting recently about legal considerations and how to deal with these did know how…. the laws and regulations are so complex that you need an army of legal specialists to figure it out.'*

*[SME Stakeholder, EV15]*
*'How can I as a producer sell to the grid, this is a continued concern by producers of solar energy. When it comes to bio, wind and gas there are all sorts of discussions about the surplus energy that may or may not be put into the grid…. there are green lists, red lists, lists of sorts. These are very complicated constructions on what is allowed and not allowed. And when it is transport, the fiscal policy is not favourable to cars driving green gas…. compared to Hybrid. Hybrid is an extension of fossil fuel transport and we try to bring about a transition towards sustainable vehicles….' [Policy Stakeholder, EV13]*

*'We do not make enough profits to be able to spend, let us say about 20% of our turnover in R&D, so that we can keep our leading position, we can only do so because there is subsidy available….' [SME Stakeholder, EV23]*

*'There are a lot of strategies; they are like scenarios except that they vary immensely. That is also one of the problems that you have as industry…there are scenarios that show diminishing demand for gas in Europe and at the same time we ask the Russians to invest billions to maintain gas supply for the coming decades. They are perplexed. Thus, no strategies, typical of innovation….' [Industry Stakeholder, EV9]*

*'I would prefer the objectives [of the national energy agreement] to be on framework conditions. I would prefer the market parties, private with public parties together, to have the room to initiate changes and that the right conditions are in place….'*
*[Academic Stakeholder, EV24]*

*'I understand that Netherlands [the government] accrues a lot of money through the energy tax and sees…. [the end in sight]. As more sustainable energy is produced [for own consumption] less energy taxes are paid and then there is a deficit.'*
*[SME Stakeholder, EV15]*

Stakeholders above described different issues and concerns even as policy is often the subject.

Next, examples of priorities and strategies are illustrated below.

*'There are many, many strategies….types of scenarios that could be and they vary tremendously. That is one of the problems that the industry is dealing with…scenarios that show that the demand for gas in Europe is declining steeply and yet we ask the Russians to invest billions to keep up its gas supply in the decades to come…. no strategy, purely innovation…something happens and quite suddenly…everyone tries something and at some point it seems one or more technology becomes mainstream or is attractive….' [Industry Stakeholder, EV9]*

*'There is a huge tension in terms of the organization of Energy Valley. Energy Valley does not have energy efficiency as its core business and we do not agree with this….*

*…. but of course everyone has their own focus points….on the local level we have our collaborations with the city council here… on the northern [regional] level, there are collaborations…. for strategic interests. The need to collaborate due to Europe2020 as we cannot do this alone…. we can be happy if we can put North Netherlands on the map in Brussels…' [Policy Stakeholder, EV13]*

Quotations on different solutions and related policy:

*'I think that Netherlands is lagging far behind…. Germany is a fantastic example…. the emergence of European Union…. I think that there is awareness that we cannot continue to exploit earth in the way we have been doing with energy….'
[SME Stakeholder, EV4]*

*'We focus on all forms of renewable energy production….to guarantee energy security for the future….we have here very large gas consumers [industry] and if we can help them be more sustainable…these companies can be foreseen for years…. for example a cheese factory which uses a lot of gas. If you can help these heavy industrial users, their 'right to stay' will be more certain.' [Policy Stakeholder, EV20]*

*'Developments in sustainable energy, solar, how do we integrate this into the existing system? There needs to be sustainable energy, the issue you could say is to produce sustainable where possible and where needed use other options…. The problem is that there is ten times more solar energy [in the summer] than in the winter but you need more in the winter. But when solar panels are commercially viable without subsidies, and this is possible for homes already, then it will happen naturally…. and that shall have major effects on energy situation and the role of natural gas. Because in the summer you cannot get rid of the surplus energy…. and then you get these ideas to convert to synthetic natural gas….' [Industry Stakeholder, EV9]*

*'Energy is not only a question of building big power plants but energy is also a question of consideration for the environment, also when you brush your teeth. It is a matter of behaviour, energy is also laws, energy is ensuring that things are recycled. Energy is also keeping what is green, green and making it better. Energy is also cultivating food in the city in empty industrial zones for example….'
[Academic stakeholder, EV6]*

*'Offshore wind is very important for us…. offshore wind is one of the limited sustainable energy sources with the potential for large-scale production and if well executed, a very reliable source of energy without the protests [opposition] of land-based renewable energy. Another reason we are keen for this is the optimal location that we have to assemble and maintain these wind parks. The number of direct jobs from a 1350 MW park is about 3000 or 4000 jobs… this is a problem with the power plant in the Eems harbour there are now jobs for 3 or 4 or 5 thousand jobs but once finished it offers only 100 jobs. And at the moment the jobs [for the power plant] are temporary and mostly foreigners, Hungary, Portugal, Turkey, as we do not have the capacity….' [Policy Stakeholder, EV8]*

*'16% renewable energy and 20/20…. can be set up, as cheaply, production formulae…. but the problem is not solved…. sustainable production and consumption, of sustainable energy…with a higher potential than 16% and a sustainable system (is needed).' [Policy Stakeholder, EV8]*

*‘Strengthening R&D in North Netherlands is the most important objective knowing that there are no large corporations with R&D departments…. so the higher education institutions have to realize this with partners within and outside of the Netherlands.’ [Academic Stakeholder, EV3]*

*‘In 2023, 16% of our energy needs to come from other sources, and this has implications…. The utility companies are calling out ‘we need to invest, a lot of investments, increase capacities’…. their call is to make room but this rolls over consumers because grid investments have to be paid by consumers…. till now it has been child’s play…. incorporating 20% into current system… is not viable through large scale grid enlargement…. that needs to be close to consumers.’*
*[Academic Stakeholder, EV24]*

*‘I think we need to make a huge catching-up effort to ensure that what we are doing also touches the citizens…. it is an opportunity to reach citizens, also because of the economic effect…. why have we not been successful to inform the citizens what the advantages are should he or she invest in renewable energy…. You need to stimulate bottom-up movements and we embrace this completely.’ [Policy stakeholder, EV13]*

*‘There are a lot of different interests and these meet in Energy Valley (organization)… there were a lot of criticism about the new coal power plant…. if we did not have it, then there was no critical mass and then we would have been not visible…thus you have to be pragmatic, if the market wants a coal power plant, at least I can have some say in it…. this is what you see that these developments have resulted in different paths in the transition to sustainability but also the traditional path….’*
*[Academic Stakeholder, EV3]*

Quotations related to need for different and collective effort:

*‘There was a study and everybody wanted wind energy, but…not in my backyard…the local council has accepted the need for significant wind energy if they want to be neutral [local energy production]… there needs to be a very good communication strategy to achieve this and I believe that if want to bring the energy to us, then it needs to be ‘of the citizens’ rather than a few shareholders…. where the top man earns a lot of money…. especially when the people have little or no work and they see profits made by a select few…. as an example. There are other examples, in Friesland, where windmills belong to the village with a committee overseeing the distribution of the power…. there is a different experience.’ [Policy Stakeholder, EV20]*

*‘The most important issues that we need to work on collectively, big and small, all humanity, is to make energy affordable for the long run…. I choose ‘affordable’ and not cheap as this could lead to a negative spiral…. affordable is also connected to my second point, which is that we need to have more control, that which you can…. which means also ownership and the third point is that we need to make it sustainable; and that through self-sufficiency….’ [SME Stakeholder, EV4]*

*‘Energy transition is a process in which we move from an old way of meeting energy demands to a new way. And this new way will include not being dependent on global developments. The choice of what this new way will be is not determined by me (us) but by the new generation. And the only thing I can do is to create*

*conditions for these young people, the new generation, to be facilitated in the process of search, to align the process….that is all we can do. It is important to stress that the need to create the right conditions and not to determine the physical choices. The choices will be made if the right conditions are present…It is an energy transition, we as a society are in the innovation, and that is society, therefore we need young people in that process… to make the paradigm shift.' [Academic Stakeholder, EV24]*

In conclusion, stakeholders underlined that Energy Valley faced urgent issues and that there was a need to deal with such changes but there were differences in focus, interests and priorities. Stakeholder responses reflect diversity and complexity of the energy cluster:

*'Energy Valley is different things to different people… on the one hand you have the [local] governments that are focussed on keeping employment in the region. The same for the Hanze and the university as well and other higher education institutions and that is to attract students and to keep the students in the region….' [Academic Stakeholder, EV6] [Also in Lesson 1, p. 176]*

This sub-section showed differences in stakeholder perceptions of urgent challenges and strategies for solving them. The next sub-section categorizes these challenges thematically to gain insights into the challenges facing the cluster.

### 4.6.2 Thematic mapping of contextual changes

The data from stakeholders on urgent challenges faced in Energy Valley reflected that the main themes addressed could be categorized as 'societal', 'regions', 'politics', 'economics', and 'technology'. The thematic mapping is provided in the illustration below. The middle circle also captured concerns voiced by stakeholders. These were, the need for (new) collaborations, complexity of challenges, unpredictability of future, urgency of challenges, need for focus and long-term perspectives and support for self-organization.

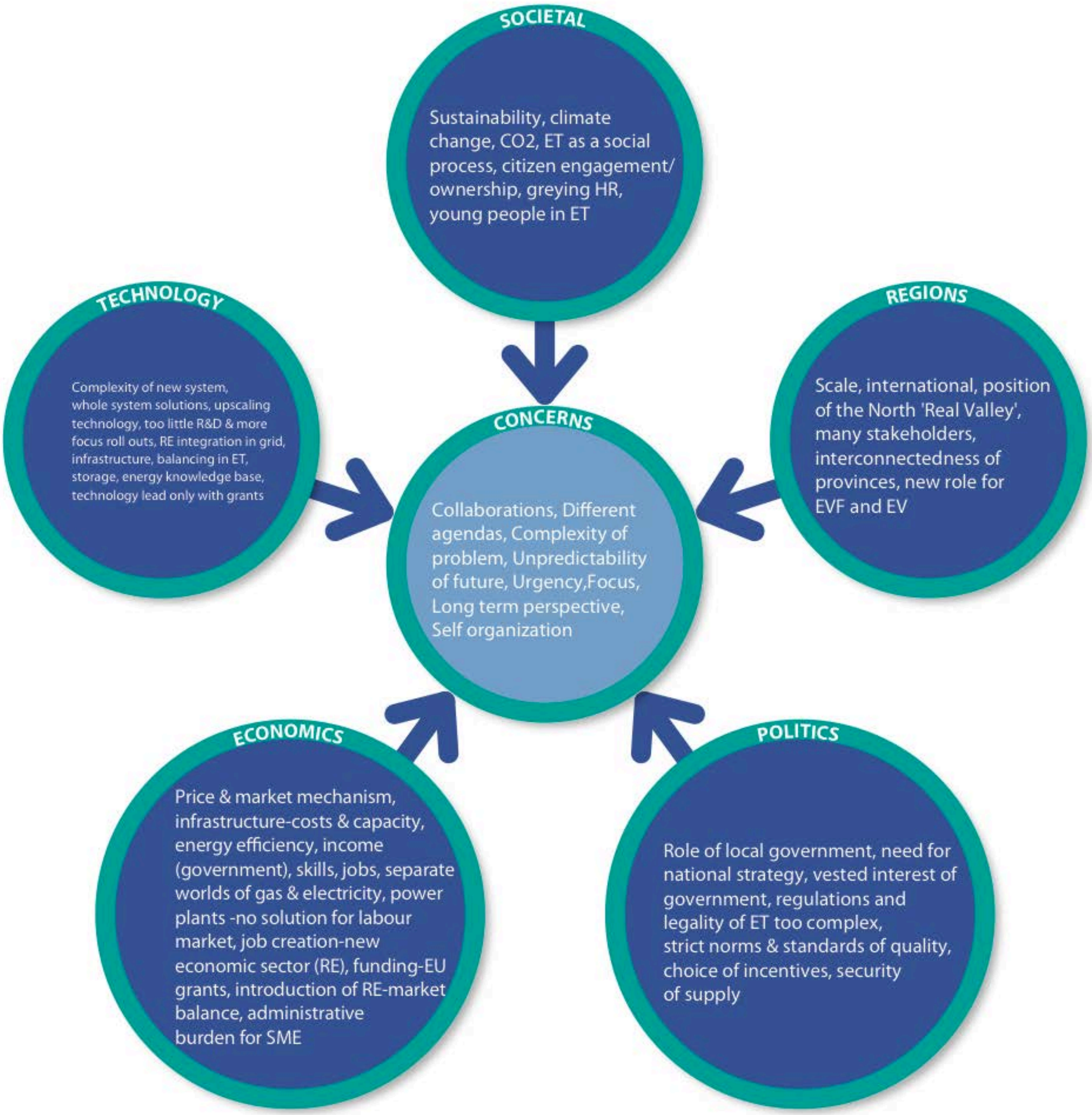



*Figure 25 Thematic mapping of urgent, complex issues in Energy Valley*

The thematic mapping made explicit that energy transition and energy cluster developments involved all aspects of society and that 'energy' and 'technology innovations' were entrenched in larger contextual challenges. The mapping reinforces the notion that energy transition and policy challenges in Energy Valley were tied to broader contextual challenges, and of the embedded nature of energy cluster developments. These challenges were described as being complex, unpredictable and urgent due to different agendas, inadequate policy, a lack of long-term perspectives, limited collaborations and a lack of support for self-organized initiatives (See also Lesson 1, pp. 178-180).

This sub-section captured the main themes and main concerns facing Energy Valley as described by the stakeholders. The next sub-section describes stakeholders' perceptions of drivers of change behind these urgent challenges.

### 4.6.3 Stakeholder perceptions of drivers of change

This sub-section captures the degree of coherence in the cluster based on stakeholder perceptions of what is driving change. The information from stakeholders was analysed in two different ways. Firstly, differences in perceptions of stakeholder groups were mapped (next sub-section) and secondly, drivers of change were mapped thematically (sub-section 4.6.4).

#### *4.6.3.1 Mapping diversity of perceptions*

A mapping of stakeholder groups' perceptions of drivers of change related to urgent challenges identified in Energy Valley showed both differences and overlap in their perceptions. Common drivers identified were the EU and issues of scale, decentralization movements and price of energy.

The illustration below captures drivers of change by stakeholder groups. Overlaps are indicated either between 2 groups or in the circle if more groups identified similar drivers.

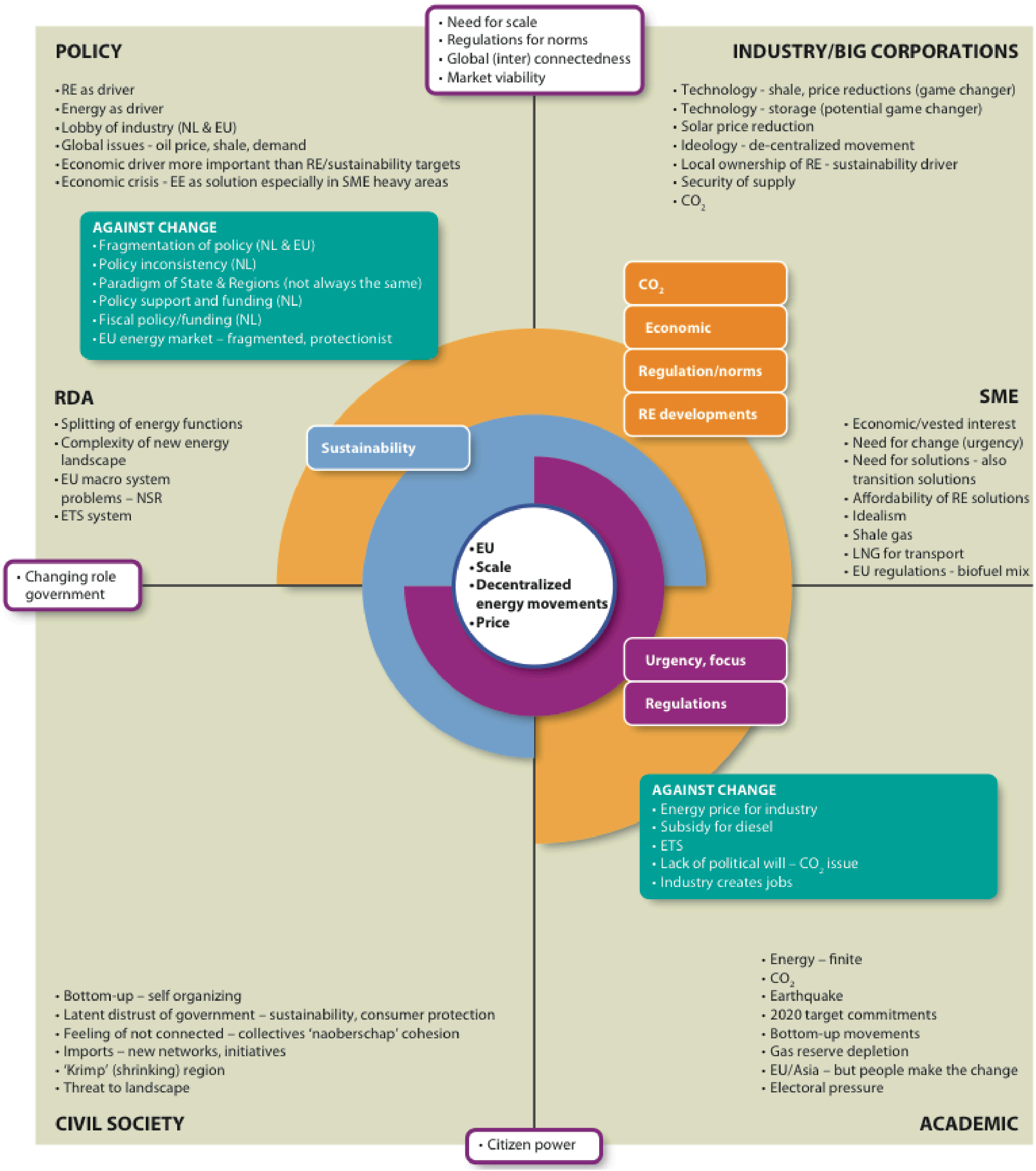



*Figure 26 Mapping stakeholder views of drivers of change in Energy Valley*

The drivers of change mapping above captures the diversity of stakeholder groups in their focus and perceptions of what is important and relevant to the cluster. Common drivers of change identified (core of the circle) were 'EU', 'scale', 'decentralized energy' and 'price'. These drivers were related to energy transition developments and the need for new solutions. The map also illustrates 'against change' and these were drivers identified that were barriers to change. Lesson 1 illustrated how 'new 'voices'' and other developments were contributing to these changes (pp. 176-177).

Drivers of change responses captured broader developments and changes in the local context. Drivers of change and the contextual changes were often interconnected and related to other aspects. To illustrate the complexity, a number of quotations have been included and discussed.

> *'Geopolitics definitely plays a role, look at Fukushima and its impact, look at Shale gas and its impact, it has influence [on Energy Valley]. Especially price mechanisms could have a strong influence and this is what we are facing now, that because the markets are not yet functioning properly, and this is the driver that gas in Europe is expensive. The market mechanisms are not working perfectly. Maybe due to inadequate regulation that needs time [to mature] or, too much regulations…[next point] for example, Russians want to sell their gas with as high a price as possible…. but on the other hand, what the Russians did to the Ukraine, it is still in our minds, and we want to avoid these situations. A few years ago, these incidents could have led to fatalities.' [Industry Stakeholder, EV10]*

The stakeholder identified geopolitics, market mechanisms and sensitivity to escalations due to incidents in the above quote as important drivers of change and he also described the complexity of the energy markets in part due to interrelatedness of different factors.

Another stakeholder from 'industry' described a different interrelated complexity at the local level. The quote below captures the main points.

> *'…. in the past, the NAM and Gasunie [gas corporations] were always cited as being engaged with locals to support communities where they had their exploitation sites. However, with the earthquakes it has become clear that this [ties] was not strong enough… people still want to live there but want the risks to be addressed, as opposed to if this was in Amsterdam, there would have been a different dynamic than what has been happening here. I think we can learn a lot from this case… it is not only a question of compensation, we need to work to keep the region attractive to businesses and locals [despite the quakes]… it is not only an urgency but also an opportunity…. We could not just repair but also offer more, make the houses more insulated, reduce energy bills…tap into the interests of the citizens to make it work… local contractors are happy as there is work because of the quakes, the construction industry has been depressed….' [Industry Stakeholder, EV16]*

The stakeholder has addressed a number of other issues in this quotation. The region had enjoyed a symbiotic relationship with the gas industry as it had provided community development and was engaged with the communities. However, the response to the earthquakes was not adequate and this led to anger and disillusionment by the communities as they felt that they were not taken seriously, as exemplified by the quote ‘it is not only a question of compensation’. Other interviewees and media reports supported this aspect of the aftermath of the quakes. The negative impact of the quakes, threat to economic development and further job losses were the main consequences of gas exploitation. However, the quakes were also instrumental in the creation of work in the construction sector at a time of ‘depressed’ markets. The communities were also rooted to their regions and did not want to move despite risks even as they were angered and disappointed.

Citizen initiatives and a shifting focus of government on sustainability issues as perceived by citizens is captured in the following quotation:

> *‘The ‘energized society’ is coming from bottom-up initiatives; citizens have a strong wish to engage in activities that support sustainable energy… [Where is this coming from?] We think that it is coming from a latent distrust of government that is not taking on its role – the government is no longer the custodian of sustainability…. environment protection laws, subsidies were once government domain…. corporations were enemies, they were opposed to regulations, [but] government took care of environmental [sustainability] issues…. also, energy is becoming more large-scale and more international…. there is no feeling of connectedness even though energy is a basic necessity; rising prices and concerns about affordability; these various concerns resulted in self-organized groups that focussed on local self-sufficiency that went beyond energy - care, neighbourliness - social cohesion and engagement in villages in Drenthe….’ [Policy Stakeholder, EV10]*

An increased need for social cohesion and self-sufficiency was mentioned due to the changes in energy supply and government roles. Citizens increasingly demanded sustainable and affordable energy futures.

Descriptions of complex challenges (also Table 30 below for overview of complexity and drivers of change) reflected how energy system developments were embedded in larger global and local contextual developments. The perception and responses of a community in the examples above could deter or support planned energy developments, be it gas extraction or, as expressed in other interviews, carbon storage, windmill parks, etc. Similarly, global geo-politics and shifts in energy systems elsewhere, shale and subsequent cheap coal dumping from the US, were examples of how external developments could affect energy developments locally. The lacks of trust and need for self-sufficiency by citizens were strong drivers of change and needed to be identified and understood as being part of the larger context.

The different issues faced by Energy Valley were not isolated factors but were interconnected and this is what added to the complexity. To illustrate, climate change and the need for more sustainable fuels, due in part to the threat of fossil fuel resources depletion both in Energy Valley and globally, resulted in higher premiums for fossil fuels and this led to new technology and new fuel resources like shale gas and more affordable renewable energy sources to be developed and marketed. Developments in shale gas exploration and low prices in the US led to the export and dumping of cheaper (US) coal in Europe, and this led to gas and other renewable energy developments to become less competitive and resulted in increased coal in the energy mix in the Netherlands, which led to higher $CO_2$ emissions. The decreased role of government in these developments due to a more globalized energy market, in turn fed into citizens' distrust of government as custodian of sustainable futures, which led to increased citizen initiatives towards self-sufficiency and more local energy sources. This was possible due to availability of new and cheaper technologies such as solar panels and smart grids. The various factors were interrelated and extended beyond local contexts, and beyond energy issues.

### 4.6.4 Thematic mapping of drivers

This mapping captured thematically drivers of change as described by the stakeholders interviewed. Major categories of drivers of change in Energy Valley identified were 'Technology', 'Global', 'Economics', 'Politics' and 'People – local and regional'. In the diagram below, a separate circle represents each category with specific aspects included. In addition, dominant trends and concerns are captured in the circle in the middle. Stakeholders identified 'role of government' and 'grassroots [movements]', 'global and technology drivers' as becoming more important in the cluster whilst the 'dominance of economic drivers' to the extent of 'economics before sustainability and RE' as a prevalent trend was also a concern.

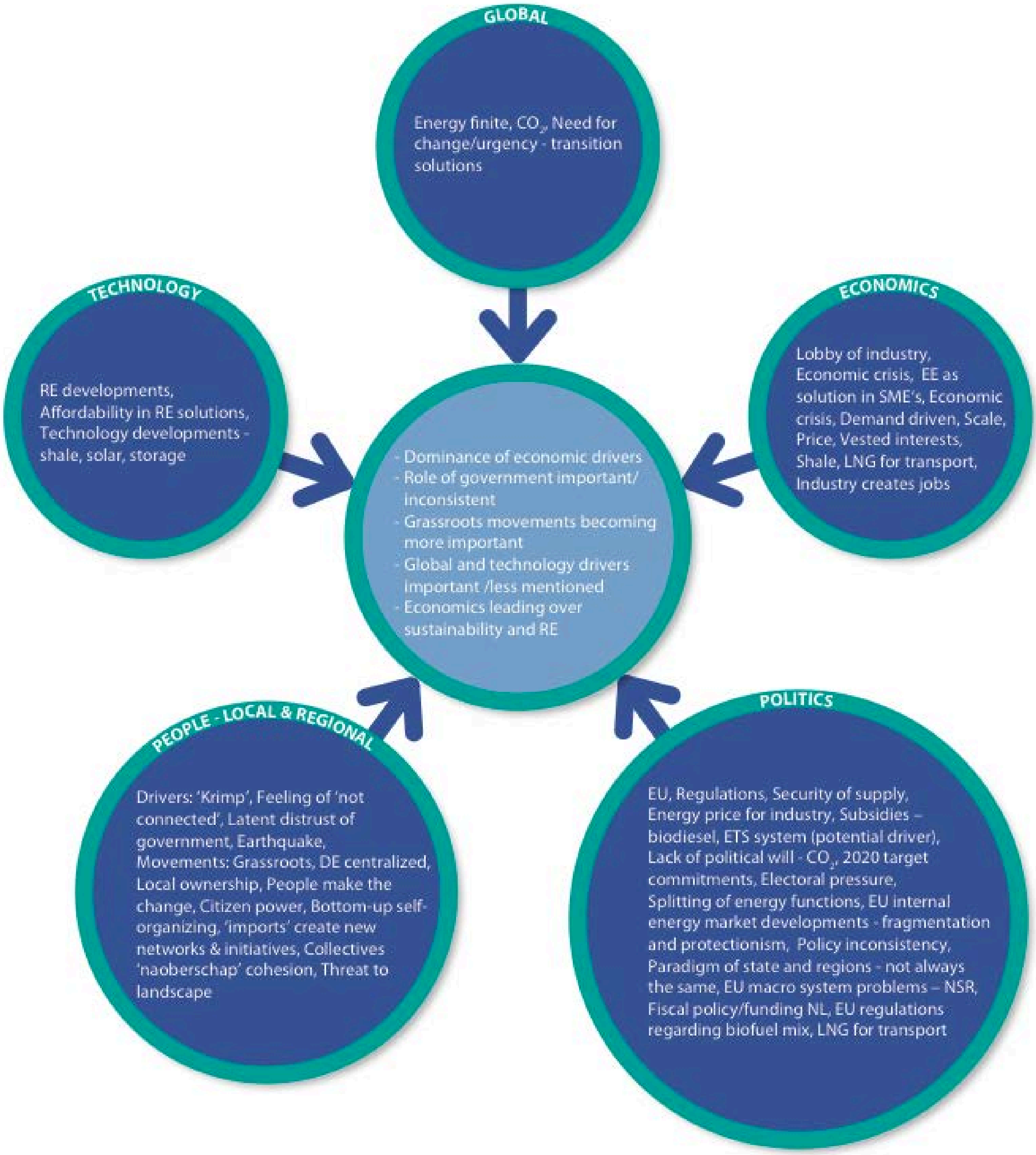



*Figure 27 Drivers of change in Energy Valley*

Quotations cited in this and earlier Lessons referred to the drivers of change. However, a few related to EU and national policies, demands of businesses, energy transition, sustainability goals and regional issues have been included here.

> *'I think that sustainability will become the norm in the Netherlands but that the prevailing framework conditions change frequently which is not good for long term investment climate and I think that this needs to be improved and that the*

*government must cater for a robust investment climate… in the Netherlands these conditions change almost after the first four years in a manner of speaking, and this makes it difficult for companies to respond…. something has to change.'*
*[Industry Stakeholder, EV10]*

*'The inconsistency, the swaying and switching policy of the Hague is killing for our ambitions, killing for our businesses, what investment decisions can you make, what perspectives does the State give regarding energy savings in built environment… it is not available. What is the long-term perspective for efficiency? What is their argument in The Hague? Hopeless. What is the long term perspective for re-sale of energy or for sustainability agreements with energy companies, long-term perspective for offshore wind…zero, zero, zero.' [Policy Stakeholder, EV8]*

*'Movements in the world is often due to economic drivers… there are big interests and industries have come about…. but we have blamed everything on economic 'laws' but I am not sure if this is always sensible….' [SME Stakeholder, EV4]*

*'My picture of Europe is that, my gut feeling is that they could make bigger progress in the area of efficiency in the future than at present, they could be more enforcing but the big car lobby and other lobby groups are not allowing this to happen.'*
*[Policy Stakeholder, EV8]*

*'Realizing that we are energy suppliers, but for how long…. and [also] realizing that we need to reduce $CO_2$emissions due to climate change…. [energy] has become a social issue so let us do something positive for the region to give back….and] the whole earthquake danger, we need to do something…. we cannot ignore it.'*
*[Academic Stakeholder, EV3]*

Drivers of change as described in these quotations and in the previous sub-section (and those of Lesson 1, pp. 178-180) showed how they were related to different aspects of interconnected regional, national, EU and global levels as well as technical, social, economic, political and ecological aspects. The drivers of change analyses reflect, like the analyses of new urgent challenges of Energy Valley, the increased complexity of the cluster's context due to interconnected developments.

The next sub-section describes how regional differences in Energy Valley contributed to added complexity.

### 4.6.5 Mapping regional differences

Energy Valley spanned four provinces and regional differences were part of the cluster's context. This sub-section captures the regional differences even as they shared common issues. The illustration below captures regional differences of key challenges, focus and priorities, as well as common aspects.


*Figure 28 Mapping urgent challenges in Energy Valley capturing regional differences*

The common aspects included 'ownership' of Energy Valley; SMEs, decentralized power developments, particularly biomass; being down-to-earth and generous (in Dutch, the 'gun' factor); limited technical R&D; and focus on job creation. The common need to collaborate to focus on energy transition developments underlined formation of the cluster.

The different regions had specific issues and foci and these are elaborated below.

Drenthe, a land-locked province, faced challenges related to resistance to windmill parks; energy efficiency and self-sufficiency needs; need to preserve nature and landscapes due to its tourism industry and its cultural heritage; and to connect to jobs in energy sector.

The province of North Holland North (NHN, northern half of province) faced challenges in meeting growing energy needs of Amsterdam metropolis area and other economic sectors of the province; and in promoting energy efficiency. NHN, a coastal province with harbour facilities, also focussed on offshore wind park developments with an Energy Board to coordinate its energy challenges. The national energy research centre, ECN, was also situated in this province. NHN was more autonomous in its developments due to its relationship to Amsterdam and its industries, including the off-shore energy developments.

The province of Friesland, a province dominated by dairy and agricultural sectors, waterways, manufacturing and SMEs, focussed on energy efficiency and decentralized solutions, and this was strengthened by its autarkic cultural values.

The discovery of natural gas, developments of the gas industry, and, in recent times, earthquake risks and damages shaped challenges facing the Province of Groningen. Vested interests in gas included positioning gas in energy futures, and seeking large-scale energy solutions as 'big' gas, power and chemical companies were dominant in the province. The need to attract and service large investments in Eems Harbour and Delzijl connected to energy generation and energy-intense industries were priorities in Groningen. Energy Valley Foundation (EVF) and Energy Academy Europe (EAE), located in Groningen, needed to capitalize the large student populations to boost knowledge and human capital developments. Groningen was also an agricultural based region with significant SMEs and therefore biomass and decentralized energy developments were also important to them.
Quotations from stakeholders illustrating regional differences in Energy Valley:

> *'It is the policy of four provinces, the policy of Friesland, North-Holland, Drenthe, Groningen are not the same sustainable energy policy. And Energy Valley [Foundation] also has her own independent goals and that is okay. That is why its there. There is overlap and that means that the Energy Valley sometimes does things that we as a province do not have any or little interest and vice versa, you can think what are they doing…but it does not clash.' [Policy Stakeholder, EV14]*

> *'Look we also do not know where the end solution will be, but which direction we need to go…on the one hand, for example, Friesland, they would very much like to take the more autarchic route, we want to solve this ourselves, local biogas, green gas, sun, wind and connect everything to each other… whereas in Groningen they*

*are looking more at the European context and you know, we need both, the [centralized] and decentralized [energy]…thus they are not conflicting but complementary to each other, only, the vision behind can be different… and the interests….'*
*[RDA Stakeholder, EV1]*

Regional differences added complexity to the cluster due to the divergent priorities and developments that could undermine Energy Valley's developments although all provinces stressed the importance of their collaborations in dealing with energy transition in Energy Valley.

The next sub-section provides an overview of Energy Valley's complexity and drivers of change.

#### 4.6.6 Overview of Lesson 3 and proposition

Lesson 3 described how Energy Valley's changing contexts were leading to increased complexity in the cluster reinforced by drivers of change. In addition, diversity of stakeholder perceptions and regional differences in framing urgent challenges added to the complexity. The table below provides an overview of the complexity in Energy Valley, and related internal and external drivers of change.

| | |
|---|---|
| **Complexity in Energy Valley** | - Complex, inter-related and unpredictable context of energy transition<br>- Energy transition/technological innovations embedded in social and economic transitions and crises<br>- Energy transition shift from national to EU and private sector dominance<br>- Traditional, dominant energy sector faced with new energy landscapes and players and v.v. (dominant corporate and economic interests)<br>- Shift in energy system complexity due to new energy and market developments and balancing needs<br>- Global and EU context connected to local and regional challenges<br>- National dominance challenged by EU and grass roots movements<br>- Differences in stakeholder groups about urgent issues and drivers of change – diversity in interests, priorities and scope<br>- Fragmented and limited knowledge and innovation development<br>- Protective role of government superseded by national economic interests |
| **Drivers of change** | - Geo-political shifts<br>- Energy security<br>- Energy market liberalization – EU internal energy market<br>- EU legislations<br>- Large scale power outage and blackouts in Europe – need for big investments in energy infrastructures<br>- Sustainability and Climate change<br>- Technology<br>- New energy resources and balancing<br>- Cheap coal and shale distorting energy market |
| **Internal drivers included** | - National policies<br>- Depletion of gas<br>- Increased earthquake risks<br>- 'Lag' region issues e.g. economic growth and jobs<br>- Consumer demands and initiatives<br>- Role of local/regional government – branding, collaboration, jobs, earthquake issue |

*Table 30 Insights into complexity and drivers of change*

Insights into Energy Valley's contextual changes and its drivers have been developed into a proposition in the table below with a summary of insights from Energy Valley.

| | |
|---|---|
| *Cluster developments, connected to context and contextual changes, and driven by internal and external drivers of change, are becoming increasingly complex.* | - Different stakeholders defined context and change in context of clusters differently.<br>- Contextual changes were related to societal, regional, political, economic and technology issues.<br>- Drivers of change were both internal and external to the cluster.<br>- Regional differences also contributed to differences in perceptions on what constituted contextual changes. |

*Table 31 Proposition on contextual changes and cluster developments*

The proposition on contextual changes and cluster developments is discussed in more detail in Appendix 14.

Lesson 3, in mapping urgent challenges and drivers of change in Energy Valley, reflected the interconnected nature of such challenges and the underlying drivers. These developments, in turn, resulted in new cluster dynamics, which is described next in Lesson 4.

## *4.7 Lesson 4: Cluster dynamics – interrelated systems dynamics*

Lessons 1, 2 and 3 explained how Energy Valley cluster was framed by its cluster condition and its changing cluster context. Lesson 4 describes the cluster's response to such changes, its cluster dynamics. The Lesson explains interrelatedness of cluster dynamics based on a general description of Energy Valley's developments and that of EnTranCe in its initial stages. Key insights into aspects of its cluster dynamics, its 'attractors', 'fitness to landscape' and 'significant differences', and the resulting proposition on cluster dynamics are included.

### 4.7.1 Interrelated cluster dynamics

Energy Valley was moving towards a more varied energy sector characterized by significant growths in renewable energy sectors. The shift included a need to redefine and reposition gas in the changing energy landscape. Related developments leading to new cluster dynamics included external threats of EU policy that classified gas as a fossil fuel; EU's climate change agenda; local developments such as grassroots demands for more renewable energy; and more decentralized solutions by provinces and businesses (see Lesson 1, pp.172-175).

The strong growth of demand-side dominance of energy markets meant that gas corporations sought collaborations related to decentralized developments, and this included more joint efforts with the electricity players regarding integrated energy grid systems. Furthermore, traditional energy companies were seeking new connections to SMEs in new energy services and in renewable energy. New types of businesses based on digital technologies and new business models were needed in the new energy landscape. The need to connect to the 'other' in order to extend scope, competences, resources and flexibility was acknowledged. Although not a new phenomena, the extent and scope of such developments was novel. The dominant role and position of 'gas' in the Dutch energy sector was weakened and new collaborations needed went beyond traditional practice (see Lesson 1, pp.178-180; pp. 187-188).

The urgent need to adapt to the contextual changes, in terms of search for new partners, resources and competences, was present at all levels of the cluster. Local energy co-operatives were searching for information and alliances with other energy co-operatives both within and outside the cluster; provinces sought to join forces within Energy Valley, etc.; globalization, EU internal energy market developments and EU funding programmes supported trans-regional and international foci, influencing Energy Valley's initial regional focus. There were shifts to increased international scope and activities (see Lesson 1, pp.176-177; pp. 187-188).

Energy Valley's changes and need for new strategies as described above reflected responses to the increasing complexity, and unpredictable future of energy transition. These responses included strategies characterized by a need for enlarged scope and diversity to cope with the growing complexity. To extend scope and diversity, leveraging significant differences offering new solutions for energy transition and regional challenges became more urgent at all levels, crossing traditional boundaries and groups. The diagram below illustrates how attractors as responses to changes in context influence new strategies to 'fit' changing landscapes, and that this in turn, meant exploring significant differences to develop such strategies to enable enlarged scope and capacities.

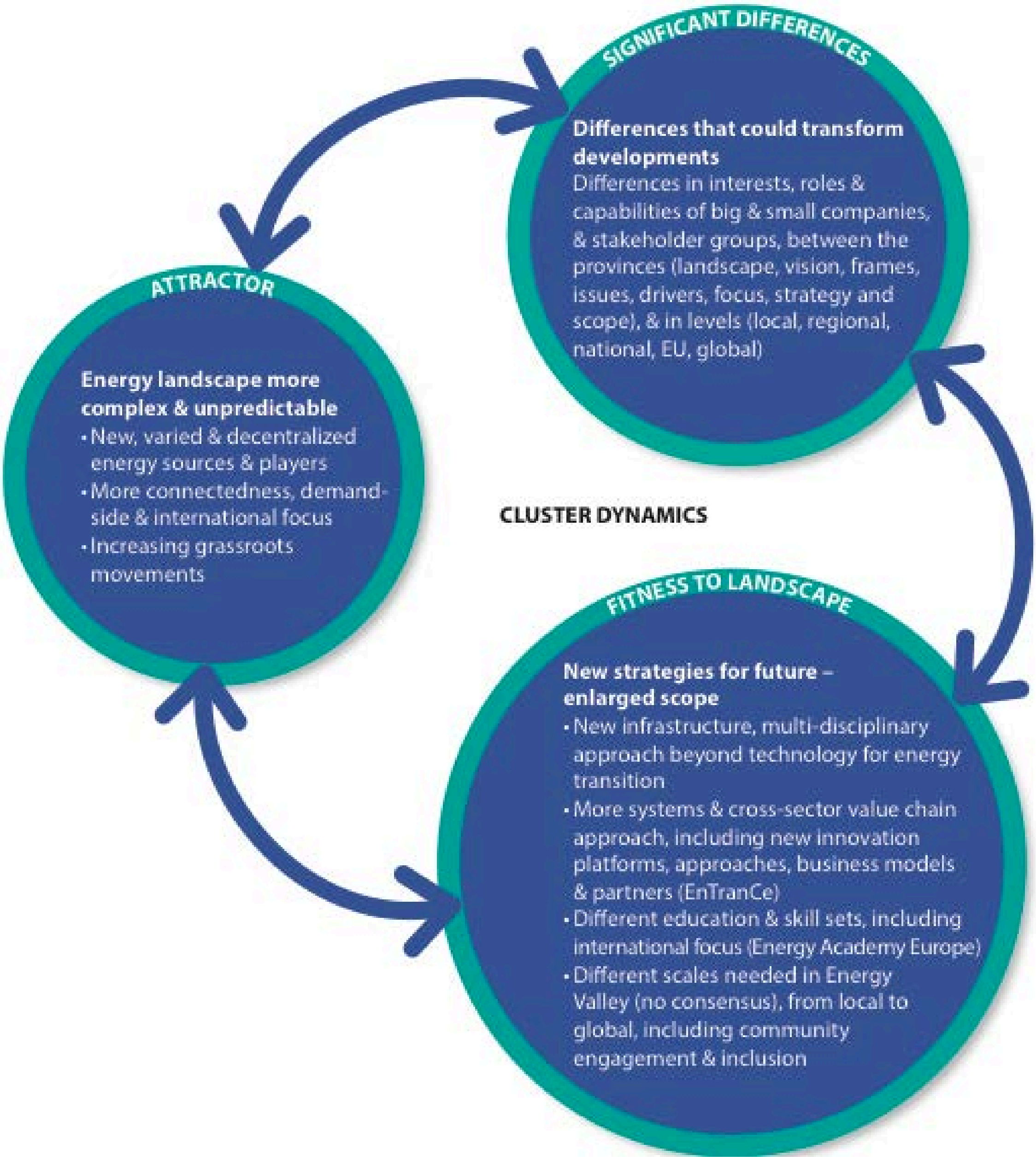



*Figure 29 Energy Valley's cluster dynamics*

In order to illustrate cluster dynamics, two examples are provided below.

The need to find practical solutions for the energy transition resulted in EnTranCe. It was an initiative of GasTerra (main gas trading company), Hanze University, BAM and ImTech (energy infrastructure companies). This new collaboration pattern (attractor) was driven by a need to seek solutions for integrated energy systems (fitness to landscape) by bringing together partners across the value chain, namely, gas trading company, infrastructure companies and university (significant differences). The need for new approaches meant new collaboration patterns, and thus creating new attractors including a more varied playing field. The scope of energy companies needed to be extended and new competences and resources were needed, and this meant that the more urgent the need to change, the more urgent the search for significant differences beyond traditional strategies, and in turn, the greater the impact on attractors (systems responses). With EnTranCe, the initial founders felt that they needed to include new businesses with IT competences, battery and fuel cell innovations, legal and financial competences, etc. to deal with energy transition challenges. EnTranCe illustrates shifts in cluster dynamics.

A different phenomenon associated with cluster dynamics is the increase in number of earthquakes due to gas exploitation. The larger economic interests of gas took precedence over the safety and well being of local constituents (Commission Meijer Advisory Report, 2013). The financial crises and European budgetary norms put pressure on the treasury such that economic and corporate interests dominated policy decisions. This brought about responses by local constituents (including businesses) and regional governments (attractor developments). Local protests and collaborative legal actions were part of responses by private parties whilst regional governments (provinces) and northern SER coalitions (platform for socio-economic developments) negotiated and developed new strategies that included compensation and injection of capital to boost economic growth in the region, and carried out negotiations to reduce earthquake dangers. Dialogue sessions were organized in the affected region to bring differing factions to the table and to seek new and acceptable solutions (fitness to landscape/significant differences). The systemic responses of significant developments of citizen protests and collective efforts (attractors), resulted in a search for new strategies by all parties (fitness to landscape), and in turn, new innovation potential was sought (significant differences). Lesson 5 also describes earthquake developments as part of cluster developments.

### 4.7.2 Quotes and additional aspects of cluster dynamics

Quotations illustrating attractors in movements in Energy Valley follow:

On the Eems harbour and North Sea developments:

> *'There is a complete complex at Eems harbour that has been in development for a long time now, the chemical and energy [sector] that includes pipelines to allow exchange of different energy streams….' [RDA Stakeholder, EV1]*
> *'Now you see the ENSEA project as an example, that there is active cooperation with the Germans, and this has been extended to the Norwegians and Scots. Also*

*with the Danes when it comes to rolling out LNG.... in all of the Wadden Sea. Therefore, internationalization is accelerating.' [Academic Stakeholder, EV7]*

*'On shifting energy positions and convergence, and new collaborations:*
*And then there is the connection between gas and electricity...gas to power and power to gas interactions.... With the increase in sustainable energy with its inherent difficulty to manage, there is an increase need for buffers of storage, etc. At the same time, you see that the electricity world tries to solve this in their electricity domain and the gas world says that they will do it for gas by [gas] storage means....'*
*[Industry Stakeholder, EV16]*

On shifting energy transition and consumer behaviours:

*'What we now describe, a trending term, is the energetic society or the do-democracy, this is a term that you hear when citizens themselves create sustainability experiences and this is on the increase.... what we see is that a lot of citizens try to take it [sustainability] up.... through energy.... energy is visible, tangible.... you can put solar panels on the roof, you can save [energy], it gives an immediate good feeling, and that is a driving motive. Next to it you have organizations that have deeper sustainability goals. We want to have a more coherent neighbourhood; we want to have rural development using energy as a business case, etc. In Drenthe, you have about 40 visible groups that are active....'*
*[Civil Society Stakeholder, EV19]*

Eems Harbour was deemed an important transport hub that could facilitate cross border and international developments, which would connect Energy Valley to foreign energy sources and markets. Developments at Eems Harbour included setting up LNG terminal facilities and storage capacities; realizing on-shore and offshore assembly capacities for the North Sea wind parks; realizing facilities that supported transport and maintenance of North Sea wind parks; developing facilities for landing offshore energy supply and for the distribution to European hinterlands. Development of Eems Harbour contributed to transforming Energy Valley's capacities to meet changing energy landscapes.

Lesson 1 (pp.187-188) also describes these developments with related quotations.

Quotations capturing fitness to landscape strategies and competences needed:

Need for different competences and focus on 'applied sciences'

*'There is also a need for a Beta and Gamma combinations in personnel and also people who can work in teams. For example, social acceptance is a big issue that could break us and we need to have people who talk differently and think differently and they have to be taken seriously... the faculty of economics and business administration in Groningen is the largest faculty in the Netherlands with I think 6000 students...there is also a need for applied sciences and people are*

*afraid to be labelled as being applied and therefore also getting a label of second class from your colleagues if you are too much involved in practical applications….'*
*[Academic Stakeholder, EV7]*

*'…. alpha beta and gamma combinations that offer more multi-functional education…. what needs to be included in fundamental knowledge but also in applied programmes is the systems integration aspect – how different elements interact with each other. How do you balance wind with gas…. EnTranCe-type developments.'*
*[RDA Stakeholder, EV1]*

*'Need for different scale is illustrated in various settings and aspects:*
*There should not be energy tax on renewable energy…windmills and solar energy… and then, you can also realize large-scale projects, for example a field of 1megawatt and that you deliver to the end user without energy taxes….*

*Look if you look at the market in the North, take the 3 northern provinces and if we could all cooperate and procure collectively solar panels then we could get lower prices….*

*That is also important to grid companies [utilities] that they can avoid buying expensive power when the price is high by having storage in batteries… you need to realize these solutions, not in individual homes but perhaps in transformer stations….'*
*[SME Stakeholder, EV15]*

*'The international contacts that we use are contacts for knowledge sources… here Germany is leading… knowledge bearers around the North Sea is for us a focus, but in principle, at Energy Academy, the world is our stage… Knowledge is in institutions, but also there is also [knowledge] in practice….' [RDA Stakeholder, EV1]*

*'We are with ENSEA [European North Sea Energy Alliance] working on this [internationalization] and this is why we initiated this. Perhaps we need to also include the Danes and perhaps also the Baltic region for what we want to realize…. not just the research only here but also the coordination and steering, and thus the nerve centre.' [Academic Stakeholder, EV7]*

*'What we are doing here is 'small' but actually in Brussels it is a big agenda…we shared with Brussels how it [energy transition] needs to develop, the environment that is needed, so we have shown it on a small-scale but it is a question of whether all of us want to go with it and make it a success [on larger-scale]….' [Academic Stakeholder, EV24]*

Lesson 1 (p.185; 178-180) also describes fitness to landscape strategies and need for new competences with related quotations.

Quotations below illustrate significant differences in the cluster and how these potential solutions and strategies were considered:

*'….the essential change the transition has seen, and that is interactions between electricity and gas; between large scale and small scale; between the different*

*forms of infrastructure; between the triple helix [partners]. Through all of this, the playing field has become more complex.' [RDA Stakeholder, EV1]*

*'The focus is clear and if we try to create opportunities [to support sustainable energy]…. the story is about the energy trail in the Veen Colony where [you can choose] large-scale energy with big investments or [choose] making houses energy neutral and keep the money in the region; if we can link to local housing corporations then we have an interesting concept and that is we put our energy.' [Civil Society Stakeholder, EV19]*

*'Offshore wind is very important for us…. offshore wind is one of the limited sustainable energy sources with the potential for large-scale production and if well executed, a very reliable source of energy without the protests [opposition] of land-based renewable energy. Another reason we are keen for this is the optimal location that we have to assemble and maintain these wind parks. The number of direct jobs from a 1350 MW park is about 3000 or 4000 jobs…. this is a problem with the power plant in the Eems harbour there are now jobs for 3 or 4 or 5 thousand jobs but once finished it offers only 100 jobs.' [Policy Stakeholder, EV8]*

*'Besides the level of knowledge, in applied sciences university, there is more of the transverse [horizontal] part of 'T' whilst in fundamental knowledge development is per definition in the vertical part and this is why there is in terms of contents divided segments…. the Hanze have a different role in the game ….you can in any case say that Hanze has an important task…. to ensure that the various disciplines of knowledge is channelled to create value…. you need to do two things, you need to bring the different segments together and get people to work together and Hanze needs to be made accountable for its responsibility to make this happen.' [Academic Stakeholder, EV24]*

*'…. if you consider the stakeholders then you have a few initiators that are responsible for the energy transition process and the national government is one of them. But also the regional [governments] have a role to create the framework conditions to enable initiatives to take place. There is role to create the right framework conditions but this is very difficult….' [Academic Stakeholder, EV24]*

Lesson 1 (pp.187-188) also provides insights into significant differences present and the search for 'new' competences and resources.

There were large differences in Energy Valley that contributed to increased complexity with its threat of discord in the cluster due to limited coherence in stakeholder strategies, whilst providing diversity and innovation potential needed to deal with complex energy transition and regional challenges. In other words, Energy Valley's significant differences could support or weaken attractor developments, whilst attractors and changing landscapes causing the diversity and complexity demanded new fitness to landscape strategies. At the same time, potential 'risks' due to the diversity and the need for policy and coherence in the cluster were also addressed below in the following quotes:

Embedded nature of energy developments and complexity

*'There will be a need for a macro system in the future; certainly when 60 to 90 Giga watt wind parks are realized in the North Sea, and concentration of large demand for energy lies in middle Europe. We then have a logistics problem to meet differentiated demand and supply challenges…. and gas is an important part [of the solution], but also, for example, energy storage can be accommodated in the pumping systems [of gas].' [RDA Stakeholder, EV1]*

*'The concept of working together in the region, internationalization, like Hansa Economic Corridor, [HEC]….it is different [for us]. All four provinces acknowledge the necessity…but we do not know exactly what needs to be done; we know that there is a lot to be done….' [Policy Stakeholder, EV8]*

Consistency and direction in policy

*'It is not so much about policy incentives but that policy was something that people can blindly trust and go their way about things. Let us say that the government chooses to set out a policy based on gas only, but then at least we know what the direction is. Right now, we do not know, it changes too much.'*
*[Civil Society Stakeholder, EV19]*

*'There is a whole process under way in the Netherlands to reach a national energy accord, for which we are happy as it is not only steered by politics but by a more broader [coalition], but also because of a more consistent policy…. you are asking a lot of businesses to invest in things that will be there for 20-25 years and if you keep changing your direction every 2 year, and then its wind energy that is important and then its solar, that is killing.' [RDA Stakeholder, EV1]*

Top-down steering of national policy

*'There is something to be said about regions…. and the State too has its ideas about clustering, smart specialization…and looked at how they could fit these in and they looked at Top Sectors for example. They have identified a number of top sectors, smart specializations….. following this, they explored how this can be implemented in the regions, and that was a puzzle… we have indeed looked at top sectors in terms of sectors but that is not quite regions, and that is problematic….yes, and that is always via the Ministry of Economic Affairs or [Ministry of] Internal Affairs.'*
*[Policy Stakeholder, EV14]*

Distrust and negative image of sector (see also Lesson 1, pp. 182-184)

*'The sector is not able to be transparent and communicate with the general public and this has had a negative effect on the image. The industry has shot itself in its foot; you see that with the $CO_2$, with the Shale gas, and with the earthquakes. I think that they were not handy in their approach and so they need to learn and ensure that it gets done differently.' [Industry Stakeholder, EV10]*

*'There are more projects [abroad] where the support from the government is a lot more comprehensive, but also longer. There is a more solid foundation and you can see that the markets [there] develop faster and are further in their developments. In the Netherlands, in the last five years despite the pressure and subsidies that are*

*supposedly meant for this, there is relatively little upgrading taking place, for example in biogas installations. If we talk about England or Germany, there is almost a doubling every year [of upgrading].' [SME Stakeholder, EV23]*

To summarize, potential risks related to cluster dynamics and developments were:

- Potential lack of coherence in cluster
- Risk of fragmentation by sub-clusters (e.g. North Holland's Energy Board) and spin-offs of specialized energy cluster (LNG cluster, biomass hubs)
- Risk that regional and cluster scales may not be the 'right' scale or the only scale necessary; flexible scales needed to meet complexity of different challenges
- Growth of distrust in cluster related to national economic interests supersedes public safety, regional developments and energy transition developments
- Potential 'cluster drain' due to limited knowledge capacities, market and regulatory conditions
- Risks of delay in energy transition and uncertainties in energy sector developments

More details on cluster dynamics are found in Appendix 9.

#### 4.7.3 Overview of Energy Valley's cluster dynamics and proposition

This sub-section provides an overview of key aspects of Energy Valley's cluster dynamics followed by a proposition on cluster dynamics based on these insights. The table below is a summary of the key points.

| | |
|---|---|
| **Attractor** | **Increased complexity and unpredictability** in the cluster<br><br>– Pull of redefining and positioning of **gas in energy transition** - gas for balancing function<br>– Pull of **decentralized energy** developments by grass-roots movements related to pull of autonomy and **self-sufficiency needs**<br>– Shift from supply-side focus to **more demand-side focus**<br>– Pull to **more connected energy sector** (gas and electricity, small and big)<br>– **Pull of 'outside'** related to R&D, innovation and markets (resources, capacities & opportunities)<br>– Pull of **internationalization**, partly due to EU programmes and opportunities, parallel developments and globalization<br>– Pull of **sustainability agenda** (resource efficiency, renewable energy, CO2 emissions, 'green' consumerism)<br>– Pull of **economic and job creation needs** of policy seemed stronger than energy transition demands<br><br>**Attractors underestimated or not made explicit** in Energy Valley – e.g. risk of 'cluster drain', national economic and corporate interests mitigating developments on energy transition, citizen safety, job creation and rural community sustainability policies |
| **Fitness to Landscape** | – To meet energy transition challenges, need for more<br>- Multi-disciplinary competences<br>- Cross-sector value chain innovations<br>- New business models, knowledge and sectors (IT, business services)<br>- **Systemic** approaches<br>- Multi-sectoral collaborations<br>- Trans-regional and international collaborations<br>- **More SME support** for innovation and energy efficiency<br>- More citizen awareness and engagement<br>– **New infrastructure** connecting different and new sources of energy (smart grids) were needed and this meant that new competences and accelerated innovation and deployment was needed<br>– **New institutions and innovation spaces** were deemed necessary to bundle fragmented knowledge, research and innovation efforts in energy transition (e.g. Energy Academy Europe and EnTranCe serving different collaboration needs)<br>– **Varying 'scale'** were needed for energy transition and cluster development – both small-scale - local and regional - to trans-regional (e.g. village co-operatives, city council, Hanze Energy Corridor, North Sea Region)<br><br>Energy Valley<br>– **Needed to be part of the national dialogue** – shifts in national policy to top-sector and new energy agenda at national and EU levels<br>– Different support strategies needed<br>- **Support for large-scale energy related projects and competences** through Eems Delta developments **in Groningen** (LNG terminal, off-shore wind park assembly and landing of cables, etc.)<br>- Support for SME and industries to become more energy efficient and decentralized energy production in Friesland and Drenthe<br>- More inclusive community engagement and outreach to support decentralization and grassroots movements in energy |
| **Significant Differences** | Significant differences were present in the following:<br><br>– **Big corporation and SMEs** with their different resources, scope, goals, competences, visibility, flexibility, innovations, access to markets, equity, policy, etc.<br>– **Academic and research institutes** had different capacities and goals<br>– Local municipalities, provincial government and regional development agencies had different agendas, resources and roles<br>– **NGOs and consumers** had different demand 'pulls' that could influence energy transition<br>– **'Outside' and 'in-crowd' groups** had different positions, interests and insights into developments in different places in the cluster<br>– The **four provinces and local regions** had distinctive histories, landscape, frames, issues, drivers, focus, strategy and scope that could offer diversity needed to address the complex challenges faced by the cluster<br>– **Local, regional, national and EU levels** were part of Energy Valley's context and container and this included differences in roles, responsibilities, resources, interests, scope and power<br>– The energy cluster was embedded in a region with a strong agricultural sector, waterways and water-related activities<br><br>**Innovation potential in Energy Valley required broadening existing container** and seeking 'significant differences' |

*Table 32 Insights into cluster dynamics*

Energy Valley's cluster dynamics provided insights that have been formulated as a proposition in the table below supported by these insights. The proposition is discussed in more detail in Appendix 14.

| | |
|---|---|
| *Cluster dynamics are interconnected system responses to changes in its context; namely, attractors to new movements and changing stakeholder perceptions, fitness to landscape strategies to meet changing contextual challenges, using significant differences as a potential for new path creations.* | - Cluster response to contextual changes was noticeable in shifts in underlying processes and patterns.<br>- Changing cluster context affected connectedness, scope and scale of cluster dynamics.<br>- Risk of 'cluster drain' due to inadequate capacities and resources in the cluster and 'pull' of external factors (resources, innovation conditions).<br>- New competences and strategies needed to 'fit' the changing contexts that included an enlarged scope (beyond traditional knowledge development, sectoral and regional borders).<br>- Shifting underlying patterns and processes, attractors, connected to need for new competences and strategies, fitness to landscape, and existing significant differences.<br>- Significant differences in cluster contributing to shifts in underlying processes and patterns and offering new opportunities for change and path creation. |

*Table 33 Proposition on cluster dynamics*

This Lesson described findings on cluster dynamics of Energy Valley and also insights into the interrelated nature of cluster dynamics. The next Lesson focusses on findings related to cluster transformations.

## *4.8 Lesson 5: Cluster transformations – transforming systems development*

Lesson 5 focusses on Energy Valley's cluster transformations, which include two aspects, transforming interactions and emerging patterns. Overlaps between cluster dynamics and cluster transformations are inevitable as cluster dynamics captures underlying and expected changes whilst the cluster transformations are the visible changes.

Energy Valley's transforming interactions resulted in shifts in strategy, vision, scope, scale, stakeholders' roles and governance structures; new or different types of collaborations, interactions, communications, organizations, platforms and stakeholders; and changes in feelings of trust and how this in turn drove new developments (Details in Appendix 9). A few examples of changing interaction and collaboration patterns are described below to illustrate these findings.

EnTranCe, the subject of the initial pilot study, illustrates how transforming interactions in Energy Valley were taking place. This example has been used to illustrate cluster dynamics and in this section, the change in the nature of interactions will be highlighted. Organized meetings and informal sessions at the local football club's Skybox brought together key stakeholders where the future of energy in Energy Valley was a regular theme. These sessions were responsible for the emergence of EnTranCe where GasTerra, BAM, Imtech and Hanze University of Applied Sciences decided to create an open innovation space for energy transition challenges. These various partners decided to initiate a collaboration that would invite energy businesses along the value chain to collectively seek solutions to the energy transition. The open innovation nature of the facilities was new where competitors would share knowledge and facilities. The urgent need to deal with the unpredictable and complex nature of energy transition pushed stakeholders to deeper levels of collaborations. The collaborating partners also had to agree to collective strategies and joint experimentation including the whole value chain and engaging a systems approach were also transformations that were new to the cluster. At EnTranCe, partners were also sought outside the traditional energy sector as challenges related to digital infrastructure and business models were expected. New laws were also needed to facilitate new and more integrated energy systems that would break down sectoral barriers. The re-sale of solar energy at recreational facilities and car parks for e-vehicles is an example of how developments for new technology, regulations and fiscal policies have been supported through projects at EnTranCe. Storage of surplus decentralized energy within homes and through gas systems are more examples of interdisciplinary and cross-sectoral solutions realized by the new collaborations emerging at EnTranCe and elsewhere.

The following quotation illustrates how EnTranCe worked and the how transforming interactions that resulted in dealing with energy transition challenges.

> *'At EnTranCe, companies contribute their expertise and work together with other companies' expertise to move forward [on energy transition challenges]. With a few companies we have identified an agenda and we work with the formula that they send their surplus capacity to EnTranCe and RenQi to work on collective projects. This has happened, just like, 'omheind' [fenced off], but super important…. these are small examples of how we can do this without banks [investments]…. One example, a programme of 15 – 20 partners which is halfway and there is an interim evaluation; what began as a group of strong egocentric partners, has become partners and you see how they communicate, look each other up, there is a*

*high degree of collective effort.... they know each other, they together they identified common challenges and that is a big step in a short time and there will be follow-up activities to continue the collective approach. So you see how this works and can work. ' [Academic Stakeholder, EV24]*

Energy Academy Europe (EAE) is an important example of the changes in collaboration. This new institute has given visibility to newly developed 'energy' programmes. The commitments of the two universities in the city of Groningen to the 'energy' developments are reflected in this initiative. The close collaboration of these two universities in this venture reflects a breaking down of barriers between the more prestigious academic university and the more highly valued professional educational institute that serves industry as well as a convergence of goals regarding energy transition challenges. The setting up of this separate energy institute has forged increasing international collaborations and visibility of Energy Valley's knowledge capacity and developments. There have been more regular visits to and from the European Commission and its agencies. Joint master classes organized by the EAE meant that new interactions and networks between students of both universities have been realized. The following information from EAE's website describes details of recent collaborations and transforming interactions:

*'Since its inception appointments of internationally renowned energy staff, including its director; collaborations with national (ECN, TNO) and international institutions (in Shaanxi) for energy research and education; collaborations with social partners for national public debate on energy; and collaborations with EU Energy Charter Secretariat for joint research and knowledge sharing in energy specializations.'*

*[Summary of press releases; http://www.energyacademy.org/press-centre/press-releases; retrieved 22 April 2016]*

Another development in Energy Valley was the development of new integrated energy systems, which needed new infrastructure and policy frameworks as well as research, development and innovation. These new energy systems were being developed at the micro level, in homes and neighbourhoods; at the meso-levels such as green gas hubs/business transition parks and cities; and at the macro-levels such as the Hansa Energy Corridor and North Sea programmes. These integrated energy systems developments were examples of transforming interactions that displayed new and joint vision, new collaboration structures, convergence of knowledge capacities and interests that were at the core of the changes in Energy Valley cluster. The following quote illustrates the micro, meso and macro-level transforming interactions:

*'Meppel energy is an example. In Meppel a new neighbourhood is developed with 400 houses that can deploy smart grids. The same was for Hoogkerk that is going into phase 2.*

*Another example is what we call the energy transition parks. These are local nodes of businesses and electricity. A good example is Wijster in middle Drenthe, an industrial area where Attero a waste incinerator generates warmth, electricity and gas and working with targeted parties, through working sessions, there is a profile of this being an energy transition park. A heat exchange grid has been realized where electricity is transmitted to and fro. A chicken waste processing company has located here as it needs heat for its processes and it has biomass available for Attero, and as such a closed loop is realized on location.*

*There is a formal collaboration with North Germany, Norway and Scotland in the ENSEA programme where these countries jointly identify collective challenges of the next decades, which is also relevant to Europe. Grid infrastructure for offshore wind is an obvious challenge. Identifying if specific laws and regulation in the different countries form a barrier for interactive energy exchanges. Those types of challenges are being addressed with the North Sea partners…. obvious connecting issues….the similar mentality….' [RDA Stakeholder, EV1]*

The collective development of the diverse regional and municipality administrations in Energy Valley, namely, 'De Plus van Noord Nederland', 'Green Deal' and 'Switch' initiatives as described in the earlier section on transforming interactions, reflected a deeper collaboration in the cluster. These documents also reflect more coherence in Energy Valley even as the diverse interests have been embraced. The need to collaborate and to strengthen the peripheral position of the northern provinces and that of Energy Valley resulted in this transformation. The quotation below captures the shifts and transformations of energy policy developments for the North Netherlands.

*'Around 2007, the first big energy accord North Netherlands was reached, thanks to Ed Nijpels…. that brought a lot more alignment. We started working programmatically…. And now, 2.5 years later, we decided to take it to a higher level, have more focus…. and that is how the [energy] vizier resulted.'*
*[Policy Stakeholder, EV8]*

Lesson 1 described transformative interactions with related quotations about new collaborations, governance and trust patterns (pp. 187-188, 182-184 and 185 respectively).

The second part of cluster transformations is its emerging patterns. Energy Valley cluster shifted from a relatively simple and regionally based energy cluster to one that was the more complex and 'open' connecting to new energy and new players, scopes and scales, new types of businesses with new business and financial models, more systemic ecosystems approaches whereby both centralized and decentralized developments and movements were taking place. These shifts in Energy Valley reflected a new playing field with new systems dynamics evolving as a result of EU liberalization of energy markets specifically but also other drivers of change.

Lesson 1 also captures evidence of emerging systems patterns, particularly the 'ecosystems thinking' (pp. 192-193). Below are quotations capturing systems changes in the cluster:

> *'.... the essential change the transition has seen, and that is interactions between electricity and gas; between large scale and small scale; between the different forms of infrastructure; between the triple helix [partners]. Through all of this, the playing field has become more complex.' [RDA Stakeholder, EV1]*
>
> *'It began as local, then it was regional and now it is supra-regional with the Hansa connection in particular….' [Academic Stakeholder, EV6]*
>
> *'I think that it is now the post-natural gas era as we are moving that way…. You see how GasTerra now is exploring Power to Gas as an example, now that KEMA bought the Gasunie Research arm and are focussed on gas, they [GasTerra] are suddenly thinking about electricity. Thinking of wind and solar.' [Academic Stakeholder, EV6]*

Emerging developments at Energy Valley showed that energy transition challenges demanded new combinations of organizations, knowledge, stakeholders, solutions and ideas which when successful developed into new energy sub-clusters. The complexity and scope of Energy Valley and the developments related to energy transition all contributed to the need for diverse responses and solutions.

The transforming interactions and collaborations are indications of changing systems pattern in which changing collaborations included alliances across borders, different energy and other sectors, and new stakeholders and groups, spanning different and new levels, from local to international. The increasing collaboration that extended beyond traditional boundaries reflected a growing trust even as bottom-up developments were partly influenced by a lack of trust (see cluster dynamics earlier). Furthermore, these changing collaborations reflected growing diversity and complexity, that was also reflected in new strategies and patterns in Energy Valley – diversity, enlarged scope and scales, more local and grassroots developments of bottom-up and self-organizing processes. Increased collective efforts in the cluster indicated more alignment, coherence and accountability. The visible transformations captured local activities and patterns of interactions, but also that there were qualitative changes to cluster systems.

The illustration below captures the two aspects of cluster transformations.

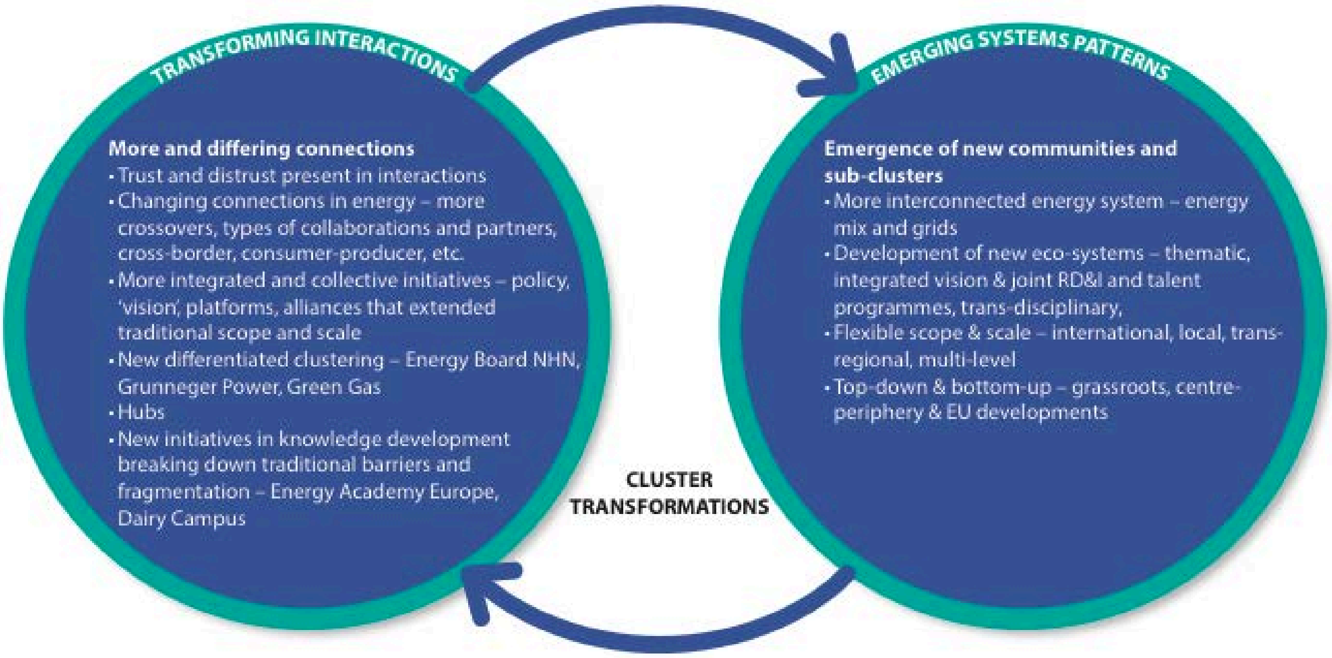



*Figure 30 Cluster transformations in Energy Valley*

The next sub-section provides an overview of cluster transformations and propositions related to cluster transformations.

### 4.8.1 Overview of cluster transformations and propositions

Key findings on transforming interactions and emerging patterns including insights into changes in the cluster's organizing principles are captured in the table below.

| | |
|---|---|
| **Transforming interactions and collaborations** | – **More connections in energy –** between gas and electricity sectors, traditional and renewable energy players, 'big' and 'small' energy, producers and consumers<br>– **More cross-sectoral connections** between water and energy ('blue energy'), energy and agriculture (bio-fuels, bio-gas), transport and energy (e-mobility), etc.<br>– **Trans-regional initiatives** reflected new types of collaborations in energy transition e.g. Groningen-Niedersachsen (NW Germany) and ENSEA project with partners from the North Sea region<br>– **More integrated policy 'vision'** due to developments mentioned above e.g. North Sea Energy Vision, 'De Plus van Noord Nederland', 'Green Deal', 'Switch', etc.<br>– **New regional platforms created** to meet local energy challenges – e.g. Energy Board in North Holland, Drents Energy and Climate Change Platform<br>– **Breakdown of traditional fragmentation** (between universities, businesses and between sectors) and **more systemic innovation based on value chain approaches** made possible through new initiatives in EnTranCe and Energy Academy Europe<br>– EdGar Research was an example of an **extended research programme** to boost gas related energy research to support the position of gas in the future energy scenarios<br>– **New energy stakeholder groups** became visible - e.g. farmers producing green and bio-gas, energy funding agencies, NGOs supporting energy efficiency and sustainable energy initiatives at community levels<br>– **Citizen initiatives growing** e.g. Grunneger Power and other village and neighbourhood energy co-operatives to increase self-sufficiency<br>– **Trust as being conditional** depending on the situation and issues at hand; adverse effects of gas exploration in local communities due to increased earthquake danger and the compensation offered and guarantee of safety made distrust an issue for communities in the region; there was also mention of latent distrust as reflected in grassroots movements seeking autonomy and self-sufficiency in energy |
| **Emerging patterns** | Energy cluster was becoming **more 'open' and more connected** to new players, the scope was becoming **more local and more international,** and **opening up** to new businesses and business and financing models – reflected a **new playing field**<br><br>– Energy System becoming **more complex**<br>  - Interconnectedness of gas, electricity, renewables<br>  - Interconnectedness of market crossing national borders – energy players extending markets and buy-ins e.g. RWE, Vattenval in NL<br>  - Grid interconnections beyond national borders<br>  - More cross-border and international collaborations – inter-cluster collaboration to Niedersachsen<br>  - International connectedness at local levels – village co-operatives to German co-operatives<br>– A **more systematic approach** – ecosystem for knowledge-based innovation<br>  - More integrated and collective vision<br>    o N NL vision of 'quality of life' innovation agenda ('De Plus of Noord Nederland')<br>    o EV vision aligned to national policy (e.g. 'Switch' response to 'National Energieakkoord' strategy)<br>  - Development of energy innovation, research and talent capabilities - breaking down traditional barriers and fragmentation creating broader knowledge-based innovations<br>  - Systems integration approach to energy developments in Energy Valley<br>  - Movement to issue-based cross-sectoral collaborations e.g. Bio-based economy<br>– **Different scope and scales** in Energy Valley – both larger and local scales<br>  - More visibility and changes in scope and position of Energy Valley<br>    o Northern Netherlands strategic partner on energy with national government,<br>    o New EU partnerships in trans-regional initiatives<br>    o More inter-cluster collaborations<br>    o Branding region as an 'energy hotspot' at different scales – local, regional and EU region of excellence (North Sea Region)<br>  - More self-organized collaborative efforts at different local levels<br>    o Citizens (neighbourhood and village co-operatives)<br>    o Business collaborations (transition parks, green gas hubs)<br>    o Open innovation facilities (RenQi and EnTranCe)) |
| **Self-organizing vs. top-down** | – Both **top-down and bottom-up initiatives** included EU, national, regional and local levels in Energy Valley cluster and energy transition initiatives<br>– National and EU policy leading but<br>    o Centre and peripheral relations of NL and EV shifting<br>    o Traditional hierarchical line from National government to provinces to local governments shifting, EU part of change<br>– Self-organizing grassroots movements and NGOs – new bottom-up movements<br>  - EU funding for regions and inter-regional collaborations support provincial and local movements<br>Provincial energy funds support SME and consumer initiatives on decentralized and sustainable energy |

*Table 34 Insight into cluster transformations*

Insights into Energy Valley's cluster transformations and organizing processes have been developed into propositions in the next table. These propositions are discussed in more detail in Appendix 14.

| | |
|---|---|
| *Cluster performance is visible in transforming interactions and contributes to macro level emergent systems patterns.* | - New connections and collaborations in cluster due to changing dynamics and context.<br>- Changes in stakeholders, competence and knowledge developments, interactions and collaborations, vision and scope were visible in cluster, transforming interactions.<br>- Fragmentation of knowledge developments occurred less frequently and new stakeholders were more connected to cluster.<br>- 'Trust' was conditional reflecting changing governance patterns.<br>- System level changes in cluster, emergent patterns, included more 'open' and different connections; movements to more 'local' and more 'international' scales; more 'complex energy systems'; more systemic approaches; changes in strategy, position, visibility, vision, organizational structures and governance; more 'self-organized business, citizen and innovation spaces'. |
| *Cluster developments are influenced by both top-down steering and self-organizing processes.* | - Cluster developments were marked by both top-down and bottom-up initiatives that extended from local to EU levels: shifts in centre-periphery relations between national government and cluster were visible as well as the traditional cascading hierarchical structure from national to regional to local was changing in part due to EU policies (regions connected to European regional developments); new bottom-up movements, self-organizing processes, were emerging, supported in part by EU policies |

*Table 35 Propositions on cluster performance and organizing processes*

This Lesson captured insights into cluster transformations. The next Lesson describes findings on systems development patterns at different systems levels.

## 4.9 Lesson 6: Systems-in-systems developments

Energy Valley is embedded in national and EU levels. Information on Energy Valley, national and EU policies were addressed in the interviews with stakeholders and policy officials, also at national and EU levels. Key findings are described in this section. Further information on energy developments at the national and EU levels is provided in Appendix 9.

The 'systems-in-systems developments' showed that similarities and differences in the different levels in responses to contextual changes and some of these aspects are described here with quotations to illustrate. The focus of the descriptions has been the EU levels as Energy Valley and national levels have also been addressed in the earlier Lessons. An overview of the findings is presented later in the section.

Shared context and hierarchical relationships of the EU and its Member States (MS), and national governments and regions accounted for parallels in systems patterns and developments in the case of the EU, the Netherlands and Energy Valley region/cluster. The shared context comprised globalization and global trends as drivers of change, specifically those related to energy transition developments. Part of the shared context is also EU policy. The EU 'frames' matters regarding energy security, EU internal market, sustainability and innovation agendas supporting sustainable competitiveness. The shared context contributes to similar emerging systems patterns across all levels.

> *'No energy company invests on the basis of national policies only, they watch Brussels, investments for 30, 40 years… and they look at ETS policy…. what Brussels will do with $CO_2$ policy….other policies…you see that Brussels is increasingly setting the reference framework…. and the market makes its choices based on this.'*
> *[Dutch EU representative, EV25]*

Differences in systems developments at the three levels could be accounted for by path dependent factors. The EU with 27 Member States, each with its own history, politics, geography and socio-economic composition meant that different needs, interests and resources were reflected in their energy mix and policies. Taken as a whole, at the EU level, the diversity of energy resources and energy mix meant that different energy policies were pursued compared to the Netherlands with its gas dominant history and interests.

> *'…. it has been determined that Member States are responsible for their energy sources. Thus The Netherlands decides on its energy reserves to give an example. Member States are responsible for their energy mix so we determine how we, and whether we [use] gas or nuclear or…. the Commission is responsible for security of supply even as States are responsible to facilitate [renewable] energy and energy efficiency and therefore they provide guidelines on targets for [renewable] energy but they do not say how you must do it.'*
>
> *Also,*
> *'….I think historically, the countries are for example pro-nuclear….France, UK and other countries as well, Czech, Slovakia….others want all [nuclear] plants in Europe closed, Luxumberg, Belgium, Germany, Austria, Denmark… they decided for an energy mix that is not suited for this…'*
>
> *And,*
> *'….there are countries who are huge producers of fossil fuels like Netherlands, UK and these are also countries with a lot of gas. There are also countries like Germany, [but also] Spain who do not have any fossil fuel, yes they have very different interests…'*
> *[Dutch EU representative, EV25]*

The EU aimed for self-reliance to limit its dependence on oil and gas nations such as Russia. This meant that renewables are favoured over fossil fuels, strengthened by its climate change commitments. In the Netherlands, gas dominance in the energy mix and policy continued to prevail even as the Netherlands were committed to reaching renewable energy targets set by the European Commission. For some Member States but also for the EU, reliance on Russia is an important aspect of energy policy:

> *'Therefore, the EU is a huge chance for them through infrastructure, gas pipes from North to South and West to East instead of only the pipes from Russia…. Thus the internal market and new infrastructure us a huge opportunity for [increased] security of supply – risks and dependence on Russia to be reduced.'*
> *[Dutch EU representative, EV25]*

The move or 'pull' towards diversity and sustainability in the energy mix rather than dominance of any one particular energy source at the EU level was a visible attractor pattern. Energy Valley and the Netherlands also saw attractors that moved towards more sustainability but existing energy mix and energy policies veered towards protecting vested interests (fossil, gas).

> *'On 15 December 2011, the European Commission adopted the Communication "Energy Roadmap 2050". The EU is committed to reducing greenhouse gas emissions to 80-95% below 1990 levels by 2050 in the context of necessary reductions by developed countries as a group. In the Energy Roadmap 2050 the Commission explores the challenges posed by delivering the EU's decarbonisation objective while at the same time ensuring security of energy supply and competitiveness. The Energy Roadmap 2050 is the basis for developing a long-term European framework together with all stakeholders.'*
>
> *[Energy2020, http://ec.europa.eu/energy/energy2020/roadmap/index_en.htm]*

Shifts in patterns related to stakeholders had similarities across the levels due to energy transition developments, namely, stakeholders from different sectors were becoming engaged in energy, consumer and business roles were changing, power and influence of traditional and new energy players were also shifting. There were, however, visible differences in governance structures. Dutch consensus model (polder model) and closer collaborations between Triple-helix partners were evident compared to fragmentation (protectionism and opportunism by MS and lobby groups) that was prevalent at the EU levels.

An important commonality of all levels was the growing complexity of energy transition's context. Insights into systems-in-systems developments reflect both the significance of interconnected systems developments and of initial conditions of path dependency, container and stakeholders at the various levels.

### 4.9.1 Overview of systems-in-systems findings and proposition

The table below provides an overview of key findings of emerging systems patterns of the different levels, showing the systems-in-systems interconnectedness.

| Cluster framework | System patterns of Energy Valley (EV), Netherlands (NL) and EU |
|---|---|
| Complexity & Drivers of change | **Complexity**<br>**All levels reflected growing complexity**<br>- Energy is never isolated issue but interconnected to social, political, technology, economics and ecological issues<br>- All levels display unpredictable future due geo-political developments, market prices and new energy developments, crises, etc.<br>- EU level complexity is more complex than EV/NL due to differences between Member States (MS) that in turn has to do with their history, geography, political past, energy reserves and capacities, etc.<br><br>**Drivers of change**<br>**External drivers of change are similar to all levels e.g.**<br>- Geo-political and global developments, climate change, financial crisis and recession, technology, new energy and global market shifts, consumer demands<br>**Internal drivers of change are different at the different levels due to path dependency and scale**<br>- Earthquake is an issue in NL and EV<br>- Gas depletion is an internal driver of change for EV/NL (similar to UK) |
| Container | **EU frames targets, guidelines and regulations on**<br>- Energy security, internal market developments,<br>- Environment and sustainability,<br>- Innovation and competitiveness measures, etc.<br>**Shared containers**<br>- Energy security, energy transition to sustainable energy systems<br>- Global energy markets framing EU and NL markets<br>- Economics leading in energy transition<br>- Sustainability has high priority in EU and MS (NL) have to comply<br>- EU policy leading in NL/EV policy in all issues in energy except the energy mix<br>**Differences in container**<br>- Sovereignty of MS<br>- Energy mix and energy innovation differences – gas in NL crucial; in EU gas is important but not to same degree as in NL; EU has a more diverse energy mix<br>- Gas trading as a key economic strategy for NL, e.g. development of LNG and global gas markets |
| Path Dependency | **More conflicting interests and negotiations at EU level**<br>- Due to 27 MS with different infrastructure, energy resources & strategies<br>- Energy developments and policy in MS due to different history<br>**Differences between EU and NL/EV**<br>- NL/EV differences existed due to path dependencies of provinces, etc. but more consensual practices existed – Dutch polder model<br>- Lock-in risk greater in NL due to gas dominance |
| Stakeholders | **For all system levels**<br>- Increasing trend of new and other stakeholders<br>    o Civil society and consumers in particular<br>    o New energy sectors such as ICT, construction industry and agriculture<br>    o More SME players in energy transition<br>- More cross-border and international stakeholder engagement and influence<br>- Some stakeholders are more visible and have more power/influence than others e.g.<br>    o Fossil stakeholders more influential than renewables stakeholders<br>    o SMEs and grass root movements have less influence than industrial players<br>**Differences**<br>- Triple-helix collaboration closer in NL than at EU level<br>- EU has more fragmented lobby groups and MS protectionism and opportunism |

| | |
|---|---|
| **Attractor** | **Shared attractors in all 3 levels - examples:**<br>- Sustainable economic growth<br>- Energy efficiency, decentralized energy and demand side focus<br>**Differences**<br>- NL and EV – focus on future of gas in energy transition and innovations vs. EU with a broad range of energy sources<br>- EU pull to be independent from external energy sources vs. NL/EV connecting to EU and global energy markets |
| **Fitness to Landscape** | **Shared at all levels**<br>- Longer term policy and investment perspectives needed<br>- Compliance structures, and dialogues to seek solutions for complex problems and differences<br>- Collective energy vision and commitments, 'EU thinking' where needed<br>- Need for multi-disciplinary competences, cross-sectoral value chain innovations, new business models, new governance models, trans-regional and international collaborations and new infrastructure |
| **Significant Differences** | **Shared**<br>Collaborative and consensus practice in dealing with conflicts of interests<br>**Differences**<br>- Most important difference in EU is that of the MS and regions with their individual politics and energy mix<br>- Difference in innovation capacity in different energy arenas vs. NL more focused on biomass, bio-gas and on gas innovations and off-shore developments<br>- Differences in own specialization, interests, etc. as seen in the lobby culture and organization vs. NL collaborations of large and small corporations, industry and universities, fossil and renewables, etc. |
| **Trans-forming interactions** | **Shared processes**<br>- More visible policy on energy innovation and energy transition<br>- Clear targets and compliance with energy goals<br>- More coordination and connectedness in infrastructure and energy market developments<br>- Alliances and collaborations on energy developments<br>- More cross-border and regional collaborations due to EU and internal market<br>**Differences**<br>- EU policy dominated by politics, Member States and lobby (fragmentation due to path dependency and scale) driving alliance formation<br>- NL policy converging in collaborative platforms; innovation tables;<br>- EV – cluster participation; thematic digital and network communities; |
| **Emerging patterns** | **Similar patterns at all levels**<br>- More collaborative commitments to broader sustainable growth<br>- More interconnected energy and infrastructure developments<br>- More technology push in energy system<br>- More decentralized energy<br>- More complex energy system<br>- More trust and engagement<br>- Framing of energy/climate objectives as well as economic framing<br>- More cluster-based approaches and more regional based developments<br>- More horizontal interactions and collaborations (cross-border, cross-sectoral, cross-disciplinary, more private-public collaborations, EU internal market)<br>- More vertical directives and practice (EU and Member states' policies, more connections to bottom-up, demand/consumer driven) |
| **Self-organizing vs. top-down** | - More top-down dialogues and coordination in policy<br>- More bottom-up collaboration and initiatives |

*Table 36 Comparison of system patterns between Energy Valley, the Netherlands and EU levels*

The systems-in-systems analysis supports insights into Energy Valley cluster developments in its broader systems context. The insights show how systems at different levels are interconnected and undergo similar developments whilst differences stem from their different initial conditions and the subsequent dynamics and emergent systems patterns. These insights have been developed into a proposition on systems-in-systems developments based on the findings of this Lesson.

| | |
|---|---|
| ***Clusters are systems-in-systems connected to higher-level systems (national and EU) where parallel emerging patterns as well as tensions are present due to differences in systems at different levels.*** | - All 3 levels of systems (EV, NL, EU) reflected increasing complexity and common external drivers of change.<br>- Similarities in container features existed at all levels related to energy developments; global markets and economics were framing energy transition; sustainability was a high priority; and EU was leading in most aspects of energy policy for the lower level systems of NL and EV.<br>- Path dependency and lock-in risks were different at different levels; diversity and conflicting interests were greatest at EU level whilst lock-in risk was greater at NL/EV level than at EU level.<br>- Stakeholder developments were similar at all levels where new sectors, consumer engagement, cross-sector, cross-border and international stakeholders were evident; power differences, dominance and visibility of fossil stakeholders due to resources were also present at all levels; closer stakeholder relations and collaborations were present at EV/NL level compared to EU levels; consequently more fragmentation at EU levels (in part due to path dependency).<br>- Common attractors were sustainable economic growth, energy efficiency, decentralized energy and demand-side focus; differences in attractors were for EV/NL focus on role of gas in energy transition and innovations but EU was aiming at energy independence.<br>- Fitness to landscape strategies, where the need for new and sustainable energy solutions included cross-sectoral and multi-disciplinary competences and innovation and collaborations, were present at all levels.<br>- Significant differences whereby differences were leveraged were seen in collaborative and consensus practices in EV/NL and the EU; there were however differences in levels such as the fragmentation and strong lobby culture in the EU where fossil and new energy players pitted against each other; the Dutch 'polder model' tended towards dialogue with traditional and new energy stakeholders as part of triple-helix partners.<br>- Transforming interactions reflected more interactions, coordination, collaborations and policy on energy, innovation and energy transition at all levels; EU levels showed more fragmentation and lobby culture whereas in Energy Valley collaborative platforms (Dutch polder model) and dialogues were more dominant.<br>- Emerging patterns in all levels showed more commitment to sustainability, which fostered more horizontal interactions and collaborations; however, economic agendas remained important in energy policies; Systems developments were both self-organizing and steered centrally. |

*Table 37 Proposition on systems-in-systems developments*

This Lesson explained interrelatedness of embedded systems developments. Lesson 7 describes developments in Energy Valley of interrelated and overlapping systems.

### *4.10 Lesson 7: Interrelated overlapping systems developments*

Lesson 7 expands the findings of Energy Valley's developments (Lessons 1-5) by mapping energy transition developments and challenges onto the insights into its developments. The analysis looks at 'energy transition' relates to cluster developments and the other dominant frames of 'economic' and 'regional' aspects (see Lesson 2). Inputs from energy experts provided additional insights into energy transition developments in Energy Valley. The diagram below captures energy transition developments mapped on to Energy Valley's developments. Insights from the other Lessons were included in the mapping.

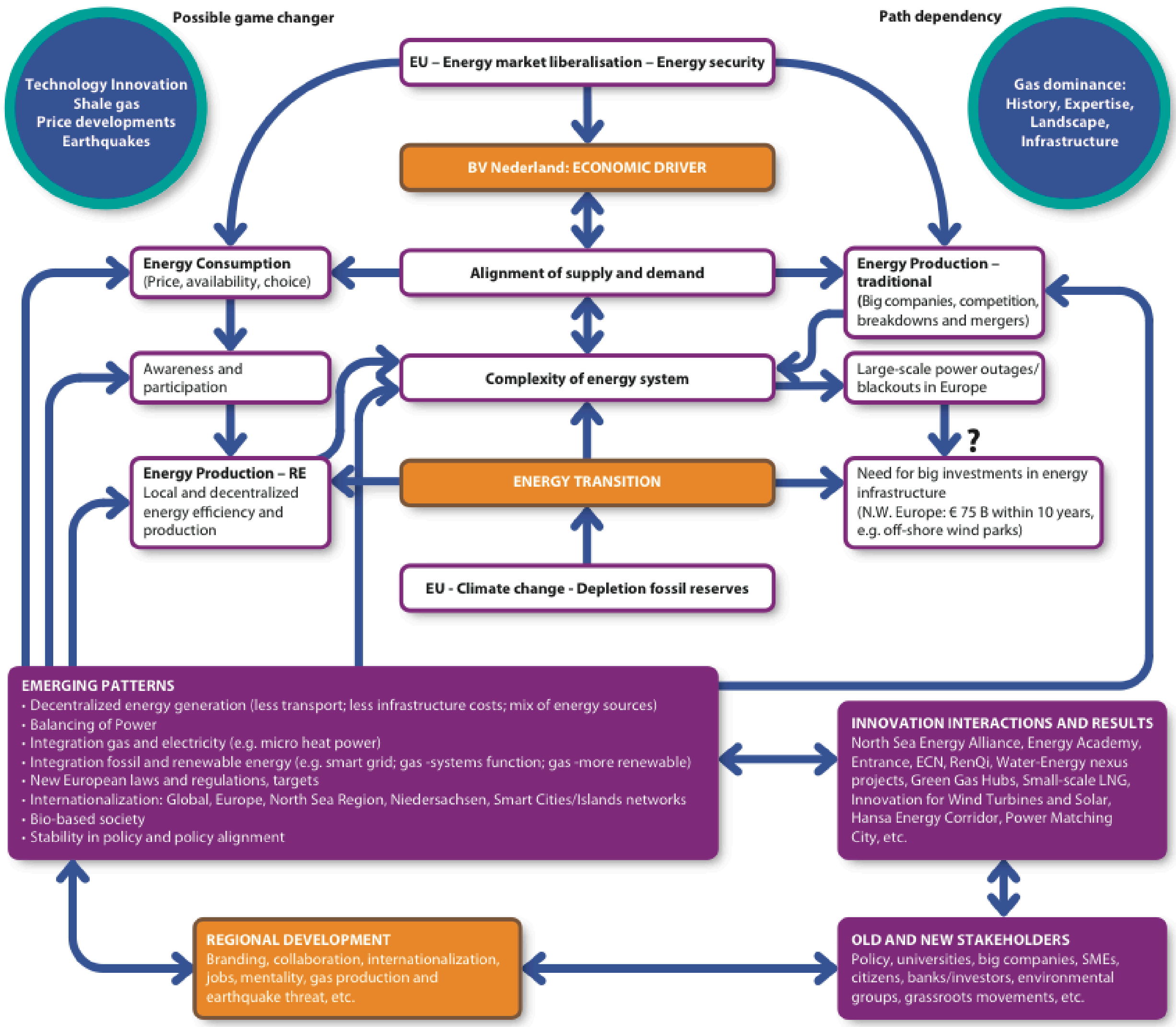


*Figure 31 Energy Valley's interconnected energy and cluster developments*

The three dominant frames are captured in orange in the diagram above whilst feedback loops (arrows) connect different aspects (white boxes) related to the main domains. Finally, cluster developments are captured to show changes in interactions, stakeholders and the emerging patterns (purple boxes). Highlights of systems interconnectedness are described below.

The analysis shows how energy systems are complex and interconnected to various developments of energy production, consumption and infrastructure whilst energy developments are also connected to EU policies and developments, national economic interests (BV Nederland/Netherlands Inc.), regional agendas and developments, path dependent factors of the cluster, and possible game changes (shale, earthquake, etc.).

EU market liberalization developments, driven by energy security needs, saw shifts in consumption and production developments. Production and consumption of energy in the Netherlands became more complex. The EU, consumer behaviours, decentralized energy solutions with related infrastructure challenges contributed to the complexity. Energy market developments due to market liberalizations meant new competition, new players in Energy Valley including mergers and take-overs, shifting consumer roles to become producers (prosumers), etc. Consumer behaviour changes in turn boosted renewable energy production even as energy transition agenda fuelled local and decentralized renewable energy productions. Local energy systems were becoming increasingly complex, which in turn meant huge investments and innovations needed to meet decentralized and new energy systems developments. The increased complexity of energy systems was also at other levels (see Lesson 6) seen in outages at the EU level that also reflected the need for new infrastructure investments and developments.

Looking at Energy Valley developments from the regional development perspective, emerging patterns and changes, including EU regulations and targets, as well as the initial EU market liberalization changes, resulted in changes in stakeholders and stakeholder interactions in Energy Valley. New emerging patterns in turn influenced regional development strategies and developments.

The overlapping systems analysis showed cluster developments of Energy Valley as being intertwined with energy transition, regional developments and economic interests and developments at the EU, national and local levels. Systems interactions of related and overlapping systems were demonstrated to be significant to cluster developments in this analysis in which path dependency and game changing drivers of change had a part.

### 4.10.1 Quotations supporting insights into energy transition and cluster developments

The following quotations are based on inauguration speeches of energy experts at Hanze University of Applied Sciences on developments in energy transition and regional developments. They capture key aspects of energy transition developments in the context of Energy Valley.

**Role of EU - market liberalization; climate change and depletion of fossil fuel**

> *'The need for an energy transition is no longer a discussion for the majority. The European Commission has indicated in its plan of action 2050 the necessary steps to be taken, namely, that the energy system needs to be "ontkoold" [removal of coal] and that energy efficiency and renewable energy needs to be stimulated.' [Expert 1]*

> *'Within Europe, each member state is allowed to implement its own energy politics. Even as Germany chooses for "atom-ausstieg" ['nuclear-exit'], France does not intend to reduce its nuclear generated electricity capacities. Green and grey energy need to be transported via the same grids…' [Expert 1]*

> *'The energy transition, in my opinion, is not driven by the depletion of fossil energy supplies but by climate change needs.' [Expert 2]*

**Energy transition (changing energy sector)**

> *'In the development of the energy sector from a relatively closed system to more market [system], but also moving from a supply to demand driven one, it is important to a) keep what is good b) keep things running during the transition, and c) anticipate resistance. The 'good' stands for safety, security of supply, affordable energy prices, availability and sustainability.' [Expert 1]*

> *'The integration of fossil and renewable energy; the energy transition will take decades.' [Expert 3]*

> *'Energy transition is a huge challenge. Affordability is key to success...' [Expert 3]*

**Alignment of supply and demand (challenges and risks)**

> *'The matching of supply and demand, also known as balancing, is becoming more important due to the addition of off-shore wind parks in our energy system. The*

*matching becomes increasingly difficult, and this could lead to overloading the electricity grid network and to outages, also known as black-out.' [Expert 2]*

*'Since 2000 and up to March 2013 there were major European outages. In some cases these were due to external factors (extreme snow fall), but more often, the cause of this was overload of the grid. One example of this is the overload of the electricity grid in Germany in November 2006, when millions of people in part of France, Italy, Spain, Austria, Belgium, the Netherlands and Croatia were without power.' [Expert 2]*

**Complexity of energy system (energy production shifts)**

Energy production – traditional

*'The energy infrastructure forms a link between energy production and energy consumption. The current infrastructure is based on the use of large scale production capacities such as electricity power plants, in which the energy is brought to the consumer in [cascading] steps according to the "waterfall principle".' [Expert 3]*

Energy production - RE

*'There is a change. Increasingly, energy production is decentralized. Decentralized production, think of sun and wind [energy], is independent of local demands of energy. This means that energy infrastructure has an additional task to fulfil...mobility of energy [to balance needs and supply]' [Expert 3]*

*'The energy challenges are concentrated around the question of demand and supply of centralized energy developments such as wind energy parks, and of decentralized sustainable energy developments that are increasing taking place in neighbourhoods, villages and cities.' [Expert 2]*

**Complexity and impact of energy systems developments**

Need for big investments

*'The model [of relying on adjacent energy supply] requires very large investments of main grids. In the next 10 years, expansion of electricity transmission capacities in North-West Europe requires at least 75 billion euros; this translates to 1000 euros per family. And this is only the beginning of the energy transition.' [Expert 3]*

**Emerging patterns in energy transition**

Decentralized energy generation

*'In the first place, we need to ensure that as little as possible energy needs to be transported ' [Expert 3]*

Power balancing

*'Due to increasing sustainable energy sources, wind, sun, biogas, the need for innovative balancing arises.' [Expert 1]*

*'We are moving towards a model in which households, municipalities, regions and perhaps countries are increasingly realizing their sustainable electricity generation in terms of their annual needs; but even when this is not realized, there is electricity exchange with the adjacent next level as a buffer; and when this is not possible, the energy exchange moves to the next higher level.' [Expert 3]*

**Integration of gas and electricity**

*'The integration of gas and electricity brings a lot of advantages. Transport of gas is 10 cheaper than transport of electricity. Gas storage is more than 1000 times cheaper.' [Expert 3]*

*'We can neglect gas and focus on using 100% electricity. But this is very expensive. One alternative is to use the existing gas infrastructure. Gas gets a systems function in the increasingly sustainable energy supply. Gas in itself can be made sustainable through the green gas route. In this way, we make energy transition affordable. And hence increases chances of success' [Expert 3]*

**Integration fossil and renewable energy**

*'This [affordable energy transition] can be achieved through limiting energy transport; alignment of gas and electricity; and use of existing gas infrastructure as a system function… and the need to improve our innovation capacities.' [Expert 3]*

*'The SER Energieakkoord [energy agreement] aimed at sustainable growth had a lot of attention for smart energy networks, the supportive role of gas and the flexible use of gas.' [Expert 2]*

**New European laws and regulations**

*'The energy infrastructure was up to a few years' ago mostly top-down, increasingly there is a new development, more bottom-up. Decentralized generation of energy leads to new standards and guidelines, also applicable to energy infrastructure' [Expert 2]*

*'In the third European package [packet], European guidelines are described in which it describes how member states are expected, on the one hand, to safeguard European security of supply, and on the other hand, how to develop local 'smart grids'. The European Grid code provides norms in regulating how energy at the European level is transported amongst member states. Interconnection between member states is seen as being critical for an integrated European energy market. Interconnections between member states are realized via energy infrastructure, which is inadequate at the existing moment.' (Expert 1)*

The analysis showed how energy transition developments were connected to EU policies, changing energy production, consumer demands for renewables, increasing complexity of energy systems and the impacts of such complexity at the global (climate change), EU, national and local levels (outages, integration of national energy systems, balancing, new regulations and standards) and impacts on the energy sector. At the same time, these changes were in turn creating new systems patterns within the energy system but also for the energy cluster, and national and economic interests reflecting interconnectedness of energy systems developments. The insights of this Lesson reinforce insights on systems-in-systems developments of Lesson 6.

| | |
|---|---|
| *Clusters are embedded in related and overlapping systems interacting and influencing cluster developments.* | - EU level energy systems developments influenced local cluster developments that resulted in shifts in the nature of supply and demand and alignment of these in the local energy system.<br>- Energy transition as a result of fossil fuel depletion and climate change agenda also influenced local energy systems and increased renewable energy and more complex energy systems resulted.<br>- Consumer behaviour supported increased decentralized and sustainable energy sources that increased complexity of local energy systems as intermittency of supply needed to be met.<br>- Increased decentralized energy systems meant huge investments in infrastructure were needed, strengthened by outages at EU levels, due to infrastructure challenges.<br>- Regional developments respond to energy liberalization and energy transition developments.<br>- EU energy systems, energy transition, consumer behaviour patterns had influences on local and regional systems. |

*Table 38 Proposition on related and overlapping systems in cluster developments*

The proposition on cluster developments of related and overlapping systems is discussed in more detail in Appendix 10.

Energy Valley cluster developments, interrelatedness and dynamics of systems within and across different systems were demonstrated in this Lesson. The next section provides an overview of Lessons 1-7 and resulting propositions.

## 4.11 Overview of propositions on cluster developments

The propositions on cluster developments based on the findings of Energy Valley are provided in the table below.

| | |
|---|---|
| *P1* | *Cluster developments, connected to context and contextual changes, and driven by internal and external drivers of change, are becoming increasingly complex.* |
| *P2* | *Cluster developments are connected to their initial conditions of container, stakeholders and path dependent factors.* |
| *P3* | *Cluster dynamics are interconnected system responses to changes in its context; namely, attractors to new movements and changing stakeholder perceptions, fitness to landscape strategies to meet changing contextual challenges, using significant differences as a potential for new path creations.* |
| *P4* | *Cluster performance is visible in transforming interactions and contributes to macro level emergent systems patterns.* |
| *P5* | *Cluster developments are influenced by both top-down steering and self-organizing processes.* |
| *P6* | *Clusters are systems-in-systems connected to higher-level systems (national and EU) where parallel emerging patterns as well as tensions are present due to differences in systems at different levels.* |
| *P7* | *Clusters are embedded in related and overlapping systems interacting and influencing cluster developments.* |

*Table 39 Propositions on cluster developments*

The next section presents insights into interconnected cluster developments based on additional analyses of case studies (Appendix 13) and discussions of the case studies (Appendix 14).

## 4.12 Insights into cluster systems dynamics

The analyses of the additional cases of Karlstad and Silicon Valley and revisiting Energy Valley provided enhanced insights into cluster systems that built on the initial propositions on cluster developments (Table 39 above). Detailed analyses of Karlstad and Silicon Valley in the light of Energy Valley's propositions are found in Appendix 13.

The supplementary cases and reiterative analyses of the three cases (Appendix 14) offered insights into clusters that were based on these clusters with their different sectors, regions, phases of development and contexts.

The next sub-section provides the resulting insights into cluster systems developments based on the final analyses of all three cases.

### 4.12.1 Overview of insights into cluster systems dynamics

Specific insights into Energy Valley were verified and enhanced through the analyses of the supplementary cases of mature clusters from different sectors and geographical areas with different cluster conditions and developments.

These additional cases and reiterative analyses of all three cases resulted in more nuanced insights into cluster systems dynamics that were grounded in multiple cluster contexts. The insights into cluster developments as interconnected systems are presented in the table below.

| ***Cluster aspect*** | ***Insight into cluster systems developments*** |
|---|---|
| *Changing context* | *Cluster developments are interconnected to developments in the region and the larger context, and become increasingly complex due to internal and external drivers of change, and different responses of stakeholders.* |
| *Cluster condition* | *Initial conditions of container, stakeholders and path dependent factors are important in determining subsequent cluster developments whereby dominance of one or more stakeholders or path dependent factor could increase risks of lock-in where limited external linkages are present, or if there are too many differences, a risk of diffused cluster developments exists.* |
| *Cluster dynamics* | *Cluster systems respond to changes in the context, reflected in attractors, fitness to landscape strategies and significant differences leveraged for new path creations, which in turn, contribute to cluster transformations.* |
| *Cluster transformations* | *Transforming interactions in cluster developments, as a result of changing cluster dynamics often include shifting sensemaking processes of stakeholders, resulting in emergent systems patterns of shifts in scope and scale of activities, and roles of stakeholders, increased cross-over collaborations in knowledge and industry developments, and emerging sub and new cluster formations, which cumulatively reflect increased interconnectedness and complexity in macro level systems patterns.* |
| *Organizing processes* | *Cluster developments are influenced by both top-down steering and self-organizing processes.* |
| *Related (horizontal) systems* | *Clusters are embedded in related and overlapping systems that interact and influence cluster developments.* |
| *Embedded systems (systems-in-systems)* | *Clusters reflect systems-in-systems developments such that parallel and differing emerging patterns prevail due to similarities and differences in the different systems levels.* |

*Table 40 Insights into cluster systems dynamics*

These insights into cluster systems dynamics were instrumental in shaping the proposed model on cluster emergence presented in the next section. Both these outcomes of the research, the insights and the model, are discussed in Part 3 whilst implications for theoretical developments and policy are discussed in Chapter 5.

The next section presents a model on cluster developments, Cluster Emergence Model, as the next outcome of the research.

### *4.13 Cluster Emergence Model*

The research developed an initial framework based on existing scholarship in Complex Adaptive Systems in interface studies. This framework distilled relevant concepts from the literature that included cluster and regional studies to ensure alignment with developments in these areas (see section 3.13). The research findings offered insights into cluster systems dynamics showed how these concepts were interrelated (Lessons 1-7). The growing insights on cluster developments during the research led to various improvements and development of the initial framework (Appendix 8).

The culmination of insights into interrelated aspects of cluster systems emerging from the research and evolutions of the initial framework led to the development of the Cluster Emergence Model (CEM).

The model captures cluster developments as interconnected to contextual systems and its own dynamics. CEM captures interactions of various aspects of cluster systems through the use of CAS concepts and the emergent insights of the research.

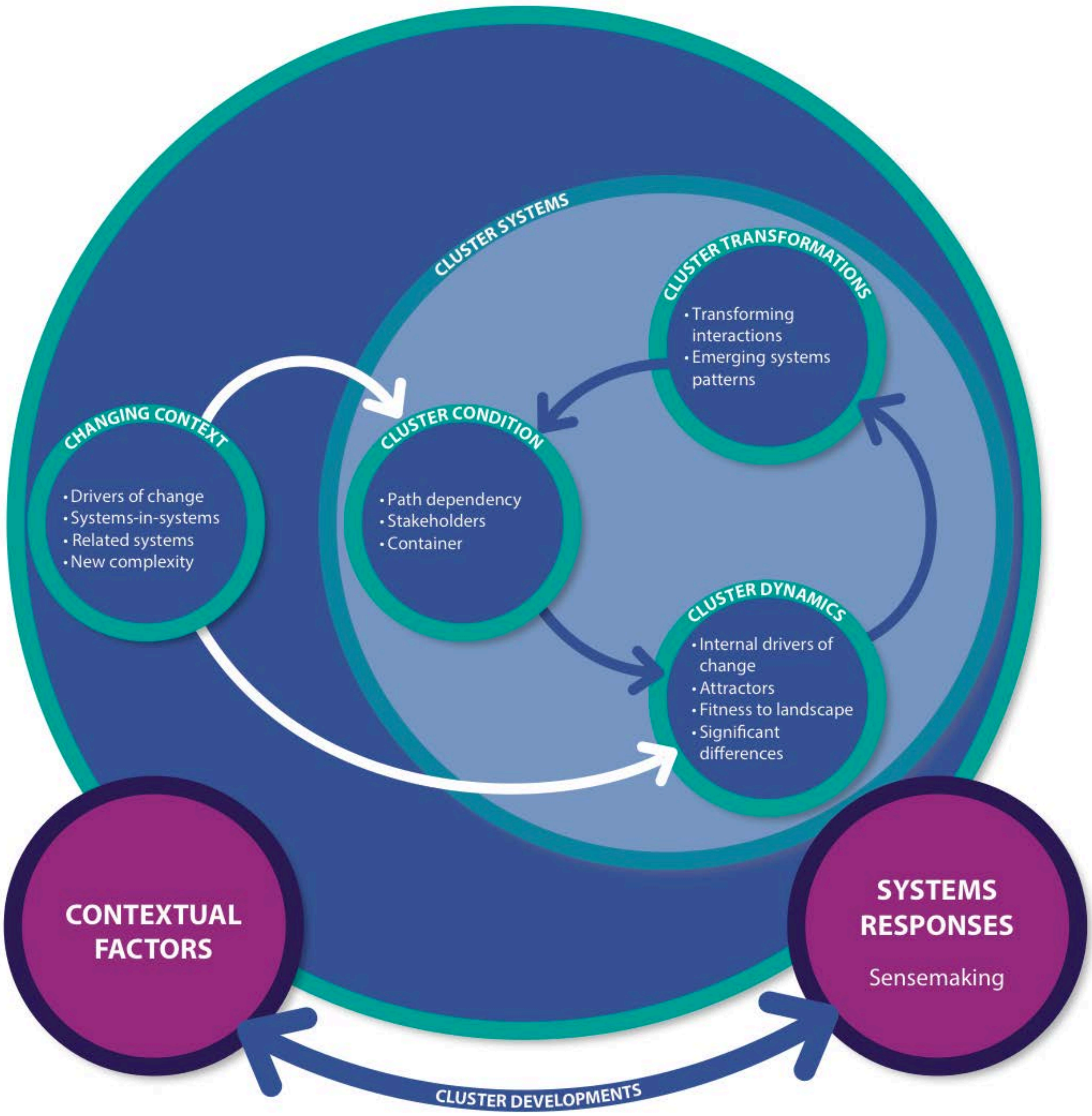



*Figure 32 Cluster Emergence Model capturing interconnected cluster developments*

The model has a 'meta' level (purple circles) that captures the interconnected nature of clusters in their contexts. Here, 'Cluster developments' is shaped by interactions of 'Contextual Factors' and 'Systems Responses' with 'Sensemaking' of stakeholders being central to 'Systems Responses' (in keeping with CAS theory).

The next level of the model, the outer blue circle, captures 'Clusters Systems' and their 'Changing Contexts' whereby the latter includes 'drivers of change', 'systems-in-systems', 'related systems' and 'new complexity'. These aspects highlight capture different aspects of this changing context.

The next layer is the 'Cluster Systems' with 'cluster condition', 'cluster dynamics' and 'cluster transformations', each with related concepts. 'Cluster condition', affect 'cluster dynamics' which in turn affects 'cluster transformations'. In addition, changing contexts also affect cluster conditions and dynamics that feed into cluster transformations and therefore cluster developments. The interrelatedness of these aspects are described in the 'insights into cluster systems developments' of the previous sub-section.

CEM is a representation of cluster systems developments. The table below provides concepts in the model and their definitions.

| | | | |
|---|---|---|---|
| Contextual Factors | | Changing Context | **Drivers of change** – external contextual developments that impact cluster developments |
| | | | **Systems-in-systems** – individual systems affects the next level system, both above and below, known as upward and downward causality |
| | | | **Related systems** – related systems overlapping and influencing cluster systems |
| | | | **New complexity** – complex or 'wicked problems' often paired with high levels of uncertainty and disagreements |
| Systems Responses (Sensemaking) | Cluster Systems | Cluster Condition | **Path dependency** – significant factors from the past that still determine the cluster's activities, and could include history, geography, culture, etc. |
| | | | **Stakeholders** – key actors including gatekeepers and stakeholder groups in cluster systems |
| | | | **Container** – defining features of cluster system including scope, boundary, vision, identity, governance structures, etc. that reflect the cluster's 'playing field' and governing 'rules' |
| | | Cluster Dynamics | **Attractor** – constraining forces reflecting direction of cluster developments, including changing stakeholder perceptions and behaviours in cluster systems |
| | | | **Internal drivers of change** – changing features within clusters that impact cluster developments |
| | | | **Fitness to landscape** – strategies to co-evolve or transform to 'fit' changing contexts that include development of capacities |
| | | | **Significant differences** – differences that could support better 'fitness' to changing contexts through new combinations and innovations |
| | | Cluster Trans-formations | **Transforming interactions** – visible shifts in interactions and collaborations that result in new, transformed activities and developments often through cross-boundary combinations |
| | | | **Emerging systems patterns** – systems level patterns emerging from micro-level cluster dynamics responding to changing contexts |

*Table 41 Overview and definition of concepts in Cluster Emergence Model*

Most of the concepts are similar to those of the initial framework (p. 155) with enhancements in formulation.

Changes in definitions and additional concepts reflected new insights on cluster developments. Changes include internal drivers of change, systems-in-systems, new complexity (as opposed to complexity) and cluster transformations (as opposed to cluster performance). The CEM model also captured 'related systems', which was not part of the initial framework. The concept of self-organizing processes inherent to attractors of (autonomous) stakeholder responses and to cluster transformations and, given that both top-down and bottom-up processes were present, this concept was not included in the CEM as a separate aspect. In addition, the concept of 'sensemaking' that captures autonomous responses of stakeholders has been included. These changes have been based on the 'insights into cluster systems dynamics'.

To conclude, the CEM model captures interconnectedness of cluster systems developments in their larger contexts, and is a synthesis of CAS approaches, related cluster theories, policy and practice approaches tempered by insights from case studies of Energy Valley, Karlstad and Silicon Valley. Discussion of the model in the light of cluster study is found in Part 3.

### *4.14 Conclusions of Part 2*

Part 2 described insights from Energy Valley as seven Lessons on aspects of cluster systems and interrelated developments of contextual and related systems. These insights were formulated as propositions on cluster developments, which in turn, were further explored in the light of two supplementary cases of Karlstad and Silicon Valley. The outcomes of the three cases resulted in insights into cluster systems developments and the Cluster Emergent Model.

Part 3 presents the discussion of the research findings.

## *4.15 Part 3 Discussions of the findings*

## *4.16 Introduction*

The in-depth case study of Energy Valley was an exploration of changing cluster contexts and cluster dynamics and their influence on cluster developments. This investigation resulted in propositions on the interconnected nature of cluster systems developments, which were substantiated and enhanced by analyses of Karlstad and Silicon Valley cases. The outcome of the research was insights into cluster systems developments as parts of larger systems. In addition, adapting Complex Adaptive Systems approaches enabled the research to map interrelated emergent processes influencing cluster systems in their broader contexts, and this in turn, resulted in the development of a CAS-based model of clusters systems, the Cluster Emergence Model.

Part 3 discusses implications of the research findings for theoretical developments of cluster study in particular. The discussion is organized in 3 sub-sections, in which the first discusses the application of complexity approaches to cluster study; the second, implications of 'insights into cluster systems developments'; and the third, Cluster Emergent Model and its relevance and contribution to cluster study.

## *4.17 Key findings and the link to literature*

### 4.17.1 Complexity approaches, research findings and cluster literature

Complex Adaptive Systems has been acknowledged as a meta-theory of change (Ramalingam *et al*, 2008), and this research used CAS approaches to understand changes in complex cluster developments. Adopting the CAS approach allowed the investigation to capture clusters as complex systems interconnected to contextual developments; behaviours of cluster agents and systems as being path dependent and subject to lock-in risks; significance of stakeholder perceptions and behaviours in clusters; significance of defining features (container) in clusters; significance of attractors in cluster systems; emergence of new interaction and collaboration patterns of cluster transformations through leveraging significant differences and developing fitness to landscape strategies; connections between micro-level agency and resulting cluster developments; and interconnected developments of clusters and related systems. The application of CAS to understanding cluster developments was therefore fundamental to the research and the outcomes. CAS has been acknowledged to support both *ex ante* and *ex post* analyses of complex systems developments (Ramalingam *et al*, 2008). The case studies provided insights into cluster developments as *ex post* analyses using CAS. The Cluster Emergence Model, developed to support cluster study, can be used both for *ex post* analyses as in this research, and as an *ex ante* tool for cluster analysis and policy developments. The use of CEM in policy developments is addressed in sub-section 5.6.3.

The behaviour of clusters as multi-agent systems interacting at multiple scales, displaying unpredictable and complex patterns of developments is acknowledged in cluster literature (Martin & Sunley, 2007, 2015; Carbonara *et al*, 2010; He *et al* 2011; Cooke, 2012, 2013, Uyarra & Flanagan, 2013). The convergence of Evolutionary Economic Geography studies and of Regional Innovation Systems studies to include complexity approaches was addressed in Chapter 2. To illustrate, Cooke's work (2012) elaborating his theory of transversality and relatedness in co-evolving innovative regions, 'complex adaptive innovation systems', integrated components of complexity approaches into regional and cluster studies.

The research findings supported theoretical developments exploring clusters as complex adaptive systems. The Cluster Emergence Model operationalized a whole systems approach acknowledging complex adaptive systems' behaviour of clusters and their changing contexts, incorporating interconnected systems developments, reflecting emergence and innovation through agency in spatially rooted interaction patterns. CEM as a model offers an overarching developmental instrument to explore cluster changes in their wider context, and to supporting an integrated perspective of cluster systems. This alternative approach to understanding cluster developments goes beyond equilibrium-seeking, supply-driven, narrowly focussed knowledge interactions assumptions dominant in regional studies. In addition, CEM as an analysis tool meets cluster theory's search for broad policy instruments that allow understanding specificities of individual clusters and the search for potential path creations in their unique setting.

The next two paragraphs discuss the research findings in terms of extant theories of Regional Innovation Systems (RIS) and Evolutionary Economic Geography (EEG) as reviewed in the literature.
When compared to RIS approaches as captured in Table 6 (sub-section 2.5.3), Cluster Emergence Model contrast to RIS in that it is not subject to 'closed systems' focussed on local linkages and limited stakeholder range (of only tripe-helix). In

addition, CEM also caters for multi-level analysis, exploring the ‘adjacent possible’, micro-learning processes, and broad definitions of knowledge. The research findings based on non-linearity principles of CAS therefore go beyond RIS assumptions of causality, narrow focus on institutional settings, influence on innovation through agents and networks in systems, and assumptions of innovation processes supported by structural and top-down features (sub-section 2.5.3). The research findings hence extend the scope and study of clusters of more traditional RIS approaches as described in this sub-section.

The link of the research findings to EEG is discussed here. The research identified concepts from EEG that overlapped or were relevant to a CAS approach and were included, or adapted and these included *path dependency*, *significant differences* (EEG’s related variety), *emergence* (EEG’s evolution) and *adaptive systems* (EEG’s adaptation and adaptability). Convergence of EEG with complexity approaches was discussed in the literature and reflected the growing relevance of complexity theories for regional studies. Concepts of emergence and self-organization were incorporated in EEG’s theoretical developments (Martin and Sunley, 2015). These too are important aspects of CEM even as self-organization is not mentioned as a separate component. In addition, like CAS, EEG also embraces whole systems and interactionists’ perspectives (Table 7, sub-section 2.6.2). Like RIS approaches, the institutional frameworks and structures are prominent in EEG as important constraining forces in evolution of cluster and regional systems (sub-section 2.6.4). The research proposed non-linearity and semi-autonomous agency at the core of cluster developments true to its roots in CAS and therefore does not specifically give prominence to one realm of systems agency over others and this has been shown in the findings. It was shown that agents and patterns of interactions of agents in cluster systems were significant to cluster developments even as path dependent factors (among others institutional structures) played critical roles. The CEM approach offers an alternative model of cluster (and regional) developments that embraces much of EEG‘s evolutionary principles including adaptability potential; historical evolution; and holistic and multi-level approaches (see Table 7, sub-section 2.6.2) whilst going beyond narrow scopes of routine and rule-based assumptions underlying selection, retention and evolution. The theoretical discourse and developments of this field of study are broadening its perspectives to incorporate complexity and interconnectedness of systems developments. The CEM approach and insights into cluster systems developments contribute towards this end.

The research, in embracing complex adaptive systems approaches, built on its epistemic and ontological perspectives, brings these frames in the theoretical discussion of regional sciences. Assumptions of 'not knowing it all' (section 3.4), and context specific, non-linear inter-connected systems developments of clusters are at the core of the research. These assumptions were not new to regional studies and were part of the on-going discourses on how to address such perspectives in regional studies developments (in Evolutionary Economic Geography or Regional Innovation Systems). One of the difficulties faced in regional studies is the diffused nature of the broad range of theories and their epistemologies. Cluster studies, labelled as 'work in progress', therefore had room for new insights and approaches in its developmental discourse. This research offers empirical and analytical insights into increasing complexity of interconnectedness of regional and cluster developments, and an integrated approach to deal with such phenomena.

The discussion of the findings in this sub-section has been focussed on the broader paradigmatic and theoretical discussions of extant cluster theories and that of complexity and complex adaptive systems theories, and indicated possible contributions to theoretical developments in cluster study, including epistemological issues.

The next sub-section of this discussion delves into specific aspects of the research findings and discusses the relevance of these findings to developments in cluster theory and complex adaptive systems approaches.

#### 4.17.2 'Insights into cluster systems developments' and theoretical discourse

At the core of the insights into clusters systems from the research, and hence of the discussions, is the interconnected nature of cluster developments. The following two sub-sections discuss these interconnected aspects of cluster systems developments by clustering the insights. The first sub-section discusses insights into increasing complexity and interconnected cluster developments, and the second, focusses on insights related to cluster dynamics due to contextual changes. Both sub-sections discuss the findings in the light of cluster literature.

#### 4.17.2.1 *Insights into increasing complexity and interconnectedness in cluster developments*

This sub-section looks at the interconnectedness of cluster developments at the systems levels in relation to its changing contexts. Four specific aspects have been acknowledged and addressed in the research findings related to the phenomena of interconnected cluster developments in their changing contexts. These aspects are captured by the concepts of drivers of change, related systems, systems-in-systems, and new complexity. These aspects are explained in the light of cluster literature and how they could add to theoretical developments.

In order to understand what changes are relevant to cluster interconnectedness and developments, the concept of drivers of change has been included to acknowledge and discover specific drivers of change relevant to a cluster's developments. The specificity principle, or uniqueness, of cluster systems is an important aspect of cluster developments. Both CAS and cluster theory acknowledge this principle, whilst the challenge in cluster theory was developing universal theories for cluster developments. In addition, the literature review also addressed the need to include notions of regional innovation systems as 'open' systems subject to external and global developments (sub-section 2.6.5).

A different aspect important to cluster developments with regards to contextual changes is horizontal systems developments of related systems. Systems' interconnectedness of cluster developments with related systems in their context were evident. Examples of these were seen in clusters co-evolving with related fields, such as developments in energy transition, agriculture and chemical industries (Bio-based economy) in Energy Valley, developments in forestry and pharmacy in Karlstad, and developments in aerospace industry in Silicon Valley. Martin and Sunley (2015) expressed the significance of such interconnected developments and the need to deal with 'how industries emerge and develop across space' (p. 713) by spatial economies and specifically EEG. Scholars acknowledged the increasing complexity of 'path inter-dependencies' and 'transversality' (Cooke, 2012, 2103; Uyarra, 2010; also Boschma, 2015; Gertler & Wolfe, 2006; Martin & Sunley, 2006, 2007, 2012, 2013; Wolfe, 2009). The insights presented in the research findings therefore reinforce the interconnectedness of 'horizontal' systems but where the research adds to the theoretical development is in its conceptualization of such developments as part of broader interconnected systems developments that includes vertical systems-in-systems interconnectedness, and interconnectedness to contextual changes (drivers of change and new complexity).

The next aspect capturing interconnectedness of cluster systems developments is the concept of systems-in-systems. This concept describes how 'individual systems affects the next level system, both above and below, known as upward and downward causality'. Examples of such behaviour were shown in the case study of Energy Valley where energy transition developments were reflected at the cluster, national and EU levels. Differences in systems developments were also present due to different path dependent factors at the cluster, national and EU levels. Both upward and downward interconnectedness were also seen in the study. For example, grassroots movements and demand side developments were reflected in EU policies whilst EU policies for sustainability and more decentralized energy systems were reflected in energy transition developments in Energy Valley, and in the Netherlands. Examples of path dependent systems developments were seen in terms of different energy histories at national and EU levels in the case study. The systems-in-systems aspect helps identify how clusters developments are part of interconnected systems developments whereby both cluster systems developments and higher-level systems developments interact and influence each other, contributing to increased complexity (see new complexity below). The research makes explicit the presence of vertical systems interconnectedness as an integral part of cluster developments.

The vertical interconnectedness of systems-in-systems is acknowledged in cluster theories. One example of vertical interconnectedness of clusters is in the description of institutional and rule-based behaviours in RIS and EEG where socio-economic institutional cultures and structures are shared (sub-sections 2.5.3 & 2.6.6). These vertical interconnectedness addressed in RIS and EEG refer to local systems structures of regions of which clusters are a part. Agglomeration literature also shares the significance of local institutional structures but once more do not extend beyond the local. However, exogenous factors and their impact on regional and cluster developments could be regarded as vertical interconnectedness. In EEG, the significance of the environment is acknowledged as it explores how clusters evolve in response to changes in their environments. However, systems analyses of clusters as embedded systems are not extensive, and cluster literature is deemed as 'work in progress' (see section 2.7). The systems-in-systems concept in this research supports cluster theory developments to address interconnected and interacting systems developments as part of cluster developments by understanding how lower and higher levels of systems developments constrain each other.

Interconnected aspects of cluster developments including drivers of change and contextual systems contribute to increasing complexity in cluster. The next concept captures new complexity in interconnected cluster developments. New complexity is described as complex or *wicked problems* where uncertainty and disagreements prevail (see Table 9; also sub-sub-section 2.8.1 for *wicked problems*). Including this concept in cluster study extends understanding of the nature of cluster developments and its interconnected systems developments. As discussed in the literature, there is a convergence of cluster and regional studies fields towards complexity approaches in recognition of the growing complexity in cluster and regional studies. This research adds new complexity as an important facet of cluster developments.

In summary, the following insights reflect the increasing complexity and interconnectedness of clusters:

*Cluster developments are interconnected to developments in the region and the larger context, and become increasingly complex due to internal and external drivers of change, and different responses of stakeholders.*

*Clusters are systems-in-systems connected to higher-level systems (national, political and economic blocs or regions) where parallel emerging patterns as well as tensions are present due to differences in systems at different levels.*

*Clusters are embedded in related and overlapping systems that interact and influence cluster developments.*

These insights on cluster developments capture interconnected systems developments of clusters and their changing contexts. This sub-section also explained how concepts of drivers of change, systems-in-systems, related and overlapping systems, and new complexity support deeper understanding of such interconnected cluster developments in their contexts.

Complexity literature as described in Chapter 2 offered theoretical insights into the deeper mechanisms that connect aspects of multi-layered and multi-agent interactions, and of the relations between micro or lower level systems and macro or higher-level systems emergence. The interconnectedness of cluster developments form the essence of "lessons learnt", namely, the insights into cluster developments and the Cluster Emergence Model discussed in the next two sub-sections.

#### *4.17.2.2 Insights into cluster dynamics resulting from contextual changes*

This sub-section addresses the interconnectedness of changing contexts and cluster dynamics and developments. The research showed how cluster developments were systems responses to changing contexts. Systems responses are related to cluster conditions (container, stakeholders, path dependency), cluster dynamics (attractor, fitness to landscape, significant differences) and cluster transformations (transforming interactions, emerging systems patterns).

The research introduced the concept of container that supports understanding the significance of cluster boundaries and identities of cluster systems, and how changing cluster container affects (relevance of) stakeholders and vice versa. The notion of container goes beyond traditional cluster definitions as it encompasses systems features including systems rules or governance structures, vision, scope, and boundaries of its playing field, that is, its systems boundaries. Cluster boundary and identity are important to complex adaptive systems developments. Understanding cluster systems definitions offers potential intervention points to influence future developments. Cluster theory addresses cluster features and identity, specifically innovation systems theories and EEG address shared socio-economic institutions and structures, but the container concept is broader than these aspects, and it offers an operational instrument to identify and influence systems processes in cluster conditions (described in policy interventions in section 5.6).

Stakeholders, an important aspect of cluster condition, influence container (Lesson 4). The research showed, how stakeholder frames influenced sensemaking, and that when more stakeholders with different frames were involved, more complexity resulted due to greater differences. However, there is also a need to understand that risks of path dependent factors include stakeholder dominance and lock-in risks. Inclusion of new stakeholders therefore also has the potential for new path development. The next paragraph discusses changes in cluster stakeholders and relates it to the research findings.

In cluster studies, focus on triple-helix stakeholders was dominant but is changing. The literature on clusters showed that beyond the triple-helix, financial institutions (Sölvell and Williams, 2013; European Cluster Observatory; see Cluster approaches in Literature Chapter), and civic leadership and associations (Authors *et al*, 2009; Ebbekink *et al*, 2015) were becoming relevant and that changing governance structures were implied. The extended triple-helix model of Farinha and Ferreira (2013) included socio-economic and environmental contexts to capture governance mechanisms, but did not include additional stakeholders. The EU's RIS3 implementation guide indicated an extension of triple-helix partners was important to strategy development (EU, 2012a, see Literature Chapter). Cluster literature and policy therefore acknowledged the need to expand definitions of triple-helix partners, and the significance of civic leaders, civil associations and financial agencies were also described. The research findings also reflected these developments and showed how venture capitalists and angel investors (Silicon Valley case), farmers and other new energy players, citizen initiatives and NGOs (Energy Valley case) were present. These findings suggest that the triple-helix concept needs to be extended not just in a generic way, but to accommodate cluster specific groups or institutions. The research findings also highlight that cluster developments are not only about knowledge and human capital developments but are also about interconnectedness to other aspects specific to a cluster and its context.

The concept of cluster conditions also includes path dependency. This concept is shared by cluster theories recognizing spatial specific features, including the acknowledgement of lock-in risks and the need for path creation opportunities by building on regional strengths (EEG, RIS and Smart Specialization Strategies of EU). The research findings, in examining path dependent conditions in changing cluster context, found that besides lock-in risks, there was also a danger of 'cluster drain' when insufficient capabilities or unattractive conditions existed. The concept of 'stickiness' and attractiveness are common to regional studies to describe this phenomenon. However, the research introduced the concept of 'cluster drain' to capture escalating processes of systems responses (attractor movements to 'outside'). In Energy Valley, the lack of knowledge and innovation developments and resources, and environmental constraints were reasons for stakeholders to seek linkages outside the cluster that did not seem to support local cluster developments. Poor local cluster conditions could therefore trigger ‘cluster drain’. Similarly, Karlstad was faced with strong competition from urban centres of Stockholm, Gothenburg and Oslo with their urban-pull, and the threat of urban-spread whereby Karlstad could become a ‘suburb’ of one of these metropolises. The peripheral position of Energy Valley and Karlstad regions was a key factor contributing to potential risks of ‘cluster drain’.

Another aspect of cluster condition was a risk of a lack of coherence as seen in Energy Valley due to the regional diversity and growth of new diverse energy players and consumer movements. Cluster developments are therefore subject to risks of both cluster drain and cluster diffusion, due to their initial cluster conditions.

The insight below captures the significance of container, path dependent factors and stakeholders, and potential risks for cluster developments:

*Initial conditions of container, stakeholders and path dependent factors are important in determining subsequent cluster developments where dominance of one or more stakeholders or path dependent factor could increase risks of lock-in where limited external linkages are present, or if there are too many differences, a risk of diffused cluster developments exists.*

Other aspects of cluster systems responses in the face of changing contexts are elaborated in the next part of this sub-section. The discussion above showed how cluster condition is not static, and that the various aspects of cluster condition are interconnected. Interconnectedness of cluster condition extends to cluster dynamics since stakeholders, container and path dependent factors influence cluster dynamics and cluster transformations. The next part of the discussions looks at the interconnectedness of systems responses.

The research captures interconnected systems responses in terms of cluster dynamics with concepts of attractors, fitness to landscape and significant differences; and cluster transformations with concepts of transforming interactions and emerging systems patterns. This portrayal of cluster systems developments is new to cluster theory. The rest of the sub-section highlights how these aspects as interconnected systems responses relate to existing cluster theory.

More insights into cluster dynamics were achieved through the study of attractors, fitness to landscape and significant differences. Attractors, constraining path trajectory and 'narrowing the repertoire' (see Complexity Literature), generate new clusters dynamics as they deviate from existing order, and pave the way for new path creation. These new path developments bring with them new stakeholders, interests, competences, innovations, collaboration practices, and as such, new diversity to the cluster. Thus attractors not only change path trajectory and its 'repertoire' but also add variety, and increase potential significant differences in the cluster. In addition, stakeholders respond to changes in the context to seek 'fitness' by developing new fitness to landscape strategies. The resulting new cluster dynamics reflects the interconnected changes in attractors, significant differences and fitness to landscape aspects of cluster developments. Systems responses captured in these three aspects is new to cluster study even as the term significant differences overlaps 'related variety' and fitness to landscape to 'fitness' notion in EEG's. The novelty to cluster study lies in bringing these concepts as interconnected systems aspects of cluster dynamics. The term 'cluster dynamics' was also new to the cluster study.

To understand cluster dynamics, additional aspects of attractors in cluster developments are included, given the significance of its role in cluster dynamics. Understanding attractors in cluster developments help uncover 'hidden order' of complexity (Ramalingam *et al*, 2008). As explained in Chapter 2, complex adaptive systems are unpredictable but have underlying structures (attractors) that constrain emergence. Silicon Valley's attractor patterns governing mentoring and nurturing firm developments, start-ups, splintering and regeneration of firms were constraining how, what and why firm developments took shape as they did. Other attractor patterns were new capital and social capital developments, and integration of start-ups by large corporations (see Appendix 12 and 13). The interacting nature of attractors in cluster developments helps understand why cluster developments need to be understood in their specific systems developments.

Attractor patterns are also shared across systems levels and accounts for similarities in system-in-systems developments in the research. In Energy Valley, sustainability attractors of the system were important to developments in the energy cluster and sector locally but also at national and EU levels, reflecting 'vertical' systems-in-systems interconnectedness.

In addition, overlapping and related systems developments, the horizontal shared systems developments could also be better understood by uncovering shared attractors. In Karlstad, the sustainability attractor influenced developments in both the forestry and paper and pulp sectors, leading to new collaborations and systems patterns, for example, biomedicine developments and more sustainable forestry value chains.

One type of attractors addressed in CAS is 'strange attractors', which helps understand major transformations of cluster developments. Strange attractors are attractor patterns of path developments that result in systems change where new attractors emerge, and this usually occurs when critical threshold levels in the system are surpassed. Such system transformations are 'bifurcations' (Goldstein, 2008; see CAS Literature). Bifurcations occur where major transformations result. In Energy Valley, the 'Shifting Landscape' overview showed how various attractor movements were present, changing a once stable, homogeneous energy sector in the Netherlands towards complex and decentralized transformations. A bifurcation in the energy cluster of Energy Valley might be close. At the time of the research, incumbent energy stakeholders, large corporations, provincial governments and the Dutch government were still dominant in the system and therefore there were system shifts but not a bifurcation. Whether Energy Valley cluster was close to bifurcation was not clear but this is more easily identified in retrospect. Transition management models capture broader transition developments but this was beyond the scope of this study. The research therefore chose the term attractors to describe constraining forces in systems developments whilst it chose the term cluster transformation to capture systems shift of clusters.

The concept of fitness to landscape in the research captures the significance of 'landscape' in cluster developments. Energy Valley's 'Shifting Landscape' conveyed the significance of changing contexts, the landscape in which clusters operate. In addition, agglomeration and cluster theories stress how proximity (spatial, socio-economic, cultural, cognitive and technological, etc.) was significant for innovation, and economic success. Darwinist evolutionary theory described 'fitness' as the ability of organisms to adapt and survive, part of its 'selection, retention and survival' principles. On the other hand, Kaufmann's 'fitness landscape' sketches a metaphorical landscape of fitness peaks of adaptive solutions (see Adaptive Complex Systems for comparison). The research used fitness to landscape to reflect the evolutionary notion of 'fitness'. The notion of 'resilience', particularly in cluster and regional policy studies, explores how 'fitness to landscape' strategies could be designed to deal with external shocks (Appendix 14).

A related concept that needs to be addressed in the light of fitness to landscape developments is the role of stakeholder perceptions and sensemaking in this process. Sensemaking has been mentioned earlier in relation to the increase in complexity due to increased stakeholders with new frames and sensemaking. This research, in line with developments in cluster theory (EEG), reinforces significance of stakeholder perceptions and sensemaking through its empirical work and theoretical developments. CAS addresses significance of agent responses to changes in the context and the sensemaking processes of stakeholders were addressed in discussions on cluster condition.

The concept of significance differences facilitates in CAS approach is comparable to the concepts of 'related variety' and 'relatedness' in EEG, and in traditional views of complementarity in agglomeration theories of industrial districts (section 2.6). However, significant differences, 'differences that matter', include differences that may not be obviously related but are relevant to new path creations (sub-section 2.9.1). The importance of seeking new collaborations and combinations to emerge in transformations, and consequently new path creations goes beyond traditional approaches to 'variety' in regional studies. Significant differences extends beyond knowledge-bases and industrial differences reflected in regional studies, and instead includes differences amongst and between individual agents, stakeholder groups, resources, capacities, interests, ambitions, strategies, vision, scope, scale, etc. In addition, uniqueness of cluster systems developments is captured by significant differences as this concept conveys retrospectively its specific cluster developments, and of clusters' potential path creations. Also, CAS theories explain that the internal diversity (of significant differences) of systems needs to match the (increased) complexity of their context to be adaptive and resilient (section 2.8.3).

In conclusion, systems responses of cluster dynamics, with concepts of attractors, significant differences and fitness to landscape, offered cluster theory understanding of interconnected systems processes, including interconnectedness to contextual changes. This insight of changing cluster dynamics as systems response to contextual changes as interconnected developments is described below.

*Cluster systems respond to changes in the context, reflected in attractors, fitness to landscape strategies and significant differences leveraged for new path creations, which in turn, contribute to cluster transformations.*

Cluster transformations with its interconnected aspects of transforming interactions and emerging systems patterns are discussed in relation to the literature next.

Transforming interactions result from sensemaking processes of interacting actors due to changing cluster dynamics. These shifts in interactions often include new interactions with existing and new stakeholders both within and beyond the cluster systems boundaries as mentioned earlier, and in the three cluster cases. Cluster and agglomeration theories expounded the significance of tacit and traded exchanges in explaining innovation, and successes of firms, networks of firms, industrial districts and clusters (section 2.4).

Central to exchanges between stakeholders is the sensemaking process. Weick *et al* (2005) explained how meaning emerges in interaction with others in order to inform and determine action and identity in context-specific, retrospective discourse (sub-section 2.8.1). The concept of sensemaking contributes to understanding 'transformations' of new interactions and collaborations patterns in cluster developments. This was seen in Energy Valley where integrated policy and collective vision, new collaborative platforms and innovation spaces emerged in the cluster, provinces and cross-border regions to boost energy transition and regional developments (see Energy Valley findings).

To summarize, the concept of transforming interactions provided insights into new transformed activities and developments in the cluster, and often through cross-boundary combinations changes in clusters due to contextual changes and resulting cluster dynamics. The concept of sensemaking introduced to the cluster approach, provided understanding of stakeholder exchanges and their constraining social context that showed visible transformations in activities and developments of the cluster. These concepts capture deeper understanding of cluster interactions and collaborations and shifts in systems patterns, and support theoretical developments in this area of cluster study. These two concepts are brought into cluster development discourse. Sensemaking as part of agent behaviour in complex systems is not a new concept in CAS (Dooley, 1997; Axelrood & Cohen, 2001; Vogelsang, 2002) but the research brings this concept to the foreground in its approach to cluster study.

The concept of emerging systems patterns captures systems level transformations. These patterns emerge from interactions and interconnectedness of micro-level activities. Goldstein (2008) explained how systems emergence seemed to have 'a life of their own' that could not be explained by behaviour of lower components. Holland's notion of 'distributed, interacting parts' with each its own local rule (1992), also expresses the non-causality principle of CAS. At the core of complex adaptive systems is, the interconnected nature of independent local based agency engaged in dynamic interactions (section 2.9). The research showed emergent systems patterns of cluster developments in all three cases: stronger industry-academic linkages focussed on knowledge developments in Karlstad and Energy Valley with new innovation spaces, platforms and education programmes established; Silicon Valley's resurgent emergent pattern of mature firms reconnecting to Stanford for new innovation and knowledge bases; and, new 'ecosystem' approaches, technological paradigms and international outreach and connections in Energy Valley and Silicon Valley. Most significantly, the cluster studies reflected emergent systems patterns of increasing complexity in clusters (increased scope, scale, stakeholders, levels, etc.) and resulting increased diversity, and emergence of new policy, governance and organizing patterns. These cluster systems developments could be described as qualitative shifts due to interconnected processes in which addition and disappearance of qualitative structures and organization take place in different time and space (Maguire *et al*, 2011; also, sub-sections 2.8.3 & 2.9.1.3). The research therefore brings to the field of cluster study a qualitative understanding of cluster systems developments.

To understand qualitative shifts of cluster systems, the role of self-organization needs to be acknowledged. Stakeholders responding to contextual changes are semi-autonomous in their behaviour and contribute to cluster developments as discussed above in cluster dynamics. In the research, however, the role of policy (local, regional, federal/national and EU) was evident in shaping cluster developments in all three cases. Policy and dominant stakeholder (top-down steering) influencing cluster developments were seen in Energy Valley whereby large energy corporations and the Dutch government determined energy infrastructure and energy mix in its initial phases, and in Karlstad where Region Värmland and the Karlstas Municipality became more important in later developments. The research showed that both top-down and bottom-up developments were present and impacting cluster developments. This insight brings to CAS theories the need to address also the role of centralized steering in complex adaptive systems. Although one could argue that policy and dominant incumbents in clusters and other systems are also agents in the system, there is a qualitative difference in the influence and impact of policy, particularly in cluster developments. CAS recognizes change agents and system agents but it is not clear if policy agents could be similarly recognized by CAS unless policy acts as 'gatekeepers' to the existing system. One explanation, based on CAS, is that policymaking also responds to changes in context and other agents in the systems through sensemaking. In this case, top-down processes would be considered part of self-organizing property of complex adaptive systems. This research did not explore this issue beyond acknowledging the presence of both top-down (policy measures) and bottom-up processes in cluster systems development. Recommendations for future study are offered in the next chapter.

In addition, cluster developments being continuous mean that emerging systems patterns contribute to new solutions, lock-ins, risks, problems, opportunities, policy, and new complexity. This new complexity would then initiate new cluster systems responses. Silicon Valley's long history provided insights into new cluster developments when new complexity arose. For example, Silicon Valley's early successes driven by Stanford's research driven firm formation policy and activities were not sufficient in the 1990s due to competition from other regions; Silicon Valley responded by renewing the region's technology knowledge base in part through the Joint Venture Silicon Valley Platform changing collaborations between Stanford and the industry and firm formation developments to have more formal structures. Silicon Valley displayed continuous interactions between new developments and new systems responses. This reflects whole systems developments of over time inherent in evolutionary and CAS approaches. The discussion of the CEM approach in the next sub-section also elaborates on the emergent nature of cluster dynamics.

The research brings to cluster study whole systems developments through the concepts of emerging systems patterns, systems responses and self-organizing processes, but also attractors, as they address systems wide dynamics. These concepts, interconnected to all other aspects of cluster developments, are brought together in the Cluster Emergence Model.

To conclude, insights into cluster transformations and underlying organizing processes of cluster systems are captured below.

*Transforming interactions in cluster developments, as a result of changing cluster dynamics, contribute to emerging macro level systems patterns of more interconnectedness and complexity; transforming interactions often include shifting sensemaking processes of stakeholders, shifts in scope and scale of activities, and roles of stakeholders, increased cross-over collaborations in knowledge and industry developments, and emerging sub and new cluster formations.*

*Cluster developments are influenced by both top-down steering and self-organizing processes, particularly in the face of increasing complexity and scope of activities.*

The insights on cluster developments reflected above were based on clusters that transformed in the face of increasing complexity and the resulting diversity and use of diversity as described in earlier insights. The clusters described in the cases could be considered 'successful' in that they continued to develop in the face of changing contexts. Suggestions for future research are included in Chapter 5 to explore declining clusters systems dynamics unable to meet increased complexity and ensuing challenges due to contextual changes.

This sub-section discussed insights into cluster systems developments in terms of the literature and contributions to theoretical developments of cluster study.

The next sub-section discusses the Cluster Emergence Model in relation to models and approaches relevant to cluster practice and policy, and to EU policy developments.

#### 4.17.3 Cluster Emergence Model and literature and policy developments

Theoretical and empirical explorations, and dialectic were translated to what has resulted into the Cluster Emergence Model (CEM), which provides cluster study with a whole systems approach. CEM shows how cluster developments are interconnected systems developments of contextual changes and cluster systems responses. It also shows that aspects of cluster systems are interconnected with horizontal and vertical systems. In this sub-section, CEM is compared to the eight models and approaches reviewed in section 2.19, namely, Scottish Enterprise's cluster dynamics model, 'Cluster Commons', NRC Canadian model, Triangulating the Triple-Helix, Dutch Associative Governance lessons, Dutch Transition Model, Cooke's Complex Adaptive Innovation Systems Model, and Leadbeater's Systems Innovator. These eight approaches were indicative of developments in theory, policy and practice supporting holistic, systems approaches relevant to cluster study. The rest of this sub-section compares CEM and its underlying approach (referred to as CEM approach) to demonstrate any overlap, improvements and contributions of CEM and the CEM approach to cluster practice and cluster study.

Three of the models/approaches, namely, Dutch Transition Model, CAIS Model and Systems Innovator, addressed and included complexity and systems innovations aspects in their approaches. Hence, these approaches were closest to the research. Common to these approaches is acknowledgement of collective participation and alliance forming, path interdependencies, broader scope and definitions of cluster and innovation systems, interconnected nature of developments, and in Systems Innovator approach, distributed leadership and ownership. The Associative Governance lessons also addressed some of these issues, and in particular, stressed the need for new governance and co-creation based on whole systems perspectives. In addition, a call for civic and institutional entrepreneurship was part of this approach. Ecosystems perspectives were also stressed in both this approach and that of the extended Triple-Helix model. Governance aspects were also addressed explicitly in the NRC and extended Triple-Helix models explicitly even as other models cover governance implicitly. The Scottish Enterprise, 'Cluster Commons' and NRC models were specifically focussed on cluster developments, whilst other models and approaches had broader scopes but shed light on literature developments related to cluster and regional development studies, and therefore included in the review and in the discussion of CEM's relevance and contributions to such developments. Having addressed the value and position of these various models and approaches in terms of broader, holistic, systems study of clusters, the next paragraphs discusses each of these extant models/approaches separately including a comparison with CEM.

The Scottish Enterprise's cluster model (Smith and Brown, 2009) offers a systems perspective on cluster dynamics captures principal feedback loops in cluster developments. The proposed model, CEM, compares to the Scottish Enterprise's model in that they both show interconnected systems developments through feedback loops and capture contextual drivers. The Scottish model addresses five interconnections in cluster developments, namely, inter-firm rivalry, inter-firm collaboration, venture attractiveness, collaborative advantages and future focus. Their model also captures contextual factors, firm motivations and capabilities. Where the CEM differs from the Scottish Enterprise's model is in its underlying approach. CEM is based on CAS whilst the Scottish model is based on systems approach. The Scottish model, based on systems theories, affirms the need for feedback loops capturing interactions within and outside the cluster but focussed on firm-level interactions. Whereas, CEM based on CAS assumptions of non-linear emergent properties due to multi-scalar, multi agent interactions and systems developments captured more and different aspects of cluster developments and interconnected systems developments.

The 'Cluster Commons' model presented on the EU Cluster Observatory shows weaknesses and gaps faced in cluster systems. The model identified innovation gaps and the need to bridge such gaps in cluster systems to support development of 'world class clusters'. The need to expand firm connection to other 'agents' coincides with the notion of enlarged cluster 'container' of the CEM. This approach, like that of the Scottish Enterprise, focusses on firm activity and supportive conditions for innovative firms, coherent to its underlying innovation systems and Porter's competitiveness approaches. CEM captures broader systems interconnections compared to the Cluster Commons model even as the focus on linkages within and outside cluster systems are common to both approaches. The centrality of firms in clusters in the Cluster Commons differs from CEM and other approaches taking a more 'ecosystems' and agency perspectives. Also, CEM captures a broader scope of cluster developments compared to the Cluster Commons 'model' given its firm-focus and focus on identifying key innovation gaps and strengths of linkages in clusters.

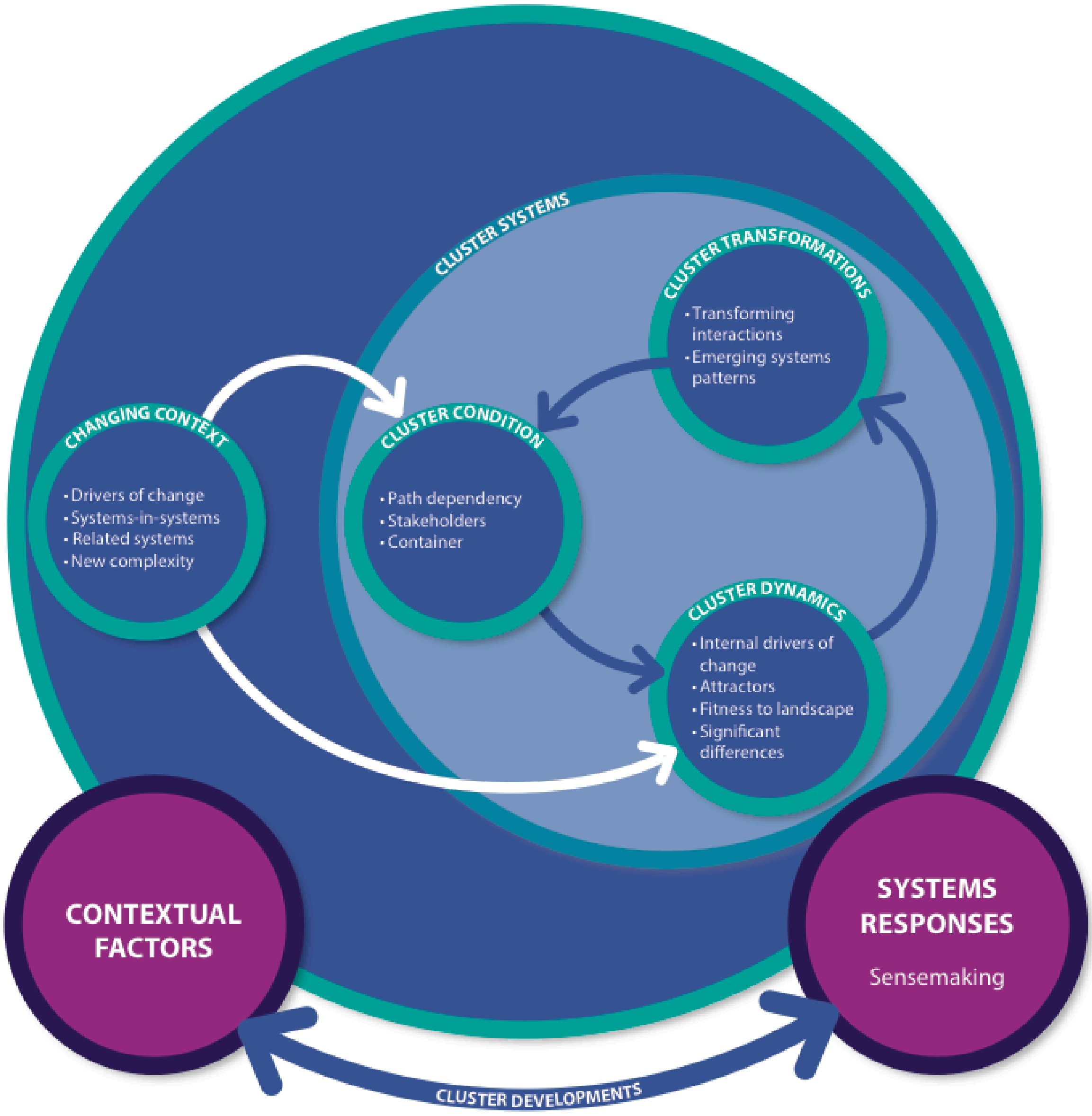
The Canadian NRC cluster model contributed to the development of the CAS conceptual framework (sections 3.6.2.1 and 3.13) and therefore also to that of CEM. Concepts of cluster condition and cluster performance from NRC model were adopted in the initial conceptual framework. The research however, extended and modified NRC's two categories and developed a model of four aspects, namely, cluster context, cluster conditions, cluster dynamics and cluster transformations. In addition, CEM captures clusters as systems in interaction with its context. Another difference between NRC and CEM was that NRC model focussed on input-output measures of cluster developments even as it emphasized significance of past and current conditions for future performance, acknowledging interconnectedness of these aspects, whilst CEM captures insights into qualitative cluster systems developments by exploring various aspects of systems interconnectedness. CEM does not focus on input-output measures specifically. The contribution of CEM is on qualitative shifts rather than on quantitative measures. However, recommendations for future research on this aspect are offered in Chapter 5 (sub-section 5.5.1).

The Systems Innovator, Dutch Transition Management and Complex Adaptive Innovation Systems (CAIS) models offer policy intervention recommendations based on complexity and systems approaches. The former two approaches are not specific to cluster developments whilst CAIS stems from RIS approaches and included clusters complexity in its developments (see section 2.19.7). These models/approaches are discussed below.

Leadbeater (2013) indicated that systems innovations would become the single most important focus of all societies, and that businesses and governments would have to take ownership of interconnected systems failures and contribute to the 'interactive and distributed leadership' needed (section 2.19.8). His 'new rules' coincides with key aspects of CEM. The new rules included need for insights into stakeholder behaviour (stakeholder perceptions and sensemaking in CEM), systems specificity (CEM captures insights into specific cluster systems), interactions and collaboration patterns (CEM's cluster dynamics and transforming interactions), visible 'social contracts' (CEM's transforming interactions), mix of leadership styles (CEM's organizing systems patterns), history (CEM's path dependency), and leapfrogging (CEM's (strange) attractors and emerging systems patterns). CEM therefore can be seen to operationalize Leadbeater's systems innovation approach for cluster study. In addition, the Systems Innovator approach stressed the need to understand and leverage potential values of systems to deal with complex challenges facing modern societies, rather than focus on product or sector specific innovations. To this end, CEM provides clusters (and their regions) support for systems innovations.

The Dutch Transition Management also addressed broader interconnected societal challenges and is based on complexity approaches to deal with these challenges, focussing on processes of social learning and collective initiatives. Transition Management approach was incorporated into regional studies (Cooke, 2012) and relevant to cluster study. Similarly, CAIS recognized the significance of path interdependent developments in systems, incorporated CAS in its approach (Cooke, 2012, 2013; sub-section 2.19.7). Cooke stressed the need to include interconnected path dependent developments in support policy facing complex social challenges in regional and cluster studies. CEM, based on CAS and adapted for cluster study specifically, adds to these developments. All three approaches discussed above corroborate the need to extend cluster study to include broader systems (societal) innovations and transitions developments incorporating complex systems approaches.

In adopting and operationalizing CAS to cluster studies, CEM also embraced epistemological and non-linearity aspects of this approach as well. This meant that CEM, both the model and the underlying approach acknowledged limitations of knowing and that notions of causality were framed in terms of interconnectedness and underlying processes to be discerned through the 'lens' of complexity and empirically, through the 'lens' of stakeholders. Hence, CEM adapted and refined CAS approaches to make sense of cluster developments in their complex environments as a comprehensive approach, building on extant cluster theories. The illustration below offers the model with its defining concepts as a whole.




**Changing context**
- Drivers of change: external developments that impact cluster developments
- Systems-in-systems: upward & downward causality of cluster systems
- Related systems – related systems overlapping and influencing cluster systems
- New complexity: 'wicked problems' of high levels of uncertainty & disagreements

**Cluster Condition**
- Path dependency: history, geography, culture, etc. impacting cluster activities
- Stakeholders: key actors of gatekeepers & stakeholder groups in cluster systems
- Container: defining features of 'playing field' & governing 'rules'

**Cluster Dynamics**
- Attractor: constraining forces influencing cluster systems developments
- Internal drivers of change: changing cluster features impacting developments
- Fitness to landscape: developing new competences & strategies to 'fit' changing context
- Significant differences: differences that can influence 'fitness'

**Cluster Transformations**
- Transforming interactions: visible transformed developments via cross-boundary combinations
- Emerging systems patterns: systems patterns emerging from interconnected cluster dynamics

*Figure 33 The Cluster Emergence Model and its defining concepts*

The research had reviewed EU policy to understand cluster policy context and policy needs in section 2.11 and Appendix 5. The next three paragraphs look at EU policy and discuss how CEM relates to supporting policy issues and developments.

In reviewing EU cluster policy developments, and EU's strategy for its future in the aftermath of the 2008 crisis, key challenges for policy lay in implementing effective economic growth policies, including cluster policies, in its 27 member states. In addition, the EU recognized that structural weaknesses, interconnected global markets and financial models, and climate change and resources threats needed to be addressed. These interconnected issues were seen as urgent social and economic challenges. The Europe 2020 Strategies reflected not only national and EU level strategies but there was a significant focus on improving framework conditions at the micro-level, including strategies to support for innovation, SMEs, citizen and local capacities, such that 'grand social challenges' were addressed at the local (regional) level. One of the strategies to support local competitiveness in globalized business settings, and more demand driven developments, was cluster policy.

Implementations of EU cluster policy that needed to boost local and regional capacities whilst taking into account the complexity and diversity of its 27 member states and their diverse regions, meant customization and comprehensive approaches were crucial. The CEM model as a policy tool can be used to gain insights into local cluster systems and their potential to transform local ecosystems as well as to evaluate and monitor cluster systems developments due to its versatility supporting both *ex ante* and *ex post* analyses. The model supports analysis of local challenges by mapping stakeholder perceptions and strategies and systems interconnectedness but also as an intervention instrument to build shared vision and collective strategies as part of facilitating systems innovations (discussed in previous sub-section). Policy recommendations in the use of CEM approach are found in section 5.6.

Facilitating cluster developments through a CAS approach supports local, micro-level activities sensitive to regional diversity and therefore relevant to EU and national policies. Related to strengthening local capabilities is the need to address and solve 'grand social challenges'. There was a need to understand interrelated social challenges and cluster developments, and this research offers a policy instrument to this end. In the study of Energy Valley, urgent issues of energy transition, climate change, peripheral regional challenges, and national and EU economic challenges were interconnected to Energy Valley cluster's developments. CEM supports deeper understanding of cluster systems developments embedded in larger societal challenges such that cluster policy developments and implementation are sensitive to these interrelated developments. Recommendations for policy are found in section 5.6.

This sub-section discussed the resulting model on cluster development, CEM, in the light of cluster literature, policy approaches and EU policy to appreciate its relevance and contribution to theoretical and policy developments. Chapter 5 provides specific policy conclusions, recommendations; addresses issues of validity, transferability, limitations of the model; and offers recommendations for future research in relation to CEM and the research findings as a whole.

#### 4.17.4 Conclusions of Part 3

Part 3 described the research findings and showed that the research was able to avail itself of the diverse facets and developments in cluster theory and practice.

The research showed how clusters were interconnected to their contexts and these were shown to be interconnected systems developments that reflected mutual influences. These developments resulted in increasingly new complexities as part of contextual changes. In addition, it was shown that clusters were part of embedded systems of local, national and regional blocs, showing vertical interconnectedness, and also that they were reacting to overlapping and related systems developments, the horizontal interconnectedness of clusters with sectoral and regional developments. Likewise, impact of contextual changes on cluster systems identified as internal and external drivers of change were also part of the interconnected developments that marked the CEM model and approach. The discussion focussed on the research's adaptation of complexity approaches to cluster study and how this provided deeper understanding of contextual changes and cluster developments as interconnected systems developments, reflecting the extended scope of cluster study through CEM and the underlying CAS approach.

The next part of the discussion focussed on insights into cluster systems responses as a result of the contextual changes. The insights related to cluster dynamics and cluster transformations shaped by initial cluster conditions and showed how the research was able to describe systems developments through stakeholder perceptions and understanding of such changes and the emergent responses and developments. These findings were discussed in the light of literature as reviewed in the thesis and the main conclusions were that there were overlaps in some aspects but the value of the research lay in the whole systems approach that brings together different aspects of cluster developments together as part of contextual changes and interactions. The research strengthened literature developments in regional and cluster studies through the empirical and analytical findings of the research as well.

The discussion of CEM in relation to models and approaches reviewed in the literature on cluster practice demonstrated overlap and differences between them. For example, CEM shared with systems innovation, key principles and CEM could be considered a possible operationalization of this approach for solving complex systems/societal challenges. The NRC model that had supported initial developments of the research's conceptual framework was one of the models discussed. This and other models compared had overlaps in certain aspects but each of the approaches had different underlying principles, set-up and, or purpose. This meant that differences were inevitable even as these models were selected for incorporating complexity and, or systems and holistic approaches as indicators of developments in the literature relevant to cluster study. The main conclusion was that whilst most of these approaches had valuable inputs and, or served as valuable tools, also for cluster study, they were limited in their ability to capture larger systems interconnectedness of cluster systems developments; internal dynamics of clusters; to connect micro-level perceptions and behaviours of cluster agents to that of emergent systems patterns. CEM as a model and the underlying approach, referred to as the CEM approach in the discussion, is able to provide such insights and therefore goes beyond extant theories. The next paragraph summarizes inherent features of the underlying approach of the research and of the limitations of the research findings and the discussions.

The epistemological perspective of CAS of fragmented and limited knowledge assessable in complex systems was also reflected in the findings and the subsequent discussions. The discussions, like the findings, pointed to overlaps, parallel developments, affirmations and differences between the research findings and theoretical discourses. The fragmented nature of the discussion was in part due to the existence of different discourses of different strands of theories and scholarship in cluster literature and complexity approaches. This was reflected in the use of different words, concepts, perceptions of what is foreground or core, focus on specific aspects, etc. In addition, both cluster and complexity disciplines were recognized as not a ‘single, unified’ fields of study, but as ‘work in progress’. The diversity of approaches within these studies however provided a rich pallet of approaches and models that were valuable in dealing with the complexity and diversity of cluster systems. The application of CAS to new fields of studies (interface studies) offered new opportunities for exploration. This research contributes to the repertoire of interface studies by adopting CAS to cluster studies. Insights into cluster systems developments and the Cluster Emergence Model provided specific insights, additional concepts, and approaches that enhanced cluster study. The convergence of complexity theories in regional studies and policy meant that the research contributed to this on-going development, and offered new words, concepts, ways of thinking about cluster systems developments in specific aspects such as attractors, transforming interactions, fitness to landscape, significant differences, etc. and more generally, on systems interconnectedness (systems interactions within and outside of the cluster). The CEM approach offers understanding of qualitative changes to cluster systems in their changing, complex contexts. Moreover, the application of CAS to clusters contributes to a growing field of interfaces with CAS (Allen *et al*, 2011).

The research, having chosen Energy Valley as its main case study, discussed energy cluster and the broader developments of energy transition to illustrate the complexity and interrelatedness of such clusters. Specific insights and reflections on Energy Valley is included in Chapter 6 as part of the conclusions of the research.

The next chapter draws conclusions on the research and in doing so addresses the research questions and objectives. It also addresses limitations of the research as well as recommendations for policy development, cluster practice and future research.

# 5 Conclusions and Recommendations

## *5.1 Introduction*

The research was motivated by challenges faced by the European Union in its effort to promote economic competitiveness of businesses, new industrial developments and regeneration of existing and declining industries and regions. Cluster policy was a key instrument in this endeavour. The diversity of regions, businesses and industry across Europe, and the changing contexts in which clusters needed to succeed meant that there was a need for insights into these broad challenges and new policy approaches. The research had set out to understand cluster developments in their changing contexts through complex adaptive systems approaches.

This chapter describes the conclusions and recommendations of the research for cluster practice and policy, and future research. There are four parts to this chapter. The first part describes the conclusions; the second part provides recommendations for policy and practice, including specific recommendations for Energy Valley and other energy clusters; the third part describes limitations of the research and future research agendas; and the fourth part is a personal reflection on the research process.

## *5.2 Part 1: Conclusions*

The research set out to understand how complex contexts of clusters affected their developments, and whether a complex adaptive systems approach could provide insights into these developments. The research chose energy clusters, and specifically, Energy Valley as the main case study given the complexity of energy transition challenges, and in the case of the Energy Valley, the additional complexity of being a peripheral region.

The conclusions are organized in relation to the research sub-questions and the main research question. The sub-questions are: '*What is changing in the context of clusters and influencing cluster development?*' is addressed in 'Cluster context and cluster developments' whilst *'How are stakeholders and other factors at the micro-level influencing cluster development?'* is addressed in 'Cluster condition, cluster dynamics and cluster transformations' and the third sub-question, *'Can CAS* *approach be incorporated into cluster theory to support the future of cluster development?'* is answered in 'CAS and cluster study'.

The main research question '*What drivers of change and cluster dynamics, in particular for energy clusters, are significant to cluster developments, and what revisions might be needed for cluster theory?'* is discussed in the final sub-section of Part 1. The insights supporting answers to the research sub-questions provided inputs for this part of the conclusions. The discussion also addressed implications of these conclusions for cluster theories.

### 5.2.1 Cluster context and cluster developments

The research showed how cluster developments were interconnected to cluster contexts and how drivers of change were important to cluster systems responses. This sub-section describes key conclusions on these aspects of cluster context and cluster developments based on the *insights into cluster systems dynamics* as presented in section 4.12.

The research showed that drivers of change, both internal and external, contributed to increased complexity of cluster contexts. Common drivers identified in the case studies were globalization, increasing competition from other regions and clusters, technological advances, financial and knowledge resources, national, federal and, or regional policies, etc. Drivers of change were slightly different for each of the cases even as overlap existed. For example, in Energy Valley, EU market integration, EU policy and geo-political developments were significant external drivers of change whilst earthquake risks and 'green' consumer demands were examples of internal drivers. In Karlstad, regional and municipality policies were important internal drivers whilst urban sprawl of larger cities, urban migration and global competition were examples of important external drivers. Silicon Valley also displayed different drivers of change in its different phases of development. Clusters therefore display specific external and internal drivers of change, and these in turn are influenced by cluster developments due to interconnectedness of systems developments as described later in this sub-section.

An important element to understanding contextual changes of clusters was the recognition of stakeholder perceptions of contextual changes and the related drivers of change. Energy Valley's mapping of complex issues and drivers of change reflected a divergence of perceptions, interests and focus of its stakeholders. One of the conclusions of the findings was that stakeholder perceptions and sensemaking contributed to the increasing complexity of cluster contexts. In addition, stakeholder behaviours resulting from perceived changes in the context contribute to cluster systems responses.

Another aspect of changing contexts of clusters was the influence of cluster developments on their contexts as described in Silicon Valley and Energy Valley. In Silicon Valley, the rise of the cluster as a contender for government grants changed federal government research resources allocation, and gave rise to a new trend of innovative firms locating at Silicon Valley. In Energy Valley, earthquake damages and local protests led to national policy shifts in its energy policy and developments; whilst the success of EnTranCe supported EU energy systems developments. The research also illustrated systemic aspects of cluster developments and influences on cluster contexts.

Furthermore, the research enhanced understanding of cluster context by including nested systems, described as systems-in-systems aspects. Developments of national and supranational systems of the cluster, namely, that of the Dutch and EU systems in the case of Energy Valley, were impacting lower systems developments of clusters. At the same time, cluster developments influenced EU systems developments. The internal energy market and liberalization of energy markets developments at the EU level directly impacted Energy Valley's cluster developments. Conversely, changes in Energy Valley, such as grassroots movements and momentum, new technology advances, systems integration paradigms and open innovation platforms contributed to EU energy developments. Systems-in-systems share common drivers of change and complex challenges, and have both common and different path dependent factors and systems dynamics, which could result in both parallel developments as well as differences. Systems-in-systems pathway developments in Energy Valley were described in Lesson 6. The research captured interconnected contextual and cluster systems developments, due to systems-in-systems nature of clusters and their larger systems.

The insights provided on energy transition and energy cluster developments also reflected another aspect of cluster developments, namely, that of overlapping contextual and cluster systems developments as described in Lesson 7. The increasing complexity of energy transition and the energy cluster landscape was also related to national, sectoral and corporate interests, and to local and regional challenges. In Karlstad, sustainability agendas and developments, and regional agendas also overlapped with the developments of the paper and pulp industry. The research showed the significance of related systems that included industries and sectors, regional economics and welfare, and national and corporate economic interests.

The main case study of Energy Valley provided a deeper understanding of energy clusters and their contexts. The study showed how key drivers of change, particularly that of energy transition and related challenges were important aspects of Energy Valley's changing contexts that influenced its developments. These drivers of change included climate change, sustainability, market developments, geo-politics and EU energy market developments that contributed to new challenges and complexity in the energy cluster. Details of these developments, of new and diverse energy sources, technologies, players, business and social developments at different scales, both within and beyond the cluster, made the energy cluster's landscape complex. In addition, stakeholder perceptions of energy transition challenges showed differences in problem definition and problem resolution in terms of solution, scope, scale and organization. Energy Valley and its context had complex systems developments that were captured in the overview of 'Shifting Landscape' of Energy Valley (Lesson 1) with details in the rest of the case study (Lessons 2-7). The main case study therefore provided specific insights into contextual changes and impacts on cluster developments in energy clusters as illustration of complex cluster developments.

Details of the case studies provided insights that reinforced the fact that clusters and their contexts are unique and showed interrelated developments. This meant that individual clusters needed to be mapped to understand their specific contextual changes and systems developments.

To summarize, insights related to contextual changes and cluster developments were:

- Changes in cluster context were connected to internal and external drivers of change and resulted in new complexity

- Stakeholder perceptions and sensemaking of contextual changes increased complexity in cluster context, and influenced cluster systems responses
- Cluster developments influenced their contexts and vice versa
- Cluster context included nested systems of systems-in-systems interconnectedness
- Cluster context included overlapping related systems developments
- Energy cluster and its context shared complex systems developments
- Clusters and their contexts are unique in their interrelated developments.

The insights identified in this sub-section, answered the sub-question *'What is changing in the context of clusters and influencing cluster development?* The research showed that drivers of change and the resulting complexity were important aspects of contextual changes, which in turn were made more complex by stakeholder perceptions and sensemaking. Stakeholders were also influencing cluster developments framed by their sensemaking of contextual changes. In addition, cluster developments were interconnected to contextual changes as clusters were embedded in systems-in-systems and interacted with related overlapping systems. These factors collectively reinforced the unique nature of interconnected cluster developments as part of larger contextual developments. Conclusions specific to energy clusters related to contextual changes are mentioned here but further details on energy clusters are given in sub-section 5.2.4.

The next part of the conclusions focusses on micro-level cluster systems developments.

### 5.2.2 Cluster condition, cluster dynamics and cluster transformations

The research showed how cluster dynamics, in response to changing contexts, were determined by their cluster conditions. The research also revealed that cluster dynamics could include new path creations reflected in cluster transformations. This sub-section captures key conclusions on these aspects based on *insights into cluster systems dynamics* (section 4.12).

The research indicated how clusters were defined by their cluster condition of interrelated aspects of path dependency, container and stakeholders. In Karlstad and Energy Valley, industrial key stakeholders were dominant in the cluster and faced greater lock-in risks due to path dependent monopoly and homogeneity of its key stakeholders. In Energy Valley, interlocking interests of national government and large corporations due to their gas history and revenues meant that 'gas' and large-scale energy production aligned to gas interests remained important aspects of Energy Valley's container. Silicon Valley's container was dominated by Stanford's vision and facilitation of research driven firm and industry formation, thereby defining both the cluster and stakeholders. In addition, the research showed that path dependent factors had the potential to offer new path developments. In the case of Energy Valley, its gas history meant that new developments and market potential were present in the form of bio, synthetic and liquefied natural gas, the gas roundabout construction, and biogas to meet EU biofuel requirements in transport sector. Karlstad's paper and pulp industry gave rise to new innovations and spin-offs specializations like its IT and packaging clusters. Path dependency of clusters therefore brought with them both new path creation potentials as well as lock-in risks.

The research illustrated through the case study of Silicon Valley how cluster dynamics were influenced by different cluster conditions and contextual changes throughout its history. In Energy Valley, the original landscape dominated by its gas history, gas interests and related stakeholders became a complex landscape with additional stakeholders, new dominant frames, new collaborations and alliances within and outside the cluster. Energy Valley's new landscape meant that there would be different cluster responses and cluster developments in the future. The new cluster condition of Energy Valley also illustrated how its cluster dynamics and developments resulted in new stakeholders and cluster container, expanding its initial gas dominant frames and stakeholders. Cluster condition and cluster dynamics were shown to be interrelated systems developments.

The research also showed that cluster dynamics reflected different attractor or systems movements in the face of challenges. For examples, in Energy Valley and Karlstad, attractors included sustainability movements and cross-boundary collaborations responding to contextual changes; in Energy Valley, pull to 'outside' to compensate for lack of resources, knowledge development and regulatory restrictions as well as incentives elsewhere posed risks of 'cluster drain', and similarly, latent distrust, dissatisfaction over earthquake damages and sustainability agendas fuelled citizen initiatives and decentralization developments to increase self-sufficiency and autonomy needs; and finally, in all three clusters, new stakeholders, stakeholder groups and activities were drawn into the clusters due to new challenges. Farmers and NGOs as new stakeholders, and trans-border developments in Energy Valley, collaborations with forestry and bio-industries, and liaisons with the university in Karlstad, and venture capitalists and angel investors as new stakeholders, and recruitment of global talent and resources in Silicon Valley were examples of new stakeholders and activities in the clusters.

Cluster dynamics also reflected new fitness strategies to become more resilient through new technology and competence development in all three cases. The creation of an energy academy and new innovation spaces that included new approaches to energy transition were examples from Energy Valley, whilst, Karlstad also saw creation of an industry driven technology training centre to boost competences of locally educated labour force. Stanford's research driven firm and industry formation and industry-university collaborations were also strategies to strengthen Silicon Valley's future. Energy Valley's cluster dynamics revealed a potential risk of 'cluster drain' as mentioned earlier, whilst Silicon Valley's limited local human capital developments in its renewal phase also threatened future developments. Cluster drain and dissipation were inherent threats to cluster developments should renewal capabilities be neglected.

The research showed that external drivers of change and complex challenges had a significant impact on cluster dynamics and developments. In Energy Valley, and also in Karlstad, the internally oriented regional cluster with dominant stakeholders saw new cluster developments with expanded scope and activities. The changes in European energy market developments and other drivers of change saw Energy Valley's developments to include more trans-border and international collaborations, local initiatives of grassroots movements and new energy and cross-border collaborations illustrating changes in scope, scale and activities. Influence of external drivers of change on Silicon Valley's cluster dynamics was evident with the rise of Japanese semi-conductor industry. This development pushed Silicon Valley to seek new solutions, resulting in the later dominance of venture capitalism and private wealth in its cluster developments. Increased complexity due to external drivers and contextual challenges therefore reflected increased internal diversity and cluster dynamics in the case studies.

Another aspect of cluster dynamics, leveraging different knowledge, competences, resources, interests and needs from both within and outside the cluster, resulted in new patterns of interactions, alliances and collaborations, and creation of new firms, industries, services, products, institutions, technology, and business models, etc. as part of cluster transformations. These transformations, in turn, led to systems level emergent patterns of new cross-sectoral interactions and collaborations; creation of innovative ecosystems including new knowledge developments and arrangements; expansion of cluster concept (container) to include financial and private stakeholders, citizen groups and new intermediaries such as non-governmental groups; shifting entrepreneurial nature and culture that included shifting consumer/producer relations; expansion of scope, scale and boundaries of cluster activity from localized business networks to trans-regional and global entities; changing governance and patterns of interactions between cluster and regional, national, and supranational policy levels; shifting focus of human and financial capital development agendas; shifting momentum of self-organization and trust levels; growing vision and collective efforts despite differences; and increased interconnectedness and complexity. The research showed how cluster systems developments were connected to cluster dynamics and cluster transformations.

In conclusion, the research showed how clusters reflected qualitative changes in their systems developments as a result of cluster dynamics in the face of changing contexts, framed by their cluster conditions. The behaviour of clusters at the micro-level therefore contributed to systems levels changes in the face of contextual changes. The role of stakeholders, through sensemaking and responses to environmental changes, as well as broader cluster responses, described both in this and the previous sub-sections, explained the relation between micro-level activities and cluster developments, and thereby answering the second research sub-question, *'How are stakeholders and other factors at the micro-level influencing cluster development?'*

To summarize, insights related to cluster dynamics and cluster developments were:

- Initial cluster conditions influence cluster dynamics
- Cluster conditions included interconnected aspects of path dependency, container and stakeholders
- Path dependent factors were subject to lock-in risks but also had path creation potential

- Cluster drain and dissipation as inherent threats to cluster developments when renewal capabilities were neglected
- Cluster dynamics were reflected in attractors developments and stakeholder responses to contextual changes seeking fitness to changing landscapes, leveraging significant differences for new path creations
- Changes in cluster contexts, cluster dynamics and transformations included new stakeholders, new dominant frames, new scopes and scales, new linkages and collaborations, and new cluster landscapes
- Cluster dynamics reflected new strategies to become more resilient
- Cluster dynamics reflected different systems (attractor) movements in the face of challenges
- New landscapes of cluster developments meant different future cluster responses
- Increased complexity due to external drivers and contextual challenges increased internal diversity and cluster dynamics
- Cluster systems developments were connected to cluster dynamics and cluster transformations
- Clusters reflected qualitative changes in their systems developments as a result of cluster dynamics in the face of changing contexts
- Micro-level stakeholder and other activities contributed to macro-level systems developments.

The next part of the conclusions focusses on the CAS approach.

#### 5.2.3 CAS approach for cluster study

The CAS approach adapted for cluster study provided insights into interconnected cluster systems and contextual developments, and development of the Cluster Emergence Model. The research demonstrated how CAS supported understanding cluster developments as whole systems. Conclusions on CAS approaches for future of cluster developments are presented in this sub-section in order to answer the third research sub-question *'Can CAS approach be incorporated into cluster theory to support the future of cluster development?*

Discussions on CAS and complexity theories being supportive of theoretical developments in interface and mainstream studies were addressed in the literature review, and highlights of the discussions are included here to support the contention that CAS approaches have a place in theoretical developments in Regional Studies and other related fields of study.

Regional Studies in the literature review, particularly in Evolutionary Economic Geography, and also in Regional Innovation Systems through the work of Cooke (2012, 2013), were embracing CAS approaches. Initial and continuing discourses on the need to address complexity in regional studies by Martin and Sunley (2007, 2015) were important indicators of the place for complexity approaches. Developments in economic theoretical discourse embracing complexity represented in the literature review by Beinhocker (2012) were also important indicators of the emergent convergence of complexity theories into mainstream economics. Examples of interfaces studies where CAS and complexity approaches were incorporated such as International Aid and Development described in the literature review were additional indicators of the capability of complexity theories to contribute to theoretical developments of such fields having to deal with complex challenges.

Turning to cluster study, the ability to understand clusters in their contextual changes was limited. Having considered agglomeration, innovation systems and evolutionary studies, and relevant policy and practice-oriented studies, gaps in the literature were identified. The conclusion was that there was a need to re-visit the scope and definition of cluster studies and this meant that cluster studies needed to explore

- Whole systems that included historical and path dependent factors
- Proximity and interactions that included geography versus industrial dynamics
- Boundaries of convention and geography, paradigms and collective forces, and the collective versus individual agency
- Diversity and specialization impacts
- Contextual challenges including globalization
- Interconnected challenges and adaptability capacities
- EU's context of regional diversity and structural weaknesses
- Need for integrated approaches.

In addition, the cluster practice models and approaches reviewed, as indicators of theoretical developments, included 'new' aspects or concepts such as 'dynamic loops', 'associative governance', 'cluster commons', 'cluster framework', ‘triangulated triple-helix’, ‘eco-systems’, ‘complex adaptive innovation systems’, ‘transversality’. Similarly, studies relevant to clusters were incorporated notions of ‘transition management’ and ‘systems innovator’ advocating ‘learning to leapfrog’. These terms and aspects and those described in addressing gaps and issues in cluster literature, reinforced the trend in Regional, Economic and ‘interface’ studies, namely, acknowledging increasing complexity and a need for more comprehensive systems approaches. Such an approach needs to include broader cluster and innovation systems, contextual factors, path dependent factors, boundary issues, motivations and capabilities of agents, and interaction patterns. In addition, cluster systems’ behaviour and resilience needs to be explored in an effort to address path interdependencies, distributed agency and interconnectedness. The approach likewise, needs to address diversity and underlying (collective) processes, and provide insights into societal transitions and systems innovations. CAS adapted for cluster study, in the form of CEM, offers many of the aspects mentioned. Highlights of these aspects are provided below.

CEM as an analytical model offers exploration of contextual factors and systemic responses leading to cluster developments. Contextual factors and cluster systems responses, unique to each situation and framed by cluster conditions that include path dependent factors, defining features including boundary definitions, stakeholder motivations and their paradigms. Exploring stakeholder sensemaking processes and behaviours and interconnected developments are part of the CEM approach. Acknowledging clusters as part of larger systems (its context) is also part of CEM’s approach. In addition, CEM features systems responses including underlying constraining forces (attractors) in cluster developments as well as ‘fitness to landscape’ strategies and leveraging ‘significant differences’. The transformative processes connecting agent behaviours to emergent systems patterns through concepts of cluster dynamics and cluster transformations are also found in this model. CEM therefore provides an analytical tool to enhance cluster study meeting the needs of cluster study developments.

Similarly, CEM offers an integrated analytical tool to support policy developments. Policy needs of the EU that initiated the research indicated a need to address urgent societal challenges as identified in the Europe 2020 strategies. These broader interconnected societal challenges framed the contexts of regions and clusters, and as such, there was a need to build on local strengths and capabilities to explore new economic and social developments. CAS approaches, focussing on local capacities, systems potential and constraints, was translated into an operational policy tool (more in sub-sections 5.6.2 & 5.6.3) that could provide insights into clusters (and regions). The application of CEM to three clusters, of which two were in Europe, demonstrated CEM's ability to generate insights into cluster developments in different settings and in different stages of developments, meeting the need to serve regional diversity in the EU. CEM enabled cluster analysis supportive of cluster developments in the practice.

To summarize, conclusions on CAS and cluster study are:

- CAS approach supports understanding broader, complex contexts of clusters and unique interconnected developments of clusters and their contexts through the Cluster Emergence Model (CEM), thereby conceptualizing theoretical discourses and acknowledging these developments in cluster practice
- The CEM approach offers an integrated whole systems approach to cluster developments by capturing sensemaking processes and responses of stakeholders, and constraining systems forces and path creation potentials of systems responses, both of which are framed by local cluster conditions, interconnected to contextual, transverse and systems-in-systems systems developments, leading to cluster systems transformations
- CEM supports Europe 2020 strategies by providing insights and intervention strategies to identify local capacities, potential and constraints of clusters and their regions.

The research therefore demonstrated that a CAS approach supports understanding of cluster development in its broader and more complex contexts affirming that CAS can contribute to future cluster developments. The research in leveraging and illustrating CAS approaches for cluster theory and cluster policy however acknowledges that future research could further strengthen these findings. Recommendations to this end are provided in Part 2 of this chapter.

### 5.2.4 Research question and the findings

The research set out to explore how changes in broader contexts influence cluster developments, and if there was a need to re-visit cluster theory. In the previous sub-sections, answers were provided to the sub-questions:

1. What is changing in the context of clusters and influencing cluster development?
2. How are stakeholders and other factors at the micro-level influencing cluster development?
3. Can CAS approach be incorporated into cluster theory to support the future of cluster development?

Answers to the sub-questions together with the specific insights into energy clusters from the main case study answered the main research question, *'What drivers of change and cluster dynamics, in particular for energy clusters, are significant to cluster developments, and what revisions might be needed for cluster theory?'* An elaboration follows.

The exploration of Energy Valley provided insights into cluster developments as an illustrative case of a complex cluster. Insights into changing contexts, the 'Shifting Landscape' described in Lesson 1 and details on drivers of change and related complexity in the cluster context in Lesson 3, provided understanding of drivers of change and contextual changes in the energy cluster. Furthermore, analyses of Karlstad and Silicon Valley broadened and deepened understanding of contextual changes resulting in coherent insights into cluster developments and related contextual changes. These insights, described in sub-section 5.2.1, answered the first sub-question, including insights specific to energy clusters.

Similarly, Energy Valley's cluster dynamics and ensuing cluster transformations were described in Lesson 2 through Lesson 5, whilst Lessons 6 and 7 provided insights into interconnected cluster developments and related contextual systems. These Lessons, specifically Lessons 6 and 7, showed how the energy cluster's developments were linked to challenges (and their resolutions) of energy transition at the regional, national and EU levels as well as to other challenges (and their resolutions). The research, through these various analyses, showed the complexity of energy clusters. In the conclusions, this complexity was described as interconnectedness of systems developments including cluster systems. Conclusions on cluster dynamics and cluster transformations of the other cluster studies reinforced these insights. In addition, the analysis of Silicon Valley spanning various developmental phases demonstrated how clusters undergo continual processes of interconnected systems developments due to contextual changes and shifts in cluster conditions. Insights arising from these various analyses showed how cluster

systems developments were influenced, connecting to both micro-level activities and contextual changes, answering the second research sub-question, that included insights specific to energy clusters. Details were presented in sub-section 5.2.2.
The conclusions of the research capturing insights into interconnectedness of cluster systems development are attributed to CAS approaches that framed the investigation, and thereby answering the third research sub-question on whether CAS could be incorporated to support future cluster developments. This aspect was discussed in sub-section 5.2.3.

The research had set out to understand how clusters responded to changes in their contexts from a whole systems perspective. By answering the various sub-questions, the research illustrated by the case of Energy Valley and afterwards of the other cases, what was changing in the contexts of cluster (what was driving change) and how this was related to cluster dynamics and the resulting cluster developments. The research had showed that a customized CAS approach for cluster study supported understanding cluster developments in their broader contextual developments.

Theoretical advances focussed on the future of cluster developments could benefit from the results of the research even as more work needs to be done to optimize a CAS driven approach for cluster study. The research showed how drivers of change and resulting cluster dynamics influenced cluster developments in the Cluster Emergence Model. The research findings, leveraging CAS as meta-theory, reflected broad interconnected systems developments of clusters and their contexts.

In Part 2, recommendations are made for future research based on the findings of the research and its limitations. In addition, recommendations for cluster practice in the light of the research findings are suggested.

## 5.3 Part 2: Recommendations

## 5.4 Introduction

This chapter is divided into recommendations for future research based on the research findings and recommendations for policy and practice.

## 5.5 Recommendations to enhance findings in future research

The research showed that traditional view of clusters needed re-visiting and that new agendas for cluster research were needed to build on the findings of this research and related areas. Suggestions for future research are included below.

### 5.5.1 Recommendations for cluster studies

The research delivered a CAS approach and insights into cluster systems developments in an attempt to understand the broader challenges and developments in the field of cluster theory and practice. The broad research scope gave an exploratory and illustrative case study design and future research could strengthen the findings. The chosen research scope and design meant that extensive validations and room for further exploration of specific aspects and relations between these aspects were not possible. Recommendations below include these aspects for future exploration.

The research explored an energy cluster, Energy Valley, and supplementary cases of Karlstad and Silicon Valley. Future case study research could further verify and strengthen insights into cluster developments. Similarly, the Cluster Emergence Model could be further developed and validated through extended research on additional clusters in different sectors, regions, scales and phases of development.

Aspects of the Cluster Emergence Model could also be further developed by additional research on each of the aspects of cluster developments identified. Specifically, the dynamics and reciprocal influences of self-organizing processes and top-down planned initiatives could be further explored.

Another aspect of cluster developments, sensemaking processes, could be further investigated to understand the trajectory of awareness of stakeholders of changes in the environment. This would include how they perceive these changes and what motivations and considerations play a part in their responses and interactions with other stakeholders; and how this process influences cluster dynamics and the resulting changes in interaction patterns, and systems patterns. A detailed analysis of this process could enhance understanding of cluster developments.

Another aspect introduced to cluster study was that of systems-in-systems interrelatedness. The research uncovered parallels and differences related to energy in systems developments of Energy Valley, the Netherlands and the EU. Validations of the findings through additional energy cluster cases and from other sectors would strengthen and enhance these insights. Future research could focus on interlocking developments of clusters in systems-in-systems to understand how such systems developments lead to both advantages and disadvantages for clusters and their embedded systems. Similarly, further investigations into horizontal or transversal developments, and their influence on cluster developments, would support theoretical developments.

The research showed that dominant frames were present in clusters and that these needed to be made explicit to support cluster developments. Cluster definitions and cluster strategies generally have a dominant economic framing. Future research could explore the implications of re-defining and re-scoping cluster definition to embrace political, technological, social and ecological frames as part of cluster developments.

Another aspect of cluster developments for future research is the concept of the triple-helix and the changing roles and responsibilities of stakeholder in clusters, including emergence of new stakeholders in the face of changing business landscapes. Research explorations on changing stakeholders, and their roles and responsibilities in clusters could be mapped in different clusters and in different geographic and cluster life cycles to better determine the nature of these changes and whether they are context-specific. Related to this aspect are changing governance structures of clusters. Changes in stakeholders and the nature of multi-layered systems of clusters as described in the research could be further investigated to understand how such changes and new complexities influence existing governance structures.

The research identified the need to expand the scope of clusters to incorporate context as part of cluster developments. Future research could explore boundaries of cluster contexts relevant to cluster developments and the context-specificity of such boundaries by multiple case studies in different contexts. The geography of clusters has been central to this research even as digital communities and interactions were identified as being emergent cluster systems patterns. Future research could explore the implications and impact of digitalization for cluster systems developments. This includes exploring new developments of 'knowledge hubs', 'innovation hubs' and 'global and digital communities' (as hubs and, or clusters).

In all three clusters investigated, the role of governments and policy supporting growth and future success of clusters was evident. More research on the dominance of governments and policy could strengthen understanding of this aspect of cluster developments. In addition, shifting priority in policy to address 'grand societal challenges' could be explored as part of future research on defining features (container) of clusters.

The formal and informal interactions and influences in clusters have been documented both in the literature and in this research. The notion of (distributed) agency in complexity theories does not make a distinction between formal and informal interactions, and influences of agents are deemed to be semi-autonomous (in CAS). More research on these different assumptions could offer new insights for cluster theory and CAS developments.

The research advocated stakeholder perceptions and sensemaking as being central to understanding systems developments of clusters. Future research could explore implications of people-centred cluster development approaches as opposed to resources and sectoral approaches present in extant cluster theories and policies. More specifically, how existing policy-making practices can be supported to embrace new approaches to cluster policy.

The research identified risks of 'cluster drain' and diffused clusters. Further investigation of 'cluster drain' and related cluster dissipation risks could uncover further underlying mechanisms strengthening or weakening these patterns of developments to improve policy interventions.

The research indicated that in energy clusters focus on large-scale solutions co-existed with small scale and local solutions to deal with urgent challenges.

Comparative clusters studies including other sectors could verify if local and larger-scale solutions were part of cluster developments. Understanding such developments could enhance current cluster studies and practice in support of developing resilient clusters. Similarly, further investigation into cross-boundary developments of cluster dynamics as revealed in the research, could enhance understanding and development of resilient clusters.

The research showed that inclusion of citizen and grassroots movements in energy cluster developments meant an enlargement of the scope of energy clusters. The challenge to include diffused groups such as local energy co-operatives and initiatives and also small and medium sized enterprises in formal dialogues will become more urgent with changing landscapes of energy, and perhaps also in other clusters. Future research could investigate the implications of decentralized energy communities for cluster developments and the need to re-think current approaches to cluster strategy development.

Energy transition challenges in Energy Valley illustrated the need to have flexible cluster scope to address the different levels and types of issues in the cluster. More insights into the needs of energy clusters for flexibility of scope and scale, and implications for policy and governance structures, could be another research agenda for energy cluster study.

The issue of trust identified in the research could be explored in future research to understand conditionality of trust in clusters, and whether the conditionality is related to the increasing complexity faced in clusters.

The clusters investigated in the research revealed renewal and transformations of the clusters in the face of new challenges and increased complexity. Future research could explore clusters that did not succeed in leveraging innovation potentials, and, or developing and implementing successful fitness to landscape strategies and possibly, cluster developments that led to decline and dissipation. Such an investigation could overlap the aforementioned recommended study of 'cluster drain' and related risks.

A final recommendation for future cluster study is to enhance the research findings that were based exploratory methods using qualitative approaches. Future studies could expand these findings by additional investigations encompassing qualitative and quantitative aspects of systems developments. For example, computational complexity studies could enhance the use of Cluster Emergence Model to include quantitative modelling of path developments. Qualitative shifts of cluster systems as described in the research could be mapped through quantitative time-series data to identify potential pathways or 'space of the possible' to improve policy interventions, and also to add to theoretical developments.

This sub-section offered recommendations for theoretical developments based on the research findings, whilst recognizing that limitations of the research offered new opportunities for future research to enhance the findings and policy developments. The research therefore acknowledges both its contribution and limitations in supporting theoretical and policy developments of clusters.

The next sub-section offers recommendations to enhance theoretical developments of CAS studies.

### 5.5.2 Building on research findings for CAS studies

The research adapted CAS for cluster study and delivered a whole systems approach bringing together different aspects of complex adaptive systems theory, initially as a conceptual framework and later in the Cluster Emergence Model. The research included new concepts, made concepts more explicit, and made a unique combination of CAS and other concepts. These concepts and the combination of concepts in CEM could be further explored for their relevance in other settings and, or in interface studies.

The notion of 'Shifting Landscape' to capture changing contexts of clusters in the Energy Valley case study could also be further explored for its relevance to other CAS studies. The use of metaphors in CAS is commonplace and this metaphor is added to existing repertoires.

The concept of drivers of change in the research allowed exploration of contextual factors relevant to systems developments. Further research on drivers of change could explore differences in drivers in relation to agent and systems responses in complex adaptive systems, and possible interconnected feedback loops amongst drivers.

The concept ‘fitness to landscape’ was introduced in the cluster study. The notion of ‘fitness’ existed in complexity theories but this new term captures the sensemaking process of stakeholders, in perceiving and making sense of changes in their local environment, and the need to adapt to such changes. Validation of this concept in other CAS studies could support theoretical developments, particularly in its added value next to concepts of ‘fitness’ and ‘fitness landscapes’. In addition, the notion of sensemaking, present in complex adaptive systems theory has been made explicit in this research at the micro, meso and macro levels. Future research could further explore interconnected patterns of developments of sensemaking at these different levels, and across systems.

The role of government and centralized steering, evident in cluster research, could be investigated in other complex social adaptive systems to understand how top-down steering relates to the pre-dominance of self-organizing processes postulated in CAS.

Finally, the research brought together different concepts to explain systems responses and developments due to contextual changes as CEM. A broader application of Cluster Emergence Model to other complex adaptive systems could ascertain its value beyond cluster studies. Therefore, CEM’s contributions to theoretical developments of CAS could be extended through future research. Similarly, comparative analyses of interface studies including the present research could strengthen the emerging practice of CAS applications to new fields.

## *5.6 Recommendations for policy and practice*

### 5.6.1 Introduction

Recommendations were made for EU cluster policy in the first sub-section; for cluster practice in the second; and for Energy Valley in the third.

### 5.6.2 EU cluster policy

EU 2020 strategies, designed to boost economic competitiveness and address structural weakness through successful cluster policy in different regions, meant that broader contextual issues needed to be understood in terms of local perceptions and systems responses, and a need to leverage local and regional strengths and capacities. The research offers recommendations to EU cluster policies based on the review of literature and practice, and the research findings.

These recommendations are made bearing in mind EU cluster policy's three key pillars of cluster excellence, internationalization and support for emerging industries, and its focus on support for SME and building on local strengths (Regional Smart Specialization Strategies, RS3).

The first recommendation is that EU Cluster Policy reconsiders its current 3-pillar programme to align it more closely to the Europe 2020 strategies of solving 'grand social challenges', and support to tackle new developments undermining Europe's global leadership ambitions. These new developments are related to climate change and sustainability; financial, economic and political issues of persistent recession, failing economies, and recently, Brexit and migrant crises; changing global and business landscapes impacting youth and general unemployment; and digitalization and technical advances contributing to changing business landscapes. The interconnected nature of these challenges makes them difficult to predict and manage ('wicked problems'). Challenges facing Europe are further exacerbated by its internal diversity (of member states) in seeking solutions, and by its position challenged in a changing global landscape whereby emerging economies and shifts in geo-politics. The next paragraphs recommend alternatives for Cluster Policy's 3-pillar programme.

An important recommendation is to make 'grand social challenges' part of the container of Cluster Policy. In cluster practice, this would impact cluster definitions to identify and embrace one or more relevant 'social challenge', which in turn, would result in extension or changes in their scope and scale of activities, need for new connections and collaborations. The 'grand social challenges' as a driver of change could possibly help some clusters, local industries and sectors, overcome stagnation or decline where applicable. Changing 'container' of policy and clusters would support new path creations, and this is addressed next.

Policy definitions focussed on interventions for new path creation could include funding measures, evaluation indicators, facilitating broad-based strategic platforms and ecosystem creation, changing governance structures, etc. These recommendations are elaborated below.

The research demonstrated that external funding for knowledge development and successful cluster developments were important drivers in cluster developments.

Additional funding from the Commission could support local and regional governments and agencies implement successful cluster policy. Policy fragmentation, diverse policy priorities and lack of funding were shown to lead to regulations and policy that hinder cluster and innovation developments in the research. EU policy could have a more direct influence on streamlining economic and structural goals through support for thematic or issue-based ('grand social challenges') cluster policy within the RS3 frameworks. In addition, EU policies could facilitate broader strategic and long-term orientations in developing clusters and regions to overcome any dominant and short-term economic focus. EU policy interventions, monetary or otherwise, could support new approaches that leverage sustainable developments.

In addition, aligned to EU 2020 strategies, and emphasis on 'grand social challenges' and changing in business and consumer landscapes, cluster policy developments could go beyond traditional economic performance indicators to explore new strategies of mapping interaction and collaboration patterns where visible transformations take place. Support for mentoring of start-ups is another example of benchmarking that leverages significant differences, and complements quantitative indicators of start-ups. Identifying and including indicators of qualitative improvement would support new approaches in cluster developments.

EU Cluster policy agenda could encourage creation of strategic platforms by regional governments that extend beyond traditional triple-helix players whereby systemic developments and opportunities, changing stakeholder roles and groups in cluster developments, and the significance of sensemaking processes of stakeholders and dialogues to strengthen local collective processes are embraced. The next recommendation is connected and is elaborated further.

The next recommendation for EU policy to support new path creation in cluster developments is facilitating ecosystems. The creation of 'ecosystems' and innovation spaces and innovation driven missions, illustrated in EnTranCe and Silicon Valley, are more important in realizing excellent clusters beyond focussing on quality of cluster organizations and management, and creating physical spaces. The inclusion of broad stakeholder representation beyond the triple-helix (regional development agencies, financial, civic organizations, etc.) broadens the scope and focus of cluster developments to meet the needs of grand social challenges. Therefore, people-centric and ecosystems thinking, new developments emerging in cluster landscapes, need to be part of all levels of cluster policy implementation.

Consequently, in order to support new path creations, EU policy could support clusters in facilitating new governance structures, development of competences and training capacities, and cross-boundary (sectors, regions, disciplines, judiciary and territorial) interactions and solutions orientations. Current EU policy offers some if not most of the support mentioned here, however the difference is that such support needs to be linked to a re-defined Cluster Agenda as recommended in this sub-section.

Context-specific regional and cluster policy needs to remain in new EU Cluster Policy agenda in line with Europe 2020 strategies and RS3 directives. Local and regional cluster strategy and capacity developments that could be supported by making visible and strengthening unique local capacities and opportunities for innovation and shared growth potential in its services to meet grand social challenges, going beyond benchmarking, good practice and general match-making activities. In addition, such visibility could support new path creations related to cross-border innovations. This is related to the next recommendation.

Focussed support to build on existing regional diversity (related variety) by combining different sectors, disciplines and themed clusters aimed at addressing grand social challenges, creating new industries and excellence would, moreover, enlarge the innovative scope of clusters. Such an initiative would accelerate inter-cluster collaborations, which has already been identified as one of the key pillars of EU cluster policy. However, there needs to be specific attention to the use of regional and local variety, described in the next paragraph.
The focus of current EU cluster policy is on world-class clusters and excellence. However, peripheral and rural regions that do not meet these criteria should also be valued and there are three recommendations for this. The first is to make use of significant differences of rural and urban clusters, and of less successful and more successful clusters, by exploring new path developments opportunities by such connections. The second is to connect rural and peripheral regions to each other to extend their scope and scale to achieve an enlarged and 'distributed' cluster. The idea is, to build critical mass and shared resources for accelerated growth, by acting as an enlarged entity (similar to networked cities or villages). The third

recommendation is to appreciate the need for diversity of clusters in the EU to improve its resilience in the face of increased complexity.

The increasing relevance of consumer initiatives and demand-driven developments needs to be considered in a redefinition of EU Cluster Policy. Facilitating and connecting to bottom-up and self-organizing processes in cluster and local developments could be acknowledged in EU policies. This recommendation is connected to setting-up strategic platforms that include new stakeholders, and enlarging scope and scale of clusters. Similarly, the next recommendation is related to acknowledging the interconnected developments of different systems levels.

EU policies could play a role to support alignment between the different levels (cluster, regional, national and EU). This could be by supporting and emphasizing the need for national policies to align to regional developments, structures, frames and interests, rather than the current practice of regional policies being secondary to national policies; by acknowledging and emphasizing the role of government in strengthening regional and cluster policies to be focussed on grand social challenges; by fostering local capacity building to meet such challenges; and by better aligning of EU policies and vice versa.

EU Cluster Policy could reinforce and accelerate its excellence in cluster priority by stimulating interactions and collaborations across different scales of 'clustering' and that its current programmes could be extended its definition of collaborative scope for 'clusters'. To facilitate such collaborations, mapping significant differences of local, regional and EU Regions level (Danube, Mediterranean, Baltic, North Sea, etc.) and analysis of these differences could make more explicit potential new path developments for clusters and inter-cluster collaborations.

Re-defining EU Cluster Policy to acknowledge and address broader interconnected challenges, aligned directly to Europe 2020 strategies, setting new cluster agenda that recognizes the role of complex systems developments, and includes local diversity and shifts in landscape, could serve internal and external challenges of the EU more effectively. EU Cluster Observatory and related EU agencies could also be more sensitive to new developments of solving grand social challenges and changing consumer-business landscapes and roles in their support of defining and benchmarking cluster success.

### 5.6.3 Cluster practice

Recommendations for cluster practice are relevant to cluster organizations, regional and local governments and regional development agencies. These recommendations on strategy development are based on the Cluster Emergent Model.

The first recommendation regarding cluster context is to map drivers of change and new complexity of changing contexts. Mapping contextual changes, and ideally with relevant stakeholders captures key drivers of change and new complexities relevant to the cluster, but more importantly, how stakeholders perceive these changes. The resulting insights support policy intervention in identifying presence of common frames and priorities and differences, and the need to develop collective goals and strategies. Also, the presence or absence of a sense of urgency would be established, and if needed, policy interventions could be designed.

The second aspect is cluster condition of path dependency, container and stakeholders. Mapping is an important key to gaining insights into the various aspects of cluster condition. In mapping path dependent factors, aspects of past developments determining current behaviour and responses of stakeholders and cluster systems are made explicit. Insights also broaden understanding of underlying patterns of development and risks of lock-in from dominant factors. However, these insights also contribute to exploration of new path creations when identifying significant differences in the cluster (addressed in cluster dynamics interventions).

Interventions to change cluster developments could include changing the container of a cluster. The container can be expanded or shrunk to influence cluster dynamics. Examples of changing the container include changing the scope or scale of a cluster, the number and types of stakeholders, the number and types of governance structures, norms and (funding) rules, etc. The case studies illustrated examples of container change in the various clusters. Changing the vision and goals of clusters collectively could enhance coherence in cluster developments even as diversity in clusters must be safeguarded. An important intervention is re-considering who is involved in 'the dialogue' in strategy sessions. When lock-in risks are prevalent, expanding the container by including new stakeholders and expanding the scope of the cluster would increase diversity and prevent lock-in consequences. Re-visiting stakeholder engagement could also be connected to attractor movements, connecting to new trends and developments in the broader context of the cluster.

Furthermore, feedback processes between container definition and stakeholders need to be made explicit to support new strategy developments when seeking new fitness in the changing landscapes of clusters. Analysis of cluster conditions provides insights that support interventions to influence cluster dynamics. Also, stakeholder perceptions and behaviours need to be mapped as part of cluster responses. The next part describes recommendations for this aspect of cluster developments.

The third aspect of cluster developments is cluster dynamics understood by its systems movements (attractors), fitness to landscape strategies and relevant diversity that offer new path creations and solutions for the challenges faced in clusters. Interventions related to cluster dynamics should therefore focus firstly on understanding attractor patterns and systems constraints within the cluster. Secondly, the focus needs to be on discovering 'fitness to landscape' solutions and strategies by mapping stakeholder strategies and solutions-orientations to urgent challenges brought about by changing contexts. Thirdly, the focus needs to be on identifying significant differences that could support finding solutions for the cluster's urgent challenges. Insights into these three aspects reflect directions that cluster developments may take, and help evaluate which policy interventions could support or weaken the cluster dynamics. By exploring underlying patterns of interactions of these three elements, interventions could be aimed at changing such interaction processes. The movement towards sustainability, as seen in two of the cases, is an example of an underlying process where new market and innovation opportunities lie.

The fourth aspect of cluster developments, cluster transformations, would help monitor and analyse cluster developments, particularly for policy intervention evaluations. Since transformational interactions point to successful new combinations, often cross-boundary, mapping and understanding such developments offer lessons for replication or identifying underlying patterns of change in the cluster system. Another reason to map emerging cluster systems patterns is to anticipate new urgent challenges that may arise from such developments. Policy intervention in this fourth aspect is related to learning and anticipating rather than direct interventions but this could help prepare future policy interventions. These new developments point to new cluster conditions arising and therefore, the cycle of analysis and interventions could begin anew.

The fifth aspect is that cluster developments are influenced by top-down and bottom-up self-organizing process. Mapping policy and centralized interventions as well as bottom-up initiatives is significant to understand how these developments are interconnected and to avoid fragmentation of perspectives on both sides. Where there is little recognition of these developments, interventions and initiatives may fail. The pitfall of forgetting 'missing' or hidden stakeholders could be avoided through extended mapping of both top-down and bottom-up developments and stakeholders.

The sixth aspect of mapping includes related and overlapping systems includes core and adjacent sectors and regional developments. Regional developments include social, economic and ecological developments that may provide both opportunities and risks to cluster growth and transformations. Clusters need to be connected to developments around it.

The last aspect of cluster developments relevant for practice is the aspect of systems-in-systems developments. The cluster is an integral part of sub-systems and supra systems of which it is a part. EU and national developments have significant impact on clusters as well as local systems. Mapping these interconnected developments may help gain insights into parallel and differing patterns of developments.
The CEM model therefore supports identifying current and emerging patterns of developments of the cluster and intervention points to the different aspects as described above.

The recommendations made for EU cluster policy are also relevant to cluster practice at the regional and local levels. These included incorporating ecosystems thinking and practice where learning and innovation spaces are created, bringing in cross-boundary disciplines, sectors, value chains, regions, systems levels and local-global interactions. Another recommendation included creation of broader, cross-sector and thematic visions and goals, preferably encompassing grand social challenges. Examples found in the case studies researched were bio-based economy, energy systems integration, new combinations between the paper and pulp sectors and forestry sector, etc. An example of trans-regional collaborations was found in Energy Valley's North West German and North Sea collaborations.

Cluster policy needs to support sensemaking processes and facilitate dialogues in support of cluster developments. Examples of policy support could be offering information about relevant trends and urgent challenges, creating innovation spaces to catalyse interactions and innovations, supporting appreciation of diversity, and stressing the need for solutions that cross borders in knowledge, sectors, and geography.

#### 5.6.4 Energy Valley cluster

Recommendations made for cluster practice, and to some extent that for EU Policy, are relevant to Energy Valley. However, further recommendations specific to Energy Valley are made in this sub-section.

Energy Valley had to contend with stakeholders who each perceived and responded differently to urgent challenges and their drivers, in part due to the presence of different dominant frames (national economic, regional development interests and energy transition frames). In addition, strategic dialogues were restricted to triple-helix stakeholders. To deal with such divergence, Energy Valley needed to make explicit differences in frames and work towards developing common frames and focus through sensemaking processes. Emerging patterns in the cluster showed that common vision was developed amongst policymakers and in Energy Valley Foundation, but this needed to extend to broader stakeholder groups. More inclusive strategies in Energy Valley in developing new policy directions were needed to counter the increasing complexity and risk of diffusion in the cluster. Formations of sub-clusters and new digital thematic communities in Energy Valley were facilitated by the cluster organization, but inclusion of these communities in developing shared frames and directions for the cluster could be a next step.

Looking more specifically at the shifting energy landscapes of Energy Valley, the cluster became more complex from a gas-dominated landscape to a more differentiated one. These developments helped to avoid lock-in risks of gas dominance, but had also risks of diffused cluster developments. The presence of increasingly diverse stakeholders meant different frames, interests, priorities, capacities, resources, etc. influencing responses to challenges of energy transition. Therefore new groups and their perspectives on energy transition needed to be included in dialogues and future developments. Similarly, connecting to grassroots initiatives could help increase a sense of urgency in realizing energy transition goals by leveraging electoral and consumer demands, but also to facilitate shared goals. Including new stakeholders (farmers, co-operatives, NGOs, consumer groups, etc.) could be achieved through creating broad-based strategic platforms as recommended in the EU Policy sub-section 5.6.2.

Therefore, recommendations for Energy Valley on its 'Shifting Landscape' of contextual challenges include:

- Clarity on what urgent issues are assumed and addressed
- More dialogue with stakeholders where assumptions, goals and concerns are more explicitly expressed
- More collective vision and goals-setting dialogues for the cluster
- Acknowledge and explore both internal and external drivers of change
- Broad-based strategic platforms as one way to include new stakeholders.

These recommendations are meant to support sensemaking processes between stakeholders to discover and explore urgent challenges and their drivers in order to develop common frames and strategies and avoid diffusion in the cluster.

The next part of the recommendations focus on avoiding risks of gas dominance whilst acknowledging the opportunities for new path creation that it offers. In addition, other path creation opportunities leading to transforming interactions and new systems patterns are discussed.

Energy Valley's dominance of gas and other fossil fuels, overlapping national and corporate interests to secure a prominent position for gas in future energy mix meant a greater focus on gas-related solutions and knowledge development. Likewise, gas expertise facilitated new opportunities of bio-based economy developments by leveraging biomass and biofuel developments. In addition, the systems and value chain approaches to innovation, prevalent in the gas sector, facilitated new path creation developments, but there was more scope for building on these strengths. Part of the answer lies in extending scope, activities, and visibility of the cluster, and initiating new transforming interactions. Specific recommendations are provided below.

Meeting EU renewable energy targets could accelerate knowledge development activities seeing as how the Netherlands is lagging in meeting its targets. Energy transition investments are expensive and complex, which means that Energy Valley is dependent on national and regional support for funding and offering incentives to investors. The Dutch government distributed its EU targets on renewable energy deployment amongst the provinces. Energy Valley could demand a larger share of the target in order to create critical mass that would consolidate its position in the Dutch energy landscape even further, given its energy context and capabilities. Critical mass would be attractive as well as cost effective for investors.

Another aspect of the 'Shifting Landscape' was the need to meet new and different knowledge developments and resources. Supporting new external linkages without exacerbating 'cluster drain' risks means that an inbound movement of innovation, knowledge and market development spin-offs need to be part of strategies to increase external linkages and collaborations. Knowledge transfer activities, mobility of labour, incentives to set-up headquarters and research facilities in the cluster are examples of interventions that could promote greater knowledge and resources capture within the region. Energy Academy Europe and EnTranCe, set-up for this purpose, could support such developments by enlarging current strategies and roles, as part of collective cluster vision and strategy development activities with key stakeholders of the cluster. Energy Academy Europe in particular had been set up to connect internationally and bring into the cluster new knowledge developments and expertise.

Another aspect of Energy Valley's path dependency that offered new path creation opportunities was the significant differences of the four Provinces. Alignment at the regional level of the four Provinces had been improved through shared policy vision and commitments for the northern regional development including an energy transition agenda. It is important to acknowledge that regional differences and developments could be leveraged for new path creations. Different regional strategic priority sectors and themes within the northern provinces overlap those of the cluster, and include sensor technology, water sector, dairy and horticulture, healthy ageing, water and nature recreation, and bio-based economy. Energy Valley Foundation and the northern provinces acknowledged these different clusters, innovation hubs, hotspots, etc. and of possible collaborations between them. The focus on supporting new transforming interactions to result in new emerging industries could strengthen current efforts. Supporting explorations of cross-border collaborations, stimulating R&D interfaces and new technological platforms through strategic platforms or specific professorships as seen in Silicon Valley and Karlstad respectively are some strategies to be considered. Energy Academy Europe's connection to other knowledge hubs and sectors could be explored.

Expanding the scope of the cluster was already seen in Energy Valley, through its connections to the North Sea Region and to Niedersachsen to boost knowledge developments and capacities to deal with energy transition challenges. In addition, collectively branding the North Sea Region as a European energy hot spot, meant enlarging its scope and visibility. These initial steps could be enhanced not only for large scale and top-down initiatives but also to strengthen bottom-up and decentralized initiatives. This aspect is discussed later in this sub-section. Seeking inter-cluster collaborations in other geographical areas could provide additional resources and new priorities. For example, connecting to Silicon Valley's energy cluster is an example of extending the scope and significance of the cluster's activities, and creating new opportunities and access to knowledge and resources. Similarly, aligning to EU energy developments to accelerate energy transition developments, through stronger affiliation and access to knowledge and resources from other energy and related clusters and industries, could help Energy Valley capitalize its own gas dominant expertise and resources whilst leveraging other (international) energy expertise and resources (solar and wind energy clusters) and, or other knowledge and resources from related industries (automobile, chemistry, water, IT, etc.). Energy Valley could therefore strengthen its position, networks and funding opportunities by aligning and connecting to EU and global clusters and energy developments. Connecting to and becoming more active and visible in EU initiatives could catalyse Energy Valley to be more active in EU level opportunities (European Technology Platform, European Cluster Observatory, etc.).

Stimulating deeper cluster-to-cluster collaborations and cross-sectoral collaborations to realize more complex and higher value added products, services and value-chains are part of EU's strategies to achieve global competitiveness. Health, environment and bio-economy are areas identified by the Commission where new combinations and solutions are needed. These are areas and sectors present in Energy Valley region. Therefore, exploration of deeper cluster-to-cluster and cross-sectoral collaborations of sectors and knowledge capitals in these areas aligned to developments at the EU levels could provide transforming path developments.

Related to the concept of 'deeper' collaborations, Energy Valley could leverage the success of EnTranCe and its open innovation space. This initiative incorporated 'small' and 'big' corporations, energy solutions, etc. that were close to consumer and social issues, and combined different technologies with a focussed goal on energy transition solutions. Extending the open space concept, and combining value chains of vocational and higher education, private and public research capacities and commercial exploration and exploitation in open innovation centres on energy (or other themes) could facilitate co-creation and new interaction patterns supporting more complex value chain innovations and new cluster formation. Likewise, Energy Valley could explore setting-up 'distributed open innovation centres' working on the same theme but across the whole cluster. A distributed but focussed open innovation concept permits leveraging knowledge and talent across the cluster whilst concerted effort and new path creations are explored because of differences in different parts of the cluster.

To reiterate, recommendations for Energy Valley's response to new challenges included:

- Extending scope, activities and visibility of the cluster and leveraging new path creation opportunities of gas whilst being wary of lock-in risks
- Leveraging opportunities arising from inadequate response by the Netherlands to meet EU targets on renewable energy by creating critical mass and visibility for the region
- Optimizing Energy Academy Europe's ability to accelerate new knowledge developments and collaborations by connecting to 'outside' but wary of risk of 'cluster drain'
- Leveraging significant differences of four Provinces for new transforming interactions and patterns of cross-over collaborations beyond current practice, focussed on emerging industries
- Extending scope to more international cluster activities to enhance visibility, access to resources, networks and knowledge, also from related and other sectors
- More EU alignments to engage in deeper cluster-to-cluster collaborations supporting complex and higher value added product, services and value chain developments
- Leveraging success of EnTranCe in creating open innovation spaces and centres and exploring the notion of 'distributed open innovation centres' leveraging capacities across the cluster focussed on energy or other themes/issues/ developments.

The next two recommendations are related to optimizing and organizing processes in Energy Valley. The important role of national government needs to be acknowledged since regulatory, funding and strategic policies have large impacts on local cluster developments, and could influence the scope and quality of new and transforming interactions in and outside the cluster. Energy Valley Foundation and the northern Provinces had become more a visible and strategic partner for the Dutch government on matters of energy transition. Increasing national budgets and support for cluster and regional developments were shown to be important and therefore future strategies need to focus on increasing national government funding, in addition to other external sources, as seen in Silicon Valley and Karlstad.

A different issue that needs to be addressed in Energy Valley is the need to re-build trustful relations between the gas corporation, national government on the one hand, and local inhabitants, businesses and governments on the other hand, in the face of neglect of public safety in exploiting gas in the region. Criticisms of national agencies and corporations and political pressure has resulted in improved and accelerated compensation processes but misgivings and trust issues are still present. Trust is important to collaborations and successful cluster practice. Good governance and more transparency are also relevant to building trustful relations that needs to be considered.

Likewise, Energy Valley needs to acknowledge self-organizing processes of complex cluster developments even as policy interventions are important. Policy initiatives need to support self-organizing processes in Energy Valley. To achieve this, funds and resource allocations are important to support self-organizing processes of businesses and consumers. The complexity of changing energy landscapes is in part due to the embedded nature of energy transition in social processes.

Recommendations related to organizing processes were:

- Acknowledging the importance of top-down policies, particularly national funding for successful cluster and energy transition developments
- Need for trust and transparent governance structures, particularly in the face of earthquake developments
- Need to connect to self-organizing processes and facilitating these.

The next recommendation is related to connecting to different regional strategies and developments and opportunities in related sectors and emerging industries. The bio-based economy is an example of new combination of existing strengths in the region, which served all three dominant frames. More thematic and issue-based goals, the grand social challenges, for example, could also lead to new combinations and strategy developments in the cluster that could enhance the region, energy transition and national and corporate economic interests. Karlstad's example of bio-forestry is also a combination of related and overlapping sectors and developments. Exploring more systematically opportunities of the different developments in the northern Provinces, adjacent sectors, and new developments (of emerging industries) is recommended.

Recommendations related to overlapping and related systems were:

- Leveraging differences present in Provinces (significant differences)
- Issue-based and thematic combinations could offering new path creations for Energy Valley
- Exploring connections to adjacent industries and sectors, and new developments of emerging industries.

There are tensions between the different levels of local, cluster, regional, national and EU systems due to different interests and strategies.

Finally, sensitivity to 'larger systems' developments, namely those at the regional, national and EU levels is needed. Energy Valley needs to be wary these differences and the risk of being caught in conflicting national, regional and EU interests. Energy Valley needs to strengthen its relevance and identity by strengthening links to regional development goals. However, it could benefit from EU Cluster Policy that advocates and supports cluster-to-cluster collaborations and emerging industry developments. Other EU priorities of solving 'grand social challenges' and supporting Regional Smart Specialization goals could also offer new opportunities.

Recommendations related to systems-in-systems developments were:

- Connecting and strengthening regional economic and business interests
- Sensitivity to systems interconnectedness
- Exploring and leveraging opportunities of significant differences.

In conclusion, in Energy Valley, an enhanced role and mandate of the cluster organization, supported by broad strategic think tanks or regional strategic platforms, could help combat fragmentation and diffused cluster developments. It will also be able to facilitate new innovation spaces, ecosystems, crossing sectoral, knowledge, geographic and economic-civic boundaries, and strategic developments focussed on grand social challenges and complex contextual developments. In addition, the role and scope of regional and local governments need to be aligned to meet the challenges of complex interconnected social issues, supporting cluster and economic developments and transformations. Enhanced mandates and more resources to serve both local and larger social challenges in leveraging national and EU goals and policy efforts need to be explored.

## *5.7 Conclusions of Part 2*

The research addressed and recommended new directions and enhancements for cluster and CAS literature, and for cluster practice. The suggestions for cluster practice included specific recommendations for EU policy, cluster practice (regional policy and cluster management), and Energy Valley. In this discourse, the significance and role of the different levels of policy and systems developments and the role of stakeholders, and implications for policy, were also addressed. The recommendations included more alignment to contextual changes, and national and EU level developments; enlargement of scope and vision of clusters and mandate of cluster organizations; reconsideration of the role of regional and national governments; and, the need to re-visit knowledge and industry policies strategies to explore mandates, resources allocations, patterns and processes of organizations in these areas to ensure alignment to the need to address societal challenges and complex issues.

## *5.8 Part 3 Future of cluster developments*

The final part of the research offers insights into the research journey and comments, followed by topics for future research that were tangent to the research but could add cluster developments.

## *5.9 Personal reflection*

The research offered a journey of discovery to understand interrelated developments of changing business and social domains in a global and digitalized world. The study of an energy cluster in its complex landscape, in the researcher's own region, seemed to be a logical choice. The fascination with the idea of clusters serving policy decisions (to solve economic challenges) was also one of the reasons for the choice of cluster study. An example of this was the EU's ambitions to create world-class clusters and strengthen local regions through its cluster policy instrument. The financial crisis that broke out in 2008 made more urgent the need for cluster policy to be implemented successfully. These ingredients framed implementation of EU cluster policy and offered an urgent and important challenge to tackle.

Having set out on this journey and curious about the ability of complexity approaches to support EU cluster policy, the contours of the research were clear: customization of CAS, exploration of Energy Valley, a second case to enhance findings, etc. The details were not clear but the direction and overall picture seemed clear. The journey took on different turns and challenges, testing competences and patience along the way, complicated by mirages that gave false hope. Yet, all of these added to the richness of the journey. The main concern of keeping pace, focus and diligence were tempered by the need to make space for creative abductions, processing thought trails, and being alert to new developments. The journey had its challenges but always offered opportunities to grow and overcome limitations. This journey of bringing together different knowledge fields, practice and cultural arenas proved to be larger, more complex and more trying than was expected. However, the support, confidence and encouragement received by the researcher were critical to the completion of this project. Bringing together strands of thoughts, analysis, theories and empirical evidence resulted in the insights and model that serve cluster theory and practice.

Results in earlier projects and those from students as part of their course work has already brought about positive reactions of how this 'new' perspective and analytical tool offers understanding and support in dealing with complex systems developments. The next step in the journey includes academic and policy discourses to enhance relevance and alignment to on-going developments in each of these areas.

Reflecting on the research outcomes, the main contention of the research is that strategy for cluster developments needs to encompass new approaches in which continuous strategy developments alert to both contextual changes and systems responses as well as appreciation of significance of diversity, unpredictability, role of sensemaking and semi-autonomous agency and systemic developments are present. Similarly, theoretical implications of the research were that CAS approaches supported whole systems approaches and new insights into cluster systems developments.

The research outcomes contributed to enhancing knowledge and cluster practice, and to the personal learning. There were many roads that could have led to the end of the journey, but the one travelled made the most sense at that time, and on hindsight, it was the only one to be taken.

## *5.10 Beyond the research – topics for future cluster research*

- Digital and globalized connectivity impacting agglomeration and place-based cluster developments
- Changing roles of consumer and businesses in cluster practice
- Place of trust in cluster agendas
- Meta-clusters, cluster-to-cluster alliances and the fate of stand-alone clusters
- People-centric cluster developments in comparison to firm- focussed cluster developments
- ‘Grand social challenges’ as driver of cluster agenda
- Emotion in clusters and policy decisions
- Impact of emerging industry formations on cluster identity and developments
- Autonomy of cluster governance in multi-level systems developments
- Contextual complexity simplifying cluster governance
- Impact of formal and non-formal governance norms in cluster dynamics
- Co-evolving developments of governance structures in cluster and their nested systems
- Sensemaking in institutional and regulatory developments
- Distributed cluster concept as an alternative to concentrated meta-clusters
- Leveraging isolated and fragmented facets of cluster and economic developments through re-defining cluster scope and focus
- Role of finance, impact of and need for public versus private finances, on cluster and business developments
- Systemic and transformative aspects of cluster-to-cluster collaborations
- Limitations and boundaries of cluster-size, particularly in the face of meta-clusters and cluster-to-cluster developments
- Role of trust in changing contextual complexity
- Reinforcing processes of self-organizing and planned policy initiatives in cluster systems developments
- Implications of growing significance of civic society for cluster policy
- Significance of systems agents and change agents in cluster developments.

## References


Ackerman Anderson, L., & Anderson, D. (2002). *Identifying Your Drivers of Change*. *Being First, Inc.* Retrieved from http://www.workinfo.com/free/downloads/change.pdf

Alford, R. R., King, G., Keohane, R. O., & Verba, S. (1995). Designing Social Inquiry: Scientific Inference in Qualitative Research. *Contemporary Sociology*, *24*(3), 424.

Allen, P., Maguire, S., & McKelvey, B. (Eds.). (2011). *The SAGE Handbook of Complexity and Management*. London: SAGE Publications Inc.

Allen, P. M., Richardson, K. A., & Goldstein, J. A. (Eds.). (2010). *Emergence, Complexity and Organization: E:CO Annual Volume 12*. *Emergent*. Litchfield Park: Emergent Publications.

Amdam, R. (2010). Empowerment Planning in Regional Development. *European Planning Studies*, *18*(11), 1805–1819.

Andersson, M., & Karlsson, C. (2004). *Regional innovation systems in small and medium-sized regions: A critical review & assessment*. *CESIS Electronic Working Paper Series*. Retrieved from https://static.sys.kth.se/itm/wp/cesis/cesiswp10.pdf

Andersson, T., Schwaag-Serger, S., Sörvik, J., & Hansson, E. W. (2004). *The cluster policies whitebook*. Malmo: International Organization for Knowledge Economy and Enterprise Development. Retrieved from http://citeseerx.ist.psu.edu/viewdoc/download?doi=10.1.1.197.4531&rep=rep1&type=pdf

Andriani, P. (2001). Diversity, knowledge and complexity : some introductory issues. *International Journal of Innovation Management*, *5*(2), 257–274.

Andriani, P., Jones, C., Perkmann, M., De Propris, L., Sena, V., Delbridge, R., … Neely, A. (2005). *Challenging clusters: The prospects and pitfalls of clustering for innovation and economic development*. London: Advanced Institute of Management Research.

Andriani, P., & McKelvey, B. (2007). Beyond Gaussian Averages: Redirecting organization science toward extreme events and power laws. *Journal of International Business Studies*, *38*(7), 1212–1233.

Araújo, K. (2014). The emerging field of energy transitions: Progress, challenges, and opportunities. *Energy Research & Social Science*, *1*, 112–121.

Ariff, M. (2008). New Perspectives on Industry Clusters in Malaysia. In M. Ariff (Ed.), *Analyses of Indutrial Agglomeration, Production Networks and FDI Promotion* (pp. 368–397).

Arikan, A. T. (2009). Interfirm knowledge exchanges and the knowledge creation capability of clusters. *Academy of Management Review*, *34*(4), 658–676.

Arthurs, D., Cassidy, E., Davis, C., & Wolfe, D. A. (2009). Indicators to support innovation cluster policy. *International Journal Technology Management*, *46*(3/4), 263.

Asheim, B. (2007). Differentiated Knowledge Bases and Varieties of Regional Innovation Systems. *Innovation: The European Journal of Social Science Research*, *20*(3), 223–241.

Asheim, B., Cooke, P., & Martin, R. (2006). *Clusters and Regional Development*. (B. Asheim, P. Cooke, & R. Martin, Eds.). London: Routledge.

Asheim, B., Boschma, R., & Cooke, P. (2011). Constructing regional advantage: Platform policies based on related variety and differentiated knowledge bases. *Regional Studies*, *45*(7), 893–904.

Asheim, B. T., & Coenen, L. (2005). Knowledge bases and regional innovation systems: Comparing Nordic clusters. *Research Policy*, *34*(8), 1173–1190.

Asheim, B. T., & Parrilli, M. D. (2012). *Interactive Learning for Innovation: A Key Driver within Clusters and Innovation Systems*. Palgrave Macmillan.

Asheim, B. T., & Parrilli, M. D. (2012). Introduction: Learning and Interaction - Drivers for Innovation in Current Competitive Markets. In B. T. Asheim & M. D. Parrilli (Eds.), *Interactive Learning for Innovation: A Key Driver within Clusters and Innovation Systems*. Hampshire: Palgrave Macmillan.

Atos Consulting. (2011). *Energienetwerkbedrijven in 2020: Scenario Planning*. Utrecht. Retrieved from www.atosconsulting.nl

Atzema, O., Lambooy, J., van Rietbergen, T., & Wever, E. (2009). *Ruimtelijke Economische Dynamiek: Kijk op Bedrijfslocatie en Regionale Ontwikkeling* (2nd ed.). Bussum.

Audretsch, D. B., & Aldridge, T. T. (2008). The knowledge spillover theory of entrepreneurship and spatial clusters. In C. Karlsson (Ed.), *Handbook of Research on Cluster Theory*. Cheltenham: Edward Elgar.

Australian Public Service Commission. (2007). *Tackling wicked problems: A public policy perspective*. *Commonwealth of Australia*. Retrieved from http://www.apsc.gov.au/publications-and-media/archive/publications-archive/tackling-wicked-problems

Avnimelech, G., & Teubal, M. (2008). Evolutionary targeting. *Journal of Evolutionary Economics*, *18*, 151–166.

Axelrod, R., & Cohen, M. D. (2001). *Complexiteit in organisaties: Een raamwerk voor het management*. Amsterdam: Pearson Education.

Bale, C. S. E., Varga, L., & Foxon, T. J. (2015). Energy and complexity: New ways forward. *Applied Energy*, *138*, 150–159.

Balland, P.-A., Boschma, R., & Frenken, K. (2013). Proximity and innovation networks: an evolutionary approach. In P. Cooke (Ed.), *Re-framing Regional Development: Evolution, Innovation and Transition* (pp. 186–200). Oxon: Routledge.

Bathelt, H. (2008). Knowledge-based clusters: regional multiplier models and role of “buzz” and “pipelines.” In C. Karlsson (Ed.), *Handbook of Research on Cluster Theory*. Cheltenham: Edward Elgar.

Batie, S. S. (2008). Wicked problems and applied economics. *American Journal of Agricultural Economics*, *90*(5), 1176–1191.

Baxter, P., & Jack, S. (2008). Qualitative Case Study Methodology: Study Design and Implementation for Novice Researchers. *The Qualitative Report*, *13*(4), 544–559.

Bay Area Council Economic Institute & Booz & Company. (2012). *The Culture of Innovation: What Makes San Francisco Bay Area Companies Different ?* San Francisco.

Begun, J. W., Zimmerman, B., & Dooley, K. (2003). Health Care Organizations as Complex Adaptive Systems. In S. M. Mick & M. Wyttenbach (Eds.), *Advances in Health Care Organization Theory* (pp. 253–288). San Francisco: Jossey-Bass.

Beinhocker, E. D. (2006). *The Origin of Wealth: Evolution, Complexity, and the Radical Remaking of Economics*. *Harvard Business School Press*.

Beinhocker, E. (2012). New Economics, Policy and Politics. In T. Dolphin & D. Nash (Eds.), *Complex New World: Translating New Economic Thinking into Public Policy* (pp. 134–146). London: Institute for Public Policy Research.

Belgin, H. (2008). The Rifkin Vision: Interview with Jeremy Rifkin. *European Energy Review*, (July/August), 26–40.

Belussi, F. (2006). In search of a useful theory of spatial clustering: Agglomeration versus active clustering. In B. Asheim, P. Cooke, & R. Martin (Eds.), *Clusters and regional development: Critical reflections and explorations*. London: Routledge.

Benford, R. D., & Snow, D. A. (2000). Framing Processes and Social Movements: An Overview and Assessment. *Annual Review of Sociology*. http://doi.org/10.1146/annurev.soc.26.1.611

Benner, M. (2012). *Cluster Policy as a Development Strategy: Case Studies from the Middle East and North Africa*. *University of Lüneburg Working Paper Series in Economics*. Retrieved from http://hdl.handle.net/10419/73171

Benner, M. (2013). *Cluster policy in developing countries*. *MPRA Paper*. Retrieved from https://mpra.ub.uni-muenchen.de/44257/

Bestuurlijk Overleg Noord-Nederland, & Stichting Energy Valley. (2014). Noordelijke Energie Agenda SWITCH. Retrieved from https://www.energyvalley.nl/downloads

Birkinshaw, J. M., Hamel, G., & Mol, M. J. (2006). Management innovation. *Academy of Management Review*, *33*(4), 81–88.

Boonstra, J. J. (2004). *Dynamics of Organizational Change and Learning*. Chichester: Wiley Publishers.

Boschma, R. (2004). Competitiveness of Regions from an Evolutionary Perspective. *Regional Studies*, *38*(9), 1001–1014.

Boschma, R. (2009). *Evolutionary economic geography and its implications for regional innovation policy, Report for the OECD*. Utrecht. Retrieved from http://econ.geog.uu.nl/boschma/boschma.html report for the OECD version 20 February 2009%0AAbstract

Boschma, R. (2015). Towards an Evolutionary Perspective on Regional Resilience. *Regional Studies*, *49*(5), 733–751.

Boschma, R. A. (1999). The rise of clusters of innovative industries in Belgium during the industrial epoch. *Research Policy*, *28*(8), 853–871.

Boschma, R., & Frenken, K. (2009). Some notes on institutions in evolutionary economic geography. *Economic Geography*, *85*(2), 151–158. http://doi.org/10.1111/j.1944-8287.2009.01018.x

Bosman, R., Avelino, F., Jhagroe, S., Loorbach, D., Diercks, G., & Verschuur, G. (2013). *Energielente op komst? De (on)macht van bottom-up en top-down in de energietransitie [Essay]*. Rotterdam: DRIFT. Retrieved from http://www.drift.eur.nl/?p=2802

Brambor, T., Clark, W. R., & Golder, M. (2005). Understanding Interaction Models: Improving Empirical Analyses. *Political Analysis*, *14*(1), 63–82.

Brenner, T., Cantner, U., Fornahl, D., Fromhold-Eisebith, M., & Werker, C. (2011). Regional innovation systems, clusters, and knowledge networking. *Papers in Regional Science*, *90*(2), 243–249.

Brown, B. C. (2012). Leading complex change with post‐ conventional consciousness. *Journal of Organizational Change Management*, *25*(4), 560–575.

Brown, B. C. (2014). *Sane Leadership in a Crazy World : Essentials of Complexity Leadership*. Sebastopol.

Bruggink, J. J. C. (2005). *The next 50 years: Four European energy futures*. Petten. Retrieved from ftp://130.112.2.101/pub/www/library/report/2005/c05057.pdf

Buscher, R. (2011). European cluster policy achievements and gaps to be addressed [Presentation Slide]. *Cluster Policy Cooperation in Europe: Looking Ahead to a New Policy Agenda*.

Butler, M. J. R., & Allen, P. M. (2008). Understanding Policy Implementation Processes as Self-Organizing Systems. *Public Management Review*, *10*(3), 421–440.

Carbonara, N., Giannoccaro, I., & McKelvey, B. (2010). Making geographical clusters more successful: Complexity-based policies. *E:CO Emergence: Complexity and Organization*, *12*(3), 21–45.

Carcary, M. (2009). The research audit trail-enhancing trustworthiness in qualitative inquiry. *The Electronic Journal of Business Research Methods*, *7*(1), 11–24.

Carlsson, B. (2006). Internationalization of innovation systems: A survey of the literature. *Research Policy*, *35*(1), 56–67.

Carlsson, B., Jacobsson, S., Holmén, M., & Rickne, A. (2002). Innovation systems: analytical and methodological issues. *Research Policy*, *31*, 233–245.

Castells, M. (1996). *The Information Age: Economy, Society and Culture* (Volume 1:). Oxford: Blackwell.

Cherp, A., Jewell, J., & Goldthau, A. (2011). Governing Global Energy: Systems, Transitions, Complexity. *Global Policy*, *2*(1), 75–88.

Chia, R. (2011). Complexity Thinking: Towards an Oblique Strategy for Dealing with the Complex. In P. Allen, S. Maguire, & B. McKelvey (Eds.), *The SAGE handbook of Complexity and Management* (pp. 182–198). London: SAGE Publications Inc.

Cilliers, P. (2005). Complexity, Deconstruction and Relativism. *Theory, Culture & Society*, *22*(5), 255–267.

Clemens, Jr., W. C. (2002). Complexity Theory as a Tool for Understanding and Coping with Ethnic Conflict and Development Issues in Post-Soviet Eurasia. *The International Journal of Peace Studies*, *7*(2).

Cole, C., Chase, S., Couch, O., & Clark, M. (2011). Research Methodologies and Professional Practice: Considerations and Practicalities. *The Electronic Journal of Business Research Methods*, *9*(2), 141–151.

Commissie Duurzame Toekomst Noord-Oost Groningen (Meier). (2013). *Vertrouwen in een duurzame toekomst: Een stevig perspectief voor Noord-Oost Groningen*. Groningen. Retrieved from http://www.provinciegroningen.nl/fileadmin/user_upload/Documenten/Downloads/Eindadvies_Commissie_Duurzame_Toekomst_Noord-Oost_Groningen.pdf

Communauté métropolitaine de Montréal. (2010). *Charting our international future: A competitive metropolitan Montreal region (Economic Development Plan 2010-2015)*. Montreal. Retrieved from http://www.cmm.qc.ca

Confederation of British Industry. (2013). *The next regeneration: unlocking local growth*. London. Retrieved from www.cbi.org.uk

Conklin, J. (2005). Wicked Problems & Social Complexity. In J. Conklin (Ed.), *Dialogue Mapping: Building Shared Understanding of Wicked Problems* (p. 20). Chichester: Wiley Publishers.

Cooke, P. (2001). Regional Innovation Systems, Clusters, and the Knowledge Economy. *Industrial and Corporate Change*, *10*(4), 945–974.

Cooke, P. (2010). Matrix policy - rationales and good examples. In VINNOVA (Ed.), *The Matrix - Post cluster innovation policy*. VINNOVA. Retrieved from www.VINNOVA.se

Cooke, P. (2012). *Complex Adaptive Innovation Systems: Relatedness and Transversality in the Evolving Region*. Oxon: Routledge.

Cooke, P. (2013). *Re-framing Regional Development*. Oxon: Routledge.

Cooke, P., De Laurentis, C., Tödtling, F., & Trippl, M. (2007). *Regional Knowledge Economics*. Cheltenham: Edward Elgar.

Cooke, P., & Piccaluga, A. (2004). *Regional Economics as Knowledge Laboratories*. Cheltenham: Edward Elgar.

Corning, P. A. (2002). The Re-Emergence of Emergence: A Venerable Concept in Search of a Theory. *Complexity*, *7*(6), 18–30.

Cortright, J. (2006). *Making Sense of Clusters: Regional Competitiveness and Economic Development*. Retrieved from www.brookings.edu/metro

Cruz, S. C. S., & Teixeira, A. a. C. (2009). The Evolution of the Cluster Literature: Shedding Light on the Regional Studies–Regional Science Debate. *Regional Studies*, *44*(9), 1263–1288.

Curry, A. (2006). The Architecture of the Future [web article]. Retrieved September 2009 from https://thenextwavefutures.files.wordpress.com/2007/08/curry_thearchitectureofthefuture0706.pdf

Delgado, M., Porter, M. E., & Stern, S. (2014). Clusters, Convergence, and Economic Performance. *Research Policy*, *43*, 1785–1799.

Delgado, M., Porter, M. E., & Stern, S. (2015). Defining clusters of related industries. *Journal of Economic Geography*, *16*(1), 1–38.

Department for International Development. (2004). *Drivers of change* (Vol. 4). Retrieved from http://www.shl.bfh.ch/fileadmin/docs/Forschung/KompetenzenTeams/NutztierUmweltInteraktion/LCL-Schneider-drivers-of-change-20100304.pdf

Department of Innovation and Competitiveness Policy INFYDE SL. (n.d.). *Policy Instruments for RIS3 Clusters* (INFYDE Working Paper Series) (Vol. 1).

Depret, M.-H., & Hamdouch, A. (2010). *Multiscalar Clusters and Networks as the Foundations of Innovation Dynamics in the Biopharmaceutical Industry*. *Région et Développement* (Vol. 33). Retrieved from http://region-developpement.univ-tln.fr/en/pdf/R33/Depret Hamdouch.pdf

Dervin, B. (1999). On studying information seeking methodologically: the implications of connecting metatheory to method. *Information Processing & Management*, *35*(6), 727–750.

Dervin, B. (1983). An overview of sense-making research: Concepts, methods, and results to date. *International Communication Association Annual Meeting*.

Dervojeda, K., Nagtegaal, F., Verzijl, D., Lengton, M., & (PwC Netherlands). (2012). *Methodology Report: Cluster-specific framework conditions for world-class clusters in emerging industries*. *European Cluster Observatory*.

DNVGL. (2011). Technology Outlook 2020. Retrieved from http://issuu.com/dnv.com/docs/technology_outlook_2020_lowres

Dooley, K. J. (1997). A Complex Adaptive Systems Model of Organization Change. *Nonlinear Dynamics, Psychology, and Life Sciences*, *1*(1), 69–97.

Dutch Research Institute For Transitions (DRIFT). [Website]. 'Transition Management' – overview from DRIFT. Retrieved from https://www.drift.eur.nl/?page_id=4496.

Ebbekink, M., Hoogerbrugge, M., Lagendijk, A., & Karkhof, J. (2015). *Cluster Governance - Lessen voor clusters in Nederland*. Retrieved from www.platform31.nl

ECN, Energie-Nederland, & Netbeheer Nederland. (2012). *EnergieTrends 2012*. Petten.

Edquist, C. (1997). Systems of innovation approaches - Their emergence and characteristics. In C. Edquist (Ed.), *Systems of Innovation: Technologies, Institutions and Organizations* (pp. 1–35). London: Pinter.

Eisenhardt, K. M. (1989). Building Theories from Case Study Research. *Academy of Management Review*, *14*(4), 532–550.

Eisenhardt, K. M., & Graebner, M. E. (2007). Theory building from cases: Opportunities and challenges. *Academy of Management Journal*, *50*(1), 25–32.

Eisenhardt, K. M., & Sull, D. N. (2001). Strategy as simple rules. *Harvard Business Review*, *79*, 106–116, 176.

*Energieakkoord Noord-Nederland (Energy Agreement North Netherlands)*. (2007). [Archive material].

Energieonderzoek Centrum Nederland. (2014). *Nationale Energieverkenning 2014*. Petten. Retrieved 10 October 2014 from www.ecn.nl/energieverkenning

Energy Valley. (2010). *Background Study Hansa Energy Corridor [Archive Material]*. Groningen.

Energy Valley. (2011). *Energy Valley 4: Energizing the Dutch Economy, Strategieplan 2012-2015*. Retrieved from https://www.energyvalley.nl/uploads/bestanden/3621f0ef-e22f-44fa-aea3-88a9514aa822

Energy Valley. (n.d.). Energy Valley [website]. Groningen.

Eoyang, G., & Yellowthunder, L. (2011). Complexity Models and Conflict: A Case Study from Kosovo. In P. M. Allen, K. . Richardson, & J. A. Goldstein (Eds.), *Emergence: Complexity & Organization, E:CO* (Vol. 12, pp. 311–328). Arizona: Emergent Publications.

ERRIN/TACTICS. (2012). *Integrating Cluster Policies within the Future EU Programmes. European Cluster Alliance - Tactics*. Retrieved from http://medcontent.metapress.com/index/A65RM03P4874243N.pdf

Estevão, C., & Ferreira, J. (2009). Regional competitiveness of tourism cluster: a conceptual model proposal. *MPRA Paper,* (14853), 17–51. http://doi.org/10.1016/j.polymer.2005.04.091

Etzkowitz, H. (2012). *Silicon Valley: The Sustainability of an Innovative Region*. *Triple Helix Association, Working Papers* (Vol. 52). Retrieved 12 December 2012 from http://www.triplehelixassociation.org/wp-content/uploads/2012/07/Silicon-Valley-The-Sustainability-of-an-Innovative-Region.pdf. Also in *Social Science Information*, *52*(3), 1–25.

Etzkowitz, H., Dzisah, J., Ranga, M., & Zhou, C. (2007). The triple helix model of innovation. *Tech Monitor*, 14–23. http://doi.org/10.1177/05390184030423002

EU Cluster Portal [Website]. http://ec.europa.eu/growth/smes/cluster/

Eurelectric. (2014). *Flexible gas markets for variable renewable generation*. Brussels. Retrieved from http://www.eurelectric.org/media/130545/flexiblegasmarketpaper_final_lr-2014-2250-0001-01-e.pdf

Europa InterCluster. (2010). *The Emerging of European World-Class Clusters [White Paper]*. Retrieved December 2010 from http://www.intercluster.eu

European Cluster Alliance. (2010). *Identifying the main Objectives and Activities of Cluster Programmes*. Retrieved from http://www.proinno-europe.eu/cee-clusternetwork

European Cluster Observatory. (2011). *Strong Clusters in Innovative Regions*. Retrieved from http://www.clusterobservatory.eu/common/galleries/downloads/Strong_Clusters_in_Innovative_Regions_Report.pdf

European Cluster Collaboration Platform [Website]. Retrieved from http://www.clustercollaboration.eu

European Cluster Policy Group. (2010a). *Consolidated Set of Policy Recommendations on Four Themes*. Retrieved December 2010 from http://www.proinno-europe.eu

European Cluster Policy Group. (2010b). *Final recommendation - A call for policy action*. Retrieved December 2010 from http://www.proinno-europe.eu

European Commission. (2008). *Towards World-Class Clusters in the European Union: Implementing the broad-based innovation strategy COM(2008)652 final*. Brussels.

European Commission. (2010a). *An Integrated Industrial Policy for the Globalisation Era Putting Competitiveness and Sustainability at Centre Stage, COM(2010) 614 final*. Brussels.

European Commission. (2010b). *Europe 2020: A Strategy for Smart, Sustainable and Inclusive Growth COM(2010)2020 final*. Brussels

European Commission. (2011). *State of the Innovation Union 2011, COM(2011)849 final [Report from the Commission]*. Brussels.

European Commission. (2012a). *Guide to Research and Innovation Strategies for Smart Specialization (RIS3)*. Brussels.

European Commission. (2012b). *International Cooperation in Science, Technology and Innovation: Strategies for a Changing World*. Brussels.

European Commission. (2013). *Research and Innovation Performance in Netherlands - Country Profile* (Vol. 30). Brussels.

European Commission. (2013). *The role of clusters in smart specialisation strategies*. Brussels. Retrieved from http://know-hub.eu/static/global/media_catalog/2013/12/23/169/original.pdf

European Commission. (2014a). *EU R&D Scoreboard: The 2014 EU Industrial R&D Investment*. Brussels.

European Commission. (2014a). *For a European Industrial Renaissance, COM(2014) 14 final*. Brussels.

European Commission. (2014c). *Research and Innovation as Sources of Renewed Growth, COM(2014) 339 final*. Brussels.

European Commission. (2015). *Energy Union - Fact Sheet*. Brussels. Retrieved from http://europa.eu/rapid/press-release_MEMO-15-4485_en.htm

European Commission. (2015). *Strategic foresight: Towards the 3rd Strategic Programme of Horizon 2020*. Brussels.

European Communities. (2008). *The Concept of Clusters and Cluster Policies and their Role for Competitiveness and Innovation: Main Statistical Results and Lessons Learned SEC(2008)2637*.

European Environment Agency. (2013). *Trends and projections in Europe 2013*. Denmark. Retrieved from http://eea.europa.eu

European Forum for Clusters in Emerging Industries (EFCEI). (2013). *Policy Roadmap - Actions for new linkages needed: A policy roadmap for stimulating emerging industries*. Retrieved from http://www.emergingindustries.eu/Upload/CMS/Docs/Policy_roadmap.pdf

European Organization for Quality. (2001). *Towards a European Vision of Quality - The way forward*. Brussels.

European Policy Brief - Innovation Futures in Europe: A Foresight Exercise on Emerging Patterns of Innovation, Visions, Scenarios and Implications for Policy and Practice Newletter. (n.d.). *INFU Newsletter*.

European Union. (2012). *European Competitiveness Report 2012: Reaping the Benefits of Globalization SWD(2012)299 final*. Brussels.

European Union. (2014). *European Competitiveness Report 2014: Helping Firms Grow*. Brussels.

European Union (Committee of the Regions). (2012). *Delivering on the Europe 2020 Strategy: Handbook for Local and Regional Authorities*. *Regions and Cities supporting Europe 2020: Europe's growth strategy*. Retrieved from http://portal.cor.europa.eu/europe2020

European Union Institute for Security Studies (EUISS). (2012). *Global trends 2030 – Citizens in an interconnected and polycentric world*. Retrieved from http://europa.eu/espas/pdf/espas_report_ii_01_en.pdf

Eurostat. (2014). Share of renewables in energy consumption up to 14 % in 2012. *Eurostat NewsRelease*.

Evers, H.-D. (2008). *Knowledge hubs and knowledge clusters: Designing a knowledge architecture for development* (No. 27). *ZEF Working paper Series*.

Fagerberg, J., Fosaas, M., & Sapprasert, K. (2012). Innovation: Exploring the knowledge base. *Research Policy*, *41*(7), 1132–1153.

Farinha, L., & Ferreira, J. J. (2013). *Triangulation of the triple helix: a conceptual framework*. *Triple Helix Association, Working Papers*. Retrieved 27 February 2014 from http://www.triplehelixassociation.org/wp-content/uploads/2013/01/Triangulation-of-the-Triple-Helix-A-Conceptual-Framework.pdf

Flyvbjerg, B. (2011). Case Study. In K. Denzin, Norman & Y. S. Lincoln (Eds.), *The SAGE Handbook of Qualitative Research* (4th ed., pp. 149–178). Thousand Oaks: SAGE Publications Inc.

Energy Valley Works 2014 edition [Digital brochure]. (2014). Groningen. Retrieved from https://www.energyvalley.nl/downloads

Energy Valley Foundation [Website]. Groningen. Retrieved from https://www.energyvalley.nl

Fourth European Cluster Conference (European Commission). (2014). *European Cluster Conference 2014: Declaration*. [attachment through email].

Frenken, K. (2006). Innovation, Evolution and Complexity Theory. *Economics of Innovation and New Technology*, *15*, 137–155.

Geels, F. W. (2004). From sectoral systems of innovation to socio-technical systems: Insights about dynamics and change from sociology and institutional theory. *Research Policy*, *33*(6–7), 897–920.

Geels, F. W. (2010). Ontologies, socio-technical transitions (to sustainability), and the multi-level perspective. *Research Policy*, *39*(4), 495–510.

Gertler, M. S., & Levitte, Y. M. (2005). Local Nodes in Global Networks: The Geography of Knowledge Flows in Biotechnology Innovation. *Industry & Innovation*, *12*(4), 487–507.

Gertler, M. S., & Wolfe, D. A. (2006). Spaces of knowledge flows: Clusters in a global context. In B. Asheim, P. Cooke, & R. Martin (Eds.), *Clusters and regional development: Critical reflections and explorations* (pp. 218–235). London: Routledge.

Gibbert, M., Ruigrok, W., & Wicki, B. (2008). What passes as a rigorous case study? *Strategic Management Journal*, *29*(13), 1465–1474.

Gioia, D. a., Corley, K. G., & Hamilton, A. L. (2012). Seeking Qualitative Rigor in Inductive Research: Notes on the Gioia Methodology. *Organizational Research Methods*, *16*(1), 15–31.

Giuliani, E. (2005). The Structure of Cluster Knowledge Networks : Uneven and Selective , not Pervasive and Collective. *Danish Research Unit for Industrial Dynamics (DRUID)*, (05–11), 24. Retrieved from http://www.druid.dk

Goldstein, J. (2008). Introduction: Complexity Science Applied to Innovation – Theory meets Praxis. *The Innovation Journal: The Public Sector Innovation Journal*, *13*(3), 1–16.

Graham, R. (2013). *Technology Innovation Ecosystem Benchmarking Study : Key findings from Phase 1. MIT Skoltech Initiative*. Retrieved from http://www.skoltech.ru/en

Granovetter, M. S. (1973). The Strength of Weak Ties. *American Journal of Sociology*, *78*(6), 1360.

Granovetter, M. S. (1985). Economic-action and social-structure - the problem of embeddedness. *American Journal of Sociology*, *91*(3), 481–510.

Greenhalgh, B. (2011). TACTICS Policy Recommendations on Cluster Internationalisation [Presentation Slides]. In *TACTICS Cluster/ECA - Polish Presidency Conference*, 2011.

Halilem, N. (2010). Inside the Triple Helix: An Integrative Conceptual Framework of the Academic Researcher's Activities, a Systematic Review. *Journal of Research Administration*, *41*(3), 5,23-50.

Hamdouch, A. (2007). Innovation clusters and networks: a critical review of the recent literature. In *19th EAEPE Conference* (p. 30). Retrieved 15 January 2015 from http://www.sociologia.unimib.it/DATA/Insegnamenti/2_1931/materiale/hamdouch 2007-reading for group 5.pdf

Hamdouch, A., Depret, M. H., Monino, J. L., & Poncet, C. (2009). Regional Politics, Key Levers of Regional Innovation Dynamics. In *RSA Annual Conference: "Understanding and Shaping Regions: Spatial, Social and Economic Features."* Retrieved September 2009 from http://ssrn.com/abstract=1366349

Hamdouch, A. (2011). *Investigating Cluster Emergence and Evolution Dynamics [Review]*. *Région et Développement* (Vol. 33). Retrieved from http://region-developpement.univ-tln.fr/en/pdf/R33/ReviewEssay.pdf

Hamdouch. A. (2011). Conceptualizing Innovation Clusters and Networks. In D. B. Laperche, Sommers, P., Uzunidis (Ed.), *Innovation Networks and Clusters - The Knowledge Backbone* (pp. 21–63). Brussels: Peter Lang Publishing.

Hammer, R. J. (2011). *Strategy Development Process and Complex Adaptive Systems [unpublished thesis]*. Aston University.

Han, J. H. J., Kim, K. K. K., & Kang, I. K. I. (2008). A study on the relation between properties of network activity and innovation in regional innovation clusters - perspective of social capital. *2008 4th IEEE International Conference on Management of Innovation and Technology*. http://doi.org/10.1109/ICMIT.2008.4654434

Hanauer, N., & Beinhocker, E. (2014). Capitalism Redefined: What prosperity is, where growth comes from, why markets work and how we resolve the tension a prosperous world and a moral one. *Democracy A Journal of Ideas, Winter*(31). Retrieved from http://www.democracyjournal.org/31/capitalism-redefined.php

He, Z., Rayman-Bacchus, L., & Wu, Y. M. (2011). Self-organization of industrial clustering in a transition economy: A proposed framework and case study evidence from China. *Research Policy*, *40*(9), 1280–1294.

Heylighen, F., Cilliers, P., & Gershenson, C. (2007). Complexity and Philosophy. *Complexity, Science and Society*, 117–134. Retrieved 24 November 2011 from https://arxiv.org/ftp/cs/papers/0604/0604072.pdf

Hindle, K. (2010). How community context affects entrepreneurial process: A diagnostic framework. *Entrepreneurship & Regional Development*, *22*(7–8), 599–647.

Hogeweg, Q. (2013). *Energy Valley: The inter-organizational network and its effect on the regional energy transition [unpublished thesis]*.

Holland, J. H. (1992). Studying complex adaptive systems. *Daedalus*, *121*(1), 17–30.

Horn, R. E., & Weber, R. P. (2007). *New Tools For Resolving Wicked Problems : Mess Mapping and Resolution Mapping Processes*. Retrieved from http://www.strategykinetics.com/New_Tools_For_Resolving_Wicked_Problems.pdf

Houchin, K., & MacLean, D. (2005). Complexity Theory and Strategic Change: an Empirically Informed Critique. *British Journal of Management*, *16*(2), 149–166.

House of Commons. (2009). *North East Regional Committee - First Report Industry and Innovation in the North East of England*. Retrieved from http://www.publications.parliament.uk/pa/cm200910/cmselect/cmneast/169/16902.htm#evidence

Hummelbrunner, B. R., & Jones, H. (2013). *A guide for planning and strategy development in the face of complexity*. Retrieved from http://www.odi.org.uk

IBM. (2010). *Capitalizing on Complexity: Insights from the Global Chief Executive Officer Study*. *IBM Corporation*. New York. Retrieved from ibm.com/capitalizingoncomplexity

International Energy Agency. (2014). *Energiebeleid van IEA-landen: Nederland: 2014 Landenanalyse*. Paris. Retrieved from http://www.iea.org

ISRN Management Committee. (2002). *The Innovation Systems Research Network: An Experimental Design for Knowledge Management*. Retrieved from http://sites.utoronto.ca/isrn/publications/WorkingPapers/index.html

Izsák, K., Markianidou, P., & Radošević, S. (2013). *Lessons from a Decade of Innovation Policy*. *European Union*. Retrieved from http://www.technopolis-group.com/resources/downloads/reports/decade-innovation-policy-full-study_en.pdf

Jaruzelski, B., Le Merle, M., Randolph, S. (2012). *The Culture of Innovation: What Makes San Francisco Bay Area Companies Different?* San Francisco. Retrieved 26 September 2012 from http://www.strategyand.pwc.com/media/file/Strategyand-BACEI-Culture-of-Innovation-What-Makes-San-Francisco-Bay-Area-Companies-Different.pdf

Jensen, M. B., Johnson, B., Lorenz, E., & Lundvall, B. Å. (2007). Forms of knowledge and modes of innovation. *Research Policy*, *36*(5), 680–693.

Johnson, B. (2012). Organization and Innovation: The Topic of Creative Cities. In B. T. Asheim & M. D. Parrilli (Eds.), *Interactive Learning for Innovation: A Key Driver within Clusters and Innovation Systems.* Hampshire: Palgrave Macmillan.

Jones, H. (2011). *Taking responsibility for complexity: How implementation can achieve results in the face of complex problems*. *Working Paper* (No. 330). London: ODI. Retrieved from https://www.odi.org/sites/odi.org.uk/files/odi-assets/publications-opinion-files/6485.pdf

Jones, L., Ludi, E., Beautement, P., Broenner, C., & Bachofen, C. (2013). *New Approaches to promoting Flexible and Forward-looking Decision Making: Insights from complexity science, climate change adaptation and "serious gaming."* London: ODI. Retrieved from http://www.odi.org.uk

Kaloudis, A., & Pedersen, T. E. (2008). *Sectoral Innovation Systems in Europe: Monitoring, Analysing Trends and Identifying Challenges*. *The Energy Sector - Final Report*. Retrieved 28 April 2012 from http://archive.europe-innova.eu/docs/SIW_SR_Automotive_20080509.pdf

Karlsson, C. (Ed.). (2008). *Handbook of Research on Cluster Theory*. Cheltenham: Edward Elgar.

Karlsson, C. (Ed.). (2008). *Handbook of Research on Innovation and Clusters: Cases and Policy*. Cheltenham: Edward Elgar.

Karwandy, J. (2008). *Perspectives on Industrial CLustering and the Product, Resource and Knowledge Based Views of Management [unpublished thesis]*. University of Saskatchewan.

Ketels, C. (2008). *State of the Region Report: Sustaining Growth at the Top of Europe.* Copenhagen.

Ketels, C. (2013). The EU ’ s Regional Policy Entering a New Phase: What Does Smart Specialization Mean? [Presentation Slides].

Ketels, C., Lindqvist, G., & Sölvell, Ö. (2012). *Strengthening Clusters and Competitiveness in Europe: The Role of Cluster Organizations*. Stockholm.

Ketels, C., & Memedovic, O. (2008). From clusters to cluster-based economic development. *International Journal of Technological Learning, Innovation and Development*, *1*(3), 375.

Klein Woolthuis, R., Lankhuizen, M., & Gilsing, V. (2005). A system failure framework for innovation policy design. *Technovation*, *25*(6), 609–619.

Kogler, D. F. (2015). Editorial: Evolutionary Economic Geography – Theoretical and Empirical Progress. *Regional Studies*, *49*(5), 705–711.

Laes, E., Leen Gorissen, & Frank Nevens. (2014). A Comparison of Energy Transition Governance in Germany, The Netherlands and the United Kingdom. *Sustainability*, *6*(3), 1129–1152.

Lagendijk, A., & Boekema, F. (2008). Global Circulation and Territorial Development: South-east Brabant from a Relational Perspective. *European Planning Studies*, *16*(7), 925–939.

Lambooy, J. G. (2005). Innovation and knowledge: Theory and regional policy. *European Planning Studies*, *13*(8), 1137–1152.

Lambooy, J. G., & Boschma, R. A. (2001). Evolutionary economics and regional policy. *The Annals of Regional Science*, *35*(1), 113–131.

Leadbeater, C. (2013). The Systems Innovator: Why Successful Innovation Goes Beyond Products. In G. Mulgan & C. Leadbeater (Eds.), *Systems Innovation: Discussion Paper*. Retrieved 9 January 2014 from http://www.nesta.org.uk

Levin, K., Cashore, B., Bernstein, S., & Auld, G. (2012). Overcoming the tragedy of super wicked problems: constraining our future selves to ameliorate global climate change. *Policy Sciences*, *45*(2), 123–152.

Levin, S. a. (2002). Complex Adaptive Systems: Exploring the Known, the Unknown and the Unknowable. *BULLETIN (New Series) OF THE AMERICAN MATHEMATICAL SOCIETY*, *40*(1), 3–19. http://doi.org/10.1090/S0273-0979-02-00965-5

Lewin, R., & Regine, B. (1999). *The Soul at Work: Unleashing the Power of Complexity Science for Business Success*. London: Orion Business.

Lichtenstein, B. B., Uhl-Bien, M., Marion, R., Seers, A., Orton, J. D., & Schreiber, C. (2006). Complexity leadership theory: An interactive perspective on leading in complex adaptive systems. *E:CO Emergence: Complexity and Organization*, *8*(4), 2–12.

Lindqvist, G., & Sölvell, Ö. (2011). *Organizing Clusters for Innovation: Lessons from City Regons in Europe*. *CLUSNET Final Report*. Retrieved from http://scholar.google.com/scholar?hl=en&btnG=Search&q=intitle:ORGANISING+CLUSTERS+FOR+INNOVATION+:+LESSONS+FROM+CITY+REGIONS+IN+EUROPE#0

Loorbach, D. (2010). Transition Management for Sustainable Development: A Prescriptive, Complexity-Based Governance Framework. *Governance: An International Journal of Policy, Adminstration, and Institution*, *23*(1), 161–183.

Loorbach, D. A. (2007). *Transition Management: New mode of governance for sustainable development [Thesis]*. Antenna. Retrieved from http://www.antenna.nl/i-books

Loorbach, D., Brugge, R. Van Der, & Taanman, M. (2008). Governance in the energy transition: Practice of transition management in the Netherlands. *International Journal of Environmental Technology and Management*, *9*(2/3), 294.

Lorentzen, A. (2008). The Scales of Innovation Spaces. In M. J. A. Querejeta, C. I. Landart, & J. R. Wilson (Eds.), *Networks, Governance and Economic Development: Bridging Disciplinary Frontiers* (pp. 40–56). Cheltenham: Edward Elgar Publishing.

Maclean, D., Macintosh, R., & Grant, S. (2002). Mode 2 management research. *British Journal of Management*, *13*, 189–207.

Maguire, S. (2011). Constructing and Appreciating Complexity. In P. Allen, S. Maguire, & B. McKelvey (Eds.), *The SAGE Handbook of Complexity and Management* (pp. 79–92). London: SAGE Publications Inc.

Maguire, S., McKelvey, B., Mirabeau, L., & Öztas, N. (2006). Complexity Science and Organization Studies. In S. Clegg, C. Hardy, T. Lawrence, & W. T. Nord (Eds.), *The SAGE handbook of organization studies*. London: SAGE Publications Inc.

Maguire, S., Allen, P. M., & McKelvey, B. (2011). Complexity and Management: Introducing the SAGE Handbook. In P. Allen, S. Maguire, & B. McKelvey (Eds.), *The SAGE Handbook of Complexity and Management* (pp. 1–26). London: SAGE Publications Inc.

Malmberg, A., & Power, D. (2005). (How) Do (Firms in) Clusters Create Knowledge? *Industry & Innovation*, *12*(4), 409–431.

Malmberg, A., & Power, D. (2006). True Clusters: a severe case of conceptual headache. In B. T. Asheim, P. Cooke, & R. Martin (Eds.), *Clusters and Regional Development: Critical Reflections and Explorations* (pp. 30–49). Oxon: Routledge.

Manickam, A., Matthee, H., & ter Veer, B. (2015). A New Take on Energy. Groningen: Hanze University of Applied Sciences Groningen.

Manickam, A., & van Berkel, K. (2014). Clusters and how to make it work: Cluster Strategy Toolkit. In *Results Opening Up 2011-2014*. Groningen: Hanze University of Applied Sciences Groningen.

Manickam, A., & van Berkel, K. (2012). *Adaptive Policy Framework for Cluster Development [unpublished working paper]*.

Mans, P., Alkemade, F., van der Valk, T., & Hekkert, M. P. (2008). Is cluster policy useful for the energy sector? Assessing self-declared hydrogen clusters in the Netherlands. *Energy Policy*, *36*(4), 1375–1385.

Marion, R., & Uhl- Bien, M. (2011). Implications of complexity science for the study of leadership. In P. Allen, S. Maguire, & B. McKelvey (Eds.), *The SAGE Handbook of Complexity and Management* (pp. 385–399). London: Sage.

Martin, B. R. (2012). The Evolution of Science Policy and Innovation Studies. *Research Policy*, *41*(7), 1219–1239.

Martin, R., & Sunley, P. (2003). Deconstructing clusters: chaotic concept or policy panacea? *Journal of Economic Geography*, *3*(1), 5–35.

Martin, R., & Sunley, P. (2006). Path dependence and regional economic evolution. *Journal of Economic Geography*, *6*(4), 395–437.

Martin, R., & Sunley, P. (2007). Complexity thinking and evolutionary economic geography. *Journal of Economic Geography*, *7*(5), 573–601.

Martin, R., & Sunley, P. (2012). Forms of emergence and the evolution of economic landscapes. *Journal of Economic Behavior & Organization*, *82*(2–3), 338–351.

Martin, R., & Sunley, P. (2015). Towards a Developmental Turn in Evolutionary Economic Geography? *Regional Studies*, *49*(5), 712–732.

Maskell, P. (1999). Localised learning and industrial competitiveness. *Cambridge Journal of Economics*, *23*(2), 167–185.

Maskell, P., & Kebir, L. (2005). *What qualifies as cluster theory? Danish Research Unit for Industrial Dynamics* (No. Working Paper 05-09). Retrieved from http://www2.druid.dk/conferences/working_papers.php.

Maskell, P., & Kebir, L. (2006). What qualifies as a cluster theory? In B. T. Asheim, P. Cooke, & R. Martin (Eds.), *Clusters and Regional Development: Critical Reflections and Explorations* (pp. 30–49). Oxon: Routledge.

McCann, P. (2008). Agglomeration economies. In C. Karlsson (Ed.), *Handbook of Research on Cluster Theory*. Cheltenham: Edward Elgar.

McKelvey, B. (1997). Perspective-quasi-natural Organization Science. *Organization Science*, *8*(4), 352–380.

McKelvey, B. (1999). Avoiding Complexity Catastrophe in Coevolutionary Pockets: Strategies for Rugged Landscapes. *Organization Science*, *10*(3), 294–321.

McKelvey, B. (2001). MicroStrategy from MacroLeadership: Distributed intelligence via new science. In A. Y. Lewin & H. Volberda (Eds.), *Mobilizing the self-renewing organization: The coevolution advantage*. ME Sharp.

Mckelvey, B. (2003). Using Complexity Science to Foster Distributed Seeing. *Probing the Future*.

McKelvey, B. (2011). A Scientific Realist Epistemology for Complexity Science. In P. Allen, S. Maguire, & B. McKelvey (Eds.), *The SAGE Handbook of Complexity and Management* (pp. 113–130). London: SAGE Publications Inc.

Meadow, D. H. (1999). *Leverage Points: Places to Intervene in a System*. Hartland: Sustainability Institute.

Merali, Y., & Allen, P. (2011). Complexity and systems thinking. In P. Allen, S. Maguire, & B. McKelvey (Eds.), *The SAGE handbook of Complexity and Management* (pp. 31–52). London: SAGE Publications Inc.

Mischen, P. A., & Jackson, S. K. (2008). Connecting the dots: applying complexity theory, knowledge management and social network analysis to policy implementation. *Public Administration Quarterly*, *32*(3), 314–338.

Mitleton-Kelly, E. (2003). Ten Principles of Complexity & Enabling Infrastructures. In E. Mitleton-Kelly (Ed.), *Complex Systems and Evolutionary Perspectives on Organizations: The Application of Complexity Theory to Organisations* (pp. 23–50). Elsevier. ISBN 0-08-043957-8

Mitusch, K., Montobbio, F., Tran, C. A., Cusmano, L., & Malerba, F. (2010). *National Specialisation Report: Tomorrow's Innovative Industries: Regional and national specialisation patterns and the role of the regional business environment [Output Paper of Workshop]*.

Moodysson, J., Coenen, L., & Asheim, B. (2008). Explaining spatial patterns of innovation: Analytical and synthetic modes of knowledge creation in the Medicon Valley life-science cluster. *Environment and Planning A*, *40*(5), 1040–1056.

Morrison, K. (2012). Searching for causality in the wrong places. *International Journal of Social Research Methodology*, *15*(1), 15–30.

Mulgan, G., & Leadbeater, C. (2013). *Systems Innovation: Discussion Paper*. *Nesta*. Retrieved 9 January 2014 from http://www.nesta.org.uk.

Navarro, M., Gibaja, J. J. (2012). Typologies of Innovation Based on Statistical Analysis for European and Spanish Regions. In B. T. Asheim & M. D. Parrilli (Eds.), *Interactive Learning for Innovation – A Key Driver within Clusters and Innovation Systems*. London: Palgrave Macmillan.

Nelson, R. R., Winter, S. G. (1982). *An Evolutionary Theory of Economic Change*. Cambridge: Harvard University Press.

Noor, K. (2008). Case Study : A Strategic Research Methodology. *American Journal of Applied Sciences*, *5*(11), 1602–1604.

Noorderlijke Provincies, & Energy Valley. (2014). *Energiemonitor Noord-Nederland (3de editie)*. Retrieved from https://www.energyvalley.nl/uploads/bestanden/ca64b7eb-e5c9-49f9-90e8-11485d8c3486

Noord-Nederland, E. V. R., & Rijksoverheid. (2011). Green Deal Noord-Nederland. Retrieved from https://www.energyvalley.nl/uploads/bestanden/e32eb386-aee4-476c-be76-60414b3fd5e8

Nooteboom, B. (2002). Discussion of leadership and cultural change: An economic analysis. *De Economist*, *150*(4), 439–452.

Nooteboom, B. (2000). *Learning and Innovation in Organizations and Economics*. Oxford: Oxford University Press.

North Netherlands Cluster Organizations. (2013). *De Plus van Noord Nederland: Roadmap samenwerking Noordelijke clusters, v.1.3*.

North Netherlands Cluster Organizations. (n.d.). *De Plus van Noord-Nederland: Noordelijke Crossovers [Bijlagen/Attachments]*.

OECD. (2001). *Innovative clusters: drivers of national innovation systems*. Paris: OECD. Retrieved 27 August 2012 from http://www.oecd.org/publishing

OECD. (2007). *Competitive Regional Clusters: National Policy Approaches*. Paris. Retrieved 4 June 2015 from http://www.oecd.org/gov/regional-policy/competitiveregionalclustersnationalpolicyapproaches.htm

OECD. (2008). *OECD Reviews of Regional Innovation: Piedmont, Italy*. Retrieved from http://www.oecd.org/officialdocuments/publicdisplaydocumentpdf/?cote=GOV/TDPC(2008)14&docLanguage=En

OECD. (2011). *Policy Brief: Regions and Innovation Policy*. Retrieved from http://www.oecd.org/gov/regional-policy/oecdreviewsofregionalinnovationregionsandinnovationpolicy.htm

OECD. (2014). *OECD Reviews of Innovation Policy: Netherlands 2014*. Retrieved from http://asset.keepeek-cache.com/medias/domain21/_pdf/media1796/281693-wl5ayagv99/large/0.jpg

OECD Global Science Forum. (2009). *Applications of Complexity Science for Public Policy: New Tools for Finding Unanticipated Consequences and Unrealized Opportuinies*. Retrieved from http://www.oecd.org/dataoecd/44/41/43891980.pdf.

Olsen, E. E., & Eoyang, G. H. (2001). *Facilitating organization change: lessons from complexity science*. San Francisco: Jossey Bass.

Orkestra-Basque Institute of Competitiveness. (2009). *2nd Report on the Competitiveness of the Basque Country: Towards an Innovation-based Competitive Stage.* San Sabastian.

Pecqueur, B. (2008). Territorial dynamics: Towards a New Model of Development Facing Globalization. In M. J. A. Querejeta, C. I. Landart, & J. Wilson (Eds.), *Networks, Governance and Economic Development: Bridging Disciplinary Frontiers* (pp. 30–39). Cheltenham: Edward Elgar Publishing.

Pellissier, R. (2012). A proposed frame of reference for complexity management as opposed to the established linear management strategies. *International Journal of Organizational Innovation (Online), 5*, 6–67.

Poire, M.J., Sabel, C. F. (1984). *The Second Industrial Divide: Possibilities for Prosperity*. New York: Basic Books.

Porter, M. E. (1988). Clusters and the new economics of competition. *Harvard Business Review, 76*(6), 77–90.

Porter, M. E. (1990). The Competitive Advantage of Nations. *Harvard Business Review*, *68*(2), 72–93.

Porter, M. E. (2008). *On Competition*. Harvard Business Press.

Porter, M. E. (2003). The Economic Performance of Regions. *Regional Studies, 37*(6–7), 549–578.

Prahalad, C. K., & Krishnan, M. S. (2008). *The New Age of Innovation, Driving Cocreated Value through Global Networks*. New York: McGraw Hills.

Price Waterhouse Coopers (PWC). (2011). *Regional Biotechnology: Establishing a methodology and performance indicators for assessing bioclusters and bioregions relevant to the KBBE area*. Retrieved from http://ec.europa.eu/research/bioeconomy/pdf/regional-biotech-report.pdf

Price Waterhouse Coopers (PWC). (2011). Proposed approach for the identification of newly emerging industries [Presentation Slides]. In *Cluster Conference – Polish Presidency*

Paper Province. [Website]. Paper Province. Retrieved from http://paperprovince.com/en/

Provincie Noord-Holland. (2012). *Economische Agenda 2012-2015 Samenvatting*. Haarlem. Retrieved from http://www.noord-holland.nl

Querejeta, M. J. A., Amonarriz, C. A., Aranguren, M. L., & Landart, C. I. (2008). Does Cluster Policy Really Enhance Networking and Increase Competitiveness? In M. J. A. Querejeta, C. I. Landart, & J. R. Wilson (Eds.), *Networks, Governance and Economic Development: Bridging Disciplinary Frontiers* (p. p.101-128.). Cheltenham: Edward Elgar Publishing.

Querejeta, M. J. A., Landart, C. I., & Wilson, J. R. (Eds.). (2008). *Networks, Governance and Economic Development: Bridging Disciplinary Frontiers*. Cheltenham: Edward Elgar Publishing.

Ramalingam, B., Jones, H., Reba, T., & Young, J. (2008). *Exploring the science of complexity : Ideas and implications for development and humanitarian efforts* (No. 285). London: ODI. Retrieved from http://www.odi.org.uk/rapid/publications/RAPID_WP_285.html

Regional Studies Association. (2016). Resilience Revisited. *Regional Studies*, *50*(4), 557–560.

Regional Technology Strategies Inc. (2003). *The Wood-Based Product Cluster*. Carrboro. Retrieved from http://www.rtinc.org

Rehfeld, D., Terstriep, J. (2013). Socio-cultural dynamics in spatial policy: Explaining the on-going success of cluster policices. In P. Cooke (Ed.), *Re-framing Regional Development*. Oxon: Routledge.

Rehfeld, D., & Terstriep, J. (2013). Socio-cultural dynamics in spatial policy: explaining the on-going success of cluster politics. In P. Cooke (Ed.), *Re-framing Regional Development: Evolution, Innovation and Transition* (pp. 274–294). Oxon: Routledge.

Remenyi, D. (2013). *Case Study Research* (2nd ed.). Academic Conferences and Publishing International. Retrieved from http://www.academic-bookshop.com

Reynolds, M., Forss, K., Hummelbrunner, R., Marra, M., & Perrin, B. (2012). Complexity, systems thinking and evaluation-an emerging relationship? *Evaluation Connections: Newsletter of the European Evaluation Society*, 7–9. Retrieved from http://www.europeanevaluation.org/library/connections.htm

Rhodes, M. L. (2008). Complexity and Emergence in Public Management: The case of urban regeneration in Ireland. *Public Management Review.*, *10*(3), 361–379.

Rifkin, J. (2004). *The European Dream: How Europe's Vision of the Future is Quietly Eclipsing the American Dream*. New York: Jeremy P. Tarcher Inc.

Rijksdienst voor Ondernemend Nederland. (2014). *Rapportage Hernieuwbaar energie 2003-2013*. Retrieved from http://www.rvo.nl

Ritchey, T. (2005). Wicked problems: structuring social messes with morphological analysis. Retrieved 15 Augustus 2011 from http://www.swemorph.com

Ritchey, T. (2013). Wicked Problems, Modelling Social Messes with Morphological Analysis. *Acta Morphologica Generalis*, *2*(1), 1–8.

Rittel, H., & Weber, M. (1973). Dilemmas in a General Theory of Planning. *Policy Studies*, *4*, 155–169.

Roberts, S. (2006). Energy as a driver of change. *The Arup Journal*, *2*, 22–28. Retrieved from http://www.forevueinternational.com/Content/sites/forevue/pages/1396/6_2_6_Energy_as_a_Driver_of_Change_Arup.PDF

Rotmans, J. (2012). *In het Oog van de Orkaan: Nederland in Transitie*. Bostel: Aeneas.

Rowley, J. (2002). Using case studies in research. *Management Research News*, *25*(1), 16–27.

Samenwerkingsverband Noord-Nederland (SNN). (2005). *Strategische agenda voor Noord-Nederland 2007-2013*. Groningen. Retrieved from http://www.snn.eu/upload/documenten/europa/strategische_agenda.pdf

Samenwerkingsverband Noord-Nederland (SNN). (2012). *Position Paper: The Northern Netherlands and the EU 2020*. Retrieved from http://www.snn.eu/upload/documenten/over-snn/position-paper-northern-netherlands-and-eu-2020.pdf

Saunders, M., Lewis, P., Thornhill, A. (2009). *Research Methods for Business Students* (5th ed.). New Jersey: Financial Times Prentice Hall.

Saxenian, A. (1994). *Regional Advantage: Cultural and Competition in Silicon Valley and Route 128*. Cambridge: Harvard University Press.

Science Business Report. (2012). *The Energy Technology Road Map: How to Plan Europe's Energy Future.* Retrieved from www.sciencebusiness.net

Skalman, K. N., & Mitroczuk, I. J. (2009). EU Strategy for the Baltic Sea Region adopted by EC in October 2009 [presentation].

Smith, H. L. (2008). Inter-firm networks in high-tech clusters. In C. Karlsson (Ed.), *Handbook of Research on Cluster Theory*. Cheltenham: Edward Elgar.

Smith, M., & Brown, R. (2009). Exploratory Techniques for Examining Cluster Dynamics: A Systems Thinking Approach. *Local Economy*, *24*(4), 283–298.

Snowden, D. J., & Boone, M. E. (2007). A Leader's Framework for Decision Making. *Harvard Business Review*, *85*(11), 68–76, 149.

Sociaal-Economische Raad (SER). (2013a). *Energieakkoord voor duurzame groei*. *SER*. Den Haag. Retrieved from http://www.energieakkoordser.nl/

Sociaal-Economische Raad (SER). (2013b). *Energy Agreement for Sustainable Growth (Energieakkoord voor duurzame groei, 06-09-2013)*.

Social Research Association. (2003). *Ethical guidelines*. Retrieved from http://the-sra.org.uk/wp-content/uploads/ethics03.pdf

Sölvell, Ö. (2008). *Clusters: Balancing Evolutionary and Constructive Forces*. Stockholm: Ivory Tower Publishers. Retrieved from http://www.tci-network.org/uploads/media/CKC/0001/02/fa79d48783777be8c52111f2bd40b1a84263dfaf.pdf

Sölvell, Ö., Lindqvist, G., & Ketels, C. (2003). *The Cluster Initiative Greenbook. The Competiveness Institute*. Stockholm: Ivory Tower Publishers. Retrieved from https://www.hhs.se/contentassets/f51b706e1d644e9fa6c4d232abd09e63/greenbooksep03.pdf

Sölvell, Ö., & Williams, M. (2013). *Building the Cluster Commons, Evaluation of 12 Cluster Organizations in Sweden 2005-2012*. Stockholm: Ivory Tower Publishers. Retrieved from http://www.clusterobservatory.eu/system/modules/com.gridnine.opencms.modules.eco/providers/getpdf.jsp?uid=7a70a31d-3f8a-41c9-b415-f88e464d116a

Sotarauta, M., & Srinivas, S. (n.d.). *The Co-evolution of Policy and Economic Development: A discussion on Innovative Regions*. *MIT IPC Local Innovation Systems Papers*. Retrieved from http://web.mit.edu/lis/papers/LIS05-001.pdf

Stacey, R. (1995). The Science of Complexity: An Alternative Perspective for Strategic Change Processes. *Strategic Management Journal*, *16*(6), 477–495.

Stacey, R. (2007). *Strategic Management and Organizational Dynamics* (5th ed.). Harlow: Financial Times Prentice Hall.

Stacey, R. (2016). The Paradox of Consensus and Conflict in Organisational Life. *International Journal of Appreciative Inquiry*, *18*(1), 52–58. http://doi.org/10.12781/978-1-907549-26-7

Starkey, K. (2001). In Defence of Modes One, Two, and Three: a response. *British Journal of Management*, *12*, 1–80. http://doi.org/10.1111/1467-8551.12.s1.10

Steiner, M. (2006). Do clusters “think”? In R. Asheim, B., Cooke, P, Martin (Ed.), *Clusters and Regional Development: Critical Reflections and Explorations*. London: Routledge.

Storper, M. (1997). *Regional Polarization and Economic Development in Industrializing countries: a Reinterpretation*. Los Angeles: Berkeley.

Storper, M. (1992). The limits to Globalization: Technology Districts and International Trade. *Economic Geography*, *68*, 260–283.

Suurs, R. (2009). Motors of sustainable innovation: Towards a theory on the dynamics of technological innovation systems [Thesis] (p. 304). Utrecht.

Swanson, D., & Bhadwal, S. (Eds.). (2009). *Creating Adaptive Policies: A guide for policy-making in an uncertain world* (New Delhi). SAGE Publications Inc.

Tactics Project. (2012). *Key Messages and Practical Recommendations from Tactics Project*. (E. Wise & C. Johansson, Eds.). Brussels: European Cluster Alliance-Tactics. Retrieved April 2013 from http://www.ECA-TACTICS.eu

Tactics Project. (2012). *Where the cluster winds are blowing in Europe*. (E. Wise & C. Johansson, Eds.). European Cluster Alliance-Tactics. Retrieved April 2013 from http://www.ECA-TACTICS.eu

Tan, B. S., & Thai, V. V. (2015). Global knowledge hubs: introducing a new conceptual model. *International Journal of Knowledge-Based Development*, *6*(2), 131–151.

Tan, C. S., Mohd Sood, S. B., & Leong, Y. P. (2011). *Sustainability Development through Energy Efficiency Initiatives in Malaysia* (No. 04–05). *Green & Energy Management*. Retrieved from http://www.uniten.edu.my/newhome/uploaded/admin/research/centres/iepre/2012/papers/Sustainability Development through Energy Efficiency Initiatives in Malaysia.pdf

The CLUNNET-European Cluster Alliance Consortium of Partners. (2010). *Improving the Cluster Infrastructure through Policy Actions*. Retrieved from http://www.proinno-europe.eu/clunet/publications

The Health Foundation. (2010). *Evidence Scan: Complex Adaptive Systems*. *The Health Foundation*. London. Retrieved from http://www.health.org.uk

Todtling, F., & Trippl, M. (2005). One size fits all? Towards a differentiated regional innovation policy approach. *Research Policy*, *34*(8), 1203–1219.

Todtling, F., & Trippl, M. (2013). Transformation of regional innovation systems: from old legacies to new development paths. In P. Cooke (Ed.), *Re-framing Regional Development: Evolution, Innovation and Transition* (pp. 297–317). Oxon: Routledge.

Turok, I. (2014). The Resilience of South African Cities a Decade after Local Democracy. *Environment and Planning A, 46*(4), 749–769.

Tuytens, P., Reid, A., & Miedzinski, M. (2013). *A framework for analysing global trends and drivers in the context of designing smart specialisation strategies*. *Technopolis Group*. Retrieved from http://www.technopolis-group.com

United Nations Economic Commission for Europe: Committee on Sustainable Energy: Working Party on Gas. (2012). *The Impact of Liberalization of Natural Gas Markets in the UNECE region--Efficiency and Security*. New York.

Uyarra, E. (2010). What is evolutionary about “regional systems of innovation”? Implications for regional policy. *Journal of Evolutionary Economics*, *20*(1), 115–137.

Uyarra, E., & Flanagan, K. (2013). Reframing regional innovation systems. In P. Cooke (Ed.), *Re-framing Regional Development* (pp. 146–163). Oxon: Routledge.

Van de Ven, A. H. (2007). *Engaged Scholarship: A Guide for Organizational and Social Research.* Oxford: Oxford University Press. Retrieved from http://www.oup.com

van der Steen, M. (1999). *Evolutionary Systems of Innovations: A Veblian-oriented study into the role of the government factor [Thesis]*. University Twente.

van der Steen, M., van Twist, M., Fenger, M., & Le Cointre, S. (2013). Complex causality in improving underperforming schools: A complex adaptive systems approach. *Policy and Politics*, *41*(4), 551–567.

Varney, S. (2007). Complexity uncovered. Retrieved February 4, 2012, from http://spaceforlearning.com/wp-content/uploads/2013/08/Complexity-uncovered-Sharon-Varney-Aug-07.pdf

Venton, S. (2011). Why Sensemaking is Needed for Environmental Leadership. *Business Leadership Review*, *VIII*(IV), 1–11. Retrieved November 2011 from http://www.mbaworld.com/blr

Viitanen, J., Markkula, M., & Soler, C. R. (n.d.). Systemic Development of Regional Innovation Ecosystems: Modernizing the Triple Helix. Retrieved 9 July 2013, from https://www.academia.edu/3984588/Systemic_Development_of_Regional_Innovation_Ecosystems_Modernizing_the_Triple_Helix

VINNOVA. (2010). *The Matrix: Post cluster innovation policy [REPORT]*. (A. Eriksson, Ed.). Retrieved from http://www.VINNOVA.se

Vogelsang, J. (2002). Futuring: A Complex Adaptive Systems Approach to Strategic Planning. *OD Practioner*, *34*(4), 8–12.

Wagner, F. (2014). Electricity by intermittent sources: An analysis based on the German situation 2012. *European Physical Journal Plus, 129*(20), 1–18. http://doi.org/10.1140/epjp/i2014-14020-8

Waxell, A. (2009). Guilty by association: A cross-industrial approach to sourcing complementary knowledge in the Uppsala Biotechnology Cluster. *European Planning Studies*, *17*(11), 1605–1624.

Weick, K. E. (n.d.). Leadership When Events Don’t Play by the Rules. Retrieved March 20, 2001, from http://www.bus.umich.edu/FacultyResearch/Research/TryingTimes/Rules.htm

Weick, K. E. (1979). *The Social Psychology of Organizing*. Reading: Addison-Wesley.

Weick, K. E. (1989). Theory Construction as Disciplined Imagination. *Academy of Management Review*, *14*(4), 516–531.

Weick, K. E. Sensemaking in Organization (1995). Thousand Oaks: SAGE Publications Inc.

Weick, K. E. (2001). *Making Sense of the Organization*. Malden: Blackwell Publishing.

Weick, K. E., & Sutcliffe, K. M. (n.d.). Managing the Unexpected: Business organizations must learn to operate “mindfully” to ensure high performance. Retrieved March 20, 2001, from http://www.bus.umich.edu/FacultyResearch/Research/ManagingUnexpected.htm

Weick, K. E., Sutcliffe, K. M., & Obstfeld, D. (2005). Organizing and the Process of Sensemaking. *Organization Science, 16*(4), 409–421.

Weick, K. E., & Sutcliffe, K. M. (2007). *Managing the Unexpected: Resilient Performance in an Age of Uncertainty* (2nd ed.). San Francisco: Jossey-Bass.

Wetenschappelijke en Technologische Commissie voor de biobased economy. (2013). *Strategie voor een groene samenleving*. Retrieved from http://www.biobased-society.eu

Williams, M. (2012). The Paper Province - From white spot to a world class cluster [presentation slide]. http://doi.org/10.2776/70221

Wixted, B. (2006). *Cluster Complexes: A Framework for Understanding the Internationalisation of Innovation Systems*. *MPRA paper*. Retrieved from http://mpra.ub.uni-muenchen.de/846/, also in, *Science And Technology, 4*, 1–31.

Wolfe, D. A. (2009). Introduction: Embedded Clusters in the Global Economy. *European Planning Studies, 17*(2), 179–187.

Wolfe, D. A. (2013). Regional Resilience, cross-sectoral knowledge platforms and the prospects for growth in Canadian city-regions. In P. Cooke (Ed.), *Re-framing Regional Development: Evolution, Innovation and Transition* (pp. 54–72). Oxon: Routledge.

Wolfe, D. A., & Gertler, M. S. (2004). Clusters from the Inside and Out: Insights from the Canadian Study of Cluster Development. *Urban Studies*, *41*(5/6), 1071–93.

Wolfe, D. A., & Lucas, M. (Eds.). (2005). *Global Networks and Local Linkages: The Paradox of Cluster Development in an Open Economy*. Montreal and Kingston: McGill-Queesn's University Press and Queen's School of Policy.

Wolfe, D. A., & Nelles, J. (2009). *The Strategic Management of Urban Economies and the Scope for Intermunicipal Cooperation: Alternative Approaches to Economic Development in Ontario*. *Ontario in the Creative Age*. Retrieved from http://martinprosperity.org/media/pdfs/Strategic-Management-of-Urban-Economies-DWolfe.pdf

World Economic Forum. (2012). *New Energy Architecture Enabling an effective transition*. *World Economic Forum*.

World Energy Council. (2010). *Roadmap towards a Competitive European Energy Market*. *World Energy Council*. Retrieved from http://www.worldenergy.org

World Energy Council. (2012). *Survey of Energy Resources: Shale Gas – What's New*. Retrieved 10 March 2014 from http://www.worldenergy.org

World Energy Council. (2013a). *2013 World Energy Issues Monitor*. London. Retrieved 10 March 2014 from http://www.worldenergy.org

World Energy Council. (2013b). World Energy Trilemma: Time to get real – the agenda for change. Retrieved from http://www.worldenergy.org

World Energy Council. (2014). *World Energy Trilemma 2014: Time to get real – the myths and realities of financing energy systems*. Retrieved December 2014 from http://www.worldenergy.org

World Energy Council. (2015). *2015 World Energy Issues Monitor: Energy price volatility: the new normal*. Retrieved March 2015 from http://www.worldenergy.org

Yin, R. K. (2009). *Case Study Research: Design and Methods: Essential guide to qualitative methods in organizational research* (4th ed.). Thousand Oaks: SAGE Publications Inc.

Yin, R. K. (2014). *Case Study Research: Design and Methods* (5th ed.). Thousand Oaks: SAGE Publications Inc.

Zimmerman, B. (2011). How Complexity Science is Transforming Healthcare. In P. M. Allen, S. Maguire, & B. McKelvey (Eds.), *The SAGE Handbook of Complexity and Management* (pp. 617–635). London: SAGE Publications Inc.

*Appendices*

*'Future of Cluster Developments: Case study of Energy Valley, The Netherlands'*

TABLE OF CONTENTS

# 1. BACKGROUND ON ENERGY VALLEY CLUSTER

**Introduction**

This is a background report of the Dutch organisation the Energy Valley Foundation (Stichting Energy Valley). This report provides information about the Dutch national policy, the importance of Energy Valley in comparison to the Dutch economy and energy sector, the organisation, its organisational structure, its partners, the strategy of the Energy Valley Foundation, and will end with the organisation's current projects.

**National Policy**

In June 2001, the Dutch government introduced the fourth Dutch National Environmental Policy Plan (NMP4). It is an agreement of the government, market, trade unions and NGO's, organised by the Social-Economic Council (SER). The plan included drastic targets for emission reductions with the goal to transit the Dutch system towards a more sustainable, carbon-poor energy system. Important contributors to this goal were improved energy efficiency, renewables, clean fossil fuels, nuclear energy, structural economic changes and changes in consumption patterns. This was the beginning of the Dutch transition management approach, and this in turn, shaped the energy transition approach and practice in Energy Valley.

*Historical Context*

In the history of the Netherlands, three phases have been identified in the energy transition process.

The first phase started in the 20$^{th}$ century and ended in 1945. In this period, there was a huge increase in the use of electricity and coal as city gas as a result of the industrialisation. This was coordinated locally and regionally by the respective governments. Due to an increase in use, energy productions became more centralised. The local electricity management started to shift towards provincial and national governments where the power producers were jointly responsible for the balancing and supply. City gas was controlled on regional level by large private and state-owned cooperation's involved in coke production.

The second phase lasted from 1945 up to 1980. During this phase, a new cheap source of gas was discovered: the natural gas field. This resulted in a system-wide transformation of the Dutch energy carriers: coal shifted to gas, and coal to petrol and other synthetic-based chemical industry. There was rapid population and economic growth, and automobile usage increased massively. The government's energy cooperation, DSM, shifted from coke to gas production and created the ‘gas house’ to manage the gas energy system. The state government, through DSM, Royal Dutch Oil and Exxon jointly were joint owners of the ‘gas house’, and Gasunie was set-up to run the operations.

During the final era (1980 till present), main sources of energy were fossil fuels consisting of natural gas and oil; sustainable sources were a small part of the energy mix. In this period, political issues associated with energy arose due to environmental awareness. There were debates about nuclear energy, fossil fuel sources, oil-production, air quality and global warming (Loorbach, 2009). Moreover, a new trend towards privatisation and liberalisation took place.

*Present Context*

In 2013, the SER developed the Energy Agreement for Sustainable Growth covering 2013 to 2020. The objectives of this agreement are preservation, clean technology and climate policy. The aim is to generate 14% of all energy in a sustainable manner, and to create 15.000 fulltime jobs by the end of 2020. The agreement shows a commitment of the government, market players, employers’ associations and unions, NGOs and financial institutions to creating a sustainable society and economy.

**Significance of Energy Valley in Numbers**

Over the years, Energy Valley cluster became important to the total Dutch economy and the energy sector. In 2013, Energy Valley region’s total added value was 12% of Dutch total added value. The energy sector contributed 5.1% of value added in the Netherlands. In the Energy Valley region 21% of the added value came from the energy sector (Energy Valley, 2013). Table 1 shows the absolute numbers of value added in the energy sector of Energy Valley and the Netherlands in comparison to the total added value of the region and country.

| | **Netherlands** | **EV region** |
|---|---|---|
| Energy Sector | € 29.3 billion | € 14.8 billion |
| Total | € 578.9 billion | € 70.2 billion |

*Table 1: Added value energy sector in comparison to total economy (Energy Valley, 2013)*

The Energy Valley region accounted for 21.8% of the total renewable energy consumption of the Netherlands. Figure 1 illustrates the final consumption of renewable energy in PJ of the Netherlands and the Energy Valley region in 2013.

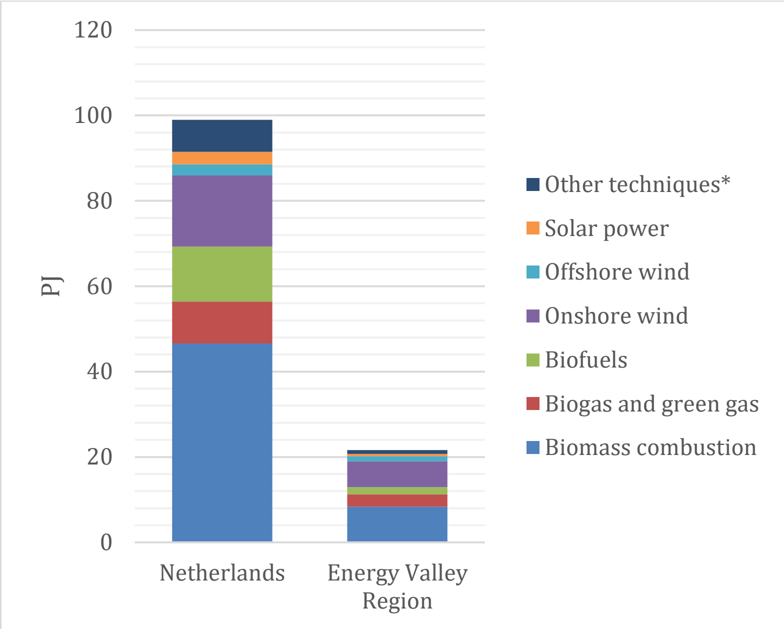



*Figure 1: Final consumption of renewable energy in PJ (Energy Valley, 2013)*[1]

The projects of the Energy Valley region are financed through investments. Figure 2 displays the investments in the Energy Valley region in the years 2003 to 2018. 68% of the investments (€17.7 billion) are invested in conventional energy, and approximately 31% (€8.1 billion) in energy transition and energy efficiency. These investments are mainly in wind energy and bio energy (EnergieMonitor, 2012).

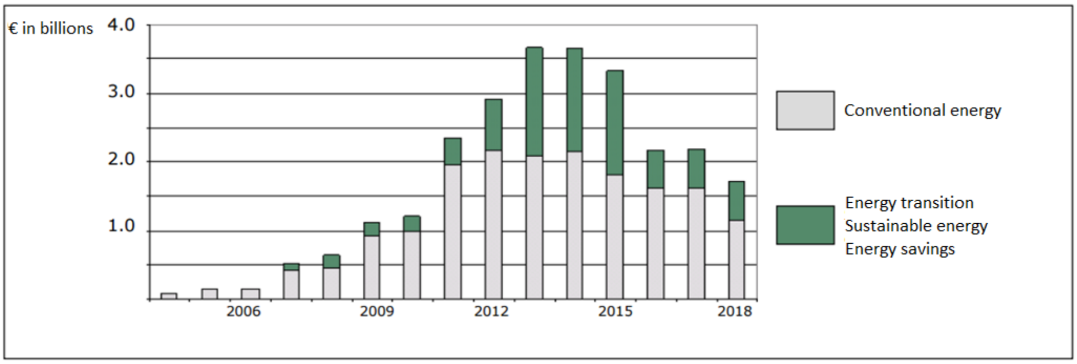



*Figure 2: Investments in the Energy Valley Region 2003 – 2018 (EnergieMonitor, 2012)*

Energy Valley had a significant impact on employment in the energy sector. Table 1 illustrates the numbers of jobs in the energy sector of the Netherlands in comparison to Energy Valley. Here, it can be seen that the Energy Valley region accounts for 13% of the total amount of jobs in the total Dutch energy sector.

1 * *Geothermal energy, hydropower and outdoor air heat*

| | | Netherlands | EV Region |
|---|---|---|---|
| **Core*** | Jobs<br>Share (NL/EV) | 78,475<br>100%/n.a. | 10,875<br>14%/100% |
| **Shell**** | Jobs<br>Share (NL/EV) | 168,450<br>100%/n.a. | 20,425<br>12%/100% |
| **Total** | **Jobs**<br>**Share (NL/EV)** | **246,925**<br>**100%/n.a.** | **31,300**<br>**13%/100%** |

*Table 2: Employment energy sector (Energy Valley, 2013)*[2]

**Energy Valley Foundation: an overview**

The Energy Valley Foundation is a network organisation that facilitates the collaboration of companies, knowledge institutions and governments with the purpose of strengthening the regional renewable energy economy. The region of Energy Valley lies in the North of the Netherlands and encompasses the provinces of Groningen, Drenthe, Friesland and Noord-Holland North. This region is the heart of the North-European gas- and power supply, and has a few important energy power ports.

In 2003, Energy Valley was founded in Groningen, the Netherlands, and became a joint venture of public and private partners in the North. The Energy Valley Foundation aims to stimulate the energy economy by advocating sustainable energy innovations that will expand business, jobs and knowledge within the region. The strategic partners finance the organisation on a project-basis.

Business and project development are the two core tasks of the Energy Valley Foundation. These core tasks help the organisation achieve its aim. As for business development, the organisation wants to stimulate energy innovations by encouraging entrepreneurs to develop products and services in the areas of sustainable gas and energy systems. The Energy Valley Foundation supports these initiators by providing a team of specialists who offer advise during the development process. With regards to project development, the organisation coordinates numerous projects that is intended to expand business, jobs and knowledge in the region. These are financed and executed by its partners.

**Organisational Structure**

[2] **Core: Producers and suppliers of energy; **Shell: Production and installation of energy technology and services focused on energy activities.*

Energy Valley Foundation has an independent Supervisory Board, a Strategic Board and an execution team of energy professionals and specialists. The Supervisory Board consists of three people, who monitor operations, personnel and finances. The role of the Strategic Board is to advise Energy Valley Foundation regarding strategic and substantive decisions. The ten members of the Strategic Board are representatives from the energy sector, governments and research institutions.

Energy Valley Foundation has a team of 17 energy professionals and specialists who are responsible for the implementation of core tasks of the organisation. They act as facilitator and driver for new (knowledge) projects and market concepts.

**Partners**

Since its inception, the Energy Valley Foundation has increased its number of strategic partners up to 25. Each partner provides various investments in new energy production, infrastructure and knowledge projects.

The strategic partners of Energy Valley Foundation in 2016 included Alliander, Attero, Eneco, Energy Academy Europe, Energy College, GasTerra, Gasunie, municipalities of Alkmaar, Assen, Den Helder, Emmen, Groningen and Leeuwarden, Groningen Seaports, Hanze University of Applied Sciences Groningen, NAM, NHL, provinces of Drenthe, Fryslân, Groningen and Noord-Holland, PWC, RUG, Stenden University of Applied Sciences and TAQA.

**Strategy**

In the preceding years, the organisation developed from a regional initiative to become a binding factor for the northern energy region nationally. During this time, the organisation contributed significantly to the sustainability of the Northern energy sector by encouraging energy innovations and developments; bringing parties together; identifying opportunities, and offering its expertise and knowledge to its strategic partners. Currently, Energy Valley's strategy also includes the European context. The strategic goals of Energy Valley Foundation are defined in its programme agenda.

*Programme Agenda 3 (2008 – 2011)*

The third programme agenda 'Energy Valley 3' mainly focused on improvements to the Dutch energy market by stimulating the energy-economy and -employment in the provinces of Drenthe, Groningen, Friesland and Noord-Holland (Energy Valley, 2011). The key tasks outlined were branding the Energy Valley region and stimulating innovative energy projects.

*Programme Agenda 4 (2012 to 2015)*

The goals of the fourth programme agenda ‘Energy Valley 4’ included further development of the regional energy market by expanding its renewable energy activities, and strengthening its competitive position in the European market.

**Projects**

The Energy Valley Foundation coordinated numerous projects in new energy production, infrastructure and knowledge, on a national and international basis.

*National*

In response to the Energy Agreement, the Energy Valley network developed the Northern Energy Program SWITCH in 2014. The goal of this programme was to increase generation of renewable energy in the region up to 21%, and to create 3.600 green jobs by 2020 (Energy Valley, 2016).

Furthermore, Energy Valley Foundation is involved in innovative projects for Gas, Bio-based Economy, Wind-on-Sea, Smart Grids, and Energy and Water. This complies with the Dutch top sector policy of the Ministry of Economic Affairs, which aims to promote growth in the Energy sector.

The Energy Valley Foundation has also secured Green Deal agreements with the national government. These Green Deals is expected to accelerate regional energy developments and projects, and eliminate barriers.

*International*

In recent years, Energy Valley Foundation has expanded its strategy focus by including the European market. This in order to strengthen their region position and accelerate innovations in Europe. The organisation joined forces with Germany, Scotland and Norway to combine efforts in energy generation in the region of the North Sea. The partnership is called the ‘European North Sea Energy Alliance’ (ENSEA). The main objectives of this agreement were exchanging knowledge between businesses and institutions, and aligning their energy systems and energy investments. The ENSEA project started on 1$^{st}$ of October 2012 and ended in 30 September 2015.

Another European project is the Clean Inland Shipping (CLINSH) project, in collaboration with Belgium, Germany and England, which focusses on the promotion of clean waterways. The CLINSH project is expected to start in 2016.

The organisation is also a member of the Benelux Energy Expertise Network since February 2015, and an associate of the Enterprise Europe Network to include Small-Medium energy enterprises in European programmes and partnerships.

*Acknowledgements to Eline Kos, IBS student research assistant and main author of Background Report on Energy Valley*

**Reference List**

Energy Valley (2012) *Energiemonitor Energy Valley en Regio Groningen-Assen.* Available at: https://www.energyvalley.nl/uploads/bestanden/56af73e4-b998-4d29-ad67-51371688ab96 (Accessed: 01 July 2016).

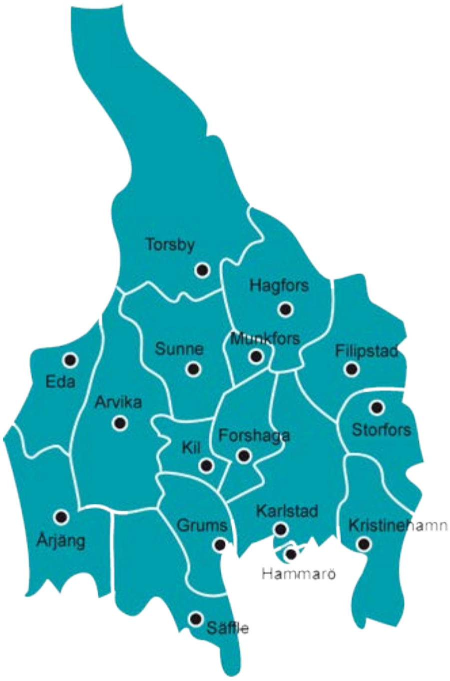
Energy Valley (2013) *Energiemonitor Noord-Nederland 4e editie (verslagjaar 2013).* Available at: https://www.energyvalley.nl/uploads/bestanden/afe838a5-0c45-4922-b0bf-17926204d77e (Accessed: 02 June 2016).

Energy Valley (2011) *Energy Valley 4: Energizing the Dutch Economy.* Available at: https://www.energyvalley.nl/uploads/bestanden/3621f0ef-e22f-44fa-aea3-88a9514aa822 (Accessed: 20 May 2016).

Energy Valley (2016) *(Inter)nationale beleidspositie.* Available at: https://www.energyvalley.nl/over-energy-valley/internationale-beleidspositie (Accessed: 20 May 2016).

Loorbach, D. (2009) 'Transition Management for Sustainable Development: A Prescriptive, Complexity-Based Governance Framework, *Governance,* 23 (1), pp.161-183. *Wiley* [Online]. Available at: http://onlinelibrary.wiley.com/doi/10.1111/j.1468-0491.2009.01471.x/abstract;jsessionid=D9941CBD3174CA1087823F6346353CB6.f04t01?userIsAuthenticated=false&deniedAccessCustomisedMessage= (Accessed: 17 May 2016).

# 2. BACKGROUND ON KARLSTAD'S PAPER PROVINCE

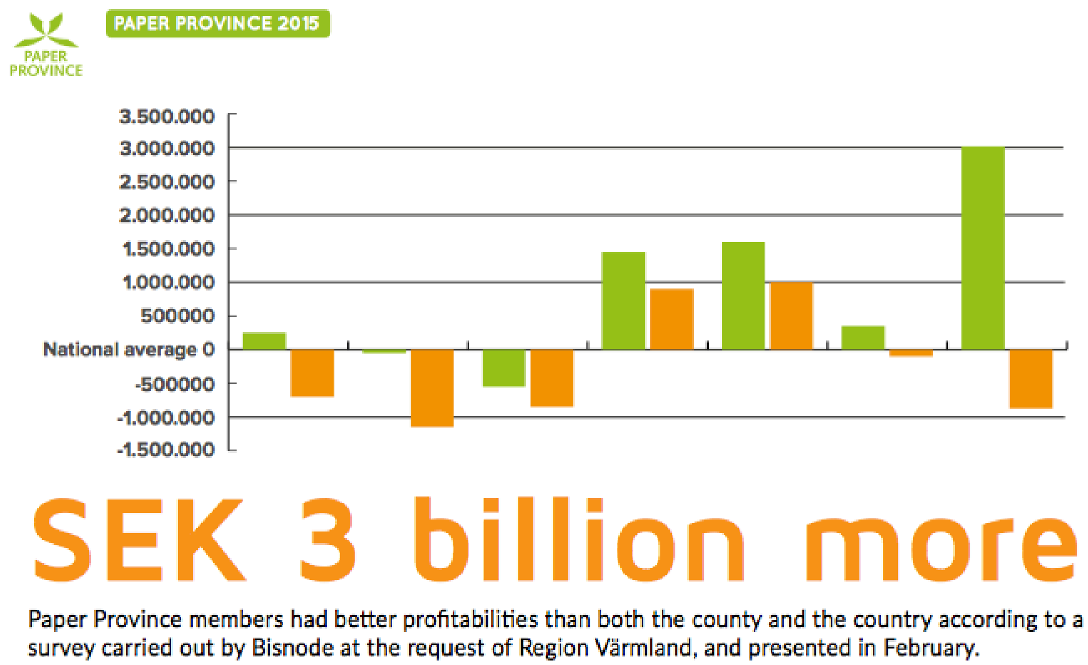



*Retrieved from, http://www.varmland.se/en/sok?keys=map*

The Paper Province (PP) was founded in 1999 and is owned and governed by about a hundred member companies. These companies included major global suppliers of pulp and paper machinery, a quarter of Sweden's pulp and paper mills and small and medium suppliers. These companies incorporate the entire value chain and the related services sector and are active in more than 100 countries.

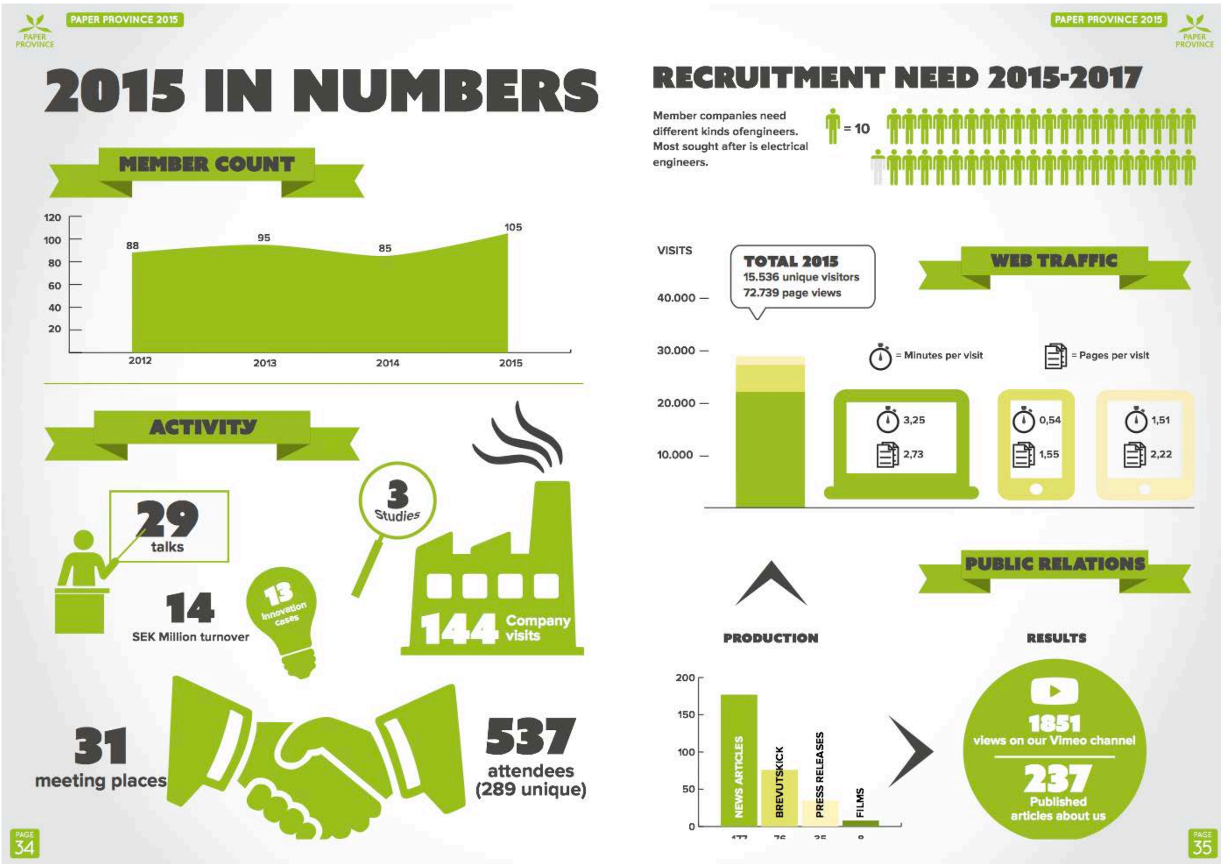
The region's concentration of more than 200 companies linked to the paper and pulp industry is unique as there is no comparison in the world showing similar accumulated expertise in the forest industry. The region has contributed to much of the technology found in pulp and paper mills worldwide.

The Paper Province is a well-developed business cluster that contributes to the region's growth and links it to global markets of products, services, people, capital and ideas. The cluster is also an important attractor of people, companies and investors. External studies have shown that being located in the Paper Province contributes to new products and services, increased sales and more jobs, see info-graphics below:




*Retrieved from http://paperprovince.com/wp-content/uploads/2015/01/annualreport_english_2015.pdf*

In addition, the next info-graphics provides an overview of its key results in 2015.




*Retrieved from http://paperprovince.com/wp-content/uploads/2015/01/annualreport_english_2015.pdf*

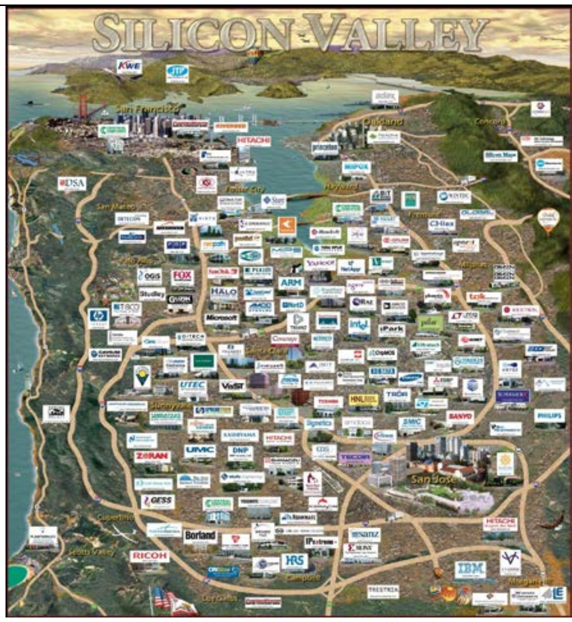
The next list captures it key milestones:

- 1999 The Paper Province was started as a project of seven companies to collaborate around supply of competence.
- 2003 The Paper Province is converted into an organization with more than 20 member companies.
- 2003 Started the Technology Club The Lusten of Värmland Museum, to ignite technological interest in general and paper technology in particular among the young.
- 2004 The Karlstad Technology Center, a big investment in higher education, was inaugurated in a PPP project in cooperation between Karlstas Municipality and Paper Province.
- 2004 Paper Province started The Packaging Greenhouse AB. The subsidiary bought a pilot machine from Metso Paper Karlstad. In this freestanding industrial environment, customers can test drive various base materials and hone their skills with the help of customized and process-related training courses.
- 2005 Paper Province is one of the initiators of the project, the Packaging Arena, an innovative environment for consumer-driven packaging development. In 2015, Paper Province and Packaging Arena decided to merger to gain mutual benefits.
- 2007 Paper Province was appointed one of the "Top European Clusters in High Innovation Regions" – the only one in Sweden. The European Cluster Observatory audited 2110 clusters from 230 countries.
- 2007 The Paper Province project "The Energy Square", a new international center for energy efficiency in the pulp and paper industry. An important link was made between universities, institutes and companies.
- 2010 Paper Province was named a European world-class cluster, one of 100 best clusters in the world. Paper Province had 90 member companies at that time.
- 2013 Paper Province was named one of the winners in The Swedish Innovation Agency, VINNOVAS' competition among regions, called "Vinnväxt". The price, approximately 130 million over ten years, to invest in a regional forest based bio-economy.
- 2014 The Paper Province is renamed Paper Province and changed its statutes; the association's aim now was to be a leading global player in forest-based bio-economy.
- 2015 Paper Province merges with the Packaging Arena and won significant expertise in packaging development.

*(Adapted from: https://paperprovince.com/en/om-oss/paper-province-historia/)*

# 3. BACKGROUND ON SILICON VALLEY

This background document on Silicon Valley is based on a joint report of the Bay Area Council Economic Institute and Booz & Company, *The Culture of Innovation, What Makes San Francisco Bay Area Companies Different?* (Jaruzelski *et al,* 2012) and all quotes are from this report unless otherwise indicated. This document refers to the Bay Area instead of Silicon Valley. The Bay Area is made up of nine counties and divided into the North Bay, South Bay, East Bay and the Peninsula with the city of San Francisco. The Bay Area is the official geographical region whilst Silicon Valley is the reference to a successful cluster of this region. Below are two maps that reflect the geographical and the 'cluster' with its successful businesses.




Retrieved from [https://www.quora.com/Whats-the-difference-between-The-Bay-Area-and-Silicon-Valley](https://www.quora.com/Whats-the-difference-between-The-Bay-Area-and-Silicon-Valley)

The Bay Area was known for its 'long history of leadership in computing, semi-conductors, software, biotechnology, the Internet and other innovation-based industries.' (p. 1). The success of Silicon Valley lay in its ability to attract talent and capital and a culture of collaboration. The Bay Area Council consisted of 275 companies in the Bay Area. The joint report identified key strategic, cultural and organizational attributes that ensured the continued success of the region. Most importantly, companies in the region were found to have successful corporate strategies that were supported by corporate cultures and capabilities, and that the percentage of such companies in the region were more than double of companies elsewhere. The following overview identifies specific features of the region and companies in the Bay Area.

The following features characterize the Bay Area (pp. 5-7):

- Many of the largest and fastest growing companies in the U.S. are based in the Bay Area.
- The Bay Area remains at the head of its peers in terms of patents granted.
- The Bay Area captures between 35 and 40 percent of U.S. venture capital investment.
- Innovation jobs represent a larger share of jobs in the Bay Area than anywhere else in the country.

The reason for the above is that this region,

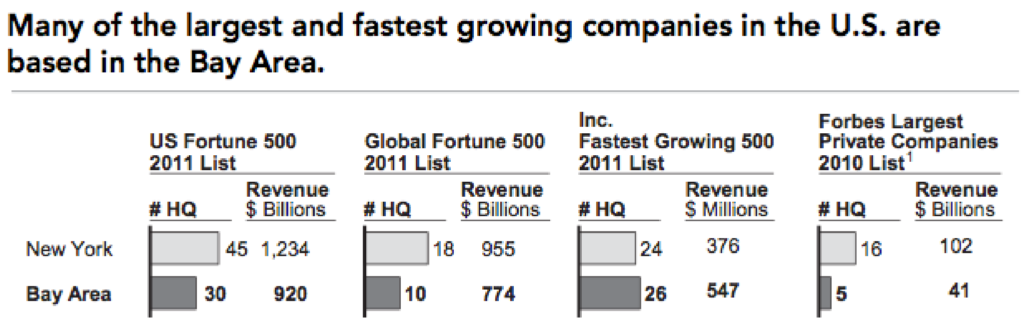
*'....many advantages as a place to start and conduct business: a strong educational and research infrastructure, a long tradition of venture capital funding, and an overarching culture that prizes technological talent, innovation, and networking. That, in turn, has led to the creation of many highly successful businesses, first in the high-technology and IT sectors, and more recently in biotechnology, Internet, digital entertainment and clean technologies.' (p.17)*

In order to understand its unique success, companies in the region demonstrated the following characteristics (pp. 18-23):

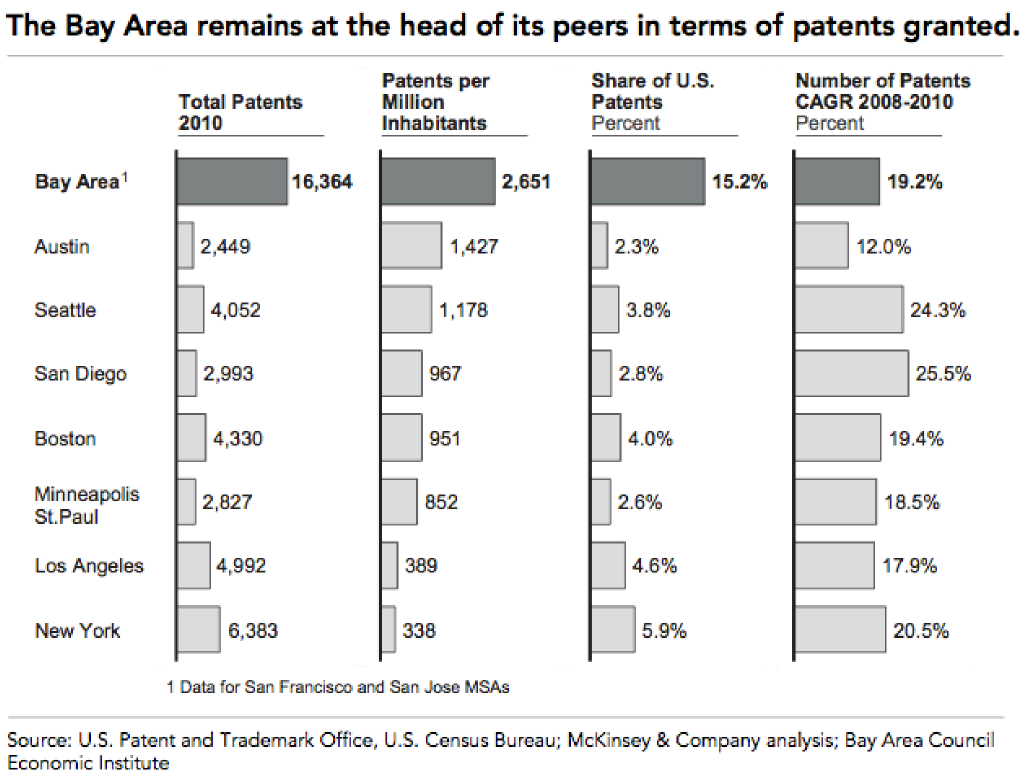
- Bay Area companies reported both stronger alignment on business and innovation strategies and cultural support for innovation strategy.
- Nearly half of Bay Area companies are Need Seekers, compared with less than a third of all companies surveyed in the 2011 Global Innovation 1000 study.
    - 'Need seekers' go beyond successful 'technology drive' strategies, they are able to address articulated and unarticulated needs of present and future customers
    - They have three attributes, namely, 'passion for the product', 'strong identification with customers', and 'an openness to ideas from all manner of sources' (also, 'the overriding culture of the entire Bay Area')
    - Companies are not only distinguished by their 'superior strategic alignment or highly innovative cultures' but also are outstanding in their 'proficiency along several organizational and operational dimensions'
- Bay Area companies have a much higher proportion of their technical leads reporting to the CEO than average companies.

- Bay Area companies have the highest proportion of their innovation agendas developed and communicated top-down.
- A large majority of Bay Area companies gave their new-product portfolio management processes high ratings for consistency and rigor.
- Most Bay Area companies view continuous refreshment of their product development talent base as a critical advantage.

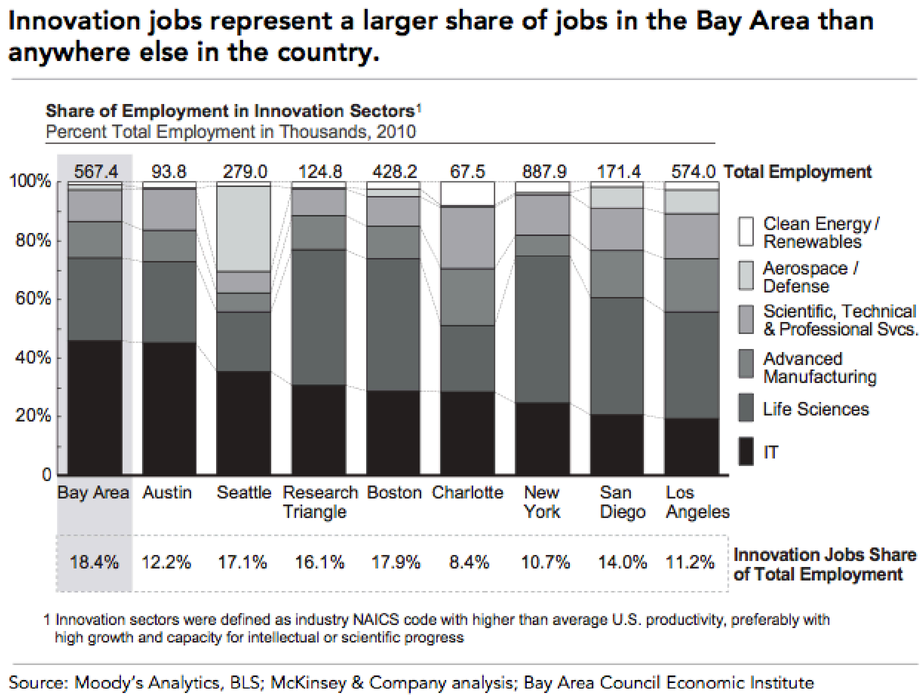
Below are five tables from the joint report that offer comparison of the Bay Area with other region on some of the aspects mentioned above to illustrate the superior performance of the region and the companies.



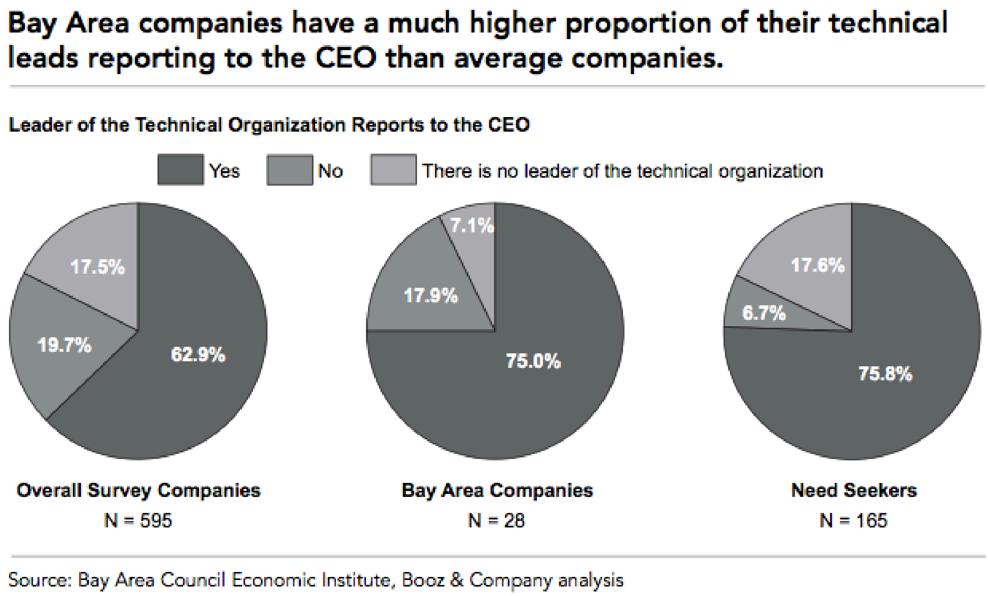

*Excerpt from Jaruzelski et al (2012, p. 5)*



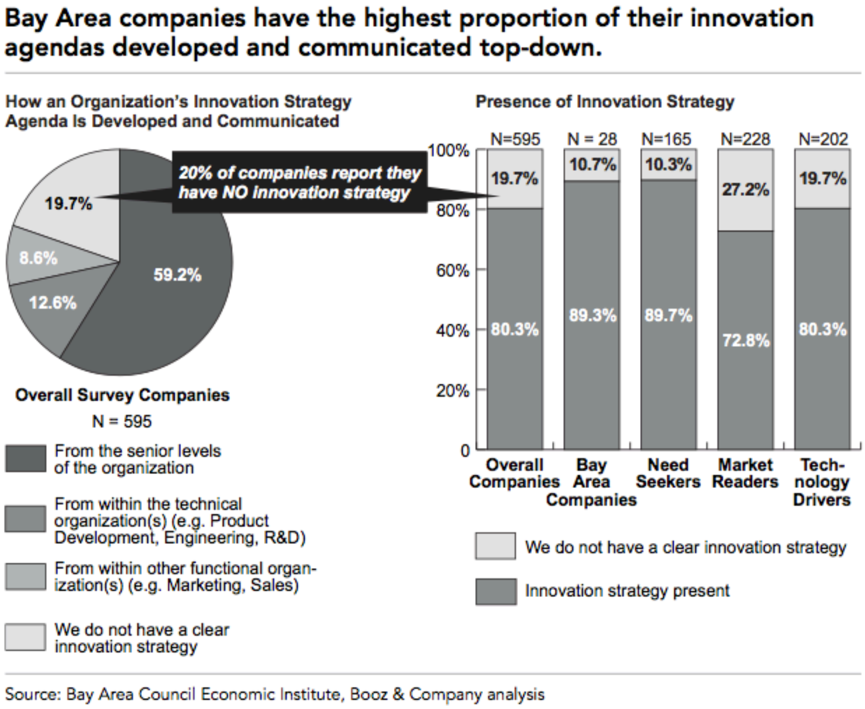

*From Jaruzelski et al (2012, p. 6)*




*From Jaruzelski et al (2012, p. 8)*




*From Jaruzelski et al (2012, p. 20)*




*From Jaruzelski et al (2012, p. 21)*

Finally, the joint report also identifies other features, which include 'excellent proximity to excellent universities and government research facilities, modern physical infrastructure, or access to capital' but stress that it has as much to do with the culture of 'openness to new ideas, and a networked environment in which ideas and people can flow back and forth, interacting fluidly.' (p. 25). They also stressed on the significance of the interactions between people, knowledge, technology, institutions (government, universities, businesses), and ideas. The power of attraction of the region (and openness to) talent from elsewhere, acknowledging the significance of entrepreneurship and the need to reward risk-taking behaviours were also part of the region's success. However, they indicated that the co-existence and interaction of the various factors mentioned and the culture supporting such interactions were part of the 'truly competitive innovation and a self-sustaining cycle of economic success.' (p.25).

*Adaptation of 'The Culture of Innovation, What Makes San Francisco Bay Area Companies Different?'* (Jaruzelski *et al,* 2012).

# 4. CONCEPTS IN CAS – DETAILS

[Overlaps main thesis]

Concepts and features of CAS are categorized into three parts: micro systems, systems features and systems responses. Where there is overlap with EEG or RIS, these are mentioned, and potential relevance for cluster study is also included.

**MICRO SYSTEMS**

The main concept of CAS is 'agents' (Axelrod and Cohen, 2001). The behaviour of agents in their interaction with their environment (including other agents) and the resulting co-evolution of a new environment through such interactions throughout the system form the basis of the dynamic processes within CAS. Agents are 'semi-autonomous' and 'seek to maximize some measure of goodness, or fitness, by evolving over time' (Dooley, 1997, p. 85). The notion of 'fitness with the environment' diverts from traditional notions of strategy where the aim is fitness to the objectives and goals set out by the individual agent or organization. In CAS, agents seek to adapt their behaviour to fit with the changes in the environment and they achieve their goals in a context of changes with the limited knowledge they posses, even as this knowledge is often shared by similar agents and rooted in schema that are 'rational bounded' (Dooley, 1997, p. 85).

Micro systems include '*bounded rationality*', '*sensemaking'* and '*schema'* that influence behaviour of agents responsible for micro level dynamics.

**Bounded rationality**

Bounded rationality expresses the fact that agents have limited information, assumptions, expectation, values and habits that form their perception of the context and that in turn, determine their actions. The notion of bounded rationality can help understand why in 'wicked' problems definition of what the problem is, is difficult. Stakeholders have different interests, expectations, language of communication, perception of phenomena and context, etc. The concept 'bounded rationality' is also used in evolutionary economics.

**Sensemaking and complexity**

Agents' behaviours are determined by 'sensemaking' of changes in the environments. Sensemaking is a process that results in agents' need to make 'meanings' to 'inform and constrain identity and action' (Weick *et al*, 2005, p. 409). The illustration below captures how sensemaking is a reaction to changes and how this manifests.

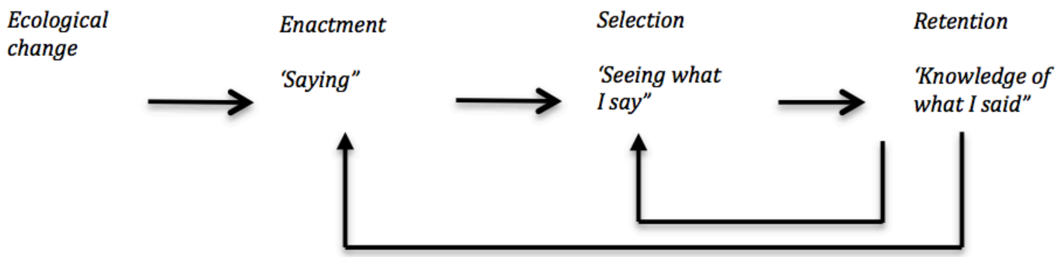



**Figure 2 Weick's notion of sensemaking (adapted from Weick, 1979, p. 132-134)**

'How can I know what I think until I see what I say?' (Weick, 1979, p. 133) is at the heart of sensemaking. 'Sensemaking is about the interplay of action and interpretation rather than the influence of evaluation on choice' (Weick *et al*, 2005, p. 409). Therefore sensemaking is context-bound, always in retrospect and in connection to others.

Sensemaking facilitates 'common language and conceptual categories, define group boundaries and criteria for inclusion and exclusion, distribute power and status' (Dooley, 1997, p. 86). Strategies used by agents are part of the context in which they operate, and can influence future strategies (Axelrod & Cohen, 2001). In addition, sensemaking processes can facilitate consensus on various aspects such as strategy, resources, vision, goals and how to reach these, indicators of success, etc. (Axelrod & Cohen, 2001).

Individual agents are constantly engaging in sensemaking, which result in choices for future. To support systems developments in highly complex situations, understanding sensemaking is important to support development of resilient responses and self-organizing behaviours. To this end, the following table has been included to better understand sensemaking and how to deal with them in complex situations.

| Property | Explanation | In complex situations |
|---|---|---|
| Social | Sensemaking is created in interaction with others. To change meaning is to change the social context. | Dialogues are needed to create shared sense moving towards shared notions of possible meanings. |
| Identity | Sense of who one is, is in a setting. Context is central to judgement of relevance and sense. | Avoiding being locked-in into too narrow roles – enabling new roles and opportunity to mitigate this. |
| Retrospect | Conceptualization comes after it happens and is experienced. History matters to appreciate what is happening. | Exploring how seeing and sensing has taken place and if it is still relevant – seeking new words to connect to strengths to become resilient. |
| Cues | Selected signals are amplified to affirm larger stories – giving a sense of what is happening. Self-fulfilling prophecies as risk. | Need to expand range and variety of cues used in stories. |
| On going | Sensemaking is dynamic and demands continuous updating and interpretations, keeping up with the pace of change. Resilience depends on workable, plausible stories. | Need to be alert that stories are aligned to new inputs, setbacks and opportunities. |
| Plausible | Plausible sense is coherent and sufficient for the purpose at hand. Plausibility is about credibility. | Ensure that there is a story that helps sensemaking (rather than an old or the story); a story which can be revised, enriched or replaced if needed. |
| Enactment | Enactment is a means to gain sense. Recovery lies not in thinking then doing but in thinking while doing, and in thinking by doing. | Doing work as small experiments that help make sense and become more resilient in complex and 'perilous' contexts. |

Table 1 Properties of sensemaking and dealing with complexity (adapted, Weick, 1995; Weick, 2001, pp. 461-3; Weick & Sutcliffe 2007)

Sensemaking is assumed in CAS, but not identified as a key concept even as sensemaking offers deeper and more comprehensive insights into micro-behaviour and interactions of agents. A related concept found in CAS is 'schema' to capture collective sensemaking notions.

**Schema**

Schein (1992, in Dooley, 1997) described that shared schema defined culture in organizations. Agents 'responding to and interpret what they experience involves constructing, reconstructing, and modifying' their schema (Vogelsang, 2002, p. 9). The process of collective sensemaking can be facilitated to create a shared schema among stakeholders, be it in organizations or in collective initiatives such as clusters. The concept of schema is similar to institutional contexts of regional studies.

***Summary of micro systems***

The sub-section on micro systems described how agents with their bounded rationality, sensemaking strategies and shared schema form the system and how their actions and strategies influence the system. The additional concept of 'sensemaking' helps understand more precisely how agents 'understand', namely, through shared discourse, values, and vision of future.

## SYSTEMS FEATURES

Complex adaptive systems display systems patterns and have interacting mechanisms across systems, and micro level interactions are connecting to systems developments. These features included *systems patterns*, boundary and identity (*container*), context (*sensitive to initial context*), shape (*phase space*) and underlying constraints (*attractors)*.

### Systems patterns

Complex systems display patterns that occur across various levels, which are often recognizable in the different embedded systems. Events occurring in one part of the system can also have an effect in a different part of the system.

- *Self-Similarity*

Simple rules (similar to Goodwin's 'deep rules') present in complex adaptive systems create similar patterns within the system at different levels, known as *self-similarity* in systems. In mathematics, the term *fractals* describe this concept. Recognizable patterns of behaviour, or physical structures, are found at different levels of the system. In nature, cauliflower is an easy example to understand self-similarity. Each part of the cauliflower repeats the shape at the next level.

Patterns of behaviour and interactions in multi-level systems (such as clusters) could reveal underlying self-similarity in systems at different levels. More details on 'simple rules' in complex systems are provided later in the concepts *simple rules* and *self-organizations*.

- *Embedded and overlapping systems*

The nature of complex systems is such that they are often embedded in another (higher) level of systems. For example, a neighbourhood is embedded in a region, which in turn, is embedded in a country and possibly, the country in a regional economic or political bloc. Each individual system affects the behaviour of the next level systems, both above and below. The behaviour of one system is often input for the next level system. In complexity, there is a notion of upward and downward causality (Maguire, 2011).

- *Local behaviour and macro-level effects*

Systems display changing and unpredictable behaviour due to agents' behaviour and decisions to seek 'fitness' with their environment are based on their local situation, their goals, etc. They are often unaware of the effects of their behaviour in remote parts of the system. This is known as the 'principle of locality' (Heylighen *et al*, 2007). Local behaviours of agents will cumulatively and spontaneously affect the global level of a system in non-linear ways. This means that micro-level behaviours cannot be directly linked to macro-level system emergent outcomes. Incidents and individual behaviours trigger pathways of change in the systems and the impact of a trigger is not foreseeable. The tsunami in Japan led to the *Energiewende* in Germany and no one could have foreseen such impacts. Similarly, a Tunisian fruit vendor's action leading to the Arabic Spring is another example.

**Systems boundary and identity – 'container'**

Systems are demarcated from their environment and this demarcation allows a system to have an identity [Eoyang & Olsen, 2001]. System boundaries or containers can be geographical, organizational, behavioural, conceptual or institutional. Examples of system containers are science parks, management teams, business units, occupational or ethnic groups, political alliances, principle-based groups, mission, policy and rules governing behaviour in groups or cultures, etc. In CAS, containers influence agent interactions with each other through a process of sensemaking as described earlier, whereby schema and system boundaries (container) determine agent interactions with their environment. The notion of container differs from traditional notions of systems as in economics and geography, where such systems do not cross boundaries or levels but operates in distinct levels or areas.

Changing system boundaries changes the dynamics of systems. Container definition and boundaries are therefore important leverage points in systems to influence action and interaction of agents (Olson & Eoyang, 2001). Influencing interactions of agents, the dynamics of systems, is one of the functions of complexity leadership (Marion & Uhl-Bien, 2011). Identifying and understanding systems boundaries and identifying clusters, its container, would therefore support understanding and influencing cluster developments.

**Sensitivity to initial conditions**

Another salient feature of complex systems, according to Prigogine (1985) is that they tend to be sensitive to local environments in which the interaction takes place, the notion of 'sensitive to initial conditions'. This sensitivity to local or initial conditions may be amplified by feedback loops present in interactions. The most common example in the literature is that of a butterfly creating a tornado in the global climate system continents away. The concept is also referred to as the butterfly effect, introduced by Lorentz (1972, in Maguire *et al*). The notion of sensitivity to initial condition overlaps with concepts of history (in sensemaking) and path dependence (in evolutionary economics).

In the literature, sensitivity to initial conditions is often linked to the notion of amplifying effects and therefore explaining non-linearity in systems, whilst path dependency is more often associated with the risk of lock-in. Both these concepts point to the effects of actions in the system, underlining the need to explore history and contexts of local (initial) conditions for both *ex ante* and *ex post* systems studies. The key lesson of CAS is that similar behaviour in one contextual setting could result in different outcomes in another setting (Van der Steen *et al*, 2013).

Path dependency and initial conditions on systems developments have relevance for understanding differential cluster developments. Evolutionary geographers include path dependency in their approaches.

**Phase space**

The possibility spaces of a complex system, due to interactions of its agents and critical values present in the system, have a maximum space within which a systems' patterns of emergence can be found (see *attractor* for constraining forces). The fact that complex adaptive systems have a defined phase space makes it different from chaos. There is a pre-defined possibility space and systems could evolve within such a space but there is no way of knowing where patterns of emergence will be found within this phase space. The use of phase space offers a way to describe complex systems in terms of their overall shape in terms of patterns that are present by focussing on key dimensions of such systems. Ramalingam *et al* (2008) explain that in social sciences tables of data could provide such insights whilst in natural sciences graphical maps use time-series data. In order to identify this 'space of the possible' (Cohen and Stewart, 1995, in Ramalingam *et al*, 2008), critical values of the key dimensions are mapped and therefore identify possible spaces. Explorations of the shape of the system by mapping patterns of interactions of key dimensions and elements can help capture how systems change and are constrained in their developments.

**Attractor**

The concept of attractor refers to the underlying pattern of order originating from mathematics (nonlinear dynamical system theory) where different phases with corresponding attractors determine behaviours (patterns) in the system. 'Attractors' therefore constrain behaviour (Goldstein, 2008). Different attractors in systems display different constraints; there are 'fixed point' attractors (trajectories converge to a fixed point), 'periodic' attractors (trajectories converge to a space of circles or ovals), and chaotic or strange attractors found in complex systems. Strange attractors have patterns of trajectories that can result in system change when critical values exceed certain thresholds:

*'This strange attractor shows that complexity – although seemingly completely disordered, actually displays order at the level of its trajectory, and that although it may be unpredictable in its detail, it always moves around the same attractor shape. This 'narrowness of repertoire' is at the heart of the order hidden in complexity.' (Ramalingam et al, 2008, p. 38)*

There are discernible patterns underlying systems developments that reflect the attractors in a system. These patterns do not mark fixed pathways but rather indicate possible 'landing places' within the constraints of such attractor phase space. The shape of strange attractors present in complex systems looks like wings of a butterfly. Thus whilst complex systems are constantly changing due to dynamic interactions of factors and agents in that system, they are held together by attractors within a phase space.

According to Goldstein (2008), when the critical threshold levels are crossed, a system transformation takes place, known as 'bifurcation':

*'A system may undergo a much more significant type of change, a phase transition into a new phase dominated by different attractors. This kind of system transformation….is termed "bifurcation"….Bifurcations result when there is a change in certain critical parameter values toward a threshold.' (Goldstein, 2008, p. 12)*

Understanding that complex systems have internal attractors constraining and shaping possible behaviour of its constituents including bifurcations that transform systems could support new discoveries about cluster developments and possibilities for new policy interventions.

***Summary of systems features***

Understanding that complex systems offered new ways of understanding cluster systems and their developments. Such developments are underpinned by dynamics of interactions; constrained by 'simple rules' or mechanisms; reflected self-similarity of underlying patterns of developments; but displayed interacting and overlapping systems of interconnected developments of micro-macro levels; were sensitive to initial conditions, in which history matters; and where boundaries and identities of systems influence their developments even as their 'phase space' is constrained by attractors, and where strange attractors are capable of systems transformations when critical thresholds are reached. Mapping clusters to uncover systems features could provide useful inputs for policy and cluster study.

## SYSTEMS RESPONSES

Complex adaptive systems respond to changes to their environments and these changes can be described in terms of strategies or goal matching (*fitness and adaptation*), the ability to deal with complexity, often reflected in variety (*significant differences*), the 'rules', dynamics and results of *interactions* and the resulting *emergent system*.

### Fitness and adaptation

There are two notions relevant to adaptation in complexity, one of *fitness* and *fitness landscape*. Both concepts are explained and whilst fitness landscape dominates in some strands of complexity theories, the notion of *'fitness'* in the broader Darwinist tradition is preferred in social sciences. Both concepts are present in complexity approaches.

- *Fitness and Fitness landscape*

The notion of 'fitness' in complexity theories reflects the need to deal with complexity resonant of evolutionary theory's 'survival of the fittest', dealing with changing, complex environments. Complexity of its environment needs to be matched by the systems internal variety (McKelvey, 1999; Merali & Allen, 2011), and in organizations, variety is recommended (Axelrood & Cohen, 2001). This is further discussed in describing the concept of *significant differences*.

The concept fitness landscape advocated by Kaufman is explained by Cooke (2012) as the landscape of complex systems as 'topography of hills and valleys' in which interactions and recombination of knowledge may be hindered or unobstructed and that diversity is important to economic growth. The popularity of fitness landscape in complexity sciences has its limitations when applied to social sciences as described in the following:

*A fitness landscape is based on the idea that the fitness of an organism is not dependent only on its intrinsic characteristics, but also on its interaction with its environment. The term 'landscape' comes from visualising a geographical landscape of fitness 'peaks', where each peak represents an adaptive solution to a problem of optimising certain kinds of benefits to the species. The 'fitness landscape' is most appropriately used where there is a clear single measure of the 'fitness' of an entity, so may not always be useful in social sciences. (Ramalingam et al, 2008, p. 54)*

Ramalingam *et al* suggest that a broader concept of 'fitness' could support understanding co-evolutionary nature of agents in interaction with the environment by adopting the notion of 'optimal trade-offs' instead of Kaufman's fitness 'peaks'. They illustrated through the example of Balinese farmers' the need to adapt to rainy and dry seasons and threat of pests. They needed not only to adapt to these environmental factors but also to each other's needs and thus engage in cooperative water sharing and pest control strategies. The Balinese ecosystem and landscape co-evolved as a result of farmers' interventions to seek 'fitness' with the environment. Individual farmers choose constantly to maximise their 'fit' based on the changes of others such that interactions of all related systems result in mutual adaptation (or co-evolutionary change) of the whole landscape (*emergent system*).

The 'fitness' seeking behaviour of agents and interdependent adaptations of local agents could help understand systems developments in cluster studies.

**Significant differences**

An important influencing factor on outcomes of interactions and interventions in CAS is the degree of significant differences in interactions. *Significant difference* is a concept that is approached differently by various scholars in complexity science.

- *Variation and diversity*

Axelrod and Cohen (2001) address variation as a key concept in their approach to complexity. Variation is essential to innovation according to them as it offers a source of potential success for existing problems. Agents, who form a varied source of knowledge, skills, history and strategies, interact with other agents, bringing with them a variety of knowledge, skills, history and strategies, which then result in a wide range of choices for action and strategy.

Diversity is recognized as an important element of renewal in urban studies and innovation in general (Johnson, 2012). Evolutionary economic geography also addresses diversity in the literature related to regional and urban development (Boschma, 2004). In evolutionary economics, the term 'related variety' is also used to reflect that diversity is important but needs to have some commonality (sub-section 2.6.3).

- *Significant differences and transformation*

In CAS, Olson and Eoyang (2001) emphasized that significant differences in complex systems can be leveraged to gain significant changes. Significant differences may be physical, mental, ideological, perceptual, experiential, social, political, etc. depending on the system. Significant differences for a system may also be different at each systems level. In a neighbourhood, families may be the significant difference whilst at the family level, it could be the roles assumed by the individuals that are the significant difference, and at a higher-level system, it could be the size of neighbourhoods that may be the significant differences. Goldstein (2008) explains that a significant difference is 'a difference that makes a difference' (Bateson, 2000, in Goldstein, 2008, p. 7)

Identifying 'significant differences' in complex systems offer insights into innovation potential, similar to the 'adjacent possible' in Kaufmann's terms (Cooke, 2012), which could perhaps support new path creations in cluster developments.

**Interactions**

Dynamic interactions of agent behaviours as part of systems responses are described through *feedback loops*, *transforming interactions* and *simple rules*.

- *Feedback loops*

Interactions and connections between the agents and their environments are important in CAS. Adaptive behaviour of agents is triggered, where mismatch occurs between agent and environment, to seek fitness to the local environments. Unlike normal scientific paradigms, connections in CAS are often non-linear because of feedback loops in interactions. Feedback loops in interactions tend to have amplifying effects (positive feedback) or regulating effects (negative feedback). The concept of *feedback loops* come from Systems Theory on which CAS builds (for details see Merali & Allen, 2011; Ramalingam *et al*, 2008).

- *Transforming interactions*

Olson and Eoyang (2001) described how significant differences could transform interactions. They used the term *transformational interactions* to capture this effect. Eoyang in a joint study with Yellowthunder on a study of Kosovo illustrated how significant differences facilitated transforming interactions, and therefore influenced emergent macro-level processes.

The occurrence of spontaneous and, or planned interactions where significant differences exist, and where continuous adaption by agents and transformations take place, often have amplified results due to the distributed nature of agents and interactions in systems. (See also *emergence* concept below).

Recognizing opportunities for transforming interactions and identifying significant differences to facilitate and broaden potential path creations can be important inputs for cluster policy.

- *Simple rules*

Complex systems are often governed by simple rules as illustrated by flocking birds or ant colonies, or military strategy in unpredictable, complex combat settings. These simple rules offer agents in the system flexibility in their choices even as they abide by these rules. The term 'semi-autonomous agents' is used to describe the local rule governance that also offers freedom of action. To illustrate, US military rules for complex combat settings are '1) capture the high ground; 2) stay in touch; 3) keep moving' (Ramalingam *et al*, 2008, p. 21). The Internet, Wikipedia and many Internet communities similarly display self-organizing systems with simple (often implicit) rules that allow autonomous behaviour for individual participants without rigid control mechanisms.

To manage complex systems and problems, understanding local dynamics of actors and their environment is necessary in order to enhance and, or enable adaptability of local actors in their local contexts, also relevant to cluster policy.

**Emergent systems**

To understand how patterns emerge in systems, concepts of *self-organization* and *emergence* are described.

- *Self-organization*

Self-organization captures how 'new emergent structures, patterns, and properties arise without being externally imposed on the system' (Goldstein, 2008, p. 9). The semi-

autonomous behaviour of agents seeking to make sense of their environment including the behaviours of other agents, and the resulting interactions explain the 'self-organized nature' of agent behaviour (see *micro systems, fitness and adaptation, simple rules* and *sensemaking* on agent behaviour). The behaviour of diverse agents, locally tapping into creative and novel behaviour, to adapt themselves to seek 'fitness' (Kaufman's 'fitness landscape') and maintain system structures without external design refers to the self organization property of complex systems (Heylighen, 2002; Heylighen *et al*, 2007).
Heylighen *et al* (2007, p. 13) refer to the ability of agents in a system to build a 'small, relatively stable 'community' of mutually adapted agents within the larger collective' that in turn, influences adjacent communities to change to fit to the new adaptation, and frequently, the pressure to change increases as adapted parts of the system grows. They explained that tension at the boundaries between adapted and not adapted communities offer triggers for change and adaptation and that these change processes, self-organizing processes, offer a larger diversity of potential adaption leading to fitness and therefore tend to be more robust in structure as compared to systems with blueprinted, command and control, top-down strategies. Change in CAS therefore emerges from interactions of agents in the system whereby diversity and autonomy exists (see *transforming interactions*) with the understanding that self-organization in itself is not a sufficient condition to initiate emergence. 'Constraining' and 'constructional operations' are often needed to support emergent systems (Goldstein, 2008; Maguire, 2011), referring to *attractors*, systems boundaries and identities, diversity of fitness strategies, interactions leveraging diversity, etc.

Understanding the role of self-organization in complex systems to support development of robust structures and resilient systems by focussing on significant differences and boundaries between such differences, and on diversity and fitness potential are inputs for resilient cluster development.

- *Emergence*

The concept of 'emergence' is critical to CAS. Holland (1992, p. 20) explains how 'individual parts of a complex adaptive system are continually revising their ('conditioned') rules for interaction, each part is embedded in perpetually novel surroundings (the changing behaviour of the other parts)'. He explains how there is no overarching rule that governs the whole system but instead there are different 'distributed, interacting parts' (p. 21) which are each governed by their own local rules (*simple rules*).

Emergence is explained in terms of how micro (lower) and macro (higher) levels relate to each other as whole systems:

*'the arising of new, unexpected structure, patterns or processes in a complex system…Emergent phenomena are understood on a "macro"-level which is considered a "higher" level in respect to the "lower" or "micro"-level components from which the emergent emerge'*

and,

*'Emergent phenomena seem to have a "life of their own" with their own rules, laws, and possibilities which are radically novel with respect to the lower level components'. (Goldstein, 2008, p. 9)*

*Emergence* is how 'properties of a complex system emerge from interconnections and interaction' with no clear relationship between the emergent properties and the contributing factors (Ramalingam *et al*, 2008, p. 21). The essence of complex adaptive behaviours of systems lies in the concept of *emergence* and they are not pre-determined and development paths are irreversible (Dooley, 1997).

Focus on interconnections and interactions, and mapping the resulting changes in structures, processes, visions, creativity, meaning, forms of collaborations, etc. would capture emergent behaviour in cluster systems. Mapping emergent changes capture the qualitative shifts in systems.

***Summary of systems responses***

Systems responses to changes in context as interconnected and distributed responses of agents can be understood through exploration of fitness and adaptation behaviours, significant differences potential, interaction patterns, and emergent systems behaviours, and their respective concepts. The emphasis on relevance and need for diversity to deal with complex changes, significance of focus on interactions and interconnections in systems developments were essential to CAS approaches. The emergent changes also reflect qualitative systems changes in its structures, visions, meaning, behaviours, responses as seen in interactions and collaborations.

# 5. EU CLUSTER POLICY AND CLUSTERS – ADDITIONAL INPUTS

**EU Policy**

Clusters have been part of EU's landscape and focus of policy since the 1980s and were identified as part of a broad-based innovation strategy in 2006 and 2008 by the Commission (EC, 2008). There was a consolidated programme of policy development to leverage the potential of clusters in recognition of clusters' role in facilitating innovative firms (see Thesis sections 2.13-2.17). In 2008, the Commission communicated its ambition to support development of 'world class clusters' (EC, 2008).

In the *Europe 2020 Strategy*, cluster policy was identified as one of the horizontal policy approaches that could support 'industrial competitiveness and innovation by bringing together resources and expertise, and promoting cooperation among businesses, public authorities and universities…' and, together with Regional and national policies, EU cluster policy was expected to 'overcome existing market failures and funding gaps, and especially to supply the bridge between companies and research institutions' (EC, 2010b, p. 14). There has been a shift in support for cluster developments from a national and regional policy to a more coordinated EU level policy approach, again recognizing the significance of clusters in innovation and SME developments.

Cluster Policies were defined as 'specific government efforts to support clusters' (European Communities, 2008, p. 10) and clusters as 'a group of firms, related economic actors, and institutions that are located near each other and have reached a sufficient set scale to develop specialised expertise, services resources, suppliers, and skills' (p. 73). Most importantly, clusters were recognized as key drivers of 'competitiveness, economic growth, productivity, innovation and employment' and their role in supporting success of firms, specifically SMEs (p. 21).

The following excerpts from the EU's Cluster Portal offer information on the scope, significance and potential of clusters:

*'Clusters operate together in regional markets. 38% of European jobs are based in such regional strongholds and SME participation in clusters leads to more innovation and growth.*

*There are about 2000 statistical clusters in Europe, of which 150 are considered to be world-class in terms of employment, size, focus and specialisation.*

*According to the European Cluster Excellence Scoreboard, for a number of selected emerging industries and regions in the period 2010-2013, 33.3 % of firms in clusters showed employment growth superior to 10%, as opposed to only 18.2% of firms outside clusters.'*

*'The Commission Communication For a European Industrial Renaissance (COM (2014) 14) highlighted clusters as being able to facilitate cross-sectoral and cross-border collaboration, helping SMEs to grow and internationalise.'*
*(EU Cluster Portal)*

The evidence for 'why clusters matter' has been documented in the Commission's working document and communications, and in the literature as discussed in the first part of Chapter 2. However, the key difficulty lies in designing and implementing effective cluster policy due to challenges faced in finding a good 'policy mix' and in dealing with the different framework conditions present in different regions. In addition, the lack of advanced evaluation measures and tools inhibits effective policy development and there is a difficulty of dealing with the different policy levels that are often involved in funding clusters, next to private funding sources and to foster alignment with different needs and measurement tools to meet the need to improve sustainable economic performance of regions (EC, 2013).

However, policy and cluster development challenges identified a need for trans-national cluster collaborations, coordination of policy instruments supporting clusters, and a need for European level cluster policy (European Communities, 2008). The establishment of the EU Cluster Policy in 2008 was seen as a way forward to realizing 'world class clusters' and raising the overall quality of cluster organizations and support for innovative SMEs.

Three key priorities of **EU Cluster Policy** are focus on **'cluster excellence'**, **'internationalization'** and **'emerging industries'**. In Chapter 2, figures for emerging industries have shown that they are higher than average and in the Flagship Competitiveness section, the importance of emerging and advanced industries have been described. Similarly, the need to internationalize and participate in global value chains has also been addressed. Therefore it is not surprising that Cluster Policy embraces *Europe 2020 Strategy's* priorities.

To summarize, EU Cluster Policy emphasises on

- Creating 'world class clusters' and cluster excellence
- Cluster internationalization for firms and clusters

- Emerging industries for new growth areas
- RIS3 priorities, opportunities for collaborations, development of niche markets and supporting RIS3 developments
- Providing information, mapping, tools and analysis of EU clusters (through the European Cluster Observatory)

Also, EU's website The Cluster Portal provides information, tools and web links for EU policy and related areas, including those mentioned above.

The description of EU Cluster Policy in this section has shown how clusters have grown from a regional and national policy instrument to one that is coordinated and facilitated by the Commission and its agencies. The significance of clusters is not disputed but policy implementation (at the local and EU levels) and optimizing cluster performance is. In the 2014 EU Cluster conference declaration, the concern for lagging regions was signalled. The main issue was the potential neglect or absence of developments in these regions and the absence of focus in cluster policy for these issues. This in turn, remains a key challenge for policy makers to implement and build on regional strengths whilst there are issues such as critical mass, fragmentation, out-dated industrial and knowledge bases, diversity of values and interests at all levels, etc.

The challenge of EU Policy and that of policy at regional level is to understand and support cluster development is at the heart of cluster challenge for both theory and practice.

The next section describes how information and communication on EU Cluster policy and cluster developments are organized.

**Clusters: information and communications**

Insights into clusters in Europe are offered through two EU portals and are described below.

**<u>The Cluster Observatory</u>**

The establishment of the European Cluster Observatory (ECO), an adaptation of Porter's Cluster Mapping practice from the US, uses cluster codes and performance indicators of competitiveness and dynamism of clusters to provide information and access to more than 1,400 clusters in Europe (Ketels *et al*, 2012), of which 100 clusters have been identified as strong clusters (ECO, 2011). An overview of EU clusters and associated organizations, the strengths and developments (Cluster Scoreboard) and resources are available that serve both practice and policy. This is an important website and tool for information on clusters and cluster developments at the micro and macro levels. A range of data on clusters as well as on new sectors, sub-industries, transnational regions, networking, innovation and research, and regional microeconomic framework conditions are provided.

A NOTE ON THE EU CLUSTER MAPPING AND BENCHMARKING

The key categorization of clusters in the mapping of EU clusters resonates with Porter's/US Cluster Mapping although the US approach has been customized and refined. The key methodology is the use of sectoral and aggregated data to measure degrees of agglomeration and specializations. However, under the leadership of the Centre of Competitiveness of the Stockholm School of Economics (which initiated cluster mapping in Sweden, and later for the European Commission), various methodologies have been developed supplementing the ECO Cluster Mapping for Benchmarking. They developed methodologies for the evaluation of cluster programmes and policy, and for identification of cluster strengths and industrial developments, including emergence of new industries; this too is presented through the Cluster Observatory website (see Sölvell, 2008; European Cluster Observatory, 2011; EFCEI, 2013).

**European Cluster Collaboration Platform (ECCP)**

The ECCP was established to allow EU clusters to profile themselves and to facilitate communication between clusters and to support trans-national and international collaborations:

> *'The ultimate goal is to facilitate cluster cooperation, both between cluster organisations, as well as between cluster members (i.e. companies, R&D institutions, other players).'*
>
> *'The European Cluster Collaboration Platform is a user-driven instrument.'*
> *(Website ECCP)*

The ECCP therefore offers information on clusters from the clusters themselves and opportunities and information are made available through the website to profile and map clusters, to participate, and communicate and interact with other clusters both within and outside their regions, within and across sectors, and internationally.

The website provides insights into clusters, cluster collaborations and into events both in the EU and elsewhere. New EU policies and priority areas, calls for projects, funding and events to support collaborations are also communicated through this platform.

**Bottom-up digital communication practice**

There are a number of cluster groups present on Linked-In where information and collaboration requests and discussions on different issues take place. The information shared and discussions available in these groups are more informal and personal, often building a community of practice around sectors (ICT, biotech), special groups (women in clusters, cluster managers) and topics (energy, innovation, EU funding). Information is often on current topics, funding opportunities, offer of services, request for collaboration, etc.

In addition, most clusters and cluster initiatives have websites that provide information on current practice. In the next section a few general highlights are presented on clusters and their contexts.

**Cluster context: current and future**

This section gives an indication of cluster context based on official reports and information provided by the Commission, EU agencies or other agencies commissioned by them. The rationale for this is to reflect EU's perspectives on cluster practice.

The first document used in the following paragraphs is that of the European Forum for Clusters in Emerging Industries in the Roadmap for Policy (EFCEI, 2013). All quotations in this section are from this report unless otherwise stated.

In describing the current context of EU clusters, it was explained that,

- Existing challenges were not met by following 'old' growth paths (p. 4) - EU 'invested intensively in research and new knowledge in order to create new growth and jobs opportunities' p. 8;
- New logic demanded 'new solutions' which comes from 'a mix of different knowledge and experiences' (p.4) often leading to new emerging industries;
- Examples of now 'mature industries' emerged in the last 10 - 15 years, such as aquaculture and mobile industries (p.11).

Their definition of 'emerging industries', was:

> *'Emerging industries can be defined as the establishment of an entirely new industrial value chain, or the radical reconfiguration of an existing one, driven by a*

*disruptive idea (or convergence of ideas), leading to turning these ideas/opportunities into new products/services with higher added value.' (Based on Hefferman and Phaal, 2009, EFCEI, 2013, p. 5)*

In addition, EFCEI explained that current contexts in the EU were not conducive to supporting new value chains creations and the transformation of existing ones. They added that present framework conditions showed policy 'being too sectoral' and 'silos' were prevalent in society. Their recommendations for policy to improve these prevailing framework conditions included (p. 17),

- New linkages across sectors/clusters/regions and ministries;
- State aid rules that support the development of new linkages;
- Public procurement as a driver for societal challenges;
- International smart observation should be supported;
- Entrepreneurial education to ensure the development of new value chains.

They also strongly advocated that clusters were in a position where they were obliged to 'play an essential role in the creation of new linkages to facilitate emerging economic activities' (p. 4).

Some of these issues have also been addressed in the main thesis on EU policies (sections 2.13- 2.18).

The EFCEI experts identified drivers of change supportive of new emerging economic transformations and these included interactions between sophisticated demand, cross-cutting technologies and service innovation, and social processes of innovation (see figure below).

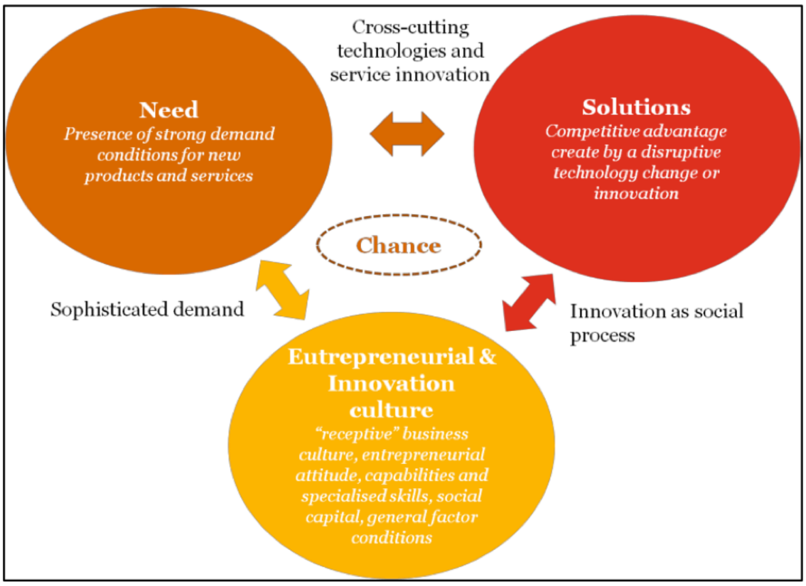



*Figure: Key drivers behind emerging industries (EFCEI, 2013,* p. 11*)*

In such processes, they felt that clusters could play a special role in support of interactions between needs, solutions and entrepreneurial and innovative cultures. They also explained that these new developments included a need for speed and ability to adapt and connect to new sectors, companies, regions, and to move up value chains. These adaptations are needed to create new solutions, and they demand new types of competences and framework conditions and the ability to recognize and support shifts or transformations in value chains. In addition, they explain that 'the epicentre is inside the new value chain, driven by an issue' (p. 14) and that issues become drivers of change. They foresaw that industries focussed on solving 'issues' will be drawn together and emerge as new industries in this process.

The EFCEI's Roadmap (2013) explained that clusters needed to shift from a traditionally sector-based focus to diversify and orientate to issues demanding complex value creations, products and service solutions. The value of clusters lies in their highly connected networks of knowledge and production and shared strong governance structures. This, in addition to being strongholds of specialized knowledge, makes them ideal vehicles to support cross-cluster linkages, cross-cluster collaborations, outreach and connection to international players and clusters in the search for 'new solutions' that would form new emerging industries. Therefore, they recommended (p. 16) a shift to cross-sectoral cluster initiatives based on 'thematic strategy, market or concept' and to formulate specific goals in that process (p. 17), namely:

- Focus on moving up new value chain and fostering cross-cluster collaboration and competition between regions based on RIS3
- Finance value chain approaches rather than single projects, where public-private financing are included
- Evaluate criteria for development of value chain and cross-sectoral collaborations, and the roles of cluster organizations in these.

The Roadmap also stresses that there needs to be policy on regulations, role of government in support of new value chain creation and skills developments including entrepreneurial skills, and that policy needs to emphasize international and future orientations.

These recommendations are about policy. What they signal are the changes in practice and future developments of cluster practice. In order to meet these challenges, cluster initiatives and management of clusters would need to develop competences to deal with more complex and broader scope of cluster practice, and need to be mandated and facilitated to take on these new roles and space for continuous and shifting transformation and re-alignments of new value chain developments. Cluster practice and management of cluster initiatives and the supporting cluster policy have been shown to be increasingly complex and this complexity appears to be part of the future of clusters.

To conclude the section on current cluster context, the 'grand social challenges' identified by the Commission reflects cluster context as one of complex and interrelated challenges. These challenges are:

- *'Health, demographic change and wellbeing*
- *Food security, sustainable agriculture and forestry, marine and maritime and inland water research, and the Bio-economy*
- *Secure, clean and efficient energy*
- *Smart, green and integrated transport*
- *Climate action, environment, resource efficiency and raw materials*
- *Europe in a changing world - inclusive, innovative and reflective societies*
- *Secure societies - protecting freedom and security of Europe and its citizens'*

*(Horizon2020 website)*

**Future context – Global trends 2030**

In the final part on cluster practice's context, future trends based on a study of the European Strategy and Policy Analysis System (ESPAS) Report on Global Trends 2030 are included. The report is not specific to clusters but is a general global trends analysis commissioned by an inter-institutional task force and carried out by the European Union Institute for Security Studies (EUISS).

The three main global trends identified for 2030 are:

1. Empowerment of individuals: a global human community but a growing expectations gap
   - Empowerment of individuals: key drivers
     - Global rise of middle class
     - Education as cornerstone of knowledge society
     - Information age as empowerment but risks to privacy
     - Global information revolution of Internet
   - Converging values and demands, and risks of extremism
     - Spread of human rights and democracy
     - Women's rights
     - Sharing the earth
     - 'Post-Huntingonian' world
     - Expectations gap and risk of extremism and nationalism
   - Demands for political participation but dangers of populism
     - Gender and politics
     - Multiple, non-conflicting identities
     - 'Development with dignity'
     - Participatory democracy
2. Greater human development but inequality, climate and scarcity
   - Rising middle class but persistent poverty and inequality
   - Climate change and scarcities: challenges to human development
   - Human security: protecting citizens
3. A polycentric world but a growing governance gap
   - A power shift to Asia but greater uncertainty
   - Diffusion of power but dangers of fragmentation
   - Global initiatives but a governance gap

In order to broaden the future context scenario for clusters, a different future trend analysis has been included that conveys a private sector/business perspective, that of Ernst and Young (2013). The previous analysis was from a EU agency and embraces a (EU) policy perspective. Both these scenarios were made in 2013 and focussed on 2030.

The Key Society Trends in 2030 according to Ernst and Young (E&Y) (2013) were:

**Scientific**

- Radical Openness – total transparency and reputation management
- Green Growth – crowded planet and resources shortage
- The Global Brain – data deluge and meaningful analytics
- Smart Living – real-time solutions and 'Mini-Me'

**Social**

- New Models – circular model and sharing culture
- Betapreneurship – disruptive innovation and global citizens

**Environmental**

- Social Capital – shared value and purpose driven

**Spiritual**

- The Good Life – positive psychology and meaningful storytelling

Both these analyses showed overlaps and they both expressed progress and developments in 2030 with potential risks and excesses. Both emphasize the connected world and the shifts, both convergence and conflict, in values, demands and expectations with the increasingly connected world. The empowerment of individuals in the future was also a common thread where more positive tones were present in the second, E&Y, analysis. The impact of science and technology is also more in the foreground in the second analysis although the dominant roles of digital and communication technologies are found in both. Also, more business-centric aspects are in the second analysis whilst the first reflects more security and policy perspectives in line with the EU agency's own policy focus.

This brief analysis of the context of clusters in the future reflects the interconnected and complex challenges to be expected due to access and growth of technological advances and a growing prosperity in greater parts of the world. The pressures of data and protection of privacy, reputations and asymmetry in information on the one hand and the pressures of resource scarcity and expectations and governance gaps on the other hand, are indicators of the changing and more complex future of the world, and of clusters.

The practice of cluster policy and clusters reflected the changing nature of innovation and market developments, and the increasing relevance of clusters to policy in supporting economic and social developments. As a conclusion to the sections on cluster policy and practice, the overview from a EU commissioned study, '*Where the cluster winds are blowing in Europe?*' captures trends in the use of clusters in policy.

**Evolution of the Concept of Clusters as a Policy Tool**

- More focus on clusters' relation to innovation
- A broadened view of the drivers of innovation
- A changed logic and scope of cluster initiatives

**Opening Innovation Processes through Clusters**

- Inclusion of various innovators, including users
- Internationalisation of cluster initiatives and cluster branding
- Cross-cluster/cross-sectoral cooperation as a way to increase innovation capacity

**Smart Implementation and Integration of Cluster- Related Policies**

- Smart Specialisation – balancing support to existing and emerging clusters
- Funding of cluster initiatives
- Coordination across policy levels
- Integration across policy areas

**Continued Strengthening of Cluster Initiatives**

- Increased participation of SMEs
- Strengthening the knowledge dimension – increased collaboration science and cluster initiatives
- Competence supply – attraction of talent and skills' development
- Use of design skills as a driver for innovation
- Service innovation as a way to strengthen innovation capacity in clusters
- More professional management and process support
- Focus on performance

# 6. CASE STUDY PROTOCOL: ENERGY VALLEY

The protocol included:

- Overview of case study
- Research question
- Research design
- Field procedure
- Data collection
- Case study report
- Content analysis
- Interview schedule
- Categorizing data
- Formats for data analysis
- Data collection procedures including number and type of interviewees, planning and storage of data
- Data capture including interview schedule, data overview and verification
- Guidance of report
- Limitations

**Overview of case study: objectives, issues and topics of investigation**

The exploratory case study research strategy has been chosen to investigate cluster development in its natural context. The research explores “how” cluster development is influenced by agent interactions in response to drivers of change in the context of clusters based on the complex adaptive systems’ assumptions on systems development. The research intended to study clusters as ‘whole systems’ in order to understand the dynamics of the cluster within a changing context that includes globalization and new economic and social developments. The intended research fulfils Yin’s criteria for choosing case study methodology, which states that case study is appropriate when it ‘investigates a contemporary phenomenon (the “case”) in depth and within its real-world context, especially when the boundaries between phenomenon and context are not clearly evident’ (Yin, 2014, p. 16). He indicated that the exploration of ‘what’ questions were justifiable for a case study approach when the intention was to develop propositions and hypotheses for further enquiry (p. 10).

Clusters are often networks of organizations that are connected and in close geographical location in which their exact boundary is not always clear. In addition, the research identified the need for reviewing existing cluster theory due to major changes in the context of clusters, such as globalization and increased connectedness through new information and communication technologies. The need for new perspectives and deeper understanding of cluster dynamics in complex contexts supported the choice of exploratory case study strategy. Eisenhardt (1989, pp. 548-549) found exploratory case studies *'well suited to new research areas or research areas for which existing theory seems inadequate'* and *'when a fresh perspective is needed'.* Additionally, the exploratory case study allows for in-depth and flexible investigation with multiple data inputs. The nature of the research required such a flexible and in-depth approach to uncover the underlying, deeper aspects of cluster dynamics and to capture the diversity of agent interactions in clusters.

**Research questions**

The case study on Energy Valley's research question was:

> *What drivers of change and cluster dynamics, in particular for energy clusters, are significant to cluster development and what revision might be needed for cluster theory?*

In order to answer this main research question, 3 sub-questions had been formulated:

a. *What is changing in the context of clusters and influencing cluster development?*
b. *How are stakeholders and other factors at the micro-level influencing cluster development?*
c. *Can CAS approach be incorporated into cluster theory to support the future of cluster development?*

The research design describes how these various questions will be answered in the case study and what data will be collected and how the analysis will take place and how the various parts of the research will be described as a case study.

**Research design**

The research investigates one main case study supplemented by pilot(s) at the beginning to develop a conceptual framework that would guide data collection and analysis. This guides the interview schedule to be developed for stakeholder interviews. In order to reduce investigator bias and to increase reliability of data, a two persons interview team is set-up. The combination of the interviewers would include a 'home' national to ensure that misinterpretations related to language or cultural references are avoided. The two-person research team will also be employed in the interpretation of the findings and analyses phase of the research where possible as translation of texts in Dutch to English could affect the quality of the data.

A supplementary case is to be conducted afterwards to expand on the findings of the main case. The pilot and supplementary case studies could add validity to the findings of the main case by supporting the outcomes of the analyses. Case studies from the literature may be relevant to reinforce the findings as well but this will depend on the nature of the outcomes and of the availability of relevant case studies in the literature.

The main case is Energy Valley cluster of the Netherlands and explores various aspects and levels of the cluster. The main data comes from interviews, archival data and research notes.

**Field Procedure: Relevance, support and access to data**

The field study for Energy Valley is to be supported by a letter from the cluster organization, Energy Valley Foundation as a source of legitimacy. The explanation and documents related to information and consent to participate will be provided to interviewees to inform them of the relevance of the research. The main relevance of the research is to inform cluster and energy policy developments. Energy Valley's support in identifying and providing access to key stakeholders in the cluster and to stakeholders and policymakers at national levels will be important to access key documents and gain access to stakeholders in strategic positions and, or involved in strategy developments. Informed and engaged academics in Energy Valley would also be important sources of information for the research.

The research would engage 'snowball' methods to have access to relevant stakeholders and experts through key stakeholders' networks and recommendations. Similarly, experts and stakeholders will be asked to identify key documents and policies relevant to the Energy Valley case study during interviews.

The case study will seek relevant information on EU energy and cluster policy through expert and stakeholder interviews.

The field procedures for the supplementary case study of Malaysian energy cluster would be identical to that of the main case study. Experts will be asked to identify an energy cluster for the study, names of key experts and stakeholders and documents relevant to the study.

**Revision to supplementary case (2014):** Malaysian case had to be replaced due to changes in political power in Malacca State and uncertainty of energy cluster developments, following defeat in general elections.

**New supplementary cases:**
Karlstad's The Paper Province and the Region of Värmland, and Silicon Valley were chosen. These supplementary cases were chosen to verify and enhance the propositions from the main case study.

The case study of Karlstad had been used to develop a 'cluster policy tool' as part of a different project, Opening Up (2012). Participants had been informed of both projects and consent for both projects were approved. The inclusion of Karlstad as a second pilot in the research had made re-visiting it as a supplementary case possible. The analysis of the Opening Up Project is presented as a paper in their final report and is included in Appendix 11.

The in-depth study of Silicon Valley by Etzkowitz (2012) was chosen due to the comprehensive analysis of the cluster's developments from its origin in the 19$^{th}$ century to the 21$^{st}$ century. This case provided longitudinal insights that supplemented the other cases.

**Data collection: interview questions**
The research needed to collect information during the field study that answered the first two questions of the research, namely:

a. *What is changing in the context of clusters and influencing cluster development?*
b. *How are stakeholders and other factors at the micro-level influencing cluster development?*

Individual stakeholders are to be asked what was driving change and how this was influencing cluster development. The answers from the various stakeholders and experts would be mapped. This is to be presented to the expert evaluation session together with the inputs for the second research question.

The second question on ‘micro-level’ activities is to be answered through information from experts and stakeholder interviews. The interview schedule for stakeholder interviews is to be developed based on the conceptual framework from CAS. The questions addressed different aspects of the interactions: perceptions and actions of the stakeholders in relation to policy, other agents and drivers of change, underlying forces and processes, including historical, geographical and cultural aspects, emergent interactions, solutions, competences and patterns, and, the scope of management of these processes. The specific questions for the stakeholder group are to be modified but always based on the CAS framework and the concepts to be identified. An interview schedule for Energy Valley cluster stakeholders has been included.

**Data storage**

Research data will be stored with back ups on separate devices. Audio files and transcripts will not be included in the thesis to protect anonymity of interviewees and also as the data collected is in Dutch. All formatted data from interviewees, translated summaries in CAS framework, different compilations and analyses will be available for reference. All analyses will also be stored in two separate devices.

**Case study report: narrative format**

As recommended by Yin (1994, p.64), a format for the case study narrative had been determined. The conceptual framework from CAS will be used to structure the case description. The structure of the case study follows the framework combining inputs from the various sources: archive materials, expert and stakeholder interviews and the analyses of these interviews. The case description will capture insights (descriptive) into cluster dynamics and drivers of change of Energy Valley. Analyses and outputs of the main case will be presented as ‘lessons’ given the exploratory and illustrative nature of the research.

The findings of the supplementary cases of Karlstad and Silicon Valley will be presented to enhance propositions arising from Energy Valley and therefore whilst a narrative structure is used for these cases, it will be structured around the propositions.

**Guidance to report on convergence and expansion of findings and alternative explanations**

CAS theory supports the research in its narrative on the findings. The CAS framework offers structure for the report. Convergence and expansion of the findings will be data-driven and using multiple mapping and analyses in accordance with the whole systems approach. Similarly, CAS stressed that complex systems demonstrated unique path developments that were irreversible and particular to that system. This meant that alternative explanations, in part due to a lack of whole systems approaches in cluster study, were difficult. The research leans on an exploratory, data-driven investigation with CAS guiding both the research and structure of the findings.

**Content analysis**

The research using qualitative data will use content analyses methods to distil themes and patterns through systematic sieving and mapping of the interviews, and converging the various interview data and those from secondary sources where relevant. The convergence of various stakeholders and stakeholder groups already provides triangulation of data. Data from interviewees will be categorized in terms of stakeholder groups and their regions (or EU and national levels) and saved as a database for further analyses and verification. Mapping feedback loops and systems patterns common to CAS approaches will also support the analysis. The initial mapping of interviews will be based on the guide to connect the interview questions to the conceptual framework's aspects of cluster study. The guide is included after the interview schedule. In addition, formats used in the analyses have also been included.

**Limitations:**

The research was limited to one in-depth study due to limitations of time and resources. This also meant that extended comparative cases and extended validation of the findings could not be realized.

**Additional supplementary case and limitations**

The inclusion of the supplementary cases of Karlstad and Silicon Valley however offered verifications and validations of the findings of the main case study. The inclusion of mature clusters but specifically the comprehensive longitudinal study of Silicon Valley complemented the main research.

**Interview schedule for Energy Valley field study (semi-structured)**

**Defining Energy Valley (EV)**

1. Who and what is Energy Valley?
    a. Is there a common vision/shared goal? Which is…?
    b. Are the players connected, loosely coupled or not connected?
    c. To what extent is EV connected to other economic sectors in the region?
    d. Is EV regional, EU or global focused?
2. Who and what is **not** part of EV?
3. How does EV help the regional development? Give 3 examples.
4. How does it help energy transition? Give 3 examples.

**Defining the Complexity**

5. Are there one or more key problems that EV needs to solve?
6. What, in your opinion, are 3 most important solutions for the problems?
7. Are there different views in EV about these key problems? Give some examples.

**Drivers of Change**

8. What is driving change in Energy Valley? Give examples.

**Path Dependency**

9. What 3 historical and geographic factors were important for the success of Energy Valley?
10. What 3 factors are limiting success?
11. What are pitfalls for EV because of its past? Give 3 examples.

**Fitness to (changing) Landscape**

12. Give 3 examples of how EV is prepared for the future of energy innovation and for economic development.
13. What new competences and knowledge is needed for EV to be competitive in the future?
14. What are possible new knowledge sources that are not yet tapped?
15. What would attract new businesses, money and talent to EV? Examples?

**Attractor**

16. What is attracting new businesses, money and talent to EV? Examples?
17. Which direction is EV moving towards?

**Stakeholders: system and change agents**

18. Who are gatekeepers in EV?
19. What are 3 most important stakeholder groups of EV?
20. Is any stakeholder group missing in EV strategy dialogues?
21. Who is changing the traditional energy landscape?
22. Is NL and EU policy changing EV? Which policies?

**Significant differences: energy innovation**

23. What differences (resources, values, power, capabilities) in EV are creating new impulses and tensions?
24. Do the triple-helix partners (industry-business-research institutions) collaborate? What results? Give examples.
25. Do new energy innovation collaborations in EV include traditional and renewable energy collaborations?
26. How is innovation and knowledge shared in EV? Give 2 or 3 examples.

**Self-organizing or top-down management**

26. Is the future of energy transition managed more by
    a. top-down (policy driven, cluster organization driven)
    b. bottom-up (companies, citizens, platforms, sector-driven)
    Explain and give examples.

**Emergent patterns**

27. What is significantly different in EV in the last 3 years in terms of
    a. Trust and commitment
    b. Collaborating partners (new partnerships)
    c. Scope (internal, regional, EU, global)
    d. New (digital) communications
    e. Knowledge sources and sharing
    f. Different innovative processes and solutions
    g. Other

**Application of interview schedule for specific groups**

The interview schedule is a guide that will be used flexibly and adapted for the stakeholder being interviewed. Additional schedules were made for specific stakeholder groups, including EU and national level experts based on the original interview schedule to cover all aspects of the conceptual framework.

**Categorizing data from Interviews to CAS framework**

Identify quotes with code/type of stakeholders. **Literally note answers**

**Complexity**

• What urgent issues for EV are mentioned?
• What solutions/directions are identified for EV?
• Differences in views on problems and solutions of various parties mentioned (include: differences between EU and Dutch politics, different visions of the different provinces, different visions EV foundation, etc.).
• Things that are mentioned that make the future of EVs and energy uncertain and unpredictable.

**Drivers of Change**

• What external (outside EV) drivers of change are mentioned?
• What internal (within EV) drivers of change are mentioned?
• Comments on the role of EU policy in EV developments
• Comments on the role of Dutch policy in the EV developments

**Container**

• Answers to "What is Energy Valley?"
• Comments on goals and visions of EV mentioned
• Answers to the internal cohesion of EV (connected, loosely coupled or not connected)
• Comments on the focus of EV (regional, national, European, global)
• Comments on position of interviewee's organization within EV
• Comments on who is leading the discussion on EV's future
• Comments on those who do not participate in the discussion about the future of EV

**Path dependency**

• What historical factors identified in the development of EV?
• What geographic factors identified in the development of EV?
• What other factors identified in the development of EV (cultural, mentality, etc.)?
• Answers to how EV is prepared for the future
• Answers to skills and knowledge needed for EVs to remain competitive in the future
• Answers to the question of what knowledge sources are insufficiently used
• Questions about missing factors in EV development (e.g. lack of research, large companies, missing competencies, SMEs not involved, answers to the question what the difference with the Eindhoven region, etc.)
• Notes on gas and how that leads to limitations (lock-in) in options, including examples, e.g. also examples outside of the energy sector

**Attractors**

• Answers to the question of what attracts companies, money, and talent to EV
• Answers to the question in what direction EV is moving towards
• Answers to the question of why EVs are moving in that direction

**Stakeholder / significant differences**

• Answers to the question "who are the gatekeepers of EV?"
• Answers to the question "Who are the three key stakeholder groups in EV"
• Answers to the question "Are stakeholder groups missing" (also, mentions on parties that are neglected or where too little is taken into account)
• Answers to the question of "Who (which stakeholders group) is changing the EV landscape?"

**Transforming interactions**

• Answers to the question whether "New combinations of innovation and regional development occurs, examples
• Note examples of cooperation between companies, governments and research /educational institutions
• Note answers to how innovation and knowledge is shared within EV

**Self-organization**

• Answer to "How are energy innovations are realized: top-down or bottom-up" and note explanations and examples

**Emergent landscape**

• Answers to the question "whether the last three years have seen changes in EV, for example, trust, cooperation, etc.?"

**Other considerations**

• Things that the interviewee wants to add
• Critical notes on EV developments

**Format for data analysis – first level**

**EV [interviewee no.] data analysis**

| **Topics** | **General comments** | **Quotations** |
|---|---|---|
| **Stakeholder Details**<br>**Connection to EV** | Policy<br>Region | |
| **CLUSTER CONTEXT**<br>Complex problems and drivers of change | **Energy Valley definition** | |
| | **Energy Valley vision** | |
| | **Connectedness/ Scope** | |
| | **Wicked, complex problems** | |
| | **Issues** | |
| | **Stakeholder – paradigm** | |
| **CLUSTER CONDITIONS**<br>Past, current and future factors influencing stakeholder interactions and capabilities | **Drivers of change** | |
| | **Path dependency - history** | |
| | **Path dependency – geography** | |
| | **Path dependency – culture** | |
| | **Path dependency – knowledge and economic infra** | |
| | **Fitness to landscape – future orientation** | |
| | **Attractor** | |
| | **Gatekeepers** | |
| | **Stakeholder** | |
| | **Stakeholder – missing** | |
| | **Differences that matter…** | |
| **CLUSTER DYNAMICS**<br>Transforming interactions where differences are leveraged and organizing processes (top-down/bottom- | **Combinations – new developments** | |
| | **Top-down/ bottom-up** | |
| | **Knowledge sharing** | |
| **CLUSTER PERFOMANCE**<br>Emergent patterns of interaction and developments | **Collaborations** | |
| | **Interactions** | |
| | **Trust/engagement** | |
| | **Other…** | |

**Format for data analysis – second level**

**(Separate compilation for each stakeholder group)**

| **Cluster context** | **Comments** | **Interviewee number** |
|---|---|---|
| EV Definition, vision and connectedness, scope | | EV |
| **Cluster condition** | | EV |
| Wicked | | EV |
| Issues | | EV |
| Stakeholder paradigm | | EV |
| **Cluster conditions** | | EV |
| Drivers of change | | EV |
| **Cluster conditions** | | EV |
| Path dependency | | EV |
| **Cluster conditions** | | EV |
| Fitness to landscape | | EV |
| **Cluster conditions** | | EV |
| Gatekeepers | | EV |
| Stakeholders | | EV |
| Missing stakeholders | | EV |
| Differences that matter | | EV |
| **Cluster Dynamics** | | EV |
| Combinations – new developments | | EV |
| Top-down/Bottom-up | | EV |
| Knowledge sharing | | EV |
| **Cluster performance** | | EV |
| Collaborations | | EV |
| Interactions | | EV |
| Trust/engagement | | EV |
| Other | | EV |

Inputs from interviewees of the stakeholder groups are compiled into this second level analysis. Thus, all policy interviewee comments, industry stakeholders, etc. are collated to be able to map their perspectives on these aspects of cluster developments.

## 7. INSIGHTS INTO ENERGY VALLEY RESEARCH PROCESS

Examples of Energy Valley's analyses provided offer insights into the research process, including its scope and complexity.

The first example is the first page of the mapping of urgent (complex) challenges identified by stakeholders. Similarly, the second sample is the first page of industry stakeholder inputs on the various aspects of Energy Valley's developments.

**Sample 1: Urgent Challenges identified by stakeholder groups**

| **URGENT CHALLENGES IN ENERGY VALLEY** | **Industry** | **SME** | **RDA** | **Academia** | **Policy** | **Civil Society** |
|---|---|---|---|---|---|---|
| **A. Complexity of challenges in Energy Valley** | | | | | | |
| **Complexity of new system (SME)** | | X | | | | |
| **Legality of RE too complex (SME)** | | X | | | | |
| **Complexity of problem (Industry)** | X | | | | | |
| **Interconnectedness of provinces (Policy)** | | | | | X | |
| **Creating right conditions for ET – complex (Academia)** | | | | X | | |
| **Conflicting parties, interests of stakeholders – conservative vs. progressive (Policy)** | | | | | X | |
| **Differences in EV - choice of decentralized and large scale; per stakeholder, per region... (RDA)** | | | x | | | |
| **Different interests, solutions of stakeholders – Conflicting interests; no consensus (Academia)** | | | | X | | |
| **Stakeholder interests different (Industry)** | X | | | | | |
| **Government has vested interest - income (SME)** | | X | | | | |
| **Differences in urgency, focus - EV and politics (Policy)** | | | | | X | |
| **Sense of urgency (Industry)** | X | | | | | |
| **Urgency of ET (RDA)** | | | X | | | |
| **Energy security of supply (Policy)** | | | | | X | |
| **Urgency for RE (SME)** | | X | | | | |
| **Solution successes for future unclear; unpredictability of future (Industry)** | X | | | | | |
| **Future unknown; future technology unknown; shale a hype, impact not known (Academic)** | | | | X | | |
| **B. Need for different strategies and support** | | | | | | |
| **E.E. solutions needed; affordability; user-centred approach needed (SME)** | | X | | | | |
| **Creating right conditions for ET – complex (Academic)** | | | | X | | |
| **Decentralized ownership - bottom-up – citizen-centred (Policy)** | | | | | X | |
| **Systems approach needed (Policy)** | | | | | X | |

| | | | | | | |
|---|---|---|---|---|---|---|
| **Affordable energy – long term (SME)** | | x | | | | |
| **Strengthening socio-economic position of North – 'real valley' (Academic)** | | | | x | | |
| **Young people in ET – new thinking; talent, HR, missing stakeholder; 'young capital policy' missing (Academic)** | | | | x | | |
| **Strict standards/norms as quality – competitive advantage (SME)** | | x | | | | |
| **Introduction of RE - market balance (SME)** | | x | | | | |
| **Price and market mechanism (Industry)** | x | | | | | |
| **Regulations and legal issues of ET, Speed of ET (economic) viability of new solutions for ET (Policy)** | | | | | x | |

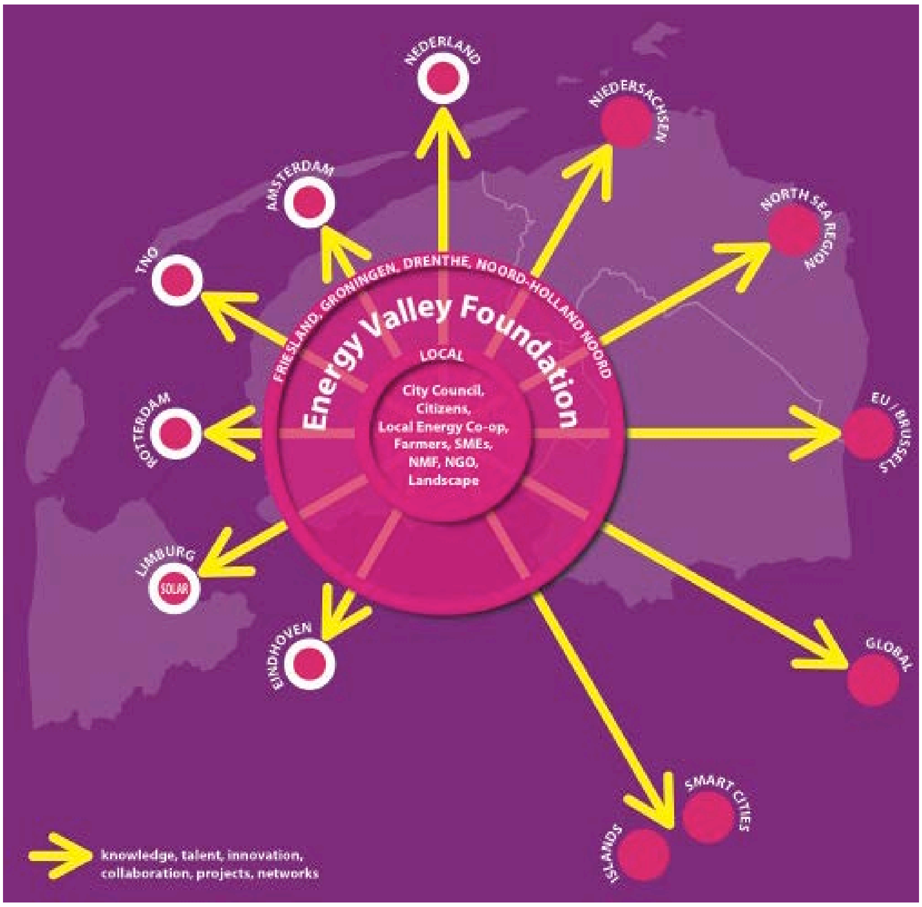
## Sample 2: Industry stakeholders' input on Energy Valley

| **Cluster context** | Comments | EV number |
|---|---|---|
| EV Definition, vision and connectedness, scope | - Platform – networking and collaborating function<br>- Connecting parties, knowledge of capacities, stakeholders, etc.<br>- Different things for different – big, small - companies<br>- Political goals – branding region as energy region – bringing parties together<br>- Competitive advantages: space, no-nonsense mentality, businesses recognized globally/European recognized as leaders in their field – gas and infra, wealthy companies<br>- Commitment to the region(al development)<br>- Innovation – connecting to university, research<br>- Success of EV org – branding, building a community/cluster?<br>- Regional scope –extending into N Germany<br>- Scale - Dutch government –defines NL as one cluster/region; EV region defers<br>- Internationalization is by default [?] – EU subsidy rules, energy is becoming international business. But the local roots are important to conserve...to avoid dilution<br>- Connecting sectors –energy and chemical | EV9 |
| | - Intermediary function<br>- Has SME focus<br>- New role could be more 'cross-border' networks<br>- Scope enlarging – from regional to national to cross-border (in the process)<br>- Companies have their own international strategies; diversity and mix of companies is huge;<br>- EV's image binds companies to EV | EV10 |
| | - Region full of energy activities – huge energy production capacity;<br>- Region is huge<br>- A lot of energy research<br>- Energy stakeholder connected to see how energy sector can contribute to the development of the region<br>- Focus on SME and innovative start-ups;<br>- How to facilitated 'connectedness' is the challenge.<br>- Even more focus in priorities than is currently present | EV16 |
| **Cluster condition** | | EV |
| Wicked | - Need for collaboration and commitment...need to connect sustainable sector to fossil sector – you need each other. Different types of people in these sectors – threat of RE...[progressive vs. conservative?]<br>- Energy politics is complex and best at national level...examples given | EV9 |
| | - Renewables, conventional supply and security of supply – balance between these is difficult<br>- Interconnectedness of German and NL energy markets; of RE and conventional markets/generation<br>- Need for long term investment incentives and policy<br>- Rapid RE industry development impact and of downturn of market demands<br>- Different interests of stakeholders<br>- Sense of urgency missing | EV10 |
| | - Expectations of stakeholders, serving selected groups...<br>- Energy transition is more than technology...social component important.<br>- German and Dutch example: local ownership/engagement in RE vs utility companies doing RE<br>- Unique situation to work together to move forward – [collective missing?]<br>- Complex problem – different interests, resources available, social acceptance, etc. | EV16 |

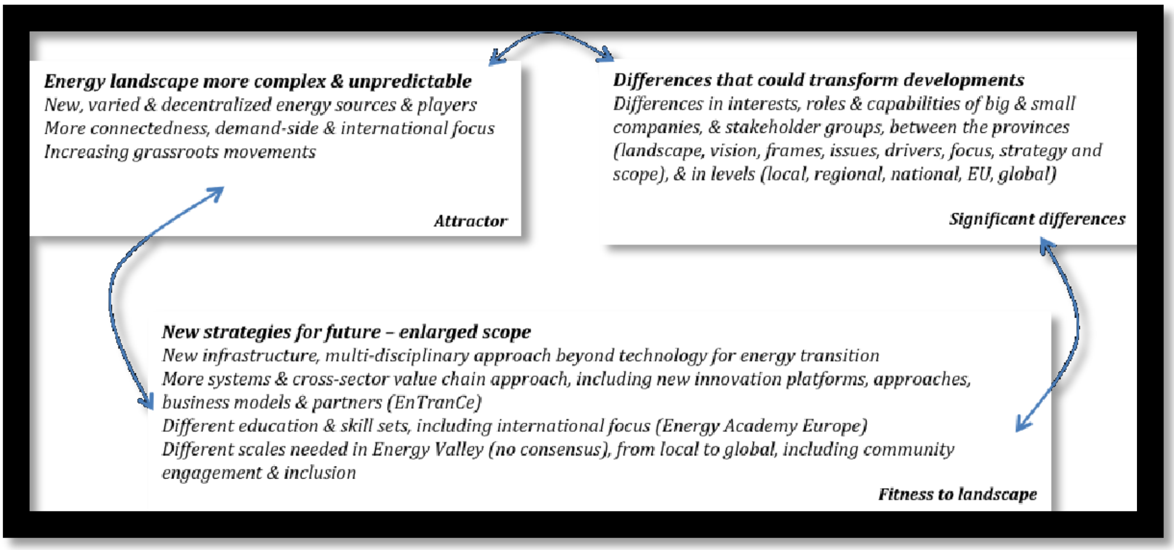
## Sample 3: Collated insights on Energy Valley (Container and Path Dependency)

| | |
|---|---|
| **Container**<br>- | There were<br>– **Three main 'frames'** – 'economic', 'energy transition' and 'regional development' – defined strategy and behavior of stakeholder groups<br>- Lack of common frame or explicit framing positions risked sub-optimal dialogues and results<br>- **Provincial differences** in local contexts and agendas present (see path dependency)<br>– EV foundation's vision/mission framed by key triple-helix stakeholders, the 'founding fathers', public funding agency (SNN) and members of the cluster – **complex collaboration**<br>- Collaboration and formation of EV cluster was a joint initiative by the 'founding fathers' in response to gas reserves depletion and dispersion of gas expertise<br>- Collaboration despite (regional) stakeholders differences reflected urgent need to face energy transition and regional economic challenges<br>– The cluster organization was commissioned to serve local energy businesses, broader energy transition developments, and regional economic developments – **complex and sometimes conflicting agendas**<br>- Large-scale developments in the Eems harbor region served national and strategic interests rather than job creation, decentralization and sustainability goals<br>- Limited capacity of cluster organization meant iconic (political and large) projects superseded local business support and job creation goals<br>– **Initial regional focus and scope** |
| **Path Dependency** | – **Gas reserves created new industry and expertise since 1950s**, whilst energy market liberalization threatened loss of energy expertise and jobs through M&A and HQ re-location<br>– **Dominance of 'gas' in the history, energy infrastructure and energy system** in the Netherlands determined Energy Valley's initial cluster condition – **lock-in** risk and power imbalance<br><br>– **Dominance of national economic interests** (BV NL) – power imbalance<br>– **Peripheral position** of North Netherlands reinforced need to collaborate to develop future strategies jointly<br><br>– **Focus of Energy Valley** cluster reflected factors related to path dependency: gas, biogas (agriculture), wind, water, NW Germany and North Sea Region<br><br>– **Knowledge base of Energy Valley limited and fragmented – 'cluster drain' and divergence risk**<br>- Lack of major corporations and R&D capacity outside of 'gas'<br>- Fragmented public research capacities and disciplines<br>- Dispersed innovative SMEs<br><br>– **Path dependence differences of socio-economic structures of provinces**: large gas corporations, autarchy, food and agro-based industry, recreational and tourism industry, horticulture industry, SME dominant, 'Veen' colony, hinterland of Amsterdam Metropolis |

## Sample 4: Mapping of attractors to 'outside': risk of cluster drain



**Sample 5: Mapping cluster dynamics of Energy Valley**




**Sample 6: Extract from Energy Valley presentation to Panel of experts and interviewees**

## Sample 7: Screenshot of database

| | | | | |
|---|---|---|---|---|
| Drivers of change | – [is this attractor? Gas is an attractor for EU and solar is de-central attractor]<br>– Need for scale…working with Germany<br>– Need for recognition by EU?<br>– De-centralized collective initiatives – co-operatives – pushed by sustainability ideals and cheaper solar panels…became ambassadors…start of movement<br>– Local ownership is most important driver to sustainability – decentralized energy is cheaper. There are technical issues – balancing,<br>– People do not look beyond electric socket, electric car…that there are coal plants needed to generate the power…<br>– Technology and regulation to assert strict norms of energy savings… at EU level, not NL<br>– Making energy costs with smart meters could also have a boomerang effect – that they spend what they saved; technology and stricter norms more effective. | EV16 | Groningen | Gas company |
| Path dependency | – Hansa connections…northern orientation<br>– Centre- periphery issues<br>– Space and down to earth mentality (nuchterheid)<br>– Germany's lead or fall? [others say Germany is exporting lessons & expertise]<br>– Dutch strategy, economics first?<br>– Dutch standards and practices in gas exploitation, ownership of land…<br>– Business model for gas assets, dividents.. vs. English model where new regulations allow innovation investments | EV9 | Groningen | Gas industry |
| Path dependency | – Gas discovery – gas grid – HR boilers – micro wkk – smart grids – impact on rest of Europe and sustainability<br>– Northern 'down to earth' mentality; rural spaciousness, calm – people are accepting of gas and its impacts but there needs to be a – balance – earthquake danger – sector learn from mistakes<br>– Green gas – introduction into gas grid – innovative<br>– Approach is systems based not only innovation of parts | EV10 | Groningen | Industry/R&D |
| Path dependency | – RE developments had favourable conditions in DU as opposed to NL eg.<br>– Taxes to finance RE, political coalition and push by Green party, local ownership of wind farms,<br>– Gas history important; unique situation in NL with 97% buildings connected to gas grid; highest density of gas grids/population; energy transition could be eased through a gas-buffered transition?<br>– Re-introduction of {shale} gas by US makes NL in a position to exploit her situation to generate knowledge/expertise and then export it to other ç..<br>– Abundance of gas and electricity in the region – opportunity to innovate in 'gas to power' and 'power to gas'<br>– A lot of energy activity and the impact on society – how do you embed energy transition and activities in affected (local) communities | EV16 | Groningen | Gas company |
| Fitness to landscape | – Energie zekerheid is goed in NL, overcapaciteit nu<br>– Energy efficiency moeilijk van grond te krijgen bv Drenthe<br>– Gas money investments in infra – eg. Rotterdam<br>– Gas revenues – invest not only consume<br>– Connecting renewable and fossil people. Companies together<br>– KEMA<br>– Space and down to earth mentality (nuchterheid) - important for future | EV9 | Groningen | Gas industry |
| Fitness to landscape | – 'doing' and solving issues, risk taking – interaction with clients to innovate<br>– They believe that gas is seen an important part of energy future [driver] - CO2 storage, green gas, smart grid, power to gas, - they invest anticipating future markets<br>– Eg. New multiphase lab for up-stream market developments<br>– Energy mix will be diverse and is important<br>– International connections needed for future relevance of EV<br>– 'easy position' in past but cycles are getting shorter, risks are bigger, need for broader perspectives<br>– Management needs to change – not only top-down<br>– Knowledge in the region not used –green gas expertise – choice for 'easy' options – electricity chosen instead of up-grading,<br>– lack of commitment and dialogue/sense of urgency – diffused | EV10 | Groningen | Industry/R&D |
| Fitness to landscape | – Dilemmas surrounding scale –you need larger scales – Gas and Energy Academy – and this makes reaching out to smaller parties difficult and to gain awareness of the need for this…<br>– Energy Academy Europe – to connect knowledge centres, multidisciplinary programmes…<br>– Excellence in research and education – in EV more difficult than Wageningen – as these are separate entities. Mass and scale needed – ECN, Delft, Eindhoven – collaboration with all institutes – NL is too small<br>– Create international hotspot<br>– Energy – water nexus – too early as there is not enough success in energy<br>– Collaboration across the provinces in their specializations is limited | EV16 | Groningen | Gas company |
| Gatekeepers | – Change agents rather than gatekeepers amongst the incumbents…<br>– Not everyone participates – not will but alignment to own company, etc.<br>– Biggest resistance to change is regulatory framework and agencies.. too much control and bureaucracy<br>– System locked into control and companies less innovative | EV9 | Groningen | Gas industry |
| [illegible] | – National governments use regulations to enforce eg. Kyoto but is not effective; de-regulation and market mechanisms are more effective | [illegible] | [illegible] | [illegible] |

# 8. EVOLUTION OF CAS FRAMEWORK

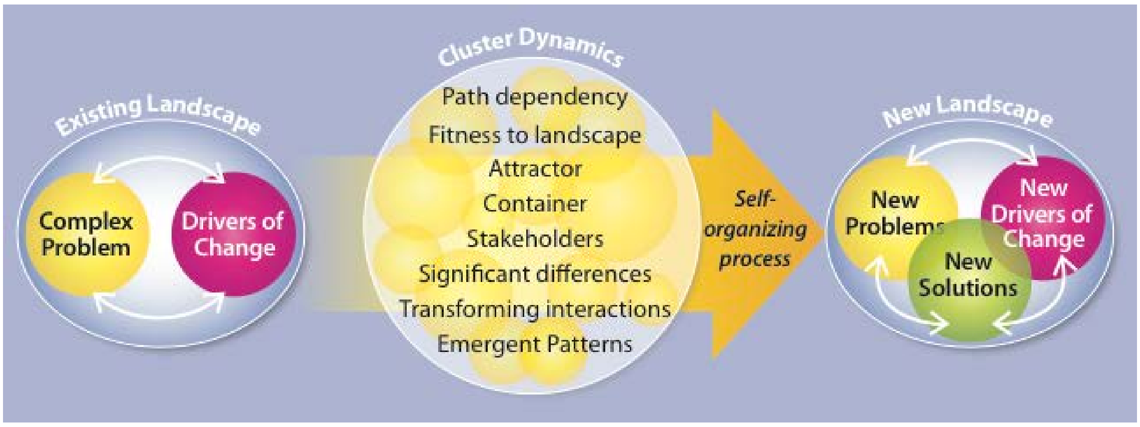
**Introduction**

The conceptual framework was developed during the research process and adapted it with growing insights, use and maturity of knowledge developments. The frameworks have been presented below with their advantages and limitations (with regards to the other frameworks). The framework has been designed to offer both insights into cluster developments by showing how cluster dynamics are interconnected to its changing contexts, and as guiding framework for deeper understanding of the systems changes of cluster developments.

The different conceptual frameworks for cluster developments have been presented below followed by highlights of the value and limitations of each of the framework.

**Conceptual frameworks on CAS Cluster Developments**

**Framework 1**



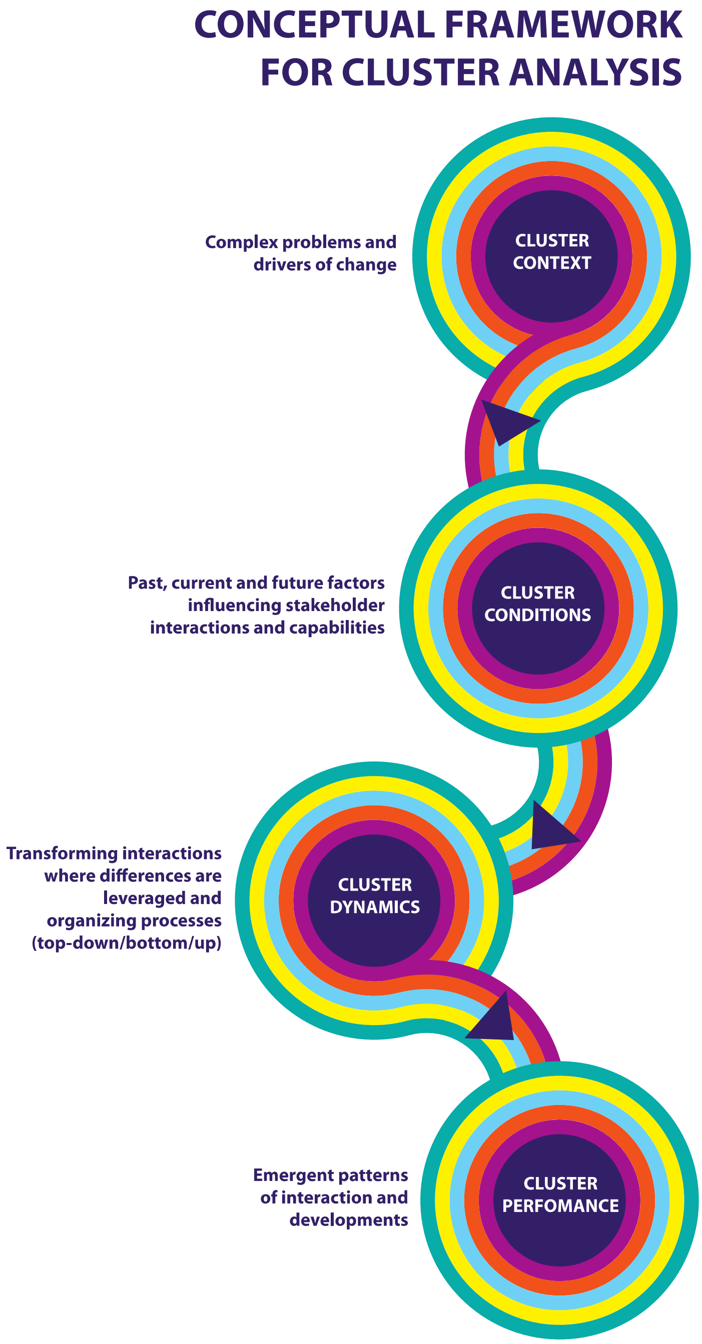

**Value of framework**

- Captures the irreversibility of history
- Captures shifts in landscapes and the interrelatedness of dominant issues and drivers of change in the landscapes
- Reflects concepts related to complexity and cluster developments
- Presence of self-organizing processes as part of cluster developments
- Captures how new problems, solutions and drivers emerge through cluster developments

**Limitations**

- Cluster dynamics is not captured/illustrated
- Top-down processes not indicated

**Framework 2**



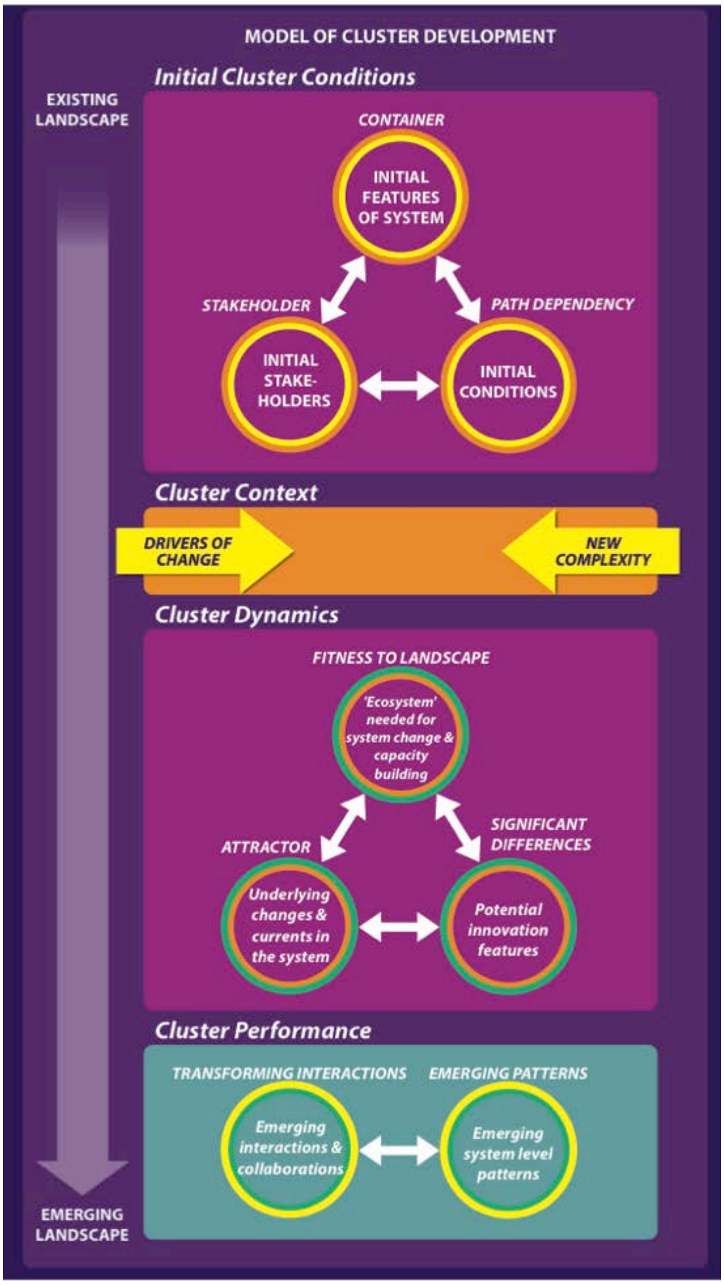

**Value of framework**

- Captures different aspects of cluster developments
- Captures highlights per aspect in description

**Limitations**

- Sequencing of aspects not accurate and suggest linearity
- Specific concepts of cluster developments not included (can be easily amended)
- Changing landscapes are not explicit

**Framework 3**



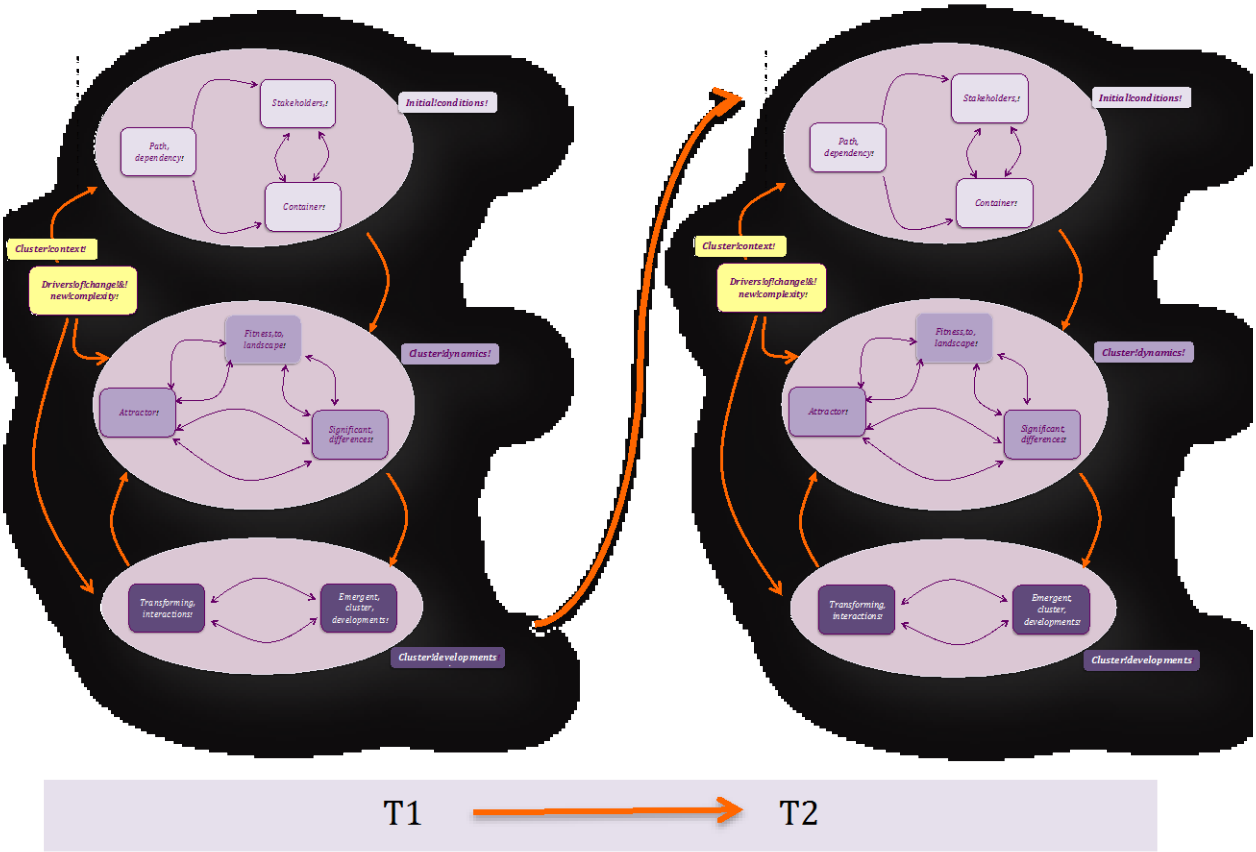

**Value of framework**

- Captures different aspects of cluster developments
- Captures interrelatedness of elements within each aspect
- Has descriptions that highlight core aspects
- Captures shifts in landscapes and therefore development over time

**Limitations**

- Sequencing of aspects not accurate and suggest linearity
- Specific concepts of cluster developments not included (can be easily amended)
- Contextual changes and drivers of change are reflected as a phase in the development
- Self-organizing and steering processes not indicated

**Framework 4**




**Value of framework**

- Captures different aspects of cluster developments
- Captures interrelatedness of elements within each aspect and between aspects
- Captures development over time and beginning of new cluster developments
- Contextual changes and drivers of change are part of cluster developments

**Limitations**

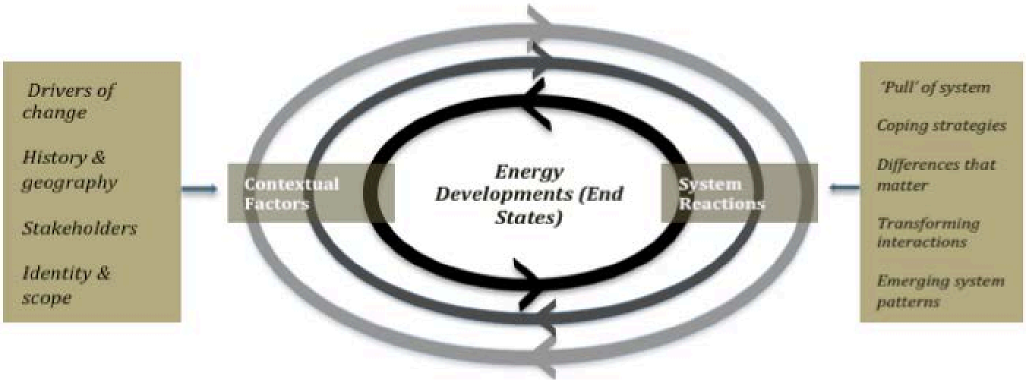
- Descriptions of aspects of cluster developments missing
- Self-organizing and steering processes not indicated

**Framework 5**

**Energy Development Framework (adaptation of cluster development framework)**

This an adaptation of the framework to capture systems developments of energy transitions based on an analysis of Energy Valley.

The research was adapted for the purposes of a parallel research that explored energy transition developments in relation to contextual factors (See Edgar Project, Appendix 10). The framework shares similar concepts but had been adapted to descriptions to avoid CAS terms to make it assessable for policy and professional use. The illustration below captures this version of the framework.




**Value of framework**

- Captures different aspects of (cluster) developments and uses lay language
- Captures systems-in-systems representation of (cluster) developments
- Captures overarching concepts of 'contextual factors' and 'systems responses' to categorize key concepts
- Contextual factors and systems responses are shown to be interconnected, but also at different systems levels

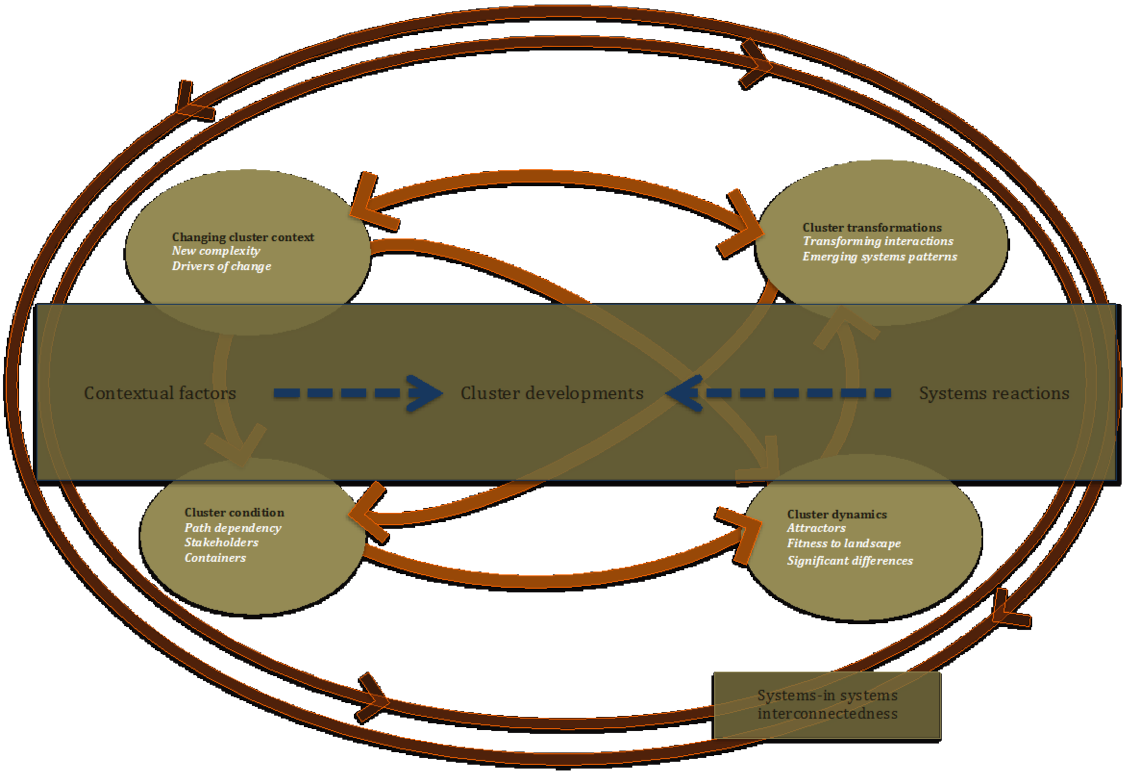
**Limitations**

- Descriptions of aspects are not precise CAS concepts
- Self-organizing and steering processes not indicated
- Interconnectedness of systems is ambiguous

**Framework 6**

**Proposed Model of Dynamic Cluster Developments (early version)**

A proposed cluster model was developed from the preceding frameworks and is illustrated below. The proposed model captures insights from the research and the underlying CAS approach.




**Value of framework/model**

- Captures overarching concepts of 'contextual factors' and 'systems responses' as key features of cluster developments
- Captures interconnectedness of cluster developments to its context, dynamics, transformations, and larger systems; but also, that cluster transformations contribute to new cluster conditions
- Contextual factors and systems responses are shown to be interconnected also at different systems levels
- Systems-in-systems developments share the 'core model' of cluster developments as systems responding to contextual factors

**Limitations**

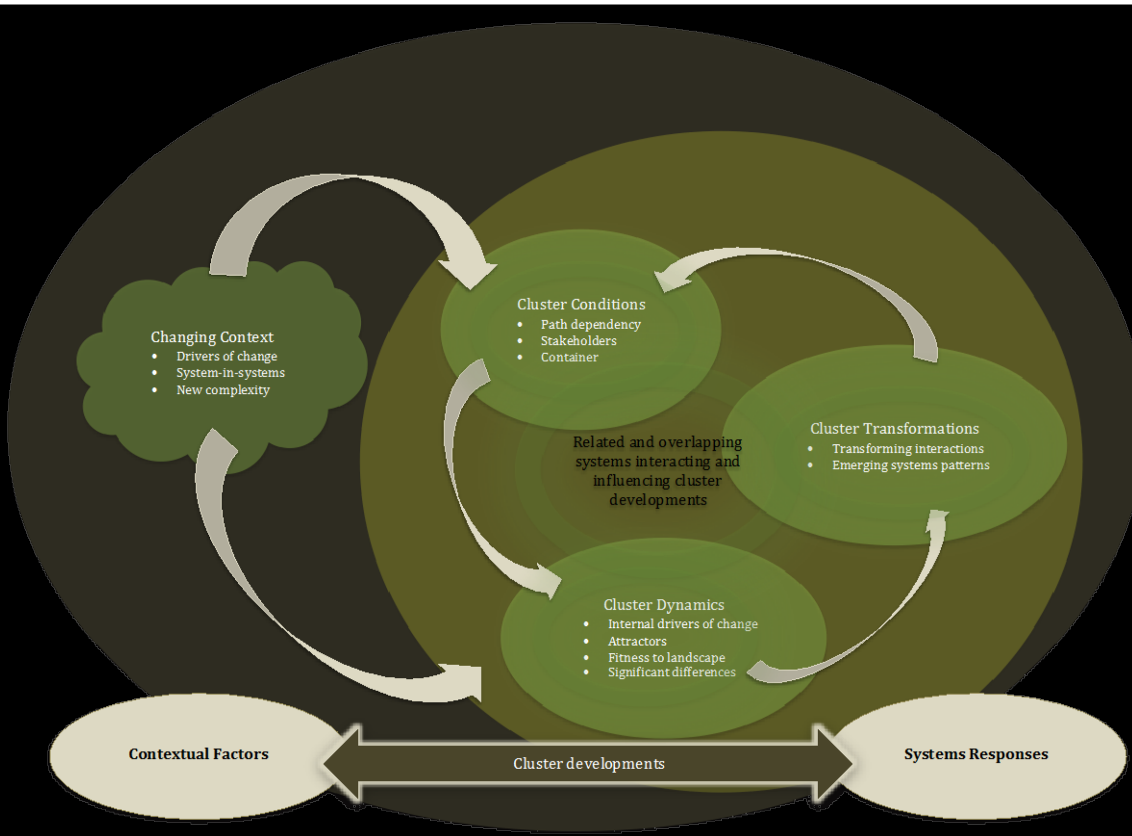
- Self-organizing and steering processes are not indicated
- Details of systems-in-systems relations are not indicated, only that these are interconnected and reflect general characteristics of systems respond to contextual factors by depicting cluster developments in the core
- Irreversibility of systems developments may not be evident

**Framework 7**

**Proposed Model of Dynamic Cluster Developments (revised)**

The proposed model was revised to better capture the various aspects of dynamic cluster developments. One of the changes shows more clearly which aspects belong to 'contextual factors' and which to 'systems responses'. The interactions of both these elements result in cluster developments and this has been better integrated into the model. Another revision is the inclusion of the systems-in-systems aspects of cluster developments as part of the changing context together with drivers of change and new complexity. The aspect of 'internal drivers of change' what was evident in Energy Valley findings has also been incorporated into the model as part of the cluster dynamics.

The model captures how *changing cluster context* affects *cluster conditions*, which in turn, affects *cluster dynamics*, and this in turn, affects *cluster transformations*. However, cluster *systems responses* are interconnected and therefore a ring is included to show that cluster systems developments are closely interconnected, given that actors respond autonomously to changes in their immediate environment, according to CAS theory. However, dominant shifts in *cluster conditions* shaping *cluster dynamics* and therefore *cluster transformations* are captured in model. These changes, *systems responses* of clusters, due to contextual changes result in cluster developments, which in turn, influence contextual changes, in line with CAS theories that espouse interconnectedness of systems with their contexts and their larger systems, *systems-in-systems.* These developments in turn, contribute to *new complexity* in cluster contexts. The exact nature of interconnectedness of cluster developments and their contexts needed further work and this is discussed in the Conclusions and Recommendations chapter.




**Changing context**

- ***Drivers of change***: external developments that impact cluster developments
- ***New complexity***: 'wicked problems' of high levels of uncertainty & disagreements
- ***Systems-in-systems***: upward & downward causality of cluster systems

**Cluster Condition**

- ***Path dependency***: history, geography, culture, etc. impacting cluster activities
- ***Stakeholders***: key actors of gatekeepers & stakeholder groups in cluster systems
- ***Container***: defining features of' playing field' and governing 'rules'

**Cluster Dynamics**

- ***Attractor***: constraining forces influencing cluster systems developments
- ***Internal drivers of change***: changing cluster features impacting developments
- ***Fitness to landscape***: developing new competences & strategies to 'fit' changing context
- ***Significant differences***: 'differences that make a difference' to support better 'fitness'

**Cluster Transformations**

- ***Transforming interactions:*** visible transformed developments via cross-boundary combinations
- ***Emerging systems patterns***: systems patterns emerging from interconnected cluster dynamics

To summarize, the model captures the following:

- Clusters are interconnected to their contexts and their cluster conditions
- Changes in contextual factors result in systems responses
- Systems responses include cluster dynamics and resulting cluster transformations
- Clusters are part of larger systems and these are interconnected, systems-in-systems
- Systems-in-systems developments share some of the contextual factors but may have different systems conditions and therefore systems responses may vary
- Cluster transformations contribute to new cluster contexts and cluster conditions, and in subsequent developments trigger new systems responses

The merits and limitations of the proposed model is discussed in the main thesis as part of the discussions of the findings. The table below captures the main concepts but also overaching aspects that are not made explict in the model.

| **Cluster Developments and related concepts** | | |
|---|---|---|
| **Contextual Context** | *Changing Cluster Context* | *Drivers of change, Systems-in-systems, New complexity,* |
| **Systems Responses** | *Cluster Condition* | *Path dependency, Stakeholders, Container* |
| | *Cluster Dynamics* | *Internal drivers of change, Attractors, Fitness to landscape, Significant differences* |
| | *Cluster Transformations* | *Transforming interactions, emerging systems patterns* |
| | *Overarching aspects* | *Related and overlapping systems interactions* |
| | | *Sensemaking (not in model)* |
| | | *Self-organizing processes and top-down steering (not in model)* |

This model is closest to the final Cluster Emergence Model. Minor improvements were made reflecting the continued learning process of the research.

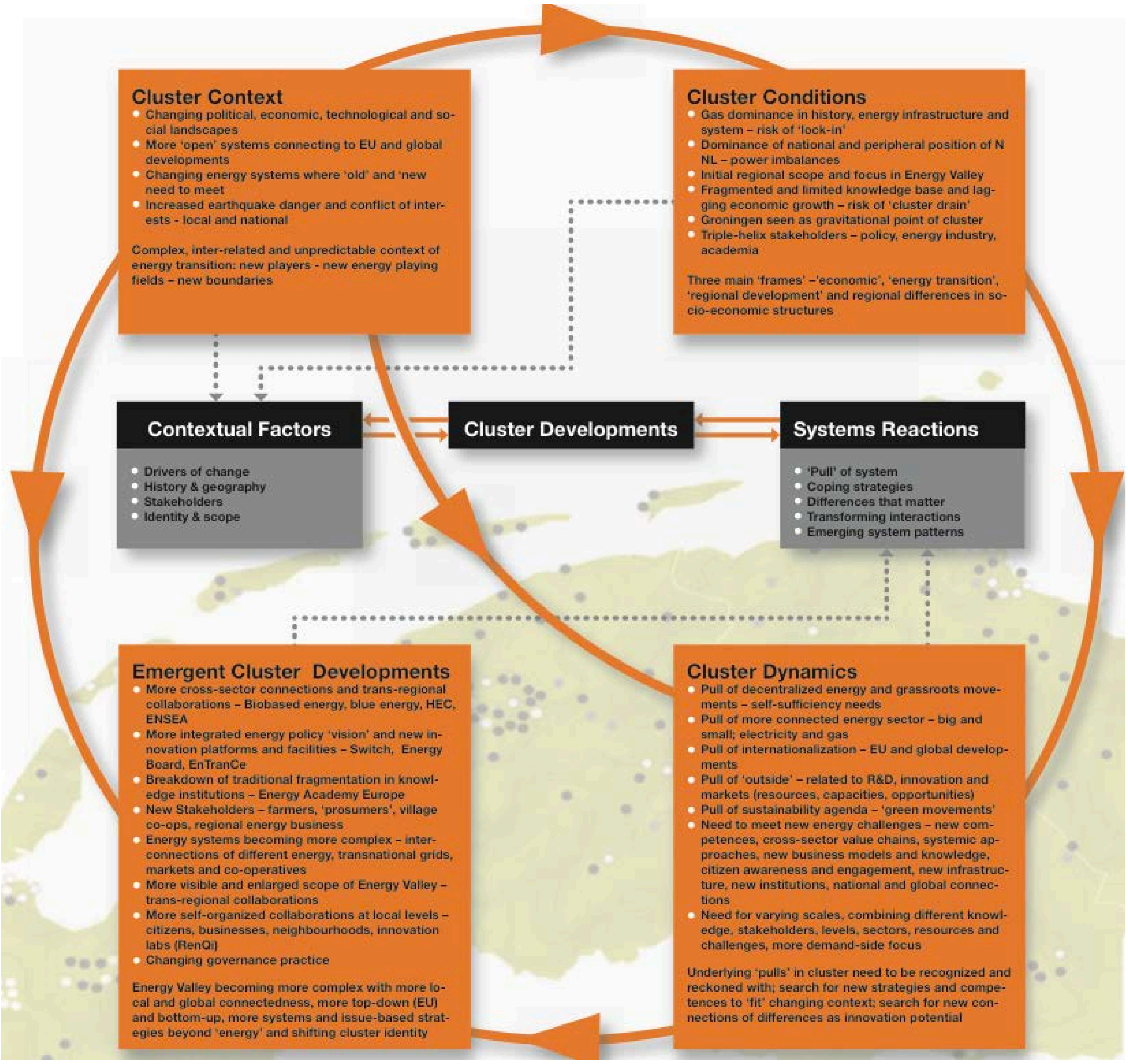
**Final version of Framework**

**Cluster Emergence Model**

The main thesis describes the final version of the CAS model in section 4.13).

**Application of the Cluster Framework to explain Energy Valley Developments Poster Presentation at the LSBU Summer School, June 2015**

The poster below captures how the cluster framework was used to capture key factors related to the cluster developments. The poster incorporated the 'Edgar' framework to show how cluster developments are interconnected to their contextual factors and cluster systems responses, and how in turn, the various cluster aspects are interconnected. The illustration represents use of the framework to show deeper interconnectedness and dynamics of cluster developments. The development of the poster contributed to the final version of the model.



# 9. ENERGY VALLEY CASE – ADDITIONAL DETAILS

This section includes additional information omitted in the main thesis pertaining to the 'Lessons'. Lesson 1 contains comprehensive information in the main thesis and therefore no additional information has been included here. Additional information on Lessons 2 – 7 is included in this section.

## Lesson 2: Cluster condition

Energy Valley's cluster conditions are described here with details on the key findings on each of the aspects of *path dependency*, *container* and *stakeholders*.

**Energy Valley's Path Dependency**

The first cluster condition is path dependency whereby factors such as geographical, historical and socio-economic factors relevant to the cluster's emergence and development of Energy Valley were identified. The findings identify which factors were significant to cluster developments. The path dependent factors are elaborated below.

- Gas reserves have created new industry and expertise since 1950s, whilst energy market liberalization threatened loss of energy expertise and jobs through mergers and acquisition [both Dutch and foreign) and re-location of the corporate headquarters out of the region.
- Dominance of 'gas' in the history, energy infrastructure and energy system in the Netherlands determined Energy Valley's initial cluster condition; this meant an inherent lock-in risk of gas-dominated solutions and a power imbalance between the national government and the northern cluster.
- Dominance of national economic interests expressed as 'Netherlands Inc.' (BV NL) meant that national economic interests were more important than regional interests.
- Northern Netherlands needed to collaborate on future strategies to gain a stronger position within the Netherlands, in part due to their peripheral and rural economic base.
- Focal points of Energy Valley cluster reflected factors related to path dependency: gas, biogas (agriculture), wind, water, NW Germany and North Sea Region.
- Knowledge base of Energy Valley was limited and fragmented, and 'cluster drain' was a risk, and there was also divergence in cluster developments due to
    - Lack of major corporations and R&D capacity outside of 'gas';
    - Fragmented public research capacities and disciplines;

  - Dispersed innovative SMEs.
- Regional differences in dominant socio-economic structures existed; in Groningen - large gas corporations; in Friesland - autarchy, food and agro-based industry; in Drenthe - recreational and tourism industry, SME dominant and 'Veen' (peat) colony; and in North Holland - horticulture industry, hinterland of Amsterdam Metropolis.

The main thesis describes Energy Valley's path dependency in Lesson 2 and how it relates to other aspects of cluster conditions (container and stakeholders).

**Energy Valley's Container**

The second feature of the cluster condition is the container. Container is 'defining features of systems including scope, boundary, vision, governance structures, etc.' (sub-section 3.13.1.1). The complexity of Energy Valley's container is highlighted below that includes divergent frames, complex set-up and collaborations that included both overlapping and conflicting agendas, and the limited mandate and scope of the cluster organization. These features are described in more detail below.

- There were three dominant frames present in Energy Valley, namely, 'economic', 'energy transition' and 'regional development'. These underlying 'frames' shaped priorities and strategies of key stakeholder groups and these meant that potential conflicts of interests and a lack of coherence in the cluster were a risk.
  - A lack of common frame or explicit framing risked sub-optimal dialogues and results;
  - Regional differences of local contexts and agendas in the four provinces enhanced risks of sub-optimal results;

- The cluster organization, Energy Valley Foundation, was dominated by complex collaboration partnerships where key triple-helix stakeholders, the 'founding fathers', public funding agency (SNN) and cluster members had to be accommodated. Collaborations were motivated by urgent needs despite inherent differences:
  - Collaboration and formation of Energy Valley cluster was a joint initiative by the 'founding fathers' in response to forecasted depletion gas reserves and fear of dispersion of gas expertise from the region;

- Collaborations despite (regional) stakeholder differences reflected the urgency of energy transition and regional economic challenges connected to the transition;

- The cluster organization was commissioned to serve local energy businesses, broader energy transition developments, and regional economic developments. This posed complex and sometimes conflicting agendas for the organization. To illustrate:
  - Large-scale developments in the Eems harbour region served national and strategic interests rather than job creation, decentralization and sustainability goals;
  - Limited capacity of cluster organization meant iconic (political and large) projects superseded local business support and job creation goals initially;
  - Priority to the ‘gas-roundabout’ strategy as opposed to local energy systems;

- There was a clear mandate to the cluster organization to limit its scope to the cluster region in the initial phase.

The main thesis describes Energy Valley’s container in Lesson 2 and how it relates to other aspects of cluster conditions.

**Energy Valley’s Stakeholders**

The third feature of Energy Valley’s cluster condition encompassed stakeholders. Key stakeholders groups were policy (including Regional Development Agencies, RDAs), industry (including SMEs) and academia (including research institutes). The cluster organization, key energy players in the region, and policy makers were dominant. In Energy Valley, energy transition developments meant that citizens and non-governmental organizations, civil society, although not part of the cluster were acknowledged as important stakeholders in the future. Stakeholders in Energy Valley’s developments are described below.

- Key stakeholders included energy stakeholders related to and representing the following groups:
  - Policy

- Energy industry
- Academia & research
- Regional development agency
- Cluster organization (EVF)

The dominance of large corporations and key public figures, such as the Commissioner to the Queen and the CEO of the gas-trading corporation, were influential in the cluster development.

- Key gatekeepers were identified as champions of Energy Valley, who increased its visibility. These included individuals, governments and the cluster organization;

- Groningen was identified as a gravitational point of the cluster due to the location and role of
    - Dominant (gas) incumbents
    - Province of Groningen
    - Cluster organization

  There were misgivings about the dominance of Groningen in the other regions.

- There were 'missing' stakeholders who were not involved in strategy dialogues and were deemed to be potential partners for future developments. These included:
    - Financial institutions as financing renewable energy developments, particularly citizen initiatives, as economic growth in this sector was expected;
    - SME representation in strategic dialogues was limited for two reasons: the diffused nature of the group; Energy Valley's Advisory Board had limited SME representation;

- Input from civil society in strategic dialogues were not present even as the number of local energy co- operatives were increasing; like SMEs, this is a broad, diffused group:
    - Decentralization of energy supply meant that new players including citizen initiatives and new SME energy services were changing

defining features of the cluster but these groups were not (yet) part of formal dialogues;

- Local municipalities and some NGOs had closer links to citizens and were more aware of the growing significance of this group but these intermediaries were also not part of strategic dialogues of the cluster;
- Energy transition decisions impacted local communities and businesses as evident in protests to wind park development, $CO_2$ storage, gas-related earthquakes, etc.
-

**Lesson 3: Cluster context – complexity and drivers of change**

This Lesson captured the diversity of perspectives that stakeholders displayed in describing urgent, complex challenges facing the cluster and the drivers related to these changes. The table below is a mapping of the problems and solutions to deal with these challenges described by stakeholders. The table captures their responses in different colours representing the stakeholder groups. This table was an initial analysis of their responses. Additional analyses were carried out and resulted in the mapping in Lesson 3 (section 4.6).

## Complex Issues in Energy Valley

| Themes | Details by stakeholder type (see legend below) |
|---|---|
| **Complexity – urgency, conflicting views, unpredictability** | Sense of **urgency**<br>**Urgency of ET**<br>**Energy security** of supply<br>**Urgency** for RE |
| | **Conflicting parties, interests** of stakeholders – conservative vs. progressive<br>**Differences in EV** - choice of decentralized and large scale; per stakeholder, per region…<br>Government has **vested interest - income**<br>**Different interests, solutions, solutions** of stakeholders – Conflicting interests; no consensus<br>Stakeholder **interests different**<br>**Differences** in urgency, focus - EV and politics |
| | **Complexity** of new system<br>**Legality** of RE too complex<br>**Complexity** of problem<br>**Interconnectedness** of provinces |
| | Solution successes for future unclear; **unpredictability of future**<br>**Future unknown**; future technology unknown; shale a hype, impact not known; |
| **Approach - desired** | E.E. solutions needed; **affordability**; **user-centred** approach needed<br>Creating right **conditions** for **ET – complex**<br>**Decentralized ownership** - bottom-up – citizen-centred<br>**Systems approach** needed<br>**Affordable** energy – long term<br>Strengthening socio-economic **position of North – 'real valley' Young people in ET –** new thinking; talent, HR, **missing stakeholder**; 'young capital policy' missing<br>Strict standards/**norms** as quality – competitive advantage<br>Introduction of RE - **market balance**<br>**Price and market** mechanism<br>**Regulations and legal issues** of ET, Speed of ET (**economic**) viability of new solutions for ET |
| **R&D – also approach** | Too **little R&D** focus, more on out-roll<br>**R&D & innovation** –<br>Traditional energy; no big corporate R&D; international and NL partners needed; funding needed<br>Technical **innovation**<br>**Innovation driven – missing in top layer of developments**;<br>Energy **knowledge base** |
| **Grants – also approach** | Technology lead only with **grants**<br>SME support [grants for innovation] **Administrative burden** for SMEs; also EU grants |
| **Approach – need for new solutions: consistency/coherence, scale, connecting/collaborations** | Job creation, new **economic** sector<br>Greying **HR**<br>Power plants not solution for **labour market (jobs)**<br>**ET is societal process; long term perspective –** ET not about labour imbalances<br>Separate worlds – **social** component of ET |
| | **Consistency of policy**<br>**Impact of national policy on regional and local policy Consistency in policy** needed, long term policy<br>e.g. SDE, solar, biomass in coal plants, off-shore wind **Policy issues:**<br>– **inconsistency** affects investors<br>– **choice of incentives**<br>– **support for energy developments**<br>– **changing focus** - first regions, then sector<br>Compare DU in policy consistency<br>**Offshore wind - change in policy** about finance, no clear long term policy;<br>Compare Germany - consistent policy even in crisis - V.O.C. - where the wind blows?<br>**Local policy also inconsistent -** with economic situations<br>**Inconsistency in** policy<br>**Consistency of policy** |

| | |
|---|---|
| | Policy and regulations – **inconsistency**, targets only **not whole system**<br>**Economic** and policy (Mis)alignment<br>Economics of energy for NL |
| | Need for **Scale – National level**<br>Need for **National Energy strategy**<br>**Position of NL** in **RE market**<br>**Up-scaling technology** – international partners needed |
| | Need for **Collaborations**<br>**Collaborations** – pragmatic nature<br>**International collaborations on RE**<br>**Interdependency** – collaborations<br>**Separate worlds** of gas and electric<br>Separate worlds – **social** component of ET |
| **Approach – need for new roles & scope: inclusion/ownership & need for new technology** | **New role** for EVF<br>Role of gas in Energy Future<br>Re-position/**new role for** EV<br>**Role of government in ET;** broad direction not details<br>Government has **vested interest – income**<br>**Government and regulations** – grants, subsidies, taxes, legal, norms/standards<br>Who is responsible for RE?<br>**Commitment of companies**<br>Energy Efficiency – **role** definition – for **local government** |
| | Energy is **international** EU, North Sea Region, NW Germany. Energiewende,<br>**Scale** issue – bigger picture needed<br>**International collaborations on RE**<br>Need for **Scale – National level**<br>**Position of NL** in **RE market**<br>**Up-scaling technology** – international partners needed<br>**Interconnectedness** with international on many aspects **Opportunities in NSR** for innovation<br>International hotspot - **branding** |
| | **Social component** of ET<br>**ET is societal process; long term perspective –** ET not about labour imbalances<br>**Self organization** – move to de-regulated energy system<br>**Urgency** for RE<br>**Citizen** engagement/ ownership – social component ET; Social media role; visibility; awareness; communication; RE common good |
| **Approach – need for sustainability and technology implications** | EE and CO2 **emissions**<br>**Sustainability**<br>**Energy savings**<br>E.E. solutions needed;<br>**Climate change**<br>Wind and zero (**CO2**) emissions<br>**Wind and sun**<br>**CO2** mitigation<br>**Sustainability**<br>**Sustainability** as policy choice not economics<br>Off-shore |
| | Smart grids – umbrella concept<br>**Storage**<br>Storage<br>**Storage** as solution –need for innovation<br>**Storage** for intermittency – RE<br>**Balancing**<br>**Balance** in ET of RE<br>**Balancing** in ET - crucial<br>RE integration **in grid – infra**<br>**Infrastructure** – costs and capacity |

| **Legend:** | Industry | SME | Policy | Academic | RDA | CS |
|---|---|---|---|---|---|---|

## Lesson 4: Cluster dynamics

In the main thesis, cluster dynamics of Energy Valley was explored by describing the interrelatedness of the aspects of *attractors*, *fitness to landscape* and *significant differences*. These three aspects of cluster dynamics described how the energy cluster responded to its changing context shaped by its underlying systemic developments combined with perceptions of new strategies needed for its future, and the existence of innovation potential in significant differences in the cluster.

These micro-level cluster dynamics descriptions collectively captured the following changes:

- Shifts in vision and paradigms
- Shifts in collaboration structures and scope
- Clustering of knowledge and innovation capacities
- Convergence and grouping of interests
- Emergence of opposing forces from bottom-up [coalitions and lobby as response to national and corporate dominance, e.g. grassroots initiatives, local energy co-operatives]

These five shifts seen in cluster dynamics are inherent in all aspects of cluster dynamics and cluster transformations. More on these underlying shifts is addressed in the Discussions of the three cases in Appendix 14.

The following three sections look at attractor, fitness to landscape and significant differences and how these contribute to cluster dynamics.

### Energy Valley's Attractors

Stakeholders recognized Energy Valley's attractor movements, namely, trends and directions of developments. Stakeholders being sensitive to their local context were able to describe new developments in the cluster and in energy transition. Underlying changes in a system may not always be explicit but responses from different stakeholder groups and in different 'places' in the cluster offered insights into the direction of change of Energy Valley. Significantly, the main change identified was its increased complexity and unpredictability. Below is a list of key attractors in Energy Valley.

- There was a strong ‘pull’ in Energy Valley to redefine and re-position gas within energy transition futures and one of the key justifications was that gas could fulfil the necessary balancing function needed for an energy mix dependent on renewable energy sources.

- There was a shift from a more supply-side focus to more demand-side focus in the energy cluster and the energy sector as a whole, partly fuelled by grass-roots movements and decentralized energy strategies.

- There was a movement towards a more connected energy sector, connecting electricity and gas sectors; connecting big and small enterprises within the energy cluster more than previously.

- There was also a strong movement towards increased grass-roots developments supporting decentralized energy developments that was motivated by a need for autonomy and self-sufficiency.

- There was a strong movement towards sustainability fuelled by agendas that advocated the need for more resource efficiency, greater share of renewable energy, and for reduction of $CO_2$ emissions by ‘green’ consumerism lobby.

- There was a strong movement towards ‘outside’ in terms of R&D, innovation and markets motivated by the need for resources, capacities and market opportunities.

- There was a strong movement towards increased internationalization, partly due to EU programmes and opportunities, parallel developments elsewhere, and increased globalization pressures.

- There was also a strong pull towards national and corporate economic interests, regional growth and job creation priorities that seemed to overshadow energy transition agendas.

The initial cluster’s internal and regional orientation shifted to include more ‘outside’ orientations to meet pressing challenges of energy transition and globalization.

Limitations of the cluster's capacities in combination with attractive external opportunities fuelled outward movements that pointed to potential risks of 'cluster drain'.

Another major concern of attractor developments was the 'dominance of national economic interests' that risked impeding regional growth, sustainability goals and energy transition developments.

The next section elaborates on Energy Valley's attractors with quotations from stakeholders. There are overlaps with the main thesis, which provided highlights of this next section.

### Attractors – narrative with examples

The underlying systems responses of attractors in Energy Valley as described previously reflected the shift from a gas dominant energy sector of the past to meet demands for renewable energy and sustainability agendas, and developments coming out of these new demands and norms. One of the changes included a shift in incumbent energy players to 'think' more demand-side and 're-think' their position in the energy landscape. Another related shift shaped by 'green consumerism' reflected a shift in thinking and behaviour of consumers. This is seen in the growing number of energy co-operatives and citizen initiatives fuelled by a need for more autonomy in energy supplies.

Another shift in Energy Valley was the increasing collaborations between electricity and gas sectors, which were once independent 'silos' with limited overlap. This also meant that 'big' and 'small' corporations in the energy sector were seeking collaborations in search of innovation and more integrated solutions. Similarly, academic and research institutions also saw the need to combining knowledge resources that was a break from previously fragmented academic disciplines and institutional 'silos'. The urgency of energy transition challenges also saw an outreach to international knowledge and resources that was a shift for the energy cluster from its regionally oriented and within firm research developments of the past.

At the same time, predisposition towards large-scale projects and developments in the energy cluster and region were still dominant due to the dominance of national and economic corporations and interests to boost regional economic growth (Groningen).

It was evident that shifts in Energy Valley were in part breaking down of old 'thinking' and 'doing' whilst other cluster developments reflected 'business as usual' (see Edgar project report, Appendix 10).

To further illustrate these changes, an outline of the development of Eems Harbour.

Eems Harbour was deemed an important transport hub that could facilitate cross border and international developments, which would connect Energy Valley to foreign energy sources and markets. Developments at Eems Harbour included setting up LNG terminal facilities and storage capacities; realizing on- and offshore assembly capacities for the North Sea wind parks; realizing facilities that supported transport and maintenance of North Sea wind parks; developing facilities for landing offshore energy supply and for the distribution to European hinterlands. Development of Eems Harbour contributed to transforming Energy Valley's capacities to meet changing energy landscapes.

A few quotations from stakeholders have been included to capture attractors in movements in Energy Valley. 'Shifting Landscape' in Lesson 1 included quotations that captured attractor movements as well.

On the Eems harbour and North Sea developments:

*'There is a complete complex at Eems harbour that has been in development for a long time now, the chemical and energy [sector] that includes pipelines to allow exchange of different energy streams…' [RDA stakeholder, EV1]*

*'Now you see the ENSEA project as an example, that there is active cooperation with the Germans, and this has been extended to the Norwegians and Scots. Also with the Danes when it comes to rolling out LNG… in all of the Wadden Sea. Therefore, internationalization is accelerating.' [Academic stakeholder, EV7]*

On shifting energy positions and convergence, and new collaborations:
*'And then there is the connection between gas and electricity…gas to power and power to gas interactions… With the increase in sustainable energy with its inherent difficulty to manage, there is an increase need for buffers of storage, etc. At the same time, you see that the electricity world tries to solve this in their electricity domain and the gas world says that they will do it for gas by [gas] storage means…' [Industry stakeholder, EV16]*
On shifting energy transition and consumer behaviours

*'What we now describe, a trending term, is the energetic society or the do-democracy, this is a term that you hear when citizens themselves create sustainability experiences and this is on the increase… what we see is that a lot of citizens try to take it [sustainability] up… through energy…energy is visible, tangible…. you can put solar panels on the roof, you can*

*save [energy], it gives an immediate good feeling, and that is a driving motive. Next to it you have organizations that have deeper sustainability goals. We want to have a more coherent neighbourhood; we want to have rural development using energy as a business case, etc. In Drenthe, you have about 40 visible groups that are active…'*
*[Civil society stakeholder, EV19]*

The next section is on Energy Valley's 'fitness to landscape' aspect of its cluster dynamics.

**Fitness to Landscape strategies**

Energy Valley's need for new competences and capacities to make the cluster 'future-proof' is described as part of its fitness to landscape strategies. The following are key factors identified by the stakeholders.

Four aspects were deemed necessary to meet Energy Valley's urgent challenges, captured in the list below.

- New infrastructure connecting different and new sources of energy (smart grids) were deemed necessary and this meant new competences, accelerated innovation and deployment.

- New institutions and innovation spaces were deemed necessary to bundle fragmented knowledge, research and innovation efforts in energy transition, to include new stakeholders and to create common grounds for the increasing diversity of players. Energy Academy Europe and EnTranCe were examples of new institutions serving as 'common grounds', accelerating transition processes and supporting collaboration and innovation needs.

- Varying 'scales' were deemed necessary to support energy transition and cluster developments. This meant that small, local, regional and trans-regional scales were all relevant, necessary and needed to be connected. Examples of these various scales were village and urban citizen co-operatives, city councils' energy programmes, Hanze Energy Corridor and the North Sea Region, the last two being trans-regional scales that connected Energy Valley to other clusters as part of larger inter-regional collaborations.

- To meet challenges of energy transition, different approaches and strategies were deemed necessary and these included:
    - o More emphasis on multi-disciplinary competences including broadened education programmes.
    - o Need for multi-sectoral collaborations that connects energy to other sectors such as water, agriculture, chemicals, etc.
    - o Need for new business models, knowledge and sectors as part of energy cluster, for example, IT and business services sectors.
    - o Emphasis on cross-sector value chain innovations and a need for different economic structures and policies.
    - o Need for more systems approach in dealing with energy transition that goes beyond technical systems.
    - o Need for more trans-regional and international collaborations such as the North Sea Region and Hanze Energy Corridor.
    - o Need for inclusion of and support for SMEs related to energy innovation and energy efficiency strategies.
    - o Need for more citizen awareness and engagement due to changing role of citizens in energy transition and market developments.

In addition, there were regional differences in fitness to landscape strategies due to underlying economic structures and priorities. The list below illustrates the regional strategies.

- Support for large-scale energy related projects and capacities through Eems Delta developments in Groningen, such as LNG terminal developments, offshore wind park assembly, landing site for offshore energy cables, etc.
- Support for decentralized energy production and energy efficiency in SME and industry in Friesland and Drenthe.
- Support for Amsterdam metropolis area; focus on horticulture sector; development of water and wind energy with own 'energy board' in North Holland North.
- Support for decentralization and grassroots movements through inclusive community engagement and outreach as new strategy in all regions.

Another aspect of fitness to landscape strategies related to power differences amongst regional governments. Energy Valley needed to strengthen its position and move away from its status as peripheral region and gain better standing at the national level. This need was in part motivated by a new national policy focussing on Top-sectors and the new energy agenda. EU energy policies also offered new opportunities for Energy Valley. Lesson 6 describes national and EU level developments whilst Lesson 4 interrelatedness of cluster dynamics gives more insights into fitness to landscape aspects of cluster dynamics.

The next section elaborates on fitness to landscape part of Energy Valley's cluster dynamics. There are overlaps with the main thesis as highlights and quotations from the next section have been included in the thesis.

### Fitness to landscape – narrative with examples

The fitness to landscape aspect looked at how the cluster needed to adapt itself to meet new and future challenges. Stakeholders indicated that new capacities and competences needed to include changes in infrastructure, approaches and strategies and institutions and innovation spaces. They also indicated that varying scales were needed to deal with different aspects of these challenges (see earlier paragraphs and section on Energy Valley's fitness to landscape). It was also clear that different interests and underlying structures in the different regions, and differences between stakeholders meant that different strategies were proposed or carried out to meet the challenges. These differences in strategies could lead to a 'lack of coherence' in the cluster, or, it could support new combinations and innovations. More on the innovation potential of these differences is described later in the narrative about significant differences.

In the narrative about attractors, development of the Eems Harbour was described in terms of developing new capacities and competences to meet changing energy landscapes. Development of smart grid technologies and systems integration was also mentioned as being part of fitness to landscape strategies necessary to be aligned to changes in the European and global energy sectors. The main strategies and approaches in fitness to landscape reflected the need to expand the scope and current practices of stakeholders in Energy Valley. This included collaborations that needed to cross knowledge, sectors, and regional and national borders. In addition, shifting business-consumer roles meant that consumer participation in energy transition needed to be acknowledged. This, in addition to SME businesses as new players in the energy landscape, meant that strategic developments needed to embrace such changes and that traditional stakeholders in Energy Valley needed to be inclusive in their strategic dialogues.

Related to the need for new competences and capacities for current and future challenges of energy transition and the cluster, was the creation of supportive institutions and innovation spaces specific to energy transition. As mentioned earlier in cluster condition, knowledge institutions and research facilities in Energy Valley were not specific to 'energy'. There were universities and applied sciences educational institutions that had relevant knowledge and professional development capacities relevant to energy transition but these were fragmented and no designated energy institute was present in the past. Two initiatives to consolidate knowledge developments and focussed research were set up in the university town of Groningen. These were the Energy Academy Europe and EnTranCe, an initiative of energy related businesses and the university. Both these institutions were considered essential in Energy Valley to support energy transition. They were also involved in unprecedented cross-boundary collaborations between faculties, institutions and companies. The section on cluster transformations provides more details on these developments. Lesson 1 on 'Shifting Landscape' has also described these developments.

Another key fitness to landscape strategy was the positioning of the energy cluster within national policies in order to ensure that energy and Energy Valley were included in the national government re-structuring of economic policies towards Top Sector Policy. The Green Deal and inclusion of energy as one of the 'top sectors' identified by the Dutch government were part of this new effort to bring Energy Valley and the northern region from the periphery to centre stage. Connection to national policy strategies is also relevant to the question of the 'right' scale to deal with challenges within Energy Valley. Stakeholders and interviewees indicated that 'varying scales' were needed for different challenges. An example of this is the Energy Accord whereby an extensive coalition of socio-economic partners came together to determine what needed to be done to achieve $CO_2$ reduction and renewable energy targets as part of the climate change pact with the EU (Switch Northern Energy Agenda). Goals for regional and national levels were identified in this Energy agreement. Other aspects of the varying scale would be facilitation of local initiatives such as energy co-operatives and trans-national scales such as the North Sea energy collaborations (more in section on cluster transformations). Yet another aspect of varying fitness to landscape strategies that was mentioned earlier was the different strategies adopted by the different provinces, due to endogenous economic and social structures. Many of these aspects have already been described in earlier sections, including relevant quotations to illustrate these aspects. Here, a few quotations have been included to illustrate differences in strategies and scales that were deemed to be necessary.

Need for different competences and focus on 'applied sciences'

*'There is also a need for a Beta and Gamma combinations in personnel and also people who can work in teams. For example, social acceptance is a big issue that could break us and we need to have people who talk differently and think differently and they have to be taken seriously… the faculty of economics and business administration in Groningen is the largest faculty in the Netherlands with I think 6000 students…there is also a need for applied sciences and people are afraid to be labelled as being applied and therefore also getting a label of second class from your colleagues if you are too much involved in practical applications…' [Academic stakeholder, EV7]*

*'…alpha beta and gamma combinations that offer more multi-functional education… what needs to be included in fundamental knowledge but also in applied programmes is the systems integration aspect – how different elements interact with each other. How do you balance wind with gas…. EnTranCe-type developments.' [RDA stakeholder, EV1]*

Need for different scale is illustrated in various settings and aspects:
*'There should not be energy tax on renewable energy…windmills and solar energy… and then, you can also realize large-scale projects, for example a field of 1megawatt and that you deliver to the end user without energy taxes…*

*Look if you look at the market in the North, take the 3 northern provinces and if we could all cooperate and procure collectively solar panels then we could get lower prices…*

*That is also important to grid companies [utilities] that they can avoid buying expensive power when the price is high by having storage in batteries… you need to realize these solutions, not in individual homes but perhaps in transformer stations…'*
*[SME stakeholder, EV15]*

*'The international contacts that we use are contacts for knowledge sources… here Germany is leading… knowledge bearers around the North Sea is for us a focus, but in principle, at Energy Academy, the world is our stage… Knowledge is in institutions, but also there is also [knowledge] in practice….' [RDA stakeholder, EV1]*

*'We are with ENSEA [European North Sea Energy Alliance] working on this [internationalization] and this is why we initiated this. Perhaps we need to also include the Danes and perhaps also the Baltic region for what we want to realize… not just the research only here but also the coordination and steering, and thus the nerve centre.' [Academic stakeholder, EV7]*

*'What we are doing here is 'small' but actually in Brussels it is a big agenda…we shared with Brussels how it [energy transition] needs to develop, the environment that is needed, so we have shown it on a small-scale but it is a question of whether all of us want to go with it and make it a success [on larger-scale] ….' [Academic stakeholder, EV24]*

In conclusion, fitness to landscape strategies identified reflected an acknowledgement of changing cluster dynamics. These strategies were oriented towards changing existing economic structures and interactions, expanding and adapting its scope as a cluster and region, inclusion of new and non-economic players in energy, gaining new knowledge and competences that meant changes in institutions and innovation spaces and becoming more sensitive to the growing complexity. Implications for changing governance were implicit and will be addressed in the next sections. Underlying the proposed fitness to landscape approaches was a search for significant differences both within and outside the cluster system to support innovation for the complex challenges.

The next part describes significant differences in Energy Valley.

## Significant Differences in Energy Valley

In order to meet complex challenges in Energy Valley, the innovation potential of the cluster was analysed in terms of its 'significant differences' as a means to expand its current capabilities. The following list captures significant differences that were present in Energy Valley:

- Big corporations and SMEs had different resources, scope, goals, competences, visibility, flexibility, innovations, access to markets, equity, policy, etc. and this could support expanding both types of entrepreneurial capacities.
- Academic and research institutes all had different capacities and goals.
- Local municipalities, provincial governments and regional development agencies had different agendas, resources and roles in cluster and regional development and these differences were relevant for new approaches.
- NGOs and consumers had different demand 'pulls' that could influence energy transition.
- 'Outside' and 'in-crowd' groups had different positions, interests and insights into energy and local developments in different places in the cluster (periphery, core, urban, rural, etc.) that offered new combinations for new solutions.
- The four provinces and sub-regions had distinctive histories, landscape, frames, issues, drivers, focus, strategy and scope, and this diversity could be important for dealing with complex challenges.
- Local, regional, national and EU levels, part of Energy Valley's context and container, included differences in roles, responsibilities, resources, interests,

scope and power that could lend themselves to centralized and decentralized solutions.
- The energy cluster was embedded in a region with a strong agricultural sector, waterways and water-related activities, offering cross-sectoral solutions.

Differences in Energy Valley also included potential risks, and these were:
- Potential lack of coherence in the cluster;
- Risk of fragmentation by sub-clusters (e.g. North Holland's Energy Board) and spin-offs of specialized energy cluster (LNG cluster, biomass hubs);
- Risk that regional and cluster scales may not be the 'right' scale or the only scale necessary to meet complexity of different challenges;
- Growth of distrust in cluster related to national economic interests superseding public safety, regional developments and energy transition developments;
- Potential 'cluster drain' due to limited knowledge capacities, market and regulatory conditions;
- Risks of delay in energy transition and uncertainties in energy sector developments.

The wide spread of Energy Valley over 4 Provinces and the differences in the cluster had therefore both potential for new solutions as well as inherent risks. The interactions and influences of the three aspects of cluster dynamics, as well as those of its context and developments, are described in the next section to better understand Energy Valley's dynamics.

**Significant differences – narrative with examples**

This part of the analysis on cluster dynamics in Energy Valley was discerned from the interviews and related documents. Significant differences has been described as the relevance of variety in the cluster was described in terms of the potential for new combinations and collaborations that would provide innovation and solutions for energy transition and regional development challenges. Some overlap with the main thesis exists.

Redefining the energy cluster to explore beyond its past scope and structures was already mentioned in the previous section on fitness to landscapes. The first significant difference is to be found at the provincial level in the cluster, which then acts as a background for all other points raised in the rest of this section.

The extensive regional coverage of the four provinces with very different economic and social structures, and visions defined Energy Valley. These regional and socio-economic differences also included different industrial and economic sectors, different ambitions and priorities. A brief introduction to regional differences in the cluster was presented in Lesson 3 to understand Energy Valley's complex context. The paragraphs that follow describe regional differences in terms of innovation potential for systems development, significant differences where 'differences that make a difference' (see Literature Chapter).

The Province of Friesland for example was focussed on decentralised and sustainable energy solutions that promoted their autarkic goals and principles. This province had strong SME and manufacturing sectors driven by its long-established agricultural and dairy sectors, which made sense to seek decentralized energy solutions. The presence of well-established waterways and lakes and the 32.5 kilometre dyke, the Afsluitdijk, meant a focus on offshore and blue energy developments. Blue energy included different water-based energy sources, namely, tidal, wave, reverse electro-dialysis (osmosis) of fresh and seawater salinity, etc. The recreational and business sectors, which focussed on water activities, were often SMEs and therefore customized and decentralized energy solutions were logical goals for the province. The maritime expertise, large base of manufacturing, agricultural and recreational sectors of this province coupled with its strong autarkic drive strengthened innovation drives towards water energy and decentralized energy systems solution. The province offered potential for crossovers between sectors: energy and water, energy and agriculture (biomass), energy and logistics, maritime (offshore), energy and recreation (e-mobility and clean waterways). This potential was present in other provinces but the autarkic drive meant that the ambitions and availability of resources to support this was significant in this province.

The Province of North Holland (NH) that borders the shared inland sea of Ijsselmeer with Friesland has similar maritime and water focussed development potential and ambition. However, the difference in North Holland North (that part which is part of the cluster) is that it has a strong horticulture industry that focuses on large-scale animal and agricultural activities that is more homogenous than that of the Province of Friesland where large (dairy) farms rather than glass houses dominate the agricultural sector. The focus on solar-based solutions for the glasshouses has an urgent significance besides the maritime and offshore focus and potential. The NH Province also houses the national expertise centre for energy research, ECN. ECN focuses on all energy sources and therefore no one solution dominates this province in its energy transition developments. The formation of 'Boards' on its main strategic priorities in NH included 'energy'. These Boards were similar to clusters at the local level. The Energy Board was in its initial stages at the time of the field research but collaborations with Energy Valley were expected. Other Boards included recreation sector, maritime, marine and offshore, medical, and agribusiness. The establishment of these Boards offered crossover collaborations for energy developments in this province. An important driver of energy developments in NH Province was serving the large metropolis of Amsterdam and its growth. The need for large-scale energy solutions was urgent in the Province of North Holland and this differed from the Provinces of Friesland and Drenthe.

The Province of Drenthe explored decentralized energy solutions, stimulating local initiatives similar to the Frisian province. Drenthe as a province was characterized by a large tourist sector that was mainly SMEs often with one or two partners (micro-enterprises). The tourism sector was also very much connected to nature and therefore energy solutions for this sector in the Province of Drenthe needed to be sustainable and local. The drive towards maintaining its natural heritage and its history of self-sufficiency stemming from the large peat reserves and forest and agricultural resources meant that biomass and wood-pellets next to solar panels were preferred. Preserving its landscape was important to its residents and in the past wind parks were met with protests. Decentralized and self-organizing energy solutions were supported with various facilities by the province and local municipalities, for example, Drents Energy Maatschappij (details in cluster transformations section following). Its rural population were supported, as were SMEs in the Province through such agencies and facilities. The drive of large populations to be self-sufficient and have sustainable energy solutions meant that demand-driven energy solutions had market potential in this Province.

The Province of Groningen had both local and large-scale energy solutions in its vizier as the province had 'large developments' in the Eems Delta region, the city of Groningen with its service oriented and educational hub needing urban energy solutions, as well as scattered and rural populations with agriculture dominant. Smaller hubs of semi-industrial and industrial hubs were present as in the other provinces. The large-scale developments were both a supply driven and demand driven development. The creation of an energy hub at the Eems harbour with its new coal fired RWE plant and facilitation of offshore wind parks and cables bringing hydro-energy from the Scandinavian countries meant that its heavy energy users that were once brought in with the lure of cheap energy (gas) could be serviced and new data centres and other industrial giants were attracted to the area. Collaborations with the North Sea (see cluster transformations section) also supported continued energy solutions for the Province but also for North Western Europe, as part of its strategy to replace the Dutch gas provisions of the last 50 years.

The different ambitions, resources, priorities, needs and traditions of these four provinces offer potential for new collaborations and solutions to the energy transition and regional developments. The section on cluster performance elaborates on the realized potential of significant differences of these provinces. The quotation below reflects Groningen's priorities and potential towards 'solving' energy and regional economic challenges.

*'Offshore wind is very important for us… offshore wind is one of the limited sustainable energy sources with the potential for large-scale production and if well executed, a very reliable source of energy without the protests [opposition] of land-based renewable energy. Another reason we are keen for this is the optimal location that we have to assemble and maintain these wind parks. The number of direct jobs from a 1350 MW park is about 3000 or 4000 jobs… this is a problem with the power plant in the Eems harbour there are now jobs for 3 or 4 or 5 thousand jobs but once finished it offers only 100 jobs. And at the moment the jobs [for the power plant] are temporary and mostly foreigners, Hungary, Portugal, Turkey, as we do not have the capacity…' [Policy stakeholder, EV8]*

Harvesting differences between large incumbent energy corporations and that of newcomers, often SMEs in terms of their competences, flexibility, resources, goals, access to markets and policy, financial equity are all ingredients that offer new perspectives for both large and small enterprises where leveraging these differences mean enlargement of future solutions for energy transition. To illustrate, new energy services to meet demand driven developments (attractor described earlier) means that IT competences that were needed could be leveraged from SMEs specialized in this field through collaborations by incumbent energy corporations. These smaller innovative companies could gain competitive advantages in such collaborations by gaining market access and specialized knowledge on energy markets as well as resources for long-term investments, etc. Changing market dynamics in general and the changing energy landscape meant that new types of collaborations between sectors and types of companies were needed.

*'… the essential change the transition has seen, and that is interactions between electricity and gas; between large scale and small scale; between the different forms of infrastructure; between the triple helix [partners]. Through all of this, the playing field has become more complex.' [RDA Stakeholder, EV1]*

Related to the need for new types of collaborations is that of collaborations and new roles for intermediary organizations that have access to stakeholder groups who were not included in strategic dialogues in traditional cluster practice. Intermediaries like NGOs reach diffuse groups such as SMEs and consumer energy co-operatives, who were becoming more important in cluster development but were difficult to reach by the cluster organization. Energy Valley connecting to 'outside' could offer other solutions for challenges in the cluster and region. The following quote is from one such intermediary and their work is described:

*'The focus is clear and if we try to create opportunities [to support sustainable energy]… the story is about the energy trail in the Veen Colony where [you can choose] large-scale energy with big investments or [choose] making houses energy neutral and keep the money in the region; if we can link to local housing corporations then we have an interesting concept and that is we put our energy.' [Civil society stakeholder, EV19]*

Knowledge development was an important component of cluster development and energy transition. Pooling knowledge and research capacities of different universities and faculties with private research centres and businesses offered an extended knowledge base and creativity to deal with complex energy transition challenges. More traditional fundamental research skills combined with applied research and industry knowledge offers a different research scope for innovation. The quotation below illustrates some of these aspects:

*'Besides the level of knowledge, in applied sciences university, there is more of the transverse [horizontal] part of 'T' whilst in fundamental knowledge development is per definition in the vertical part and this is why there is in terms of contents divided segments … the Hanze have a different role in the game ….you can in any case say that Hanze has an important task… to ensure that the various disciplines of knowledge is channelled to create value….you need to do two things, you need to bring the different segments together and get people to work together and Hanze needs to be made accountable for its responsibility to make this happen.' [Academic stakeholder, EV24]*

Another aspect of significant differences present in the region was presence of various levels of governments, and the regional development agencies. Within the cluster, there were provincial (regional) governments, municipalities (local) and across the Northern provinces, regional development agencies (RDA) which included Energy Valley Foundation as the cluster organization focussed on energy, and Stitching Samenverwerkingsverband Noordnederland (SSN), the platform of collaborating stakeholders of North Netherlands. The latter was responsible for supporting economic growth and innovation in northern Netherlands. These different government agencies had different scope, legal and statutory tasks, resources and accountability. However, energy was an important theme both at the regional and local levels. Provinces were concerned with infrastructure and physical landscape responsibilities whilst local governments aimed to facilitate local business and residents in energy transition solutions. Local governments had direct contacts with its residents and businesses and were able to support decentralized energy transition issues more directly whilst regional governments dealt with larger industrial and business needs and future growth and energy security issues. Regional governments were also a link to national governments via a platform of provinces (IPO) where regional energy agreements and developments were deliberated.

Energy Valley Foundation and SSN were both regional development agencies (RDAs) that had innovation and support to SMEs high on their agendas but they had difficulty reaching SMEs due to the diffuse nature of the target group. Municipalities, however, were closer to SMEs and were in a position to understand the general needs and make-up of their local commerce and residents. These different agencies could collectively reach larger groups, provide more accurate information and support innovation in energy transition and regional development.

Energy Valley Foundation dealt with these different levels of government, as it was answerable to the northern provinces' subdivision of the IPO. Representatives of the northern provinces were part of Energy Valley Foundation's executive board. In addition, provinces, key municipalities (cities), academic partners and energy corporations of the region were sponsors of Energy Valley and played an important part in its governance structure (see Background on Energy Valley, Appendix 1). The quotation below captures the difficulty of creating supportive governance structures:

*'… if you consider the stakeholders then you have a few initiators that are responsible for the energy transition process and the national government is one of them. But also the regional [governments] have a role to create the framework conditions to enable initiatives to take place. There is role to create the right framework conditions but this is very difficult…' [Academic stakeholder, EV24]*

Significant differences were also present in Energy Valley due to the national and EU levels present as part of its context as opposed to the local and regional levels as described in the previous paragraphs. Once more, as mentioned in significant differences section earlier, differences were present due to roles, responsibilities, resources, interests, scope and power. Opportunities and support at the EU level for regions were sometimes different to that at the national levels. The EU supported sustainable energy transition futures and offered various grants for inter-cluster and trans-regional collaborations as opposed to the national government, which sought to maintain its gas strategy for the future whilst complying with EU targets for renewable energy (RE). RE targets however were consistently reduced in the Netherlands. Local and regional governments and stakeholders could leverage advantages at the EU levels for their sustainable energy ambitions. Stakeholders aiming to maintain their gas interests could leverage the national government's vested interests in gas. The differences in these levels offered a wider scope for energy transition developments as opposed to only the national levels. More details on the national and EU levels in relation to Energy Valley are also described in Lesson 6 where similarities and differences in patterns of development at these levels are covered.

Attractors, fitness to landscape and significant differences have been described in detail in this narrative about cluster dynamics to further illustrate their presence and significance in the energy cluster supported by citations from the field study and documentations. The emerging changes of cluster dynamics will be addressed in the section on cluster transformations in terms of visible changes in Energy Valley and the shifts in the cluster's systems developments.

Before moving on to the cluster transformations, the next section discusses potential risks facing Energy Valley due to its changing cluster dynamics. Once more, overlaps with the main thesis exist on this facet of cluster dynamics.

### Potential risks of cluster dynamics in Energy Valley

Cluster dynamics can bring about positive developments or have potential risks and these need to be addressed and monitored. For example, when attractors are not explicitly acknowledged and addressed, the underlying dynamics of the cluster could result in weakening Energy Valley. This section addresses key risks that were inherent to the energy cluster.

One of the risks in Energy Valley is the potential lack of coherence due to differences in the cluster. A prolonged and extensive lack of coherence in the cluster could lead to dissipation or sub-optimal performances (more on this in the discussions section). Energy Valley is made up of four provinces and has incumbent energy players and emerging new players and markets and the inherent differences were clearly reflected in the diversity of perceptions on what constituted urgent challenges in the cluster and perceptions on plausible solutions and strategies (discussed in complexity and drivers of change sections). The rich variety in the cluster is also an important source of innovation potential as discussed in the significant differences aspects of cluster dynamics. However, the risk of a lack of coherence looms over the cluster if these differences are not harnessed into intervention points to strengthen the cluster in its changing contexts. More on coherence in Energy Valley is discussed in the section on cluster transformations.

Another potential risk of the cluster and region, given the complexity of the changing contexts, was the risk of not being the 'right scale' to deal with such changes. The need for varying scales and flexibility to meet complex challenges of the energy cluster was due to the changes that were mentioned earlier. These included increased globalization pressures, internal European market developments, game changing technological breakthroughs (shale gas exploitation) and their consequences for market dynamics, new 'prosumer' developments, shifting geo-political powers, climate agenda and disruptions to energy supply (Russian-Ukraine gas contracts). Closer to Energy Valley there were contextual changes earthquake damages and risks that saw a change in the national government's position as custodian of citizen welfare and well-being conflicting with its considerations of economic growth and financial interests. This in turn fed citizens' need for self-sufficiency and demands for 'green' solutions and energy. The larger national interests of economic growth and security of energy supply were also interconnected as mentioned earlier to the EU internal market developments, and changing geo-politics and globalization of economies. These complex interconnected issues meant that flexible and diverse solutions were needed and that therefore clusters and regions may not necessarily be the 'right' scale, or the only scale needed. The embedded and systemic nature of clusters in larger and interconnected systems meant that clusters might be at risk of losing some of their traditional identity and roles (more in the Discussions section).

*'There will be a need for a macro system in the future; certainly when 60 to 90 Giga watt wind parks are realized in the North Sea, and concentration of large demand for energy lies in middle Europe. We then have a logistics problem to meet differentiated demand and supply challenges…and gas is an important part [of the solution], but also, for example, energy storage can be accommodated in the pumping systems [of gas].'*
*[RDA stakeholder, EV1]*

*'The concept of working together in the region, internationalization, like Hansa Economic Corridor, [HEC]…it is different [for us]. All four provinces acknowledge the necessity…but we do not know exactly what needs to be done; we know that there is a lot to be done…'*
*[Policy stakeholder, EV8]*

Related to this point is the risk of growing distrust in the energy cluster and governing agencies. The dominance of national and corporate economic interests meant a conflict of interest between these economic interests and those of citizen safety, local job creation, sustainability of rural communities and urgency of energy transition. Energy transition developments were not as high a priority as attracting large-scale industrial and commercial developments. New comers to the energy sector were dominated by SME and local initiatives. These were not equally incentivized nor supported by government grants. These points were discussed in Lesson 1 on 'Shifting Landscape' of Energy Valley with stakeholder quotations to illustrate. Different aspects of these issues are illustrated by some quotations below:

- Consistency and direction in policy

*'It is not so much about policy incentives but that policy was something that people can blindly trust and go their way about things. Let us say that the government chooses to set out a policy based on gas only, but then at least we know what the direction is. Right now, we do not know, it changes too much ' [Civil society stakeholder, EV19]*

*'There is a whole process under way in the Netherlands to reach a national energy accord, for which we are happy as it is not only steered by politics but by a more broader [coalition], but also because of a more consistent policy… you are asking a lot of businesses to invest in things that will be there for 20-25 years and if you keep changing your direction every 2 year, and then its wind energy that is important and then its solar, that is killing.' [RDA stakeholder, EV1]*

- Top-down steering of national policy

*'There is something to be said about regions… and the State too has its ideas about clustering, smart specialization…and looked at how they could fit these in and they looked at Top Sectors for example. They have identified a number of top sectors, smart specializations…following this, they explored how this can be implemented in the regions, and that was a puzzle… we have indeed looked at top sectors in terms of sectors but that is not quite regions, and that is problematic…yes, and that is always via the Ministry of Economic Affairs or [Ministry of] Internal Affairs.' [Policy stakeholder, EV14].*

- Distrust and negative image of sector

*'The sector is not able to be transparent and communicate with the general public and this has had a negative effect on the image. The industry has shot itself in its foot; you see that with the $CO_2$, with the Shale gas, and with the earthquakes. I think that they were not handy in their approach and so they need to learn and ensure that it gets done differently.' [Industry stakeholder, EV10]*

A significant risk in Energy Valley mentioned earlier was the risk of a 'cluster drain' due to growing outward linkages and movements of businesses to compensate the limited resources and market opportunities within the cluster and nation. Lack of R&D,

innovation resources and facilities, talent, policy constraints, etc. resulted in a tendency to explore possibilities outside the local system. The strong 'pull' to seek solutions outside Energy Valley was a serious threat of further depletion of capacities and attractiveness of the region if this resulted in a 'cluster drain'. Programmes and mandates from the European Union supported internationalization tendencies, and provided additional resources to regional systems, enhancing the attractiveness of 'the outside'. Being connected internationally was not negative, but the 'pull' of the outside could be a threat if it did not contribute to strengthening the cluster and region's systems capabilities. Quotations below elaborate on these issues.

- The lack of resources and R&D in the cluster

*'Gasunie Research is halted; GasTerra does not do research any more; the big RWE power plants also no research done; and that is the lot. It would be really helpful if Shell for example would have laboratories here, as a suggestion. And of course now that ECN is now included here…open a lab here for those willing and it could happen in the future, but it is too sensitive right now. But it would help a lot. [Academic stakeholder, EV7]*
*The most jobs are in infrastructure and this is a regulated [sector] and NMA executes the law and tasks are strictly pre-defined and since it is not ordained that infrastructure companies may work on energy transition challenges…in England, the regulator has allowed for 5% efficiency plus 10-20 million ponds or some amount, I am making up the figures, and that they only need to justify afterwards. But they jointly work with stakeholders [on energy transition] and of course there are conditions.'*
*[Industry stakeholder, EV9]*

Another reason for the outside 'pull' were stringent environmental and regulatory policies inhibiting research and development, and limited support for innovation in the Netherlands according to this stakeholder:

*'There are more projects [abroad] where the support from the government is a lot more comprehensive, but also longer. There is a more solid foundation and you can see that the markets [there] develop faster and are further in their developments. In the Netherlands, in the last five years despite the pressure and subsidies that are supposedly meant for this, there is relatively little upgrading taking place, for example in biogas installations. If we talk about England or Germany, there is almost a doubling every year [of upgrading].'*
*[SME stakeholder, EV23]*

This outward movement and the lack of priority for energy transition in part due to other national priorities as mentioned in the previous point on 'growing distrust', meant that the risk of energy transition delays were inherent and in turn could have an adverse impact on the cluster potential and future developments. Also, the earthquake dossier and developments of the gas exploitations were adding to possible risks for the cluster. The closing down or slowing down of gas exploitations also have an immediate impact for jobs and regional developments even as earthquake damages and danger are high on the agenda. The lack of confidence in the region about the future of gas exploitations on the one hand and the safety of the region on the other hand both can affect future cluster developments. (Lesson 7 and Appendices 10 and 14 also address industrial developments and cluster developments)

To summarize, cluster dynamic shifts related to cluster dynamics included potential risks, and these were:

- Potential lack of coherence in cluster
- Risk of fragmentation by sub-clusters (e.g. North Holland's Energy Board) and spin-offs of specialized energy cluster (LNG cluster, biomass hubs)
- Risk that regional and cluster scales may not be the 'right' scale or the only scale necessary; flexible scales needed to meet complexity of different challenges
- Growth of distrust in cluster related to national economic interests supersedes public safety, regional developments and energy transition developments
- Potential 'cluster drain' due to limited knowledge capacities, market and regulatory conditions
- Risks of delay in energy transition and uncertainties in energy sector developments

This section explored cluster dynamics in detail, including potential risks to Energy Valley in its future developments.

### Lesson 5: Cluster transformations

This section describes transformations that were described by the stakeholders and related policy documents to support the analysis. 'Cluster transformations' capture shifts of Energy Valley in response to broader contextual changes.

In the earlier section on cluster dynamics, changing micro dynamics of Energy Valley were reflecting shifts in vision and paradigm, collaboration structures and scope, clustering of knowledge and innovation capacities, convergence and clustering of interests, and increase in opposing forces against vested interests. Transforming interactions reflected these visible developments. Culmination of micro-level changes is then visible in emergent patterns link to shifting cluster developments.

The next section provides key findings of transforming interactions followed by a narrative of this aspect with elaborations and illustrations.

**Transforming Interactions**

The once mono-sectoral, regional, fragmented cluster and region reflected a trend of interactions and collaborations that crossed different borders, enhanced or created new joint initiatives in search of solutions, which was captured in Lesson 1. The following list illustrates Energy Valley's transforming interactions.

- There were more and new types of connections within the energy sector that included more collaboration between gas and electricity sectors, traditional and renewable energy players, 'big' and 'small' energy players and between producers and consumers.

- There were also more cross-sectoral connections such as those between water and energy ('blue energy'), energy and agriculture (bio-fuels, bio-gas), transport and energy (e-mobility); joint innovation centres were set-up in these cross-over initiatives such as the Dairy Campus, Afsluitdijk campus, Red stacks in Friesland.

- There was more collaboration that included trans-regional initiatives in energy transition, for example, that of Groningen-Niedersachsen, North West Germany, and the ENSEA project with partners from the North Sea region.

- There were more integrated and joint policy 'vision' developments resulting from new collaborations and alliances. These included the North Sea Energy Vision (ENSEA project), 'De Plus van Noord Nederland' (Northern Provinces' joint policy vision), 'Green Deal' (joint agreement of Energy Valley/Provinces with the national government), 'Switch' (joint strategy and commitment of Northern Provinces, Energy Valley and six municipalities to realize national energy transition targets for the northern region).

- There were new regional platforms created to meet local energy challenges such as the Energy Board in North Holland, Drents Energy and Climate Change Platform of the northern provinces, reflecting changing governance structures.

- There was a breakdown of traditional fragmentation (between universities, businesses and between sectors) whilst more systemic innovation were developed that focused on whole sector and value chain approaches. Such focused innovation and collaborative spaces were made possible through initiatives such as EnTranCe (open innovation space for research collaborations between industry players, and industry and educational players) and Energy Academy Europe (joint energy institute bringing together faculties and research from the two Groningen universities).

- A joint research programme, EDGaR, was set up with numerous knowledge institutions and the gas corporations to boost energy innovation and research in support of gas in energy futures in the Netherlands and Europe.

- A new development was the rise and growing significance of new energy stakeholder groups. These included farmers producing green gas and bio-gas, energy funding agencies, NGOs supporting energy efficiency and sustainable energy initiatives at community levels, 'prosumers' that describe energy producing consumers, SMEs that were diversifying into energy production, facilitation and new energy businesses such as car parks offering solar charging facilities for vehicles, construction companies offering complete solar panel services, shared community projects through shares in wind parks, etc.

- The rise of citizen initiatives in various urban and rural areas is illustrated with examples: Grunneger Power (city), Bovensmilde and Hooghalen (villages), Hoogkerk Power Matching City (neighbourhood/village), and Texel and Ameland (islands). These energy co-operatives and not-for-profit organizations meant interactions and collaborations in local settings were changing; the main motive of such initiatives was to increase self-sufficiency and autonomy, and to avoid high energy prices in the future.

- A different aspect of changing interactions was the level of 'trust' in the cluster. Stakeholders indicated that trust was conditional, and that it depended on the situation and issues at hand; adverse effects of gas exploration in local communities due to increased earthquake danger and the resulting dissatisfaction due to low compensation and no guarantee of safety, distrust was high in the affected regions; latent distrust was also indicated in the search for autonomy and self-sufficiency in energy in grassroots movements. (See pp. 187-189)

The list above illustrated how Energy Valley's transforming interactions resulted in shifts in strategy, vision, scope, scale, stakeholders' roles and governance structures;

new or different types of collaborations, interactions, communications, organizations, platforms and stakeholders; and changes in feelings of trust and how this in turn drove new developments. To illustrate, some examples have been included to reflect the changing interaction and collaborations in the cluster. In addition, Lesson 1 also captured these aspects and quotations were provided (pp. 192-193, but also, 187-189, 190-191 & 197-198).

**Transforming Interactions – elaborations and illustrations**

In the section above, key changes in the cluster were listed and examples of these developments were presented. In order to avoid duplication, this narrative focusses on a few examples that reflected the changing interaction and collaboration patterns.

EnTranCe, the subject of the initial pilot study, illustrates how transforming interactions in Energy Valley were taking place. This example has been used to illustrate cluster dynamics and in this section, the change in the nature of interactions will be highlighted. Organized meetings and informal sessions at the local football club's Skybox brought together key stakeholders where the future of energy in Energy Valley was a regular theme. These sessions were responsible for the emergence of EnTranCe where GasTerra, BAM, Imtech and Hanze University of Applied Sciences decided to create an open innovation space for energy transition challenges. These various partners decided to initiate a collaboration that would invite energy businesses along the value chain to collectively seek solutions to the energy transition. The open innovation nature of the facilities was new where competitors would share knowledge and facilities. The urgent need to deal with the unpredictable and complex nature of energy transition pushed stakeholders to deeper levels of collaborations. The collaborating partners also had to agree to collective strategies and joint experimentation including the whole value chain and engaging a systems approach were also transformations that were new to the cluster. At EnTranCe, partners were also sought outside the traditional energy sector as challenges related to digital infrastructure and business models were expected. New laws were also needed to facilitate new and more integrated energy systems that would break down sectoral barriers. The re-sale of solar energy at recreational facilities and car parks for e-vehicles is an example of how developments for new technology, regulations and fiscal policies have been supported through projects at EnTranCe. Storage of surplus decentralized energy within homes and through gas systems are more examples of interdisciplinary and cross-sectoral solutions realized by the new collaborations emerging at EnTranCe and elsewhere.

The following quotation illustrates how EnTranCe worked and the how transforming interactions that resulted in dealing with energy transition challenges.

*'At EnTranCe, companies contribute their expertise and work together with other companies' expertise to move forward [on energy transition challenges]…. With a few companies we have identified an agenda and we work with the formula that they send their surplus capacity to EnTranCe and RenQi to work on collective projects. This has happened, just like, 'omheind' [fenced off], but super important… these are small examples of how we can do this without banks [investments]… One example, a programme of 15 – 20 partners which is halfway and there is an interim evaluation; what began as a group of strong egocentric partners, has become partners and you see how they communicate, look each other up, there is a high degree of collective effort… they know each other, they together they identified common challenges and that is a big step in a short time and there will be follow-up activities to continue the collective approach. So you see how this works and can work.' [Academic stakeholder, EV24]*

Energy Academy Europe (EAE) is an important example of the changes in collaboration. This new institute has given visibility to newly developed 'energy' programmes. The commitments of the two universities in the city of Groningen to the 'energy' developments are reflected in this initiative. The close collaboration of these two universities in this venture reflects a breaking down of barriers between the more prestigious academic university and the more highly valued professional educational institute that serves industry as well as a convergence of goals regarding energy transition challenges. The setting up of this separate energy institute has forged increasing international collaborations and visibility of Energy Valley's knowledge capacity and developments. There have been more regular visits to and from the European Commission and its agencies. Joint master classes organized by the EAE meant that new interactions and networks between students of both universities have been realized. The following information from EAE's website describes details of recent collaborations and transforming interactions:

*'Since its inception appointments of internationally renowned energy staff, including its director; collaborations with national (ECN, TNO) and international institutions (in Shaanxi) for energy research and education; collaborations with social partners for national public debate on energy; and collaborations with EU Energy Charter Secretariat for joint research and knowledge sharing in energy specializations.'*

*[Summary of press releases; http://www.energyacademy.org/press-centre/press-releases; retrieved 22 April 2016]*

Another development in Energy Valley was the development of new integrated energy systems, which needed new infrastructure and policy frameworks as well as research, development and innovation. These new energy systems were being developed at the micro level, in homes and neighbourhoods; at the meso-levels such as green gas hubs/business transition parks and cities; and at the macro-levels such as the Hansa Energy Corridor and North Sea programmes. These integrated energy systems developments were examples of transforming interactions that displayed new and joint vision, new collaboration structures, convergence of knowledge capacities and interests that were at the core of the changes in Energy Valley cluster. The following quote illustrates the micro, meso and macro-level transforming interactions:

*'Meppel energy is an example. In Meppel a new neighbourhood is developed with 400 houses that can deploy smart grids. The same was for Hoogkerk that is going into phase 2. Another example is what we call the energy transition parks. These are local nodes of businesses and electricity. A good example is Wijster in middle Drenthe, an industrial area where Attero a waste incinerator generates warmth, electricity and gas and working with targeted parties, through working sessions, there is a profile of this being an energy transition park. A heat exchange grid has been realized where electricity is transmitted to and fro. A chicken waste processing company has located here as it needs heat for its processes and it has biomass available for Attero, and as such a closed loop is realized on location.*
*There is a formal collaboration with North Germany, Norway and Scotland in the ENSEA programme where these countries jointly identify collective challenges of the next decades, which is also relevant to Europe. Grid infrastructure for offshore wind is an obvious challenge. Identifying if specific laws and regulation in the different countries form a barrier for interactive energy exchanges. Those types of challenges are being addressed with the North Sea partners… obvious connecting issues…the similar mentality…'*
*[RDA, EV1]*

The collective development of the diverse regional and municipality administrations in Energy Valley, namely, 'De Plus van Noord Nederland', 'Green Deal' and 'Switch' initiatives as described in the earlier section on transforming interactions, reflected a deeper collaboration in the cluster. These documents also reflect more coherence in Energy Valley even as the diverse interests have been embraced. The need to collaborate and to strengthen the peripheral position of the northern provinces and that of Energy Valley resulted in this transformation. The quotation below captures the shifts and transformations of energy policy developments for the North Netherlands.

*'Around 2007, the first big energy accord North Netherlands was reached, thanks to Ed Nijpels… that brought a lot more alignment. We started working programmatically… And now, 2.5 years later, we decided to take it to a higher level, have more focus…and that is how the [energy] vizier resulted. [Policy stakeholder, EV8]'*

The next section describes emerging patterns in Energy Valley.

**Emerging Systems Patterns**

This section first describes the key findings of Energy Valley's emerging patterns that resulted from changes in cluster dynamics and resulting transforming interactions. Afterwards, a narrative on these emerging systems patterns provides more details and illustrations in the next section. There is overlap with the main thesis.

Energy Valley's systemic changes were also captured in Lesson 1 on 'Shifting Landscape'. The list below provides details of four key emerging patterns in the cluster with supporting details and examples.

- On a systems level, Energy Valley's energy system was becoming more complex as a result of the following changes
    - The interconnectedness of gas, electricity, renewable energy sources in terms of infrastructure and markets meant that older separate gas and electric systems needed to be adapted and innovated to deal with more integrated energy systems of the future (EnTranCe was set-up specifically to explore future integrated smart grids).
    - Grid interconnections beyond national borders that also needed to be adapted to become more integrated energy systems to include new North Sea offshore wind parks, etc.

- Energy Valley showed more systematic approaches in creating and facilitating 'ecosystems' for knowledge-based innovations as illustrated in the following:
    - There was a shift to more integrated and collective 'vision' in the cluster.
        - There was a joint North Netherlands' 'quality of life' innovation agenda described in their vision document 'De Plus of Noord Nederland'.
        - There was an aligned Energy Valley vision to that of the national policy on energy developments, the 'Switch' initiative and policy document in response to the 'National Energieakkoord' (Dutch national energy agreement).
    - Strategic joint development of energy innovation, research and talent capabilities in Energy Valley in an effort to break down traditional barriers and fragmentation, creating broader, knowledge-based innovations for energy futures was evident in the example of Energy Academy Europe.

- The focus on 'systems integration' approach to energy developments in Energy Valley reflected a more systematic approach, replacing ad hoc and fragmented efforts.
- There was a movement towards issue-based, cross-sectoral collaborations in the region, for example, the Bio-based economy to give a new impulse to the region, building on its regional strengths that included energy, chemical and agricultural sectors.

- There was a shift in the cluster's scope and scale such that both larger and local scales were acknowledged as necessary, replacing the dominant regional scope and scale:

  - Interconnectedness of energy markets crossing national borders due to European internal energy market developments are seen in European power companies active in Energy Valley, examples are RWE's coal power plant and Vattenval's buy-in of Nuon and its power plant.
  - There were more cross border and international collaborations to foster energy transition developments and EU integrated energy markets, exemplified by the inter-cluster collaborations with Niedersachsen in North West Germany.
  - There was increased international connectedness at local levels, where local village co-operatives sought contacts with German counterparts to learn from their experiences, for example, Duurzaam Balinge.
  - Energy Valley's greater visibility and changes in scope and position were as follows:
    - As strategic partner on energy for the Northern Netherlands in negotiations and dialogues with the national government.
    - New EU partnerships in trans-regional initiatives were forged and developed.
    - More inter-cluster collaborations were developed.
    - Branding the region as an 'energy hotspot' at different scales – local, regional and as EU Region of Excellence (North Sea Region).
  - Local scale developments were acknowledged and these included:
    - Citizens (neighbourhood and village co-operatives);
    - Business collaborations (transition parks, green gas hubs);

        - Open innovation facilities (RenQi and EnTranCe).

- The presence of self-organizing processes as well as top-down policy measures was visible in Energy Valley as shown below:
    - There were both top-down and bottom-up initiatives in Energy Valley that included initiatives on energy transition and economic developments at all levels: EU, national, regional and local levels.
    - There were clear indications that national and EU policies were leading but also that changes were taking place such as:
        - Centre-periphery relations of NL and EV were shifting;
        - Traditional hierarchical line from national government to provinces to local governments was also shifting; this was in part due to EU integration of member states and internal market developments.
    - Increasing self-organizing grassroots movements and NGOs as part of a new bottom-up movements in the region:
        - EU funding for regions and inter-regional collaborations support provincial and local movements;
        - Provincial energy funds support SME and consumer initiatives on decentralized and sustainable energy.

**Emerging Patterns – elaboration and illustrations**

The next aspect of cluster developments in Energy Valley is emerging patterns, which focuses on how Energy Valley cluster is changing as a whole. The previous sections described how changes of the different aspects of cluster development were interconnected and systemic interrelations were illustrated. These interconnecting developments contributed to shifts in the whole cluster.

In the section on 'Energy Valley's Emerging Patterns', the key changes identified at the cluster level was the increasing complexity in all parts of the cluster and therefore as a whole; the more systematic approaches focussed on creating new eco-systems where collective knowledge and resources developments were increasing; and the regional cluster was more varied in its scope and scale, embracing both larger, more international collaborations as well as acknowledging and embracing local scales. The shifts in the cluster included both top-down and bottom up initiatives and therefore cluster developments in Energy Valley saw shifts ‘disrupting’ traditional dominance of national and large energy corporations.

Developments in EU integration and internal energy markets were changing the playing field of the energy sector specifically, and together with globalization and new (IT) technologies, changing markets more generally. The shifts in local-global and consumer-business relationships have been described in different sections of this chapter. Related to this last aspect were the growing autonomy and self-sufficiency needs of consumers that were also impacting cluster developments. The growing consumer demands for more sustainable energy were also changing the way energy business and energy transition agendas were being shaped, strengthening EU directives for sustainable energy systems. The response to these developments across the cluster was a more systemic inclusion of renewable and decentralized energy sources.

The local gas dominance in Energy Valley saw a movement to re-position gas within the new energy system as a viable solution to systems integration of renewables offering solutions for the balancing challenges this brings. (See Lesson7 on energy transition) This too saw more systemic and systematic developments that reflected more alignment with changes in the broader landscape of energy both locally and globally. The need to be more flexible and to incorporate varying strategies to deal with the changing landscape was reflected in Energy Valley’s introduction of new digital thematic communities to cater for the growing diversity of the cluster’s energy landscape; the collaborations with trans-regional clusters and stakeholders; and dialogues with NGOs and new energy co-operatives.

The definition and scope of the energy sector and cluster has seen a shift in Energy Valley to incorporate new players, sources of energy, more cross-boundary orientations, new business models and even new playing fields. The cluster has become more ‘open’ and more flexible across all levels and parts of the cluster. There was also an increase in coherence through the increased collaborations and joint initiatives that were described in the previous sections.

In order to illustrate the deeper systemic changes in Energy Valley, the developments of sub-clusters and clustering of communities is described here. Energy Valley saw a rise of initiatives that formed new (sub) clusters within the larger cluster. The earlier section on transforming interactions described a number of these developments. In this section, more recent developments have also been described to illustrate that there is a structural change taking place in Energy Valley.

Energy Transition Park Wijster in the Province of Drenthe was developed as a potential local energy hub system that would offer large-scale energy residue from the waste processing plant and a biomass digester to energy intensive production processes at this location. The region was surrounded by agricultural land and so a biomass gas hub was possible. The availability of surplus energy meant that the location would be attractive to businesses with energy intensive production processes. The transition park became energy hub where infrastructure was developed to support a local energy system, reducing the need to transport large amounts of energy. In 2014 Dutch Recycling Solutions built a factory at Wijster Transition Park that created a cradle-to-cradle certified product by also sourcing local biomass for its production of boards. The Province of Drenthe offered grants to integrate the production processes with the existing energy surplus producers. This initiative has grown from a transition park project to a sustainable energy and production cluster and is still growing. (See quotation in transforming interactions on meso-level changes earlier)

In the Province of Friesland, the BioNOF project is collaboration between energy utilities companies and businesses. The project supports transporting biogas produced by individual farms to a central installation for conversion to green gas, which in turn can be injected into existing gas grids. This project has created a biogas conversion hub catering to local producers in the area, which makes biogas production a more attractive option for farmers, and the larger installation makes the conversion more efficient and reliable. This joint project resulted in new expertise in developing green gas hubs that support large scale conversion and injection into gas grids, and in managing complex stakeholder collectives in sustainable energy developments. This initiative has resulted in a sustainable local energy development system, green gas hubs, as potential (sub) clusters to be replicated in other parts of Energy Valley.

Energy Valley has therefore seen the rise of innovative collaborative projects related to different aspects of energy transition that brings together stakeholders of different sectors, businesses, experts and knowledge institutes that transform new sub-clusters into sustainable organizational structures within Energy Valley.

## Overview Energy valley – Lessons 1 - 5

| **Cluster framework** | **Energy Valley** and its **complex dynamic systems** |
|---|---|
| **Complexity & Drivers of change** | **Complexity** in Energy Valley:<br>– Complex, inter-related and unpredictable context of energy transition<br>– Energy transition/technological innovations embedded in social and economic transitions and crises<br>– Energy transition shift from national to EU and private sector dominance<br>– Traditional, dominant energy sector faced with new energy landscapes and players and v.v. (dominant corporate and economic interests)<br>– Shift in energy system complexity due to new energy and market developments and balancing needs<br>– Global and EU context connected to local and regional challenges<br>– National dominance challenged by EU and grass roots movements<br>– Differences in stakeholder groups about urgent issues and drivers of change – diversity in interests, priorities and scope<br>– Fragmented and limited knowledge and innovation development<br>– Protective role of government superseded by national economic interests<br><br>**Drivers of change**<br>– Geo-political shifts<br>– Energy security<br>– Energy market liberalization – EU internal energy market<br>– EU legislations<br>– Large scale power outage and blackouts in Europe – need for big investments in energy infrastructures<br>– Sustainability and Climate change<br>– Technology<br>– New energy resources and balancing<br>– Cheap coal and shale distorting energy market<br><br>**Internal drivers** included<br>– National policies<br>– Depletion of gas<br>– Increased earthquake risks<br>– ‘Lag’ region issues e.g. economic growth and jobs<br>– Consumer demands and initiatives<br>– Role of local/regional government – branding, collaboration, jobs, earthquake issue |

| | |
|---|---|
| **Container** | There were<br>– **Three main 'frames'** – 'economic', 'energy transition' and 'regional development' – defined strategy and behavior of stakeholder groups<br>    - Lack of common frame or explicit framing positions risked sub-optimal dialogues and results<br>    - **Provincial differences** in local contexts and agendas present (see path dependency)<br>– EV foundation's vision/mission framed by key triple-helix stakeholders, the 'founding fathers', public funding agency (SNN) and members of the cluster – **complex collaboration**<br>    - Collaboration and formation of EV cluster was a joint initiative by the 'founding fathers' in response to gas reserves depletion and dispersion of gas expertise<br>    - Collaboration despite (regional) stakeholders differences reflected urgent need to face energy transition and regional economic challenges<br>– The cluster organization was commissioned to serve local energy businesses, broader energy transition developments, and regional economic developments – **complex and sometimes conflicting agendas**<br>    - Large-scale developments in the Eems harbor region served national and strategic interests rather than job creation, decentralization and sustainability goals<br>    - Limited capacity of cluster organization meant iconic (political and large) projects superseded local business support and job creation goals<br>– **Initial regional focus and scope** |
| **Path Dependency** | – **Gas reserves created new industry and expertise since 1950s**, whilst energy market liberalization threatened loss of energy expertise and jobs through M&A and HQ re-location<br>– **Dominance of 'gas' in the history, energy infrastructure and energy system** in the Netherlands determined Energy Valley's initial cluster condition – **lock-in** risk and power imbalance<br><br>– **Dominance of national economic interests** (BV NL) – power imbalance<br>– **Peripheral position** of North Netherlands reinforced need to collaborate to develop future strategies jointly<br><br>– **Focus of Energy Valley** cluster reflected factors related to path dependency: gas, biogas (agriculture), wind, water, NW Germany and North Sea Region<br><br>– **Knowledge base of Energy Valley limited and fragmented – 'cluster drain' and divergence risk**<br>    - Lack of major corporations and R&D capacity outside of 'gas'<br>    - Fragmented public research capacities and disciplines<br>    - Dispersed innovative SMEs<br><br>– **Path dependence differences of socio-economic structures of provinces**: large gas corporations, autarchy, food and agro-based industry, recreational and tourism industry, horticulture industry, SME dominant, 'Veen' colony, hinterland of Amsterdam Metropolis |

| | |
|---|---|
| **Stakeholders** | **Energy** stakeholders related to and representing<br>- Policy<br>- Energy industry<br>- Academia & research<br>- Regional development agency<br>- Cluster organization (EVF)<br><br>– Key gatekeepers **-** visible champions of Energy Valley (as identified by stakeholders)<br><br>– 'Missing' stakeholders **-** not involved in strategy dialogues<br>- Financial institutions (not part of cluster)<br>- Broad SME representation (diffused group)<br>- Civil society representation (diffused group)<br>o **Decentralization of energy supply - new players** including citizen initiatives and new SME energy services<br>o **Local municipalities and some NGOs** had closer links to citizens and SMEs but were not engaged in cluster strategy<br>o **Energy transition decisions** impact local communities and businesses as evident in protests related to wind park development, CO2 storage, gas-related earthquakes, etc.<br><br>– **Groningen was identified as a gravitational point** of cluster<br>- Dominant (gas) incumbents<br>- Province of Groningen<br>- Cluster organization |
| **Attractor** | **Increased complexity and unpredictability** in the cluster<br>– Pull of redefining and positioning of **gas in energy transition -** gas for balancing function<br>– Pull of **decentralized energy** developments by grass-roots movements related to pull of autonomy and **self-sufficiency needs**<br>– Shift from supply-side focus to **more demand-side focus**<br>– Pull to **more connected energy sector** (gas and electricity, small and big)<br>– **Pull of 'outside'** related to R&D, innovation and markets (resources, capacities & opportunities)<br>– Pull of **internationalization**, partly due to EU programmes and opportunities, parallel developments and globalization<br>– Pull of **sustainability agenda** (resource efficiency, renewable energy, CO2 emissions, 'green' consumerism)<br>– Pull of **economic and job creation needs** of policy seemed stronger than energy transition demands<br><br>**Attractors underestimated or not made explicit** in Energy Valley – e.g. risk of 'cluster drain', national economic and corporate interests mitigating developments on energy transition, citizen safety, job creation and rural community sustainability policies |
| **Fitness to Landscape** | – To meet energy transition challenges, need for more<br>- **Multi-disciplinary** competences<br>- **Cross-sector value chain** innovations<br>- **New business models, knowledge and sectors** (IT, business services)<br>- **Systemic** approaches<br>- **Multi-sectoral collaborations**<br>- **Trans-regional and international collaborations**<br>- **More SME support** for innovation and energy efficiency<br>- **More citizen awareness and engagement** |

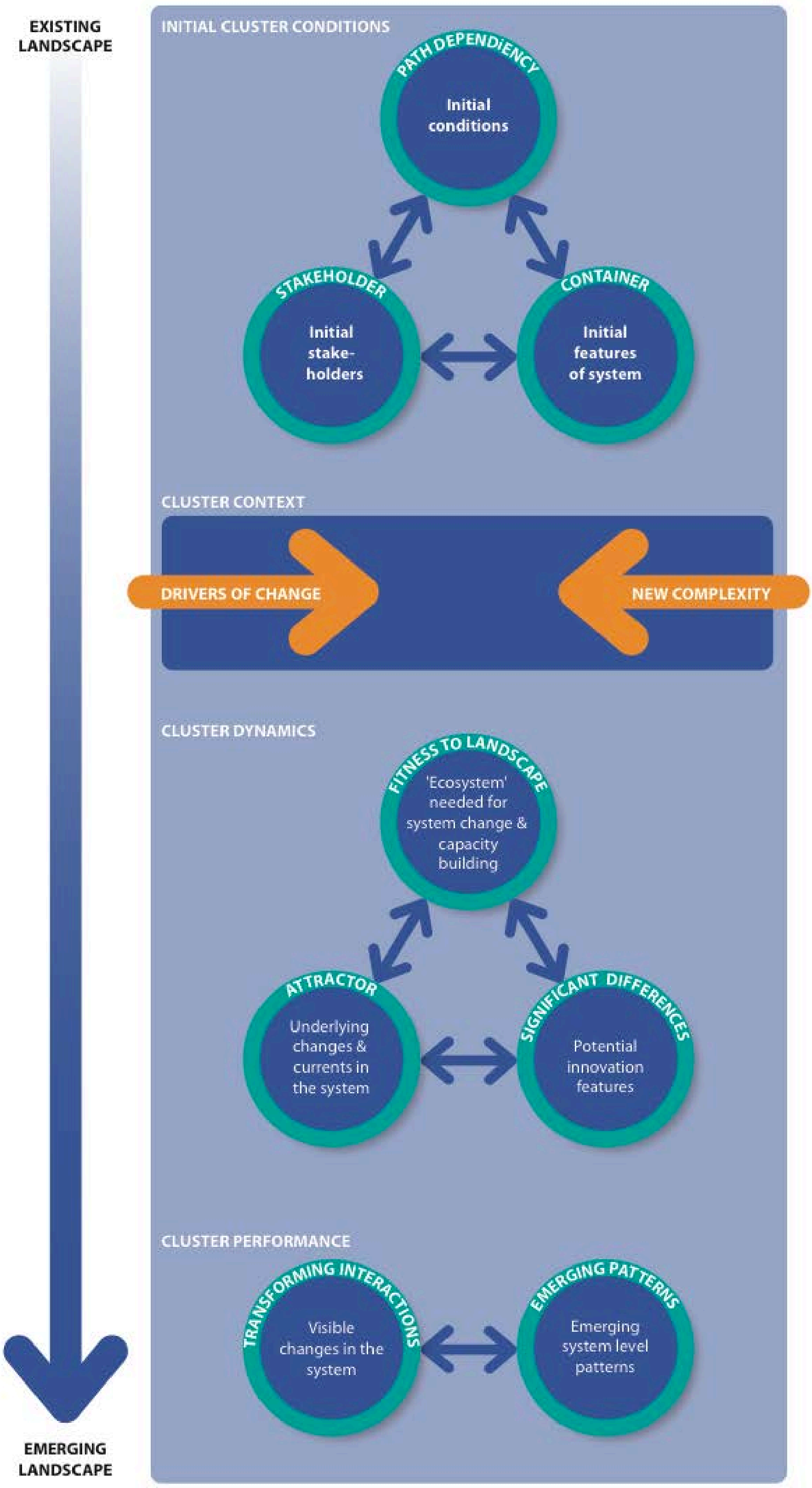
| | |
|---|---|
| | – **New infrastructure** connecting different and new sources of energy (smart grids) were needed and this meant that new competences and accelerated innovation and deployment was needed<br>– **New institutions and innovation spaces** were deemed necessary to bundle fragmented knowledge, research and innovation efforts in energy transition (e.g. Energy Academy Europe and EnTranCe serving different collaboration needs)<br>– **Varying 'scale'** were needed for energy transition and cluster development – both small-scale - local and regional - to trans-regional (e.g. village co-operatives, city council, Hanze Energy Corridor, North Sea Region)<br><br>Energy Valley<br>– **Needed to be part of the national dialogue** – shifts in national policy to top-sector and new energy agenda at national and EU levels<br>– **Different support strategies** needed<br>- **Support for large-scale energy related projects and competences** through Eems Delta developments **in Groningen** (LNG terminal, off-shore wind park assembly and landing of cables, etc.)<br>- **Support for SME and industries** to become more **energy efficient and decentralized energy production in Friesland and Drenthe**<br>- **More inclusive community engagement and outreach to support** decentralization and grassroots movements in energy |
| **Significant Differences** | Significant differences were present in the following:<br>– **Big corporation and SMEs** with their different resources, scope, goals, competences, visibility, flexibility, innovations, access to markets, equity, policy, etc.<br>– **Academic and research institutes** had different capacities and goals<br>– **Local municipalities, provincial government and regional development agencies** had different agendas, resources and roles<br>– **NGOs and consumers** had different demand 'pulls' that could influence energy transition<br>– **'Outside' and 'in-crowd' groups** had different positions, interests and insights into developments in different places in the cluster<br>– The **four provinces and local regions** had distinctive histories, landscape, frames, issues, drivers, focus, strategy and scope that could offer diversity needed to address the complex challenges faced by the cluster<br>– **Local, regional, national and EU levels** were part of Energy Valley's context and container and this included differences in roles, responsibilities, resources, interests, scope and power<br>– The energy cluster was embedded in a region with a strong **agricultural sector, waterways and water-related activities**<br><br>**Innovation potential in Energy Valley required broadening existing container** and seeking 'significant differences' |
| **Transforming interactions and collaborations** | – **More connections in energy** – between gas and electricity sectors, traditional and renewable energy players, 'big' and 'small' energy, producers and consumers<br>– **More cross-sectoral connections** between water and energy ('blue energy'), energy and agriculture (bio-fuels, bio-gas), transport and energy (e-mobility), etc.<br>– **Trans-regional initiatives** reflected new types of collaborations in |

| | |
|---|---|
| | energy transition e.g. Groningen-Niedersachsen (NW Germany) and ENSEA project with partners from the North Sea region<br><br>– **More integrated policy ‘vision’** due to developments mentioned above e.g. North Sea Energy Vision, ‘De Plus van Noord Nederland’, ‘Green Deal’, ‘Switch’, etc.<br>– **New regional platforms created** to meet local energy challenges – e.g. Energy Board in North Holland, Drents Energy and Climate Change Platform<br><br>– **Breakdown of traditional fragmentation** (between universities, businesses and between sectors) and **more systemic innovation based on value chain approaches** made possible through new initiatives in EnTranCe and Energy Academy Europe<br>– EdGar Research was an example of an **extended research programme** to boost gas related energy research to support the position of gas in the future energy scenarios<br><br>– **New energy stakeholder groups** became visible **-** e.g. farmers producing green and bio-gas, energy funding agencies, NGOs supporting energy efficiency and sustainable energy initiatives at community levels<br>– **Citizen initiatives growing** e.g. Grunneger Power and other village and neighbourhood energy co-operatives to increase self-sufficiency<br><br>– **Trust as being conditional** depending on the situation and issues at hand; adverse effects of gas exploration in local communities due to increased earthquake danger and the compensation offered and guarantee of safety made distrust an issue for communities in the region; there was also mention of latent distrust as reflected in grassroots movements seeking autonomy and self-sufficiency in energy |
| **Emerging patterns** | Energy cluster was becoming **more ‘open’ and more connected** to new players, the scope was becoming **more local and more international,** and **opening up** to new businesses and business and financing models – reflected a **new playing field**<br><br>– Energy System becoming **more complex**<br>  - Interconnectedness of gas, electricity, renewables<br>  - Interconnectedness of market crossing national borders – energy players extending markets and buy-ins e.g. RWE, Vattenval in NL<br>  - Grid interconnections beyond national borders<br>  - More cross-border and international collaborations – inter-cluster collaboration to Niedersachsen<br>  - International connectedness at local levels – village co-operatives to German co-operatives<br><br>– A **more systematic approach** – ecosystem for knowledge-based innovation<br>  - More integrated and collective vision<br>    o N NL vision of ‘quality of life’ innovation agenda (‘De Plus of Noord Nederland’)<br>    o EV vision aligned to national policy (e.g. ‘Switch’ response to ‘National Energieakkoord’ strategy)<br>  - Development of energy innovation, research and talent capabilities **-** breaking down traditional barriers and fragmentation creating broader knowledge-based innovations<br>  - Systems integration approach to energy developments in Energy Valley |

| | |
|---|---|
| | - Movement to issue-based cross-sectoral collaborations e.g. Bio-based economy<br><br>– **Different scope and scales** in Energy Valley – both larger and local scales<br>- More visibility and changes in scope and position of Energy Valley<br>o Northern Netherlands strategic partner on energy with national government,<br>o New EU partnerships in trans-regional initiatives<br>o More inter-cluster collaborations<br>o Branding region as an ‘energy hotspot’ at different scales – local, regional and EU region of excellence (North Sea Region)<br>- More self-organized collaborative efforts at different local levels<br>o Citizens (neighbourhood and village co-operatives)<br>o Business collaborations (transition parks, green gas hubs)<br>o Open innovation facilities (RenQi and EnTranCe)) |
| **Self-organizing vs. top-down** | – Both **top-down and bottom-up initiatives** included EU, national, regional and local levels in Energy Valley cluster and energy transition initiatives<br><br>– National and EU policy leading but<br>o Centre and peripheral relations of NL and EV shifting<br>o Traditional hierarchical line from National government to provinces to local governments shifting, EU part of change<br><br>– Self-organizing grassroots movements and NGOs – new bottom-up movements<br>- EU funding for regions and inter-regional collaborations support provincial and local movements<br>- Provincial energy funds support SME and consumer initiatives on decentralized and sustainable energy |

## Summary of cluster developments and its interrelatedness

The Lessons on Energy Valley have shown the interconnectedness of cluster developments. An overview of the interconnectedness is captured in the illustration below, an initial attempt to capture cluster developments. This earlier version uses the term ‘cluster performance’ instead of ‘cluster transformations’. The diagram below offers an overview of all cluster developments aspects as described in Lessons 2 – 5. The definitive version of a cluster development model is found in the main thesis (section 4.13).




Evolution of the framework is also described in Appendix 8.

### Lesson 6 – Systems-in-systems developments

This Lesson explored Energy Valley's contexts, namely, the EU and national levels. For this Lesson, inputs from policy documents, reports and interviewee inputs from stakeholders and experts were used. Extensive research into various aspects of EU policies were scanned as well as national policies. The key focus of investigations was EU and Dutch energy policies, and where relevant general economic policies.

Primary data was from Dutch policy representative/policy officer at the EU and national levels and a Dutch EU lobbyist. Additional input from other EU lobbyists, experts on EU policy were also used. Inputs from Energy Valley Stakeholders provided information on regional, national and EU levels. Secondary research was on EU and national policies. Key inputs and analyses have been included in the next parts of this section.

## Part 1 – EU level

### INPUTS FROM DIFFERENT SOURCES ON EU (ENERGY) POLICY:

### 1. EUROPE 2020 – CONTEXT OF POLICIES

In the main thesis (Chapter 2) and in Appendix 5, EU 2020 strategies and policies have been discussed in detail. Below is a table that captures important operational goals and targets, including 'climate change and energy sustainability', which are directly relevant to energy developments. The Europe 2020 policy forms an important context for all EU and national policies.

| ***The 5 targets for the EU in 2020*** |
| --- |
| *1. Employment*<br>- *75% of the 20-64 year-olds to be employed*<br>*2. R&D*<br>- *3% of the EU's GDP to be invested in R&D*<br>*3. Climate change and energy sustainability*<br>- *greenhouse gas emissions 20% (or even 30%, if the conditions are right) lower than 1990*<br>- *20% of energy from renewables*<br>- *20% increase in energy efficiency*<br>*4. Education*<br>- *Reducing the rates of early school leaving below 10%*<br>- *at least 40% of 30-34–year-olds completing third level education*<br>*5. Fighting poverty and social exclusion*<br>- *at least 20 million fewer people in or at risk of poverty and social exclusion* |
| ***Features of the targets*** |
| • *They give an overall view of where the EU should be on key parameters by 2020.*<br>• *They are translated <u>into national targets</u> so that each Member State can check its own progress towards these goals.*<br>• *They do **not imply burden-sharing** – they are common goals, to be pursued through a mix of national and EU action.*<br>• *They are **interrelated and mutually reinforcing**:*<br>    • *educational improvements help employability and reduce poverty*<br>    • *more R&D/innovation in the economy, combined with more efficient resources, makes us more competitive and creates jobs*<br>    • *investing in cleaner technologies combats climate change while creating new business/job opportunities.* |
| ***7 Flagship initiatives*** |
| • ***<u>Smart growth</u>***<br>- *<u>Digital agenda for Europe</u>*<br>- *<u>Innovation Union</u>*<br>- *<u>Youth on the move</u>*<br>• ***<u>Sustainable growth</u>***<br>- *<u>Resource efficient Europe</u>*<br>- *<u>An industrial policy for the globalisation era</u>*<br>• ***<u>Inclusive growth</u>***<br>- *<u>An agenda for new skills and jobs</u>*<br>- *<u>European platform against poverty</u>* |

*Targets and features for EU 2020 (own tabulation based <u>Europe 2020</u> website)*

## 2. INPUTS ENERGY VALLEY INTERVIEWS – KEY POINTS SALIENT TO EU

*Complex practice in EU*

National and vested interests limiting EU developments:

- Different lobbies from different energy industries and big corporations
- Different lobbies from civic and environmental groups
- Different member states with different agenda’s

- Separate roles of EU Member states and European Commission on energy issues. The Member states are responsible for energy mix and energy sources. The European Commission for security of supply together with Member states and for energy efficiency. Tension between Member states and EU, national sovereignty and interests versus energy market efficiency
- Fragmented innovation, national agenda and budgets
- Dependence of EU on lobby groups and interest groups for know-how and dependence of the different groups as EU determines policy and regulations
- Huge differences between the different nation states in energy – due to different path dependency, e.g.
  - NL, UK– Gas
  - France– Nuclear
  - E. Europe – dependence on Russian energy
  - Fossil rich and fossil poor countries
  - Internal market rule implementation varies

*Path Dependency*

EU and 27 nations - interconnections, differences, national agendas - how to harmonize.
EU and the nations as global economic, societal and political players, how to survive and grow

*Context in which EU is operating*

- Context in which EU is operating is not shared by all global players to the same degree (not level playing field)
  - Climate change and CO2 emissions
  - Stringent environmental and consumer protection norms
- Rising emerging economic players with huge energy needs: China, India in particular, BRICS countries
- Risk of dependence on Russian gas and oil resources
- New shale gas developments and US energy policy impacts
  - Cheap gas
  - Coal dumping in EU
  - Competitive advantage

*Drivers of change*

- Cohesion policy together with 'smart specialization in regions' is the main investment strategy for Europe
- Security of energy supply, scarcity of energy,
- Independence of Europe
- Competitiveness in the world; reviving the European economy
- Reducing greenhouse emissions
- Efficiency in EU market and infrastructure

*Emerging patterns*

- Infrastructure interconnection
- Market integration
- Compliance to internal market regulations
- "We are gonna need every fuel that we can get"
- New technology (fuel cells, smart grids, CHP, hydrogen and gas systems)
- Need for collaboration is evident

## 3. INPUT EU LOBBYIST (INTERVIEWEE EV2)

1. Path dependency
   - 'In the beginning the gas companies were not interested. Now they're having to do things that are driven by national regulations; Germany, Denmark, Sweden these are all very powerful very strong drivers'
   - 'As we see gas running out in Western Europe and in the UK and in the Netherlands not running out but becoming a bit more scarce and not becoming importance of energy we have to rely more on external sources such as Russia and the Russians have control over tap now into Europe and that's caused serious problems, this is why people want sources.'
   - 'some of the new developments are in extreme parts of the world where for example in the Arctic where ….. don't want people to huge environmental concerns make it cost even more but eventually the environmental concerns will be taken by desperate need for energy.'
   - 'Innovation is driven by way are scarcity of…. increasing scarcity of gas in Europe'

- 'The penetration of gas in the homes of the UK is about 90% and if you go somewhere like Germany is something like 50-60-70%, Netherlands is pretty high percentage of penetration because Netherlands is a gas country that's where the gas first came from, UK has it's own gas of course….'

2. Stakeholders
   - EU (Well the parliament of course, with support of the European Commission)
   - The energy companies
   - Lobby groups - electrical industry, the nuclear industry and all the renewable groups are so much more important and increasingly the coal… and gas lobby.
   - Group of city majors – this is more renewable than fossil fuels)
   - Countries – 'like France have almost a very large nuclear presence.. very little else indigenous fuel sources. So they need to rely on nuclear they are not gonna step back from nuclear….'
   - Consumers – 'If they are convinced enough by…. you know if they wanna be…. that can really effect things'
   - Universities, research institutes – 'yeah I think universities are really important'

   'The EU needs the lobby groups to be fed information and developments and at the same time the lobby groups need the EU because they're determining the rules….

   In the gas industry there are, there hasn't been that until about 2 year and a half ago when the gas industry lobby groups got together and set up their own … and that's proved quite effective.

   It's 14/15 different groups supporting different bits of renewables and they tend to be listened to … together as a group.

   - Gate keepers – 'So there is the commission/parliament well you can count them as 2 of .. parliament/European commission and then national local governments. And of course a fourth one if you wanna count commission and parliament as one, it's the businesses themselves the business leaders the CEO's of businesses....'

3. Drivers of change
   - *In policy documents*
     - The 20-20-20 proposal
     - European Commission TG energy…. the "Road Map to 2050"
     - 'The Eurogas, they prepared their own 2050 roadmap specifically for gas showing where gas fits in…'

   - *In issues*
     - Emissions
     - Energy efficiency
     - The move to renewables

     'It's important to get energy as efficient as possible to get them as renewable as possible these are the drivers. Europe leads significantly in the drives towards low emissions and high efficiency, the rest of the world maybe talks about it and doesn't bother…. even in the States. They were starting to build… but they never really….. behind Kyoto in all this.'

   - *Countries*
     - 'Germany, Denmark, Sweden these are all very powerful very strong drivers… So they are major pushers in the making industries comply with emissions and high efficiency really important'

4. Attractors
     - 'Still [its] shareholders that's what most businesses work for'
     - 'It's the 20-20-20 drivers that ….and act on them, people are actually acting more and more these days….'
     - '….which is clear we are gonna need every fuel that we can get. We can't dismiss any….in the years to come.'
     - 'There is a drive towards Smart Grids, more demand side, management, things like combined heating powers (CHP)'

5. Fitness to landscape
    - '….in terms of competences we need engineers who understand the new technology and the need for integrating renewables with gas or electricity or whatever. That is a new set of skills that hasn't been around before so it's important to be training people.. to do this to have these skills. Very important ….There are definitely shortages, among engineers, what I am saying is we need to be training more.'
    - 'New technology, fuel cells, smart grids, combined heating powers (CHP), hydrogen and gas systems – scaling up will be necessary'
    - 'We need to redevelop in smart people who understand the broader fuel and they need to work together.'
    - 'Europe has the skills and the people and the technology, but I also think you should always be looking anywhere to get the people you need but it would be good for me to have the people coming from around the world to Europe to learn the skills.'
    - '….flexibility is important, we have one major source of gas….. which has a tap attached to it, the Russians can turn it on and off with oil, we need to have access to any source of energy and gas from anywhere which is why some of the far-eastern developments are important ……….[37:27] very important'
    - 'Gas companies typically going back 20 years ago would be spending 1% of their turnover on research. The biggest ones. Now even the biggest ones are spending 0.1% of their turnover on research and that's a huge drop. it's not progressing it's not advancing change, because there is not enough support for R&D.'

6. Differences, variety
    - Countries – 'France nuclear, US shale, Netherlands and UK gas, China as many as possible powerplants…'
    - Energy sources (fossil, renewables, nuclear) and lobby
    - 'There is a lot of gas quality, and mixing gases as you say, and inter operability so all different appliances working with all the different possible gas mixtures, because all gas mixtures come different sources are all different properties and you wanna make sure that the appliances in Europe where they come from and work…. Then of course LNG is part of that so people are trying to manage more LNG into Europe so there is

new technology needed and money spend in that area small scale LNG, LNG been distributed to small islands rather than big countries, so there is money spend on LNG as well. But again that takes it back to the gas quality issue because all LNG's have different properties so the capability is really important issue.'

7. Transforming interactions
   - 'The EU needs the lobby groups to be fed information and developments and at the same time the lobby groups need the EU because they're determining the rules.'
   - 'Well lobby groups tend to be well battling for their own corner. They're still al working against each other, the renewable people don't really talk to fossil people….it's not always easy in the gas business to be listened to. They tend to think you're not as important as the electrical industry, the nuclear industry and all the renewable people are so much more important…. They appear to them to be so much more important and increasingly the coal… '
   - Collaborations: [example] 'work with wind energy people and the hydrogen projects'
   - Links with research (K41 Knowledge for innovation group) – technical groups, economic issues, safety, education.
   - '….it's the 20-20-20 drivers that …and act on them, people are actually acting more and more these days'
   - *Interviewer: Do you see that really governments industry and business or universities getting together to work together? Do you see that happening?*

     'Only where governments supply or provide research frameworks the…. they have these programs, where they try and provide funding or support for certain sectors that would bring the industry and the universities together… you do see that it's still not huge and…. there are cutbacks from government funding certainly in the UK.'

8. Emergent patterns
   - 'There is a drive towards Smart Grids, more demand side, management, things like combined heating powers (CHP)'
   - 'Clearly everybody is interdependent but they are all having to ply on their own forest push their own aspects. They have their own

agenda's….by the hierarchy….but I think generally there is a growing feeling that they have to work together, but they don't always…'

- 'For many years now the support for gas and reserves programmes have been zero. It doesn't make any sense 20 to 28% of the energy supply…. and they don't care about improving gas efficiency and it's just doesn't make any sense so I am never sure I trust those people on the top. Certainly the politicians. You know when a politician is lying? When his lips are moving….'
- 'I think said before that the major impact has been the 20-20-20 document, that is everybody think very hard about it. And the commission trainings scheme…. people having to work towards making renewables and the local national government legislation has changed that is a really new the last 3 or 4 years there has never been that much pressure and then of course the Russian situation the tap on the gas pipe that's very important. That's released the…. in the commission. Made them very wary so they had to have…. about their own battles. And shale gas as well.'

The table below captures the key points of the interview.

| Energy policy – EU Policy is clear |
|---|
| **EU Practice is very complex**<br>- Different lobbies from different energy industries and big corporations<br>- Different lobbies from civic and environmental groups<br>- Different member states with different agenda's |
| **Dependence of EU on lobby groups and interest groups for know-how**<br>- EU determines policy and regulations<br>- different lobby groups present<br>- dependence on lobby groups for inputs and expertise |
| **Huge differences between the different nation states in energy – due to different path dependency, example,**<br>- NL, UK– Gas<br>- France– Nuclear<br>- E. Europe – dependence on Russian energy |
| **Context in which EU is operating is not shared by all global players to the same degree (not level playing field)**<br>- Climate change and CO2 emissions<br>- Stringent environmental and consumer protection norms |
| **Rising emerging economic players with huge energy needs**<br>- China, India in particular, BRICS countries |
| **Risk of dependence on Russian gas and oil resources** |
| **New shale gas developments and US energy policy impacts**<br>- Cheap gas<br>- Coal dumping in EU<br>- Competitive advantage |

## 4. SUMMARY – REVIEW OF EU POLICY DOCUMENTS' REPORT

The following key points were identified in this report:

### Drivers of change identified in EU policy

1. Climate change
2. Security of energy supply

    **Risks**

    - Dependence on import of fossil fuel (2 x more than US)
        - Russian dependence – for gas 1/3 dependence on Russia
    - High dependence make price negotiations difficult and susceptible to price volatility
    - Member states have different dependencies of energy sources
        - Eastern Europe (ex-USSR states) vulnerable - Russian dependence partly due to history and geography

**Solutions**

- o Clean technology and low carbon Europe as solution to external energy dependence, price fluctuations and increased exports (competitiveness through energy prices)
- o More efficient local energy production demands leading R&D and cross-border infrastructure, storage and back-up facilities
- o IEA was created to support shift to renewable energy supply through 3 E
  - Energy security
  - Economic development
  - Environmental protection
  - Also, need to engage in non-EU dialogues to make a shift globally (China, India and Russia in particular)

3. Competitiveness

**Strategies in EU policy**

- Liberation of energy market – consumer (demand-pull) market
- Internal energy market (2006 with electricity, 2014 gas + electricity)
- Cross-border energy infrastructure
- Decentralization of energy production –local production for local use
- Storage to meet seasonal and excess supplies
- Increase energy efficiency
- ETS (emissions trading system) for low carbon EU ineffective due to global context where this is not aligned
- CCS (carbon capture storage) – expensive R&D

**Challenges and development in EU energy market**

- Difficulties in realizing cross-border infrastructure due to complexity of energy market and new energy developments - pathways are unpredictable
- EU energy market becoming a balancing market as consumers and businesses (decentralized energy systems) feed energy into system
- Lack of clear regulations to support balancing functions and price regulatory mechanisms due to differing national regulations
- ETS in EU ineffective due to global context where this is not aligned
- CCS – expensive R&D and civil protests

- New energy services and internal market developments hampered by differing national policies - EU policy to increase consistency and alignment of national policies to accelerate developments
- Investments in new cross-border value chains and R&D for efficient energy production and infrastructure require long term policies

*Report by van der Sluijs, 2014 (unpublished).*

# Part 2 – National level

## 1. SUMMARY OF INTERVIEW DUTCH ENERGY TRANSITION/PROGRAMME OFFICIAL (NATIONAL LEVEL – EV22)

There was recognition at the national level of the significance of local initiatives and decentralized energy generation. A second aspect that was made was the need for national and cluster level strategies to enlarge their scope to focus more on international markets and developments rather than national and local targets. NL was a small country, a ‘postzegel’ [stamp], with high density of activities.

According to the national energy transition expert, national energy policies in the Netherlands were long-term in nature and consistent with one exception, that was the change from MEP to SDE subsidy programme.
[Note: This view is in contrast to the outcomes of stakeholder interviews where the perception was that national energy policies were inconsistent and not conducive to long term investment facilitation]

*Drivers of change*
The official identified national policy as an important driver of energy developments in the Netherlands. Other drivers identified were shale, electric transport, citizen movements and the Tsunami in Japan.

Other issues identified were geographical density of Energy Valley as opposed to Brainport, and the missing middle segment between industry and consumers. This middle segment could be reached through the TKIs [*Top consortia for Knowledge and Innovation* is a collaboration platform of government, research institutes and businesses, various TKIs were established within each of the 'Top Sector' identified, of which energy was one].

*Path dependency*

The current energy developments were credited to (path dependency) presence (dominance) of gas, knowledge concentration and trade, in particular, logistics and markets. Another important fact was that the Netherlands had the second largest decentralized energy supply in the world and this meant that smart grids and wind energy were well developed.

*Fitness to landscape*

When asked about what was needed for future development of Energy Valley and Dutch energy transition, the answer lay in developing the bio-based economy where chemical, agricultural and logistics sectors would be connected. In terms of new competences needed for energy transition, multi-disciplinary competences and entrepreneurship were seen as relevant.

*New connections and emergent patterns*

The emergence of decentralized energy and centralized energy production through smart grids were seen as the most important 'new connection' from the national energy transition perspective. The need for enhanced coordination in infrastructure related to balancing and system integration and more integrated and collective vision on energy transition were identified. The integrated and collective vision needed to include citizen perspectives and this would be new to policy. It was also suggested that a plausible extension of energy transition vision could include transport and tourism sectors, and users in the Netherlands.

A final note was on the role of Energy Valley cluster organization. It was suggested that Energy Valley could service and connect SME in vibrant networks based on strategic themes in order to fulfil a hub function in energy innovation themes.

## 2. INPUTS FOR NATIONAL AND REGIONAL LEVELS

The following documents were inputs for the analysis at the national, regional and cluster levels and specifically related to energy strategies and policies. Other documents and media inputs have also provided information on the Dutch situations next to stakeholder and expert inputs:


- *Energiebeleid van IEA-landen: Nederland: 2014 Landenanalyse*, International Energy Agency (2014).: http://www.iea.org
- De Plus van Noord-Nederland: Roadmap samenwerking noordelijke clusters, versie 1.3 (2013).
- Energieakkoord Noord-Nederland (2007)
- Energiemonitor Noord-Nederland 3e editie (2014)
- Green Deal (2011). http://www.energyvalley.nl/uploads/bestanden/e32eb386-aee4-476c-be76-60414b3fd5e8
- Nationale Energieverkenning 2014, Energieonderzoek Centrum Nederland, Petten (2014)
- OECD Reviews of Innovation Policy: Netherlands 2014, OECD Publishing. http://asset.keepeek-cache.com/medias/domain21/_pdf/media1796/281693-wl5ayagv99/large/0.jpg
- Position Paper: The Northern Netherlands and the EU 2020. SSN (2011)
- Rapport: Aardgasbeleid in Nederland: actuele ontwikkelingen. Rijksoverheid (2014)
- Rapport Eindadvies van de Commissie Duurzame Toekomst Noord-Oost Groningen: Vertrouwen in een duurzame toekomst (2013)
- Research and Innovation Performance in Netherlands, Country Profile 2013 European Union (2013)
- Research and Innovation Strategy for Smart Specialization RIS3 Northern Netherlands. SSN (2013)
- Strategische agenda voor Noord-Nederland 2007-2013. SSN (2005)
- Summary Report of Energy Agreement for Sustainable Growth (Energieakkoord voor duurzame groei, 06-09-2013) SER (2013)
- Switch: Noordelijke Energie Agenda (2014). Bestuurlijk Overleg Noord-Nederland en Stitching Energy Valley
- Technology Outlook 2020. DNV GL (2011): http://issuu.com/dnv.com/docs/technology_outlook_2020_lowres
- Topsector Energie website: http://topsectorenergie.nl
- Werkprogramma’s, documenten en rapporten van Stichting Energy Valley

## Lesson 7

The following notes reflect inputs from experts, Energy Professors at the Centre of Expertise – Energy, Hanze University of Applied Sciences, Groningen). Quotations from these experts were included in the main thesis. The notes below capture key issues and solutions needed for energy transition. Note that inputs from Lessons 1-6 also contributed to the analysis of related and overlapping systems in Energy Valley. In addition, Appendix 10 describes an overlapping project, Edgar Project 'The Big Picture', which shares analyses and conclusions related to this Lesson.

### Issues and solutions needed in Energy Transition - *Views from the experts*

1. **Complex problems and dynamics** in Energy Transition
   - Move from closed system to more open system
   - Pricing of energy based on 'old' centralized system - energy price includes transport and tax - generation of RE for local use too expensive due to old pricing system
   - National government-market dynamics complex - different interests, roles, considerations, market regulation vs. free market, energy earnings for state make it more complex
   - Increased RE supply with strong seasonal and local fluctuations into energy system has generated 10 blackouts, 1 every 3 to 4 years, in Europe. Resilience of system and capacity issues.
   - EU sets energy targets, RE targets; member states are allowed to determine solutions in energy mix; capacity side targets and grid roads. Variation by member states in
     - Speed of RE implementation
     - Fluctuations in RE generation and usage
     - Market flooding
     - Implementation of RE solutions varies without any system considerations
     - French more nuclear oriented, Germany more decentralized, ??? for cheap coal
   - EU's internal market drive - energy grid
   - Long horizons in energy transition; inclination generation follows transmission (old thinking), need to consider transmission follows generation for new energy landscapes

- Planning (Ruimtelijk Ordening) principles vs. energy transition landscapes
- Location specific solutions vs. general economic and policy solutions includes

  General
    - Infrastructure solutions
    - Market price mechanism
    - Government fiscal measures

  Local
    - Landscape/quality of life
    - Social norms
- People-centred movements vs. planning in energy transition

  People-centred
    - Demand-driven
    - User-centred solutions

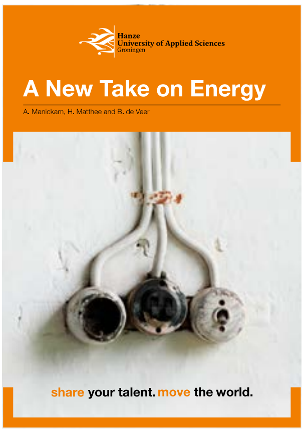
  Central planning - security of supply
    - Safety
    - Reliability
    - Affordability

2. **Cost of increasing additional and differentiated energy sources**
   - Reduce transmission distance - local generation and use
   - Connect gas and electricity grids - gas transport, storage and expansion of grid capacity to cater for growing RE generation through gas much cheaper
   - All electric solutions - not sustainable, too expensive, 25,000 euros instead of 1,000 euros per household to realize this
3. **Need for integral vision and solutions**
   - Local solutions
   - Gas to meet increase in infra and energy issues
   - Connect fossil to non-fossil

The next Appendix (10) provides additional insights that served as inputs for this Lesson. This describes the overlapping research project carried out for Edgar's 'The Big Picture' Project. The focus of this research project was to gain insights into contextual systems dynamics related to energy clusters based on Energy Valley.

# 10.CONTEXTUAL AND SYSTEMIC FORCES IN ENERGY VALLEY - THE NETHERLANDS

Chapter in *A New Take on Energy*, 2015. By A. Manickam. (Word version)




## 1.1 Introduction

This chapter describes how contextual factors and system reactions influence end state developments based on a systems approach. The chapter uses the case study of Energy Valley of the Netherlands to illustrate the influence of contextual factors on the regional energy system and how the system responded and developed. The illustration below captures system interactions with its context and eventually the resulting end state.

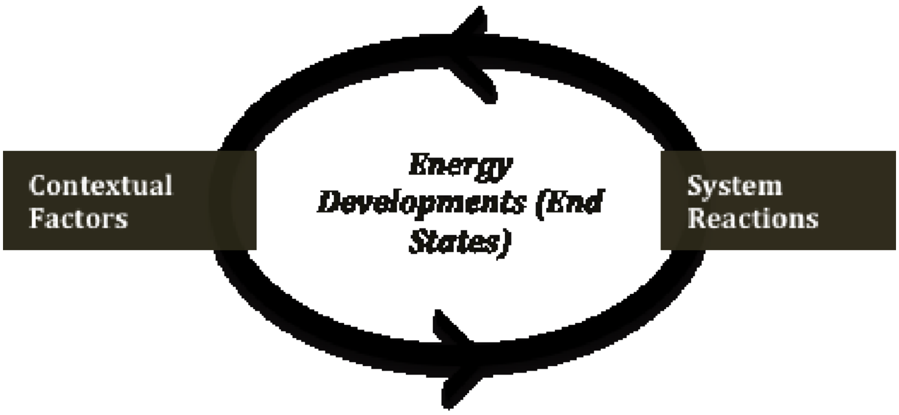



Figure 3: Systems approach

The illustration shows that energy systems respond to contextual factors and this in turn affect contextual factors. Decisions and behaviour in this energy system are influenced by contextual factors, which in turn result in energy developments. This continued loop of interactions would finally result in a particular ‘end state’ for such a system. The term ‘end states’ has been described in the introductory chapter and this chapter shows how such end states could be influenced by various contextual factors and systemic responses.

When talking about ‘energy systems’ this analysis takes a broader perspective and looks at ‘energy’ as being embedded in social, economic, and political systems and that such a system could be a district, region, country, or a regional block such as the EU. The analysis looks at ‘energy’ as being located in a specific location with a defined boundary and it can be of different scales. In the research, Energy Valley was examined as an energy system embedded in a larger energy system, which is the national energy system and this in turn, is embedded in a European energy system. Each of these systems can be examined separately, but each of these next level systems is interconnected and contributed to other levels. EU decisions and developments influenced Dutch decisions and developments and therefore that of Energy Valley. At the same time, Energy Valley developments reflected national and EU developments. This analysis compares Energy Valley and national energy developments to that of EU developments for similarities and differences in their systems patterns and behaviour later in the chapter.

Finally, it must be noted that this chapter builds on a previous chapter on ‘drivers of change’, which focuses on the macro level contexts in which energy developments take place, whilst this chapter looks at contextual factors influencing energy developments at the micro level, specifically from a systems perspective.

The rest of the chapter has 5 sections. Section 1.2 describes salient aspects on Energy Valley and the research to be able to frame the analysis presented in this chapter. Section 1.3 describes ‘contextual factors’ and how these framed Energy Valley’s energy system developments initially and then in Section 1.4, the ‘system responses’ are described and again, Energy Valley’s energy system responses are illustrated to show what this means. In Section 1.5, a comparison of Energy Valley’s energy system development and that of the EU is discussed to understand how energy systems are embedded in larger regional systems and how these systems interact. In the final section, implications of the analysis [and of a systems approach] are discussed in the light of ‘end states’.

## 1.2 Research on Energy Valley case study

Energy Valley is an energy cluster covering the Northern part of the Netherlands and was established in 2003 by stakeholders including local policymakers in response to EU and national energy liberalization policies. Energy Valley faced two major strands of development. The first, a gas driven national energy sector facing the transition to more sustainable, liberalised European energy market and the second, the economic development of a periphery region. Energy Valley cluster as a case study offered exploration into these two interconnected developments driven by changing EU and global contexts.

Energy Valley was established in 2003 and has seen changes in its scope, visibility and developments as a result of changes in its context. In order to understand how energy systems develop, the research chose a complex adaptive systems approach, which offered a systems perspective on how systems change due to responses of its agents to changes in its environment. This approach offered both micro and macro level systems perspectives which meant that local micro interactions and behaviours of agents could be understood within broader macro level energy and contextual developments. The study looked at system developments at the local, national and EU levels and these examples will be used to illustrate how energy systems develop in their (local) contexts.

The research on Energy Valley was a qualitative study based on stakeholder and expert inputs supported by secondary sources of information.

## 1.3 Contextual factors

Contextual factors in this analysis include drivers of change, history and geography of the system, stakeholders and collective definition and boundaries of the energy system.


**Figure 4: Contextual Factors in Energy Systems**

To illustrate, discovery of gas in the North NL and the development of the gas industry for NL and EU determined the key stakeholders, namely, gas corporations, the national government and regional governments. This led to an energy system built on gas as the key resource. This initial energy system dominated by gas with its stakeholders and definitions of the system responded to specific drivers of change.

### 1.3.1 Drivers of change

Drivers of change in this analysis are understood to be drivers that change the system as a whole. It has been found in this study that drivers in energy systems can be external or internal drivers. The case study of Energy Valley illustrates which drivers of change were relevant to its system changes. There were nine significant external drivers and seven internal drivers. Below are some highlights of these drivers of change and their relevance to a gas dominated system of Energy Valley.

**External drivers of change in Energy Valley**

- *Geo-political shifts*

  Major geo-political shifts such as the emerging power shifts towards Asian economies and the renewed Russian political threats to Europe are examples of drivers that required strategic responses in Energy Valley.

- *Energy security threats*

  Dependence on external energy sources (EU imports 53% of its energy needs and of this, imports for crude oil is 90%, natural gas is 66% and solid fuels 42%) and incidents such as the recent Russian threats to European gas supply (Russian gas contributes 39% of its gas imports) needed to be addressed.

- *Large scale power outage and blackouts in Europe*

  The need for improved grid infrastructure across Europe to increase reliability is directly linked to energy security issues. Major outages and blackouts in Europe that had cascading effects in other parts were present in the recent past and therefore all regions had to comply with new EU directives and legislations to mitigate such effects, including major grid investments.

- *EU market liberalization*

EU liberalization of electricity and gas markets was introduced to support consumer choice and increased competition. Energy systems are directly affected.

- *EU legislations*

  The legislations supported EU's goal towards a more reliable and sustainable use of energy and more flexible markets led by demand-side focus. Specific legislations governed grid interconnections and efficiency of energy systems to support development of a European internal energy market. Energy Valley needed to comply.

- *Sustainability and climate change*

  Long-term energy sustainability agendas that included climate change resulted in compliance of Member States to meet $CO_2$ and renewable energy targets. The EU saw gas as a fossil fuel and this had implications for Energy Valley and the Netherlands.

- *New energy resources and balancing*

  EU targets for renewable energy and energy efficiency (Policies: 2020, 2030, 2050 Energy Roadmaps) were directly relevant to developments in Energy Valley. The increased need for balancing as a result of large-scale introduction of renewable energies offered new opportunities for the gas sector in Energy Valley.

- *US cheap coal and shale*

  The US shale revolution and its move towards increased renewable energy in their energy mix resulted in excess and cheap coal being dumped in European markets, including the Netherlands. This had a strong impact on energy demands by power plants and therefore affected climate change and sustainability agendas and developments locally.

- *Technology developments*

  The shale revolution, cheaper solar and wind energy, viable smart grid technologies, bio-fuels, fuel cells and hydrogen fuels are examples of the impact of technological developments on market developments. Unpredictability was a major concern.

**Internal drivers of change in Energy Valley**

- *Depletion of gas resources*

  Depletion of the Groningen gas reserves has been estimated around 2030 at the current rate of extraction. Energy Valley's gas contributes almost two-thirds of the energy needs of the Netherlands. Earnings in 2013 were more than 15 billion euros from gas revenues. The gas industry has direct implications for local and national economies.

- *New gas reserves and biogas*

  Biomass gasification, production of syngas, creation of green gas hubs are examples of new developments in Energy Valley changing the local gas and energy sectors.

- *Increased earthquake risks*

  Increased earthquakes and damage to property directly related to gas exploitation in the Energy Valley region were creating tensions between local population, local politicians and gas corporations and national government where conflicts in interests, roles and power relations played a role.

- *National policies*

  As mentioned earlier, government economic interests in the gas revenues were conflicting with citizen safety and electoral pressures. Long-term gas contracts and legal obligations to trading partners outside of the country versus citizen and green movements were tensions in the system. National policies were leading and therefore relevant to Energy Valley's energy system.

- *North Netherlands as economic lag region*

  Energy Valley is a periphery region of the Netherlands that has lower economic growth than the national average (-3% vs. 0.75% in 2014). Regional development agendas were competing with energy transition developments and national economic priorities.

- *Citizen movements and developments*

  As mentioned earlier, a growing distrust in energy corporations and government related to conflict of interests regarding gas exploration and earthquake risks, the rising energy prices and need for autonomy and self-sufficiency were some of the key motives of citizens and grassroots movements to initiate decentralized energy solutions. Parallel to this was also the 'green' sustainable movement. Citizens producing energy were dubbed 'prosumer', producing consumers.

- *Role of local governments*

  The urgency of local governments in the economic lag region of Energy Valley to create jobs and economic growth was prevalent. The depletion of gas resources was a major threat to further economic depression coupled with youth urban migration pulls. Earthquakes risked aggravating the attractiveness of the location. The regional development agenda was a strong driver in the region that included job creation, innovation boost and mitigating earthquake issues.

#### 1.3.2 History and geography

Discovery of gas in the 1950s has and continued to have a major impact on the local energy system of Energy Valley. The region has built its infrastructure, energy mix and economic development policies based on the *gas industry and revenues*. The Dutch government has a dominant stake in the gas resources (50% state ownership) and are directly connected to national strategic interests. The local energy system of Energy Valley is therefore tightly connected to the national energy system. The *trading history* of the Netherlands and its current 'BV NL' ('Netherlands Incorporated') strategy framed economic interests as being leading. Gas is traded internationally and has larger implications beyond Energy Valley.

The *periphery and lag region* positions of the region meant that economic and social structures needed to be addressed. The region is dominated by *agriculture and rural* *economies* on the one hand, and, *large chemical and energy intensive manufacturing industries* related to national policies of the past related to availability of cheap energy. *Energy expertise* and energy related industries were dominant. However, there were other economic sectors dominant in the Energy Valley region and *regional differences* were present, for example, water and recreation, food and agro-based industries (Friesland), horticulture (North Holland North), agriculture and dairy farming (all provinces), forestry and tourism (Drenthe) and heavy industry and harbour facilities (Groningen), etc.

*Lack of strong R&D investments and knowledge centres*, public and private centres were also key feature of the system. The limited knowledge base was a key concern for Energy Valley.

#### 1.3.3 Stakeholders

Energy Valley was initiated to address a serious threat of losing the local gas industry and expertise built up in 50 years as a result of EU liberalization policies and future gas depletion. The need to preserve existing gas expertise in the local economy was an important driver to Energy Valley. The key stakeholders developing Energy Valley were therefore *regional governments, gas corporations* and *local educational institutes*. However, gas dominance in Energy Valley's energy landscape meant that *gas industry* stakeholders and the *national government* had strong positions in the current system.

#### 1.3.4 System definition - identity and scope

Identity and scope of an energy system is directly related to its key stakeholders. In Energy Valley, stakeholders from policy, business, academics, and regional development agencies were present and 'policy' included local and national policy makers and decision-makers. *Dominant stakeholders* in the energy system were identified as the national government, gas related stakeholders and provincial governments due to historical and geographical factors. This meant that the differences in stakeholders resulted in different definitions and boundaries for the system. Given the dominance of its particular stakeholders, *three main frames, 'economic', 'energy transition' and 'regional development',* were evident in Energy Valley. This in part led to complex and conflicting agendas as already mentioned in earlier sections.

The regional development focus of local policy makers meant that initially a *regional and internal focused* strategy was present although the national and trading aspects of the gas business had strong national and international scopes. The activities supported by Energy Valley's strategic focus in the initial working programmes were very much on energy and regional developments.

#### 1.3.5 Interconnectedness of contextual factors

Drivers of change, history and geography, stakeholders and system definition are all interconnected as captured in the previous sections. The illustration below captures this interconnectedness.

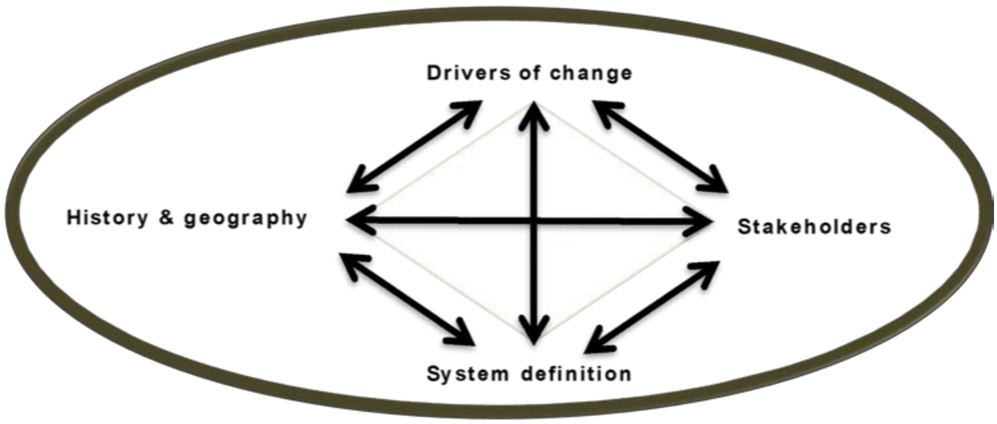



Figure 5: Interconnected Contextual Factors

Energy Valley's gas dominated system determined its stakeholders, and therefore their conceived identity and scope of the energy system and both these factors were shaped to a large extent by its (perceived) history and geography of gas and socio-economic factors related to national and regional interests. Drivers of change are connected to an energy system's definition, its identity and scope, as certain drivers influence decisions of scope, need new strategic focus, etc. In Energy Valley, the need to redefine gas dominance in its initial energy system was due to drivers of sustainability, pending depletion of local gas sources, etc.

## 1.4 System reactions

According to complexity approaches, systems change when agents in the system respond to changes in their environment. The total system change can be understood by exploring different aspects of a system that contribute to such a change. In this analysis, aspects contributing to system reactions include: *'pulls' of the system* which is the direction in which a system tends to move; *coping strategies* of agents that include developing and gathering new knowledge, resources and skills; *differences that matter* for future strategies; *transforming interactions* and collaborations. Finally, these aspects add up to a macro level system change visible in *emerging system patterns*.

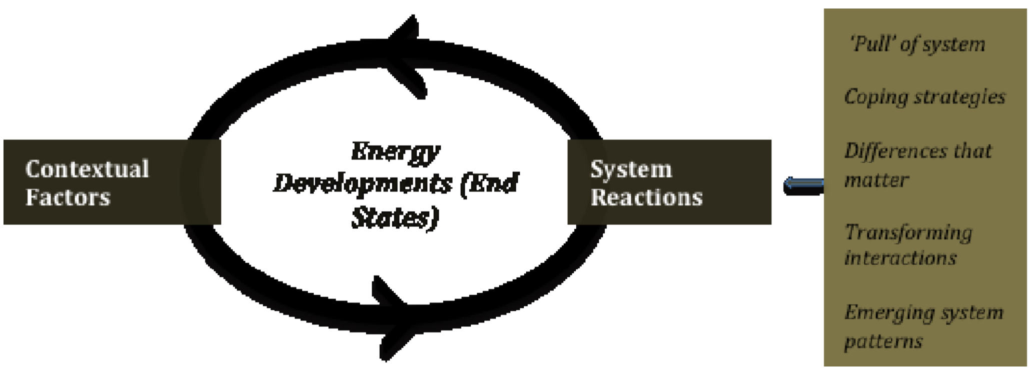



Figure 6: Contextual Factors and System Reactions in Energy Systems

To illustrate system reactions in Energy Valley, there was a pull towards more sustainable and decentralized energy solutions, connections between gas, oil and renewables. In addition, a key coping strategy was the creation of Energy Academy Europe that would bring fragmented knowledge, research, education and stakeholders together. An example of transforming interactions and collaborations was found in EnTranCe, a multi-stakeholder open innovation environment close to market. Examples of emerging system patterns were the increased presence of bottom-up initiatives next to top-down policy directives interplay of gas and electricity, cross-sector collaborators such as bio-based economy. The following sections give more details on the system reactions of Energy Valley.

### 1.4.1 'Pull' of the system

A system responds to changes in its environment and there is often an underlying direction towards which the system tends to move. In Energy Valley, the drivers of change and responses by individual agents in the system resulted in more complexity and increased unpredictability and a general movement towards the 'outside'.

The energy system was initially an internal and regional oriented system. But the changes in the context saw various shifts in this system. One example was the position of 'gas' in the energy mix. It was no longer secure due to the increase in new sustainable energy solutions. This meant that a pull to redefine and reposition gas in the new energy system. Related to this was the decentralization movement of citizens and grassroots organizations. This also meant a tendency towards more demand-side focus instead of the traditional supply-side dominance.

The lack of R&D, innovation resources and facilities, talent, policy constraints, etc. resulted in a tendency to explore possibilities outside the local system. Pilots in the UK were carried out where regulations were less stringent for new innovations. The strong 'pull' to seek solutions outside Energy Valley was a serious threat of further depletion of capacities and attractiveness of the region if this resulted in a 'cluster drain'. Programmes and mandates from the European Union supported internationalization tendencies, and provided additional resources to regional systems, enhancing the attractiveness of 'the outside'. Being connected internationally was not in itself negative, but the 'pull' of the outside could be a threat if it did not contribute to strengthening the system's capabilities.

### 1.4.2 Coping strategies

There was a need to deal with the changing landscape of Energy Valley's energy system. Stakeholders identified different strategies for its future and these included creating new and different infrastructure to deal with the emerging (complex) energy system; including new stakeholders such as local intermediaries, citizen and grassroots organizations, Small and Medium-sized Enterprises (SME), etc. in the search for broader system-wide changes; creating new cross-sector value chain collaborations; creating educational programmes with multi-disciplinary competences; creating new institutions and innovation spaces, etc. All stakeholder groups underlined the urgency for different approaches and changes in the existing policy, business, education and innovation practice. There was also an acknowledgement of the need for both large-scale and decentralized solutions, and a more inclusive strategy.

### 1.4.3 Differences that matter

In order to meet the new challenges due to the changes in Energy Valley, the innovation potential of the system had to be analysed. Exploring 'differences that matter' in a system with new combinations of potential differences in a system could result in innovation. In Energy Valley, new and different competences and capacities needed to be explored to resolve the increasing complexity in the system through new combinations (German notion of 'neue Kombination'). For example, *innovative SME collaborating with large corporations and industry* with their resources and market reach could result in accelerated commercialization of innovations, including access to international markets. *Combining fragmented research and knowledge disciplines* present in the different universities in Energy Valley could accelerate more focussed and collective solutions for energy development challenges. *Regional differences* in Energy Valley with differences in goals, ambitions, resources, market structures, networks, etc.

could be used to forge new networks, new cross-sector solutions, new business model testing, etc. The *regional and national interests* were also significant and could offer different solutions to both systems. Energy Valley had physical space and large agricultural land and farms that offered biomass solutions as a sustainable energy source whilst national government needed to deal with $CO_2$ targets and these two different goals could be achieved through the use of the differences of each system. Potential or 'missing' stakeholders in Energy Valley such as environmental groups, civil organizations, and 'prosumers' had different values, goals and motives from the established stakeholder groups. Combining these differences could offer a broader reach to the energy sustainability agenda.

### 1.4.4 Transforming interactions

When interactions take place that come from new combinations, a change takes place that transforms the original interactions. An example in Energy Valley was the creation of EnTranCe which began in the skybox of the local football club where informal discussions of different local energy businesses and the energy research centre led to the creation of an open innovation multi-disciplinary centre where businesses, students and research could come together to solve energy transition challenges. The 'gas' stakeholders had a strong systems approach and this has been adopted in EnTranCe as a key competence. Energy Academy Europe is another example of a collective initiative that resulted in a special institution for energy to overcome fragmentation and lack of 'energy' in curricula.

A different example of transforming interactions was the integration of energy – between electricity and gas, renewables and existing energy systems, micro-level energy system management for homes and neighbourhoods, meso-level energy hubs connecting businesses in transition parks, green gas hubs, and macro-level energy collaborations across regional boundaries such as in Hansa Energy Corridor and ENSEA (North Sea) projects.

Another example of transforming interactions in Energy Valley were the development of integrated energy vision clustering strengths of the different Provinces in 'De Plus van Noord Nederland', of different sectors in the 'Bio-based Economy', and aligning to national agendas in the 'Green Deal' and 'Switch' agreement and programmes.

A more inclusive strategy of extending dialogues to consumer and grassroots movements on energy developments in Energy Valley region meant that the system was changing in terms of its relationship to these groups, from end users to participants and increasingly strategic partners.

### 1.4.5 Emerging system patterns

The transforming interactions of Energy Valley were visible indications of changes in the system. These changes were coming together due in part by the responses of agents in the system and their coping strategies, building on innovation potential of 'differences', and the underlying 'pulls' of the systems. On a systems level, new or emerging patterns could be discerned in Energy Valley. These patterns indicated that the energy system was becoming *more complex*, which is partly due to the system becoming *more 'open'* as seen by the inclusion of new players, new sources of energy, more international orientation, new business models, etc.

The scope of the system was changing to become both *more local* and *more international* and there was evidence for a *more systemic approach* that went beyond the traditional notion of energy systems. Following the systemic approach, a more emergent and organic development of the energy system was visible even as more policy and top-down coordination was taking place in Energy Valley. Included in this shift were *more flexible and varying* strategies that embraced both local and international developments, traditional and renewable energy solutions on small and large-scale as necessary, thematic and on-line community developments that were self-organizing as well as strategic projects focused on 'gas and energy roundabout' policies in line with national, trans-regional and EU developments. Collaborations on international and EU levels across Energy Valley's system were another emergent pattern that reflected major shifts of the system from the once regional and locally oriented system.

### 1.4.6 Interconnectedness of system developments

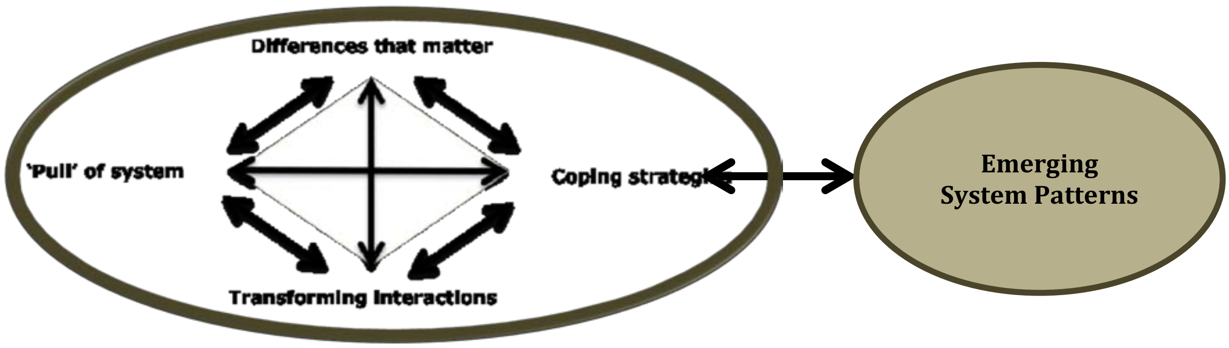



Figure 7: Interconnectedness of System Reactions

The system reactions are interconnected as shown above in the diagram and together these result in macro level system patterns as already described in the section above. When gas is re-positioned as a balancing power source in Energy Valley ('pull' of system), then realizing an integrated fossil, renewable and gas energy system ('differences') is more feasible. This allows other energy carriers to be seen as complementary rather than competitors (transforming interactions), which in turn facilitates open innovation and collective initiatives as 'coping strategies'. More collaborative and integrated approaches become part of new system patterns.

### 1.5 System patterns in Energy Valley/NL and EU

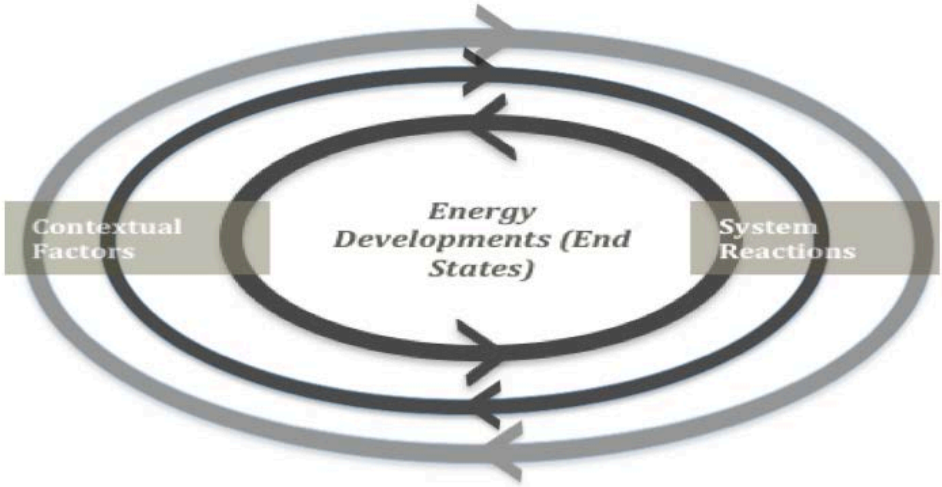



Figure 8: System in System interconnections of Energy Developments

The analysis explored how Energy Valley and the Dutch national systems reflected system patterns at the EU level. Complex Adaptive Systems (CAS) approach explains how systems are embedded in larger systems and how systems interact and feed into each other. The diagram above captured the embedded nature of energy systems as understood by CAS.

In the comparison of the three levels, Energy Valley, the Netherlands and the EU, the shifts in the contexts were similar, namely, the *growing complexity and unpredictability* of energy system developments as were the *external drivers of change* (geo-politics, financial and euro crises, new technological advances, energy market developments, etc.). Similarly, in all three levels, *energy systems were embedded in larger socio-, political, economic and ecological systems*. In all three levels, *economics was leading* and this framed energy developments in terms of enabling competitiveness. Common themes related to this are energy security, sustainable energy solutions, $CO_2$ mitigations, innovation, and smarter grid connections. *Regional social cohesion* and job creation was a key issue to Energy Valley and the EU.

On the other hand, whilst Energy Valley and the NL had a gas-dominated history similar to the UK, the EU had a wider diversity of energy sources and systems. The 'pull' of Energy Valley's system was to *keep gas in the energy mix* whilst the EU was focussed on *independence of external sources of fossil fuels* plus its commitment to *climate change* resulted in a strong 'pull' towards renewables. At the same time, the EU had a *diverse 'energy system'* with 27 different Member States (MS) with their different infrastructures, energy sources and socio-economic structures stemming from their different history and geography. In Energy Valley on the other hand, whilst regional differences were present, *national economic frame and policies were dominant*.

A common system development in all three levels was the acknowledgement of a *need for collective commitments* to build multi-disciplinary competences, cross-sector and new value chain innovations, new business and governance models, and more trans-regional and international collaborations to meet the new and complex challenges of energy. There were more visible coordination and connections in energy infrastructure and markets in all levels, more and different alliances and collaborations, new governance structures, more decentralization of energy movements, more trust and engagement to realize collective goals, more sustainability, technology and consumer push, etc. The system level patterns at all three levels had some differences but in general, there were many parallels in their system developments.

## 1.6 Implications for end states and energy futures

The system of Energy Valley at the beginning of the analysis showed how gas was the dominant factor in the system and how the stakeholders, strategies and solutions were all related to the traditional gas sector. In the second part of the analysis, the system reactions, the role and definition of gas in the new Energy Valley system had changed. Gas was also bio-gas, sync gas, gas from different sources and players, gas was also connected to smart grids and had re-positioned itself as a balancing and storage carrier within a more diverse energy system. This meant new and different 'coping strategies' including new competences and expertise beyond gas. A different aspect of the system change was the earthquake risks brought about by gas exploitation. The position of gas in the larger socio-economic system was weakened by such developments. The future of gas in the energy mix in Energy Valley has become polarized between the local and national economic interests and therefore new 'coping strategies' needed to be considered where citizen acceptance and national interests needed to be balanced.

### 1.6.1 Contextual factors, system behaviour and end states

In this analysis, the role of contextual factors has been explored in the light of Energy Valley's energy system and the resulting system reactions. The analysis also included an exploration of how Energy Valley was embedded in the national and EU systems. Based on this analysis, a number of conclusions can be drawn that have implications for end state developmental pathways. The following considerations play a role in these developments and can contribute or limit end state developments. The considerations have been categorized under their respective headings of contextual factors, system reactions and system in systems.

**Contextual factors and end states**

**Role of contextual factors**

- Energy systems are more than technological systems
- Each energy system is subject to local and global contextual factors and it is more than only drivers of change, it includes history and geography, stakeholders and system definition
- Interconnectedness and unpredictability of system interactions as a result of contextual factors

*Box 1: Elaboration on role of contextual factors*

Energy transition is not only a technical challenge but economic, (geo) political, environmental, behavioural and (civil) societal aspects play an important role. Moreover, these aspects are interconnected and unpredictable and are therefore difficult to anticipate and know what impact they could have on chosen pathways.

The future is not predictable (gas prices, earthquakes, technological advances) and therefore more attention is needed to 'fitness' of strategy to drivers of change where alertness and responsiveness to current trends and developments are important. Too much focus on long-term planning may miss current trends and opportunities elsewhere.

Focus on one dominant energy system (e.g. gas dominance) could lead to lock-in effects inherent in contextual factors. External drivers of change, e.g. a major earthquake, could have major impacts on such future end states. A diverse energy mix offers flexibility and resilience.

### System reactions and end states

**System reactions**

Due to unpredictability of energy future, planning strategies are limited in their value and therefore, more resilient strategies are needed. These could include

- being open to broader developments
- creating trust amongst a larger group of stakeholders and engaging with 'new' stakeholder
- engaging in interdisciplinary solutions, innovations and knowledge sharing
- supporting new businesses to reach critical mass, and to be part of the energy system
- creating broader system definitions and approaches, e.g. energy as eco-system
- acknowledging self-organizing processes next to coordinated policy

*Box 2: Elaboration on system reactions*

Interconnectedness and unpredictability of 'other' factors increases the urgency to engage and include stakeholders outside of energy in developments to expand the perspective and scope of strategy frameworks of energy clusters.

- Connections (especially to outside the 'normal') as opposed to fragmentation and 'silos' are vital to break down 'lock-in' risks and to make an energy system more resilient:
  - Including other stakeholders, for example, engaging politicians at all levels, connecting to consumers and consumer intermediaries especially since consumer and demand-side focus is becoming more influential
  - Connections to other disciplines instead of mono-disciplinary approaches
  - Connections in an enlarged scope, examples being gas to renewables, international connections, other sectors, value chain approach instead of product development in isolation
- Building ecosystems to accelerate innovation and knowledge sharing:
  - Includes open innovation, international, interdisciplinary, inter-sectorial, consumer involvement, focus on variety, etc.
  - Government's role in facilitating ecosystems including capacity building and knowledge development to support knowledge acceleration and excellence.
  - Major push needed to boost start-ups, large corporations and R&D centres to create critical mass to attract and keep expertise and talent in the region.
  - Attractiveness of the region is a major challenge that would influence future of the cluster. Energy Valley needs to deal with this to avoid 'cluster drain'.

- Centre and periphery issues where relevant such as a shift to include stakeholders in the margins (environmentalists, 'prosumers', consumers, innovators, funding partners), or a shift in system position from peripheral regions to more strategic positions as was the case in Energy Valley.
- Better alignment and connections between future scenarios and frames of key players need to be addressed. Balancing 'frames' of climate change, competiveness and economics, regional cohesion agendas and other local frames needed since this could result in affecting end state developments. Particularly, where
  - energy as a theme served different goals and agendas
  - major differences and misalignments in urgency and priorities were present
- Systems, and particularly complex systems, are subject to self-organizing processes. Acknowledgement of such processes and facilitating decentralized initiatives as part of good governance is needed in addition to coordination through top-down policies and guidance
- Building trust as a key aspect of energy system developments is important since this is strongly connected to how local energy systems react to new and planned development pathways. This includes
  - trust between different types of businesses, between government and businesses, citizens and governments and businesses
  - trust in large scale investments and projects especially when new technology is involved
  - trust in the 'care-taker's role' of the government and the long term sustainability of societies

**System in system and end states**

**System in systems**

Local and EU energy systems are interconnected

- Lower level systems feed into higher-level systems and therefore various local energy systems' developments and their respective energy end developments will contribute to a higher order system of end states

*Box 3: Elaboration of system in system*

- Local energy systems are connected to EU systems and this offers opportunities to connect and tap into competences, resources, energy sources, to increase scope, scale and capabilities to accelerate energy system developments locally but it also works both ways and offers national and EU level systems opportunities to accelerate and influence their preferred energy developments.
- On a systemic level, being aware and connecting to other systems' developments is an opportunity for growth, visibility and influence and at the same time, it increases complexity and unpredictability of end state pathways.
- Local energy systems tend to be 'locked in' to their contextual factors and system reactions as described in this analysis. Connecting to other local energy systems and

to the EU could help temper lock-in pulls. At the same time, at the higher EU level, the diversity of the different local energy systems and their end state pathways and goals make the EU system more resilient. Diversity of the higher level system could act as a buffer for any lack of resilience of energy systems to external shocks (drivers of change) and therefore an issue to be considered for the 'big picture' is that there could be different end states in a larger EU system but that the higher level system of the EU needs to be diverse and resilient to future drivers of change.

### 1.6.2 Complex energy systems

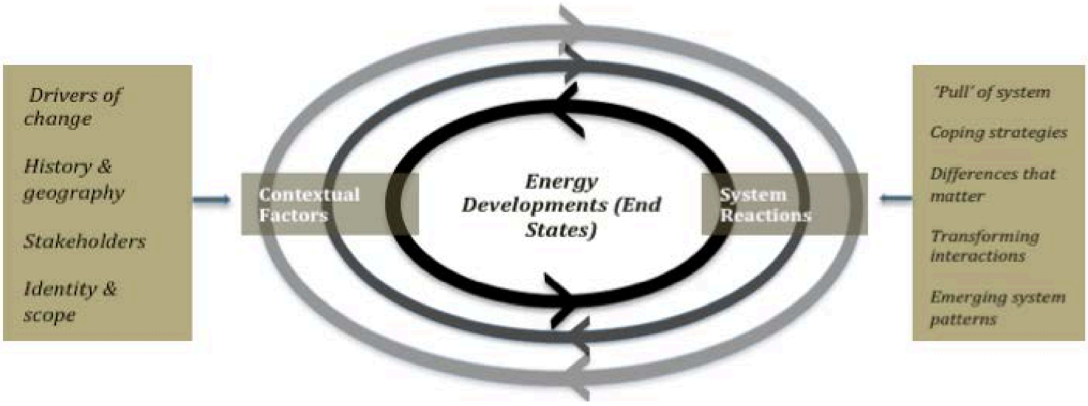



Figure 9: Complex Systemic Energy Developments

Based on the systems analysis as described in this chapter end states are determined by contextual factors of the (local) energy system and the energy system's reactions to such changes. The configurations for a specific energy system are continuously being shaped by the interaction of contextual factors and system reactions. And end states of local systems feed into higher-level end states, which in turn are affected by contextual factors and system reactions that then determine energy end states of the whole system-in-system. For Europe, local and regional energy end states feed into the European end state developments and therefore a systemic analysis of local and European end state contextual factors and possible system reactions could provide a more specific picture of constraining and supporting factors towards end states. In addition, as mentioned in the system in system analysis, the notion of different end states in local energy systems is a plausible scenario, which in turn could support a more diverse and resilient energy system at the EU level. This last consideration, of systemic interconnectedness, could become a relevant agenda in the EU's development of its Internal Energy Union and its end state pathways.

### 1.6.3 Implications for Big Picture - 3 End states

Potential limiting factors as 'risks' have been identified below for the end states, particularly from the EU perspective, to illustrate key contextual and systemic factors that could affect pathways to energy end state scenarios.

- **Risk of underestimation of 'system reactions'** as energy systems are not technology systems but social systems
    - System reactions on unexpected incidents such as nuclear disasters, shale gas risks, offshore oil disasters, earthquakes, political crises have shown their impact on energy policies and practice.

- System reactions on slow trends (boiled frogs), for example, climate change, and on sudden breakthroughs (game changers), for example, fracking technology.
- Micro level system reactions on price developments, ecological damage, push for autonomy and self-sufficiency, etc., as seen in the 'prosumer' and green movements, decentralized energy systems and emergence of small innovative firms.

**End States**: Larger risk in BAU, less risk in GAS, and least in RES.

- **Risk of miscalculation of role of governments** and regulations at European, national and regional levels
  - European Union's drive to be independent from foreign supplies (energy security focus) and its transition to low carbon society. Captured in new 'Resilient Energy Union' vision of secure, sustainable, competitive, affordable energy for every European.
  - EU's ambitions translate to national and regional regulations, for example, renewed focus on North Sea Grid to reduce Russian gas supply dependence.
  - European Union's innovation policy and funding programmes focus on strengthening regions and clusters to increase competitiveness of small and medium businesses, particularly in new emerging industries. Energy efficiency, smart grid and decentralized innovations are energy related examples. This includes shifts to regional vs. national levels, strengthening the regional and local energy systems primacy.

**End States**: BAU and GAS scenarios more vulnerable than RES.

- **Lock-in risk due to current dominance of fossil fuels**
  - Assumption of abundant fossil fuels (gas in GAS scenario), power of fossil fuel corporations, short-term thinking and growth of energy needs results in more exploration, more infrastructure for fossil and non-fossil, more expertise, etc. (more of same = lock-in).
  - Underutilization of 'other solutions' (as in RES scenario), cross-sectoral, cross-disciplinary open innovation developments.

**End States**: BAU and GAS have largest risk, RES least.

The table below captures the risks with a brief explanation for EU end states.

| Key Risks | Risk for BAU | Risk for GAS | Risk for RES |
|---|---|---|---|
| Underestimation of 'system reactions' | ++ | + | - - |
| | *Short-term thinking particularly in BAU scenario makes it more vulnerable*<br>*In RES, variety of stakeholders including demand-side innovative firms, NGOs and consumers reduce tunnel vision and increase flexibility of system.* | | |
| Miscalculation of role of governments and regulations | ++ | + | - - |
| | *Current dominance, lobby and short-term thinking of fossil fuel industry feeds into optimism of continued influence and lack of alternatives for current scenarios on the short-run*<br>*National sovereignty still dominant in EU and fossil fuel industry have powerful positions*<br>*EU ambition to be low carbon and energy independent is a push for RES* | | |
| Lock-in risk | ++ | + | - |
| | *Similar to 'role of government' risk*<br>*Current dominance and power of fossil industry and a lack of alternatives strengthen search of solutions in 'known' RES are dependent on new innovation and therefore less risk of lock-in* | | |

Table 1: Implications of Risks for End States

## 1.7 Key findings

### General

- EU's end states are unpredictable due to contextual factors and energy systems reactions
- Local energy systems influence EU end states and v.v.
- Local energy mix variations in end states (e.g. gas dominance in NL) contribute to EU's diversity and less lock-in risk, and this increases EU energy system's resilience.

### Risks

- Underestimation of 'system reactions'
- Risk of miscalculation of influence of governments and regulations especially BAU
- Risk of lock-in especially in BAU and GAS

### Opportunities

EU's combined drive for energy independence and low carbon economy ambitions create opportunities for leadership in innovation (push for RES).

*Note: The 'Contextual and Systemic Forces in Energy Valley' analysis was based on a PhD research project focussing on energy cluster dynamics that overlapped the study of 'end states' in the context of Energy Valley. Drs. Karel van Berkel was part of the research team contributing to the study. (Expected completion of PhD thesis, 2015; article on end state analysis will be submitted for publication, mid-2015).*

## 1.8 References

Asheim, B. and Parrilli, M.D. (2012). (Ed.) Interactieve Learning for Innovation: A Key Driver within Clusters and Innovation Systems. Hampshire:Palgrave Macmillan.

Bosman, R., Avelino, F., Jhagroe, S, Loorbach, D., Diercks, G., Verschuur, G. and van der Heijden, J. (2013). Energielente op komst? De (on)macht van bottom-up en top-down in de energietransitie. Dutch Research Institute For Transitions, Erasmus University Rotterdam. E 2013.02.

Carbonara, N. Giannoccaro, I and McKlevey, B. (2010). Making Geographical Clusters More Successful: Complexity-Based Approaches. E:CO, 12(3), 21-45.

Cherp, A., Jewell. J. and Goldthau, A. (2011). Governing Global Energy: Systems, Transitions, Complexity. Global Policy. Vol. 2(1): 75-88.

Energieonderzoek Centrum Nederland. (2014). Nationale Energieverkenning 2014. Petten. www.ecn.nl/energieverkenning. Retrieved: 10 October 2014.

Energy Valley. (2010). Background Study Hansa Energy Corridor. Archive Material from Energy Valley.

European Forum for Clusters in Emerging Industries (EFCEI). (2013). Policy Roadmap - Actions for new linkages needed: A policy roadmap for stimulating emerging industries. http://www.emergingindustries.eu/Upload/CMS/Docs/Policy_roadmap.pdf .

European Policy Brief. (2010). Innovation Futures in Europe: A Foresight Exercise on Emerging Patterns of Innovation, Visions, Scenarios and Implications for Policy and Practice. DG Research, INFU Newsletter, October.

Jones, H. (2011). Taking resposibility for complexity: How implementation can achieve results in the face of complex problems. Overseas Development Institute, Working Paper 330.

Kaloudis, A. and Pedersen, T. E. (2008). (Ed.) Sectoral Innovation Systems in Europe: Monitoring, Analysing Trends and Identifying Challenges: The Energy Sector – Final report. Olso: TIFU.

Lorentzen, A. (2008). The Scales of Innovation Spaces. In Querejeta, M. J. A., Landart, C. I. and Wilson, J. R. (eds.) Networks, Governance and Economic Development: Bridging Disciplinary Frontiers. Cheltenham: Edward Elgar Publishing, p. 40 – 56.

Mans, P., Alkemade, F., Valk, van der, T. and Hekkert, M.P. (2008). Is cluster policy useful for the energy sector? Assessing self-declared hydrogen clusters in the Netherlands. Energy Policy, 36 (2008) 1375–1385.

Martin, R. and Sunley, P. (2007). Complexity Thinking and Evolutionary Economic Geography, Papers in Evolutionary Economic Geography, Utrecht University, 07.03

Mischen, P.A. and Jackson, S.K. (2008). Connecting the dots: Applying complexity theory, knowledge management and social network analysis to policy implementation. Public Administration Quarterly, 32(3): 314-338.

Rijksdienst voor Ondernemend Nederland. (2014). Rapportage Hernieuwbaar energie 2003-2013. www.rvo.nl. Retrieved: 22 September 2014.

Science Business Report. (2012). The Energy Technology Road Map: How to Plan Europe's Energy Future. Science Business Publishing, retrieved from **www.sciencebusiness.net**

Viitanen, J., Markkula, M. & Soler, C. R. (est. 2012). Systemic Development of Regional Innovation Ecosystems: Modernizing the Triple-Helix. Academic.edu: https://www.academia.edu/3984588/Systemic_Development_of_Regional_Innovation_Ecosystems_Modernizing_the_Triple_Helix. Retrieved: 9 July 2013.

**Documents on The Netherlands, Northern Netherlands and Energy Valley cluster**

De Plus van Noord-Nederland: Roadmap samenwerking noordelijke clusters, versie 1.3 (2013).

Energieakkoord Noord-Nederland (2007)

Energiemonitor Noord-Nederland 3e editie (2014)

Green Deal (2011). http://www.energyvalley.nl/uploads/bestanden/e32eb386-aee4-476c-be76-60414b3fd5e8

Nationale Energieverkenning 2014, Energieonderzoek Centrum Nederland, Petten 2014

OECD Reviews of Innovation Policy: Netherlands 2014, OECD Publishing. http://asset.keepeek-cache.com/medias/domain21/_pdf/media1796/281693-wl5ayagv99/large/0.jpg

Position Paper: The Northern Netherlands and the EU 2020. SSN (2011)

Rapport: Aardgasbeleid in Nederland: actuele ontwikkelingen. Rijksoverheid (2014)

Rapport Eindadvies van de Commissie Duurzame Toekomst Noord-Oost Groningen: Vertrouwen in een duurzame toekomst (2013)

Research and Innovation Performance in Netherlands, Country Profile 2013 European Union (2013)

Research and Innovation Strategy for Smart Specialization RIS3 Northern Netherlands. SSN (2013)

Strategische agenda voor Noord-Nederland 2007-2013. SSN (2005)

Summary Report of Energy Agreement for Sustainable Growth (Energieakkoord voor duurzame groei, 06-09-2013) SER (2013)

Switch: Noordelijke Energie Agenda (2014). Bestuurlijk Overleg Noord-Nederland en Stitching Energy Valley

Topsector Energie website: http://topsectorenergie.nl

Werkprogramma's, documenten en rapporten van Stichting Energy Valley

# 11. CLUSTERS AND HOW TO MAKE IT WORK: *CLUSTER STRATEGY TOOLKIT* – POLICY BRIEF

*By Anu Manickam and Karel van Berkel*

Chapter from *Opening Up Project Report* on Karlstad's Paper Province

Clusters as the magic answer to regional economic development; firms in clusters have been proven to be more innovative; cluster policy dominates EU policy; 'top-sectors' and excellence are the choice of national policy makers; clusters are 'in'. However, clusters are complex, 'messy' and there seems to be no clear logic about how clusters grow and thrive in practice. There are many theories and models but creating successful clusters remain a challenge. Everybody, policy makers, academics, urban planners, regional development agents, cluster organizations, businesses and industry, all have their own ideas and solutions about how clusters need to be developed. Some seek collaborations and networks as ideal ways to innovate, others seek answers in value chain approaches, others in research and development and often in the triple-helix collaboration model, and yet others in econometric benchmarks; consultants seem to offer a 'one size fits all' solution that cannot work. Silicon Valley's success cannot be replicated elsewhere and this lesson has become painfully clear to many policy makers. This paper elaborates on an approach that takes into account the need for closer scrutiny of local settings of clusters in developing more customized strategies.

Clusters are diverse, complex and unpredictable. They each have a history and a cultural context that determine their development. There is need for more integrated approaches that explores different facets of clusters in their development. The cluster strategy toolkit supports strategy development from a deeper understanding of principles and patterns in cluster dynamics. The cluster strategy toolkit was developed as part of a larger research project. This policy brief is an adaptation of the findings of the research and captures the ingredients of the toolkit. The case of Karlstad in the Region Värmland, Sweden has been included in this policy to illustrate how the toolkit works and what policy inputs can be gained by such an approach.

**Part 1: CLUSTER ANALYSIS - ELEMENTS OF THE TOOLKIT**

The first part of the policy brief explains the Cluster Strategy Toolkit by describing the eleven elements of the toolkit. Information gained from these eleven aspects would provide insights relevant to mapping cluster (and regional) developments. Each element of the toolkit has been explained and where possible questions have been identified that could be raised during cluster analysis initiatives.

**a. Recognizing complexity and 'wicked problems'**

Policy makers have since the global financial crisis recognized that they are increasingly faced with challenges that are complex and systemic in nature. These challenges are often multi-facetted and have different dimensions and can be found in different spaces and places in the system. These problems are often connected to other problems and they are 'wicked'. The term 'wicked problems' has been used to describe problems that are complex and unpredictable and the following features characterize them:

Problem definition: there is no agreement about the problem as multiple stakeholders with conflicting values and interests are involved and they all have their own versions.
Solutions: No right or wrong answers, only better or worse solutions

- No test of success: No obvious test of a solution is available for wicked problems
- No end stop: the problems always continue and therefore is never resolved
- No repetition possible: wicked problems are unique
- 'One-shot' operation: each solution alters the problem, not solve it. Solutions create new problems.
- Multiple pathways: There are many ways to 'explain' the problem, and each explanation determines possible resolution
- No clear-cut solutions palette: unclear directions for seeking solutions with unpredictable outcomes of solutions
- Wicked problems are often symptoms of other wicked problems (systems of problems)
- No turning back

Identifying complex and urgent issues in the cluster is necessary and often the presence of wicked problems needs to be identified and understood. Information and perceptions of stakeholders on these major challenges in the cluster is necessary. There would be a greater need to seek solutions based on collective processes and judgements in order to deal with such wicked problems. It is important to realize that for the class of challenges identified as wicked problems, there are no expert answers, that each wicked problem is unique, and that high levels of uncertainty of outcomes needs to be appreciated. Cluster developments often encompass complexity that fringe on 'wickedness' as there are multiple stakeholders and views on strategy development. Mapping the views of stakeholders and their definitions of challenges and directions for the cluster is an important part of the analysis.

**b. Understanding current economic landscape in the region**

There economic landscape of the region and the cluster form an important part of the context of the cluster. The way businesses, industry, university and municipalities are connected to each other need to be mapped. Below are some questions that need to be part of the mapping exercise.

- How are value chains linked? Is this limited to the region, or is it connected to the 'outside' as part of global value chains?
- What horizontal and vertical linkages are present? Are sectoral structures dominant?
- Is there a dominance of large industries?
- Are there specific sectors dominating the region?
- How homogenous is the area?
- How is research and innovation linked to businesses? How are the triple-helix connected?
- What public policy support and funding incentives exist for economic development?

This part of the analysis needs to map the current landscape of the cluster and its region.

**c. Understanding factors affecting development of the region – drivers of change**

The next aspect of the analysis is mapping the landscape of the region and the clusters to understand how they are changing. Mapping the drivers of change, such as shifting geo-political powers and markets, EU internal market and policy directives, national and EU laws and regulations, digitalization of commercial and industrial processes, social network developments, etc. need to be understood. Drivers of change that specifically affect local, regional and cluster developments need to be identified. Key stakeholders and experts are good sources of information on the drivers of change.

**d. Understanding past developments – history, geography and culture**

Identifying key elements that shaped how the region to be what it is in the current situation is important. Understanding the history, geography, demographics of the region and critical events in the past would help understand issues about future developments. The local context of the cluster needs to be mapped. Questions on critical historical and geographical factors are asked. Cultural traits and other factors for the current situation are mapped in this part of the analysis.

**e. Understanding how regions expect to deal with the changes and where the gaps are – changing competences for changing landscapes**

Changes in the context of clusters and regions and how they perceive and react to these changes need to be analysed; levels of alertness to external changes and its impact on the region are important. Identifying the need for new competences and gaps in current competences and knowledge in the region need to be mapped to help become 'future-proof'. Questions aimed at identifying competences, research and resources for future development need to be posed.

**f. Identifying the reference framework of the region/cluster – scope, identity and rules**

Definition and identity of the region and cluster are important reference frameworks that need to be verified. There may be a policy definition of a cluster but stakeholders in the cluster may have differing definitions and weightage given to the role and boundaries of the cluster. The firms in a cluster may be operating from their company perspective rather than a cluster perspective. There may be different and even conflicting expectations from the different stakeholders on the role of cluster organization, policy guidelines and interventions, etc.

Definitions and identities ascribed to a region/cluster are often unspoken and may have an impact on the development, particularly, if they are divergent. Issues need to be mapped from the different stakeholders' perceptions:

- What is important to them and what are their priorities?
- Where are the boundaries of their 'business' and that of the cluster?
- How do individual stakeholders react to local changes?
- Is their focus international?
- Who is in the cluster and how is power distributed in the cluster?
- How does policy influence cluster development?
- What is expected of policy?

**g. Understanding the players and how they perceive, connect and act – stakeholders**

The way stakeholders interact and communicate in the region or cluster is relevant to understanding how the cluster will develop. Types of collaborations, perceptions on competition and collaboration, factual information on the interaction patterns can help map where innovation is being sought and where potential new clusters can be found. Consolidation of businesses (merges and acquisition) and equity flows in cross-sectoral collaborations are often indicative of new cluster development (PwC, 2012). Questions on linkages and collaborations amongst cluster members and other entities in the region are important to map.

**h. Understanding competitive advantage of the clusters - differences that count**

Recognizing the need for diversity in clusters in terms of thinking, knowledge, organizing, the degree of openness to new ideas, etc. need to be mapped to understand where complementarity and new innovation could be generated. Distinctive advantages and differences in the region and in clusters are important opportunities for innovation and growth. Information related to core competences and distinctive advantages and to inherent differences need to be explored.

**i. Understanding changes the interactions are bringing to the region – collaborations and interactions**

Exploring patterns of interaction in the cluster/region by asking about how often stakeholders meet, about who is taking part in collective strategy development, and if there is an increase in the number of meetings, and whether there are changes in the quality of such meetings, for example from informal networking to more focussed themes and strategy related sessions, etc. The outcomes from the meetings could indicate the transformations that are taking place between those involved and possibly the diffusion of knowledge and ideas beyond the meetings. Interactions in collaboration projects where new knowledge and businesses often result in innovation and these needed to be mapped. Specific examples of the nature and types of interactions and collaborations would give insights into changing interaction patterns. Outputs that reflect transformations need to be mapped to see the shifts in the cluster developments.

**j. Understanding new patterns that are emerging – emerging ideas and structures**

Changes in how stakeholders are interacting and the way business is done, who new players in the field are, new rules dominating economic participation and measures of success, new routines being established in business and innovation, are all indicators of emergent cluster development. Understanding these emergent patterns can help understand the direction and opportunities arising in clusters and their regions.

**k. Understanding where changes are coming, whether they are centrally steered, or, bottom-up initiatives – self-organizing processes**

Exploring and mapping emergent local initiatives and the role of centralized steering through policy would help understand the dynamics of self-organization and the supporting role policy may be playing in shaping current cluster developments. The space for local initiatives in policy and the need for self-organization may be important to understand in cluster developments as they are often neglected in strategy development where only leading players participate in strategy and policy developments. The policy could fill gaps to facilitate cluster interactions and collaborations, to create conducive business environments, and to facilitate knowledge and skills development. Mapping current roles and impact of policy could help understand what is needed in the next steps.

Below is an overview of the cluster strategy toolkit and the eleven aspects that have been described in the first part of the policy brief.


In order to understand how the toolkit can be applied in cluster analysis, the case of Karlstad has been used to illustrate this in the next section.

**Part 2: CLUSTER STRATEGY TOOLKIT APPLIED TO KARLSTAD REGION**

**Introduction to Karlstad and its changing context**
The county of Värmland has a population of 273, 000 people covering 17, 586 square kilometers. There are 16 municipalities and Karlstad is the biggest town with 85, 000 inhabitants. Värmland is situated in the Northern central part of Sweden bordering Norway. The region is also characterized by water (10, 512 lakes) including Lake Vänern in the south that is the largest inland lake in Western Europe. There were four clusters, The Paper Province, The Packaging Arena, Steel and Engineering and Compare (IT). The Paper Province is the oldest of these clusters and this dates back to the paper and pulp industry that was established in the 17th Century in Karlstad, Värmland region.

Stakeholders described recent changes in the context of Karlstad and Region Värmland that posed new challenges for the region. Highlights of these changes and challenges were:

- Changes in global markets in the paper and pulp industry, leading position threatened?
- Caretaker role of paper and pulp industry in the region changing - patterns of patronage in the past still lingering
- Rural-urban migration and brain drain issues
- Expanding urban hubs, Stockholm, Guttenberg and Oslo, with Karlstad in the middle - threat of absorption or redundancy
- Shortage of technical personnel due to urban pull and lack of interest in technical careers
- Sustainability agenda due to climate change and environmental pressures

- Consumer demands for ‘green’ products

**Analysis based on Cluster Strategy Toolkit**
The following description of developments in the Karlstad region and its clusters were based on interviews with key stakeholders and experts related to The Paper Province cluster. Although the case study was limited in its scope, different aspects of cluster and regional developments were identified and have been analysed and implications for policy have been identified. The purpose of the case description was to illustrate the use and value of the Cluster Strategy Toolkit. A more extensive study could provide more details and insights into changes in cluster developments regarding its definition, interaction and directions and that of the Karlstad region.

**a. Recognizing complexity and ‘wicked problems’**
The town and the region needed to deal with challenges of changing economic conditions and perspectives. There were many stakeholders: the paper and pulp industry, businesses in general, cluster organizations, local municipality policy makers, Region Värmland policy makers, local, regional and national politicians, university and research institutes, businesses, citizens, and technology institutes.
Stakeholders had their own views, interests, perspectives, and ideas about what the core issues were, how they needed to be solved, and what priorities were needed. To illustrate,

- The national government and ministry of education focused on prominent (academic) universities and allocated funds for fundamental research and development to support innovation and to develop national competitive advantages. Industry had a more urgent need for applied research but funds for applied research were limited and had less priority in national policy.
- The local Karlstad business sector were not happy with the education system and opened their own ‘technology centre’ to train young people to meet the specific labour needs of their industries.
- Local city council was seeking answers by demanding more efficiency and collaborations amongst the four cluster organizations.
- The paper and pulp industry were concerned about global market changes but it was ‘business as usual’ according to local experts.
- National and local governments did not seem to recognize the need to ‘save’ the paper mills for their innovation value – a lot of spin-offs were generated from the mills according to the cluster organization.
- There were complaints about the mill from local residents even though they were dependent on the paper and pulp industry but seemed not to appreciate its value to the community and its history.
- Spin-offs from the paper and pulp industry resulted in new clusters in the past, namely, Steel and Engineering cluster, Compare, an IT and telecom cluster, and The Packaging Arena cluster. These clusters were born out of the needs of the paper mills, knowledge and opportunities created as a result of the mills’ activities.

**b. Understanding current economic landscapes in the region**

- The tradition of the regions was one of small municipalities where one big plant dominated and many Small and Medium-sized Enterprises arose to serve the main plant.
- Paper and Pulp Industry was dominant in the Region Värmland and having an important position in the community. There were 3 other clusters besides The Paper Province, namely Compare (IT and telecom cluster), Steel and Engineering cluster, and Packaging Arena.

- Clusters were relatively independent and had a ‘comfortable position’. They had achieved success in the past and seemed to be complacent in their success according to the municipality.
- Bigger companies tended to use their own R&D facilities but were slowly changing and were collaborating more often with the local university.
- Karlstad University’s Service research centre (CTF) was one of the leading research centres in service innovation globally. Regional companies were not aware of the potential value of the research centre for them.
- Municipality and Regional development agencies funded and steered cluster development.
- There was no national and governmental level policy on clusters, only at the regional level at the time of the research.

**c. Understanding factors affecting development of the region – drivers of change**

- Internal drivers of change
    - Businesses sought growth and innovation in products and areas adjacent to their own core business.
    - The demands of the local municipality of Karlstad for more collaboration amongst cluster organizations to improve efficiency and reduce duplication.
    - The need for SME to collaborate to vie for complex tenders and projects.
- External drivers of change
    - Pressure of the urban cities of Oslo, Gothenburg and Stockholm were expanding around Karlstad and this created an urgency for Karlstad to survive and to be independent rather than become a satellite town of one of the other cities.
    - National funding and attention were also more focussed on the bigger cities.
    - EU policy was providing funding and stimulating local regional developments and clusters. The Paper Province was named a ‘world-class cluster’ by the European Cluster Observatory.
    - EU policy was pushing for ‘bigger, multi-sectoral, high-tech, excellent clusters’ that breaks down barriers between segments and sectors.
    - Environmental regulations related to sustainable forest resources, and pollution measures for both air and water contamination
    - Competition from Brazil and other up-coming markets
    - Technology innovations had led to spin-offs that became relevant for other industries. The scope of the clusters, Compare and Steel and Engineering, became larger serving not only the paper and pulp industry.

**d. Understanding development of the region – history, geography and culture**

Karlstad is a Swedish, provincial town, and the region had been dominated by its paper and pulp industry for more than three centuries. Small communities in the region were usually dominated with one main industrial player. For Region Värmland, it was the paper mills. The presence of the river and the lake enabled logging and transport of timber to paper mills, and they, in turn, had sufficient water to process the wood. Transportation of finished products was also served by shipping. Water and forests were important natural resources of the area. Skilled labour and technological innovation and service from ICT, engineering and machinery companies were also important to the growth of the industries and the region. However, the paper and pulp industry was huge, dominant, and in some ways, slow to change as it was a big investment industry (similar to many traditional industries in the world). The paper and pulp industry, and the steel and engineering clusters were heavy industry that was male-dominated. The mills tended to ‘take care of the region’ and citizens often responded to this by letting them dominate the region and to take care of them according to a cluster manager. Also, the communities in the region (as is in rural Sweden elsewhere) were often small and had a history of 'trust' and collaborations. Another historical and cultural value of Sweden was that of equality that affected policy and funding decisions as well as local collaboration patterns.

**e. Understanding how regions expect to deal with the changes and where the gaps are – changing competences for changing landscapes**

The region had grown by adapting to growing markets and offering specialized paper products through the help of technology, specialized machinery and skilled labour. The mills also consolidated over the years such that the 400 mills had been reduced to a few large mills that dominated the landscape of Karlstad region. The town and regions surrounding were dependent on the paper mills and their related industries. The wave of consolidation allowed economies of scales, efficiency and specialization.

Environmental demands by EU and national policy and in recent times by consumers meant that the industry had to meet these demands through new innovations. The industry had to change to meet market and environmental pressures to be competitive and viable. The region as a community served the industry and it grew with the industry. It was a locally driven development that had to change to meet new demands from outside. More recent developments in emerging economies had put pressure on the paper and pulp industry. Mills in Brazil, for example, were becoming competitors for the Swedish mills, also in Karlstad.

Some of the points raised by the interviewees related to the changes and the ability to change are highlighted below. Mills had a high technical knowledge component and a lot of innovation were generated by the mills although often in very specialized, narrow areas and were not 'spilling over' to the outside nor were these expertise used to create new businesses. Old industries, including the paper and pulp industry, suffer from inertia, which meant that they do not want to change, they keep existing rules, use current business models as a result of being traditionally self-sufficient and self-contained. The paper and pulp industry was the whole value chain.

- The self-contained culture was not helping them to think differently nor to use their knowledge and competences beyond their own borders.
- The demand to be clean and green required new competences and these needed to be developed and they needed to come from outside.
- New businesses and business models needed to come from the borders and through cross-sector collaborations. Examples mentioned were bio-medicine and waste deemed as a resource and with potential value.
- By joining other sectors to search for new products and industry, they could broaden existing knowledge to create new industry and businesses
- Creative people were needed, as the region was strong in engineering and a new cluster related to packaging offered opportunities to broaden existing competences.

The industry and the region needed to get new innovation, business models and new competences and these needed to be sought at or across borders, or, from outside the industry.

**f. Identifying the reference frameworks of the region/cluster – scope, identity and rules**

The cluster in Karlstad was an established cluster of more than 13 years. There cluster organization served 90 organizations that were its members. The municipality of Karlstad funded this and other clusters. The recent developments in Karlstad involved funding rules aimed to increase efficiency of all clusters by reducing duplication of administrative and other aspects of cluster management by enforced collaborations. The cluster organizations needed to collaborate closely and their scope of activities would be influenced through these changes in funding structures. Cluster members were also demanding more value for their money, and were expecting more accountability from the cluster organization. New demands were being made of the cluster organizations.

Next level collaboration was demanded of the cluster organizations by the municipality but there were no precedence of this. The demand was more inter-cluster collaborations and sharing of resources, and efficiency through collective promotion. The municipality talked of 'deeper' collaborations but there were no clear insights about what this meant.

The role of cluster organizations, their degree of autonomy and performance in a more demand-driven context could change their scope, role and identity. The degree of collective and co-design possibility space and efforts would determine the new reference framework for cluster organizations and clusters.

The clusters were being pushed to expand their scope to a higher level of collaboration at the cluster level by local and regional government agencies but also due to EU policies supporting competitive cluster development through programmes that support cluster excellence initiatives, internationalization and inter-cluster collaborations, and professionalization of clusters. There was a shift in demands of clusters to extend their activities and scope to include intra-cluster and inter-cluster initiatives and collaborations.

**g. Understanding the players and how they perceive, connect and act – stakeholders**

Stakeholders in the Paper Province were the businesses in the cluster, the cluster organization, the local municipality, the university, the regional government,
New stakeholders were spin-off companies from the main business, for example in biomedicines from forests.

Different stakeholders had different interests: the big industry players focussed on keeping the mills running and being competitive and were focussed on international developments from competitors and needed global scale for their operations. The competitiveness drive resulted in highly specialized engineering and machinery innovations, knowledge and spin-offs. A separate engineering and machinery cluster was the result. The automation of the paper mills had also resulted in a highly innovative ICT service industry that was the second spin-off organized in a cluster. The Mills had to comply with environmental regulations when the lake was polluted and this created innovations and spin-offs that have added to the quality of life of the region and strengthened the traditional ties between the industry and the community.

The paper and pulp industry have had the role of 'care taker' for the local communities as their lives and livelihood were woven with the mills. The mills and the communities seem to live this role even though a lot was changing, and there were concerns about the local communities being too 'complacent' and not taking ownership of their own future.

The trust level in this region, the clusters and the community was high as reflected in the relations of 'care taker', interdependent and spin-off economic activities. This trust comes from the close community and culture of the region. All stakeholders recognized this.

The dependence and dominance of the paper and pulp industry extended to business communities, and clusters that emerged from the original paper and pulp industry.

However, emerging developments of Small and Medium-sized Enterprises and the newer clusters looking beyond their own regions increasingly.

Triple-helix stakeholders (policy, business and research) were essential to cluster developments and were present in the cluster and collaborations strengthened linkages and interactions in the clusters.

**h. Understanding competitive advantage of the clusters - differences that count**

The existence of new and old clusters in the region offered opportunities for new collaborations. The city municipality intended to use funding rules to demand more cross-cluster collaborations and to move such collaborations to the next level.

The cluster also had top-level research done at the local university. There were limited collaborations between the university and local companies and between the university and the cluster organizations at that time.

Industry and businesses in the area needed technically skilled personal that were aligned to their needs. Schools were not producing students with these skills. Business needs pushed joint collaboration to set-up a technical education centre where expertise from businesses was brought into the classroom. Young students participated in the training programme because of the job prospects after the training. Schools were benefitting by getting new machinery and technology and improved education programmes.

Consumer demands for more sustainable and ecological sound products offered a new spin-off in forestry-based research and expertise to create a new business base, eco and bio based health products. Paper mills had traditionally generated innovation in processes and products that had value outside the paper and pulp industry. This potential is one of the main pleas for maintaining the remaining mills.

**i. Understanding changes that interactions are bringing to the region – collaborations and interactions**

The high level of trust existing in the region and the collective history of the different clusters coming from The Paper Province reflected close proximity and interactions. The need to collaborate to compete in complex project bids was mentioned as indicators of the flexible collaboration patterns and interactions in the region. Application of innovation spin-off from the paper and pulp industry to other sectors by the other supporting clusters was changing the scope and identity of these clusters. Seeking new business opportunities resulted in the creation of bio-medicines as a cross-sectoral initiative. There were also other initiatives emerging that intended to preserve the forests through more sustainable practices and this needed collaborations beyond the paper and pulp industry and the existing clusters.

**j. Understanding the new patterns that are emerging – *emerging ideas and structures***

Karlstad's clusters are pushed to work together to create 'excellence' through collaborations by EU cluster policy and that of the local municipality. No one knew what this would entail but the willingness to explore new collaborations seemed to be present. Regional and local policy and the Swedish Innovation agency were constantly offering incentives and directions for further collaborations. A new programme to create new areas of excellence emerged after mapping local research competences and local business expertise. The regional agency, Swedish innovation agency and the local municipality were involved in seeking opportunities to create new future economic growth. The result was the creation of a long-term commitment to support 10 new professorships in new knowledge and innovation developments based on the competences mapping of the region. Policy interventions and support push to new developments seemed to be a new pattern in this region.

**k. Understanding where the changes are coming from centrally steered or are they bottom-up initiatives – *self-organizing processes***

Karlstad's funding rules of the city municipality was an example of policy driven change in cluster development. The changing demands of firms for more 'value for money' from the cluster organization and the green consumer demands were examples of bottom-up developments that pushed cluster organizations to re-think their roles. The cluster organizations needed to step up to challenges posed by businesses, local, regional and EU policies and ambitions.

**Conclusions**

The paper and pulp industry's history and economic developments that had dominated the region would continue to impact future developments of the region. Strong local linkages, interactions and collaboration patterns were part of the social and economic landscapes. Although there were shifts in the way Karlstad and the region were developing, in order to deal with the changes in its context and the new challenges, Karlstad may need to re-consider its strategy for its future. Below are some conclusions and recommendations to this end.

**1. New paradigms for the region**

Karlstad's need to shift policy away from salvaging the paper and pulp industry as the main economic activity towards supporting more diverse regional development was acknowledged, but there were feedback loops and processes in the current situation that could hinder broader regional development focus:

a) Lock-in effect of existing economic, technological and social processes and infrastructures – e.g. vested interests and complacency of dominant industry and dependence role of citizens and policy
b) Lack of coherence and lack of consolidation of knowledge and market development efforts needed to be addressed – e.g. fragmentation of clusters and businesses trapped in own networks and value chains, fragmentation of university R&D and that of business and industry,
c) Lack of alignment in local, regional, national and European developments – e.g. diverse interests and focus of local, regional and national levels of policy contributing to dispersed efforts, duplication and inefficiency,
d) Silo thinking – e.g. cluster organizations served own members rather than focussed on larger regional development, universities focused on patents and publications instead of needs of industry & businesses, businesses focused on own innovation and profits instead of collaborative projects, etc.

**2. New economic principles**

Karlstad's shift from a industrial to cluster landscape had been successful in many ways but the dominance of the paper and pulp industry on the region meant that the sectoral approach had its impact in how the region was developing. A more explicit focus on new economic principles as organizing strategy could help break the lock-in effect of the paper and pulp industry's dominance.

a) Innovation as a driver of economic growth through new technology, products and services as reflected in the newly established professors.
b) Thinking in value chains beyond the paper and pulp industry. Creating new value chains (see next point).
c) Interdisciplinary and inter-sectoral collaborations and thinking. Examples were the bio-medicine and sustainable forestry initiatives.
d) Network and inter-cluster collaboration with more emphasis on triple-helix linkages. New collaborations between clusters were initiated, but these could extend to beyond the region and country as purported by the EU's cluster policy.
e) Local-global strategies for the region, as opposed to individual businesses and clusters.

Karlstad had embraced new economic structures but could enhance such efforts to realize the proposed diversified regional base. A different way of thinking about the region's future economic opportunities through its definition of its scope, borders and identity could offer new directions when guided by new economic principles that seek to unify fragmentation and mass where needed, and to break homogeneity where diversity is lacking.

**3. New attitudes**

Karlstad needed to cast off its dependence on the paper and pulp industries and its provincial town status to avoid being subsumed by the metropolitan spread of the three main cities surrounding it. The Karlstad region needed to join forces to create new value chains and collaborations to rise to its challenge of re-defining itself to overcome redundancy and economic malaise should the paper and pulp industry fail in a global competitive market. The presence of business that served the paper and pulp industry needed to take ownership of their future and to seek collective solutions through collaborations.

a) Networks and collaborations as essential for new business
b) Regional scope needs to be replaced by local-global scopes
c) Ownership of the region by all stakeholders instead of reliance on the dominant industry

**4. Different roles and behaviours**

Ownership and creation of new business and economic growth by the region's stakeholders meant that new and different roles and behaviours were needed. The need to collaborate more than in the past and the need for policy to take leadership and provide incentives in different ways needed to be established.

a) Facilitating and orchestrating role of policy that included raising awareness, offering incentives and creating new opportunities for new and different types of collaborations amongst stakeholders.
b) Collaboration instead of competition needs to be the main business mode instead of incidentally as in the past for complex projects. The realization that collaboration to create mass, to share risks and to create different and new opportunities to launch into new markets globally needs to be shared.
c) Test beds, pilots and new initiatives that would allow for collaborative learning and (open) innovation needed to be facilitated and become mainstream to accelerate new value adding and value chains. The creation of ecosystems of innovation that builds on latent trust in the region would enhance innovation capacities.

The Karlstad region has been described and the analysis offered insights into the interaction and patterns of developments in the cluster and region. The insights reflected underlying processes and systemic aspects of its developments. These, in turn, reflected the need for changes in the underlying structure and processes in the region.

## PART 3: IMPLICATIONS AND APPLICATION OF CLUSTER STRATEGY TOOLKIT

### The value of the Cluster Strategy Toolkit

1. **Description of real complexity**
The analysis does not only describe the wood and pulp industry or only the regional development, but it includes the historical perspective, the forces at work from within and without the system, the roles of stakeholders, the (missing) competencies in the cluster, the opportunities that arise from thinking about inside and outside of clusters, visions, goals, plans, actions, collaborations, etc.

2. **Sense-making**
The systems alignment mapping, that includes mapping processes and patterns such as influence of history on current developments, dynamics between stakeholders, the way the container is used (enlarging or contracting the container could lead to different connections and strategies), the role of government and other stakeholders, etc. offer deeper insights of the system interactions and developments.

3. **Capturing cluster development**
The analysis captures how clusters develop, how perceptions evolve and influence emerging interactions and collaborations within and outside the cluster, how new stakeholders are engaged, how new strategies are developed, how new competencies and networks are created and how these lead to new actions and performance that in turn, influences thinking about the future (strategies).

4. **Successful ecosystems**
The cluster as an ecosystem is implicit in the model that makes explicit the successful and less successful developments in the system and thereby offering opportunities for learning about ingredients in successful collaborations, stakeholder involvements and the impact of such interactions, about competences and infrastructures contributing to new successes, and about distinguishing fertile and less fertile ecosystems. The case study offered insights into Karlstad as an ecosystem that encompassed The Paper Province as a cluster within a larger regional system that included other clusters, local and regional policy agencies, competences, knowledge developments, new opportunities and spin offs from within and outside the cluster, etc. Potential growth opportunities in Karlstad need to be further investigated by exploring the system's patterns of development in more detail.

5. **New insights leading to new research agenda**
The model has been applied to a limited number of clusters to uncover cluster developments and emergent patterns. Further investigation and application to new cluster studies would support refinement and use of the model to map and create growth strategies for context-specific developments.

***References***
*Battie, S.S. (2008). Wicked Problems and Applied Economics. American Journal of Agricultural Economics, 90(5), 1176-1191.*

*OECD Global Science Forum (2009). Applications of Complexity Science for Public Policy: New Tools for Finding Unanticipated Consequences and Unrealised Opportunities. http://www.oecd.org/science/sci-tech/43891980.pdf*

*PwC Report (2012). "Emerging industries": report on the methodology for their classification and on the most active, significant and relevant new emerging industrial sectors. Version 1.3.* *http://www.clusterobservatory.eu/system/modules/com.gridnine.opencms.modules.eco/providers/getpdf.jsp?uid=b20af4e5-581d-4462-a3eb-d178e4754011*

*Ritchey, T. (2013). Wicked Problems: Modelling Social Messes with Morphological Analysis.* *http://www.swemorph.com/wp.html*

*Rittel, H. & Weber, M. (1973). Dilemmas in a General Theory of Planning. Policy Studies, 4: 155-169.*

*Websites on Värmland and Karlstad clusters:*
*http://www.varmland.se/sites/default/files/kcfinder/files/Made_in_Sweden_webb.pdf*
*http://www.varmland.se/en/about-varmland/brand-varmland*

# 12. SILICON VALLEY CASE STUDY – ANALYSIS NOTES

The Silicon Valley case was based on the article of Etzkowitz (2012). The analysis notes based on the CAS framework is provided below.

**Silicon Valley – notes**
Etzkowitz analysed origin and development of Silicon Valley based on a 5-phase model of development: origin, aggregation, expansion, efflorescence and renewal. The contention is that the design principles of Innovation Regions were known but not the ingredients that made Silicon Valley successful.

The key factors were *'indigenous academic entrepreneurship and government-supported R&D, as well as importation and reinterpretation of ecosystem elements like the venture capital firm'*. (p. 2)

Comparison to MIT and other cluster developments were also part of the analysis. MIT was an incubator of new firms originally focussed on bringing R&D to the then present manufacturing industries and the triple-helix model (1930s, post-war periods), the knowledge-based regional development model.

Stanford had a strategy of knowledge based economic and social development where the university-industry; university-government linkages later become *triple helix linkages*.

Stanford as *entrepreneurial university* focussed on firm formation based on academic knowledge.

**Paradigms**
*Innovative Region* - cluster was part of the I.R.
*Entrepreneurial university - spinning off industry and firms (electrical industry)*
*= Knowledge base (with spin-offs) as a source of regional development*
*University output of trained labour offers knowledge-based economic development*
*Triple-helix model*

Insight:
Problems and opportunities of local industry offers source of research questions which in turn could turn to fundamental research topics (e.g. local agriculture need to developments in genetic research).
= Entrepreneurial university motor of research (niche, possibly, fundamental R); motor of economic development
= Teaching university motor of economic development

**Path dependency paradigms**
*Distance transcendence (water, power, etc.)*
*Gold rush mentality (19 C) - unclear of impact*
*Organizing pattern of small entrepreneurial firms (mid-19 C)*
*Inventor and technical entrepreneurship culture (inventor haven)*
*Efficacy for splintering and regeneration*
*= Networked Silicon Valley - organization culture of start-ups*
*Commitment; attractiveness of Region (for inventors, small scale enterprise, like-minded techs)*
*Dense social capital - developed civil society*

*= Dense web of ties and commitment to 'collaborative pursuit of innovation' = 'spiral of innovation'*
*Individual inspiration and transfer of practice - academic entrepreneur by Terman*

**Attractors**
New corporations and older MNCs - Google, Siemens
- Draw 'start-ups into their gravitational field'
- Identify relevant technologies - hire or offer start-up offer - angel investor/vc role

= Locating in SV to draw start-ups or locating in SV to hope for acquisition by large corporations

Role of Stanford has changed in the expansion phase
- High-tech firms and entrepreneurship independently accelerate firm and innovation cluster formation
- University's role as renewal of technology (knowledge) base
- Declined state support of university is an issue - hoping that industry will support research developments

*Silicon Valley as 'entrepot-dok'* (Renewal - Phase 5, p.17)
- Shift from public expenditures of 20th C to public austerity and private excess
- Receiving point and market place for aspiring world-class entrepreneurs, technologies and business ideas
- Public money drove research, transportation and business infrastructure
- Shifting landscapes - upscale neighbourhoods, public education systems with limited resource due to conservative tax regime

= Threat of ability to regenerate itself
= Dependence on 'an self-sustaining and self-organizing processes based on 'innovation ecosystem' of law, accounting and head hunting firms, business angels and venture capitalists focussed on generating start-ups, attracting neophyte entrepreneurs to SV to gain access to their expertise' (Munroe and Westerland, 2009).

Innovation eco-system - sustained by
- University human capital production
- Government and large firm-supported research
- lack of these means demise of growth trajectory.

**Fitness to landscape** (phase 2, p.8)
*Encouraging spin-offs* as 'part of academic development strategy' - electronics technology industry (1911, 1930s)
- Linkage between science and technology
- Linkage academic department and local science-based firms
- Focus on key research areas with theoretical and practical potential
- Company visits by engineering students
- Student work that support understanding of commercial potential of electronic products and value of multidisciplinary teams
- Student flows between industry and basic research

= Support to local industry through new inventions - raised level of industry
= Common technological platform
= Dynamic interactions of industry and academia = start-up dynamics

*Research focussed strategy (later)*
- Stanford Research Institute (1946) to support industry; build research capacities by attracting government contracts

- Government contracts attracted firms - R&D and later production departments (nascent semiconductor industry, aeronautics, space)
- Federal government research funding (30% in 2010)

**Significant differences**:
- (p. 4) Distance between East and Mid-west and northern California. California had to find solutions for long distance electricity and radio wave transmissions
- (P. 5) Emergence of small entrepreneurial firms and independent inventors and Stanford University who provided a knowledge base for spinning off new industries and firms (Double Helix)
- (p. 6) Scale of government R&D resources committed to northern California
- (p.8) Social capital in Silicon Valley was based on the collaborative pursuit of innovation (not on dense social capital networks like in Italian clusters, not in pecuniary considerations, not in an individualistic risk-taking culture)
- ( p.8) Encouraging spin-offs as a key part of Stanford's strategy
- (p. 8) Interaction between firm and university created a common technological platform
- (p 10) Science park as unanticipated result of Stanford's effort to capitalize its extensive land holdings
- (10) Government procurement induced a learning curve in…. … and…., attracted firms to locate R&D and then production facilities in the region
- (p. 11) The structure of work in the academic research group with its unlimited hours… is echoed in the un-bounded hours of the start-up firm
- (p. 11) Behind innovations, there is typically an agglomeration of social, intellectual and financial capital
- (p. 12, p 16) New technological paradigms emanating from academic research (= emerging patterns), like biotechnology, networking technology, academic support strategies, etc. (= significant differences) provided the base for a firm-formation dynamic that attained critical mass
- (p. 12) Adult supervision for a new generation start-ups
- (p. 13) Collaboration between friends and colleagues
- (p. 14, 17) Formal organizational mechanisms, such as a Technology Transfer Office and a Industrial Liaison Programme, to facilitate interchange, and later, due to the recession of the 1990's, the Joint Venture Silicon Valley
- P. 15) Expansion of Silicon Valley by the partial replacement of lateral interactions by more hierarchical regimes
- (p. 18) The essential role of government, but, 'in the last phase the centripetal forces are weak' (university human capital production and government- and large firm-supported research

**Transforming interactions**

*Firm-formation process resulted in transformations*
- Technological innovations
- Triple-helix dynamics
- Start-up dynamics
- Organizational - science parks (also due to availability of land and emerging science-based firms; recognizing the value of research for firms; p.10)

*University Milieu of cooperative arrangements*
- Pre-competitive research
- Start-up dynamic of academic research project and training programmes (Hewlett/Variaan)
- Cadre of technical and managerial skills that organized successive waves of firms

- Tech innovations synthesized into new innovation (Apple - user-friendly paradigm)

= Extension of innovation from industrial processes and government projects to end-users/consumers

*'Whatever it takes' attitude*

- Hybrid of academic research focus with un-bounded hours of start-ups

= Self-management organization with goal-driven work patterns and model (research project model) - product to market goal as overriding objective - high intensity work model

*Agglomeration of 'social, intellectual and financial capitals'*
= Google as example (p.11)

*Innovative cluster development*
Start-ups (from academic or research) as interactive group, some succeeded and some separate from cluster group, become integrated MNE, return to cluster and academic base to improve product line/knowledge bases. Clusters arise, decline, revive and their technologies and firms superseded/out-dated and are acquired for product line and people (SUN).

**Emerging patterns**
*Expansion from Innovation ecosystem to 'planetary system' (Phase 3, p.12)*

- New technological paradigms - biotechnology, networking technology
- New wave and critical mass of start-ups
- Supervision by experienced entrepreneurs
- Matching activities as institutionalized activity
- Start-up culture forming 'proto firms' in existing structures and then breaking off in new firm formation
- Support structures - from friends, colleagues, research project, mentor professors, government procurement

= Facilitative eco-system and collaborative environment (Apple, Google)

Long-term perspective needed for 'highly interactive' triple helix in regional innovation clusters development

Organizational mechanisms to counter lack of firm-formation incubators in labs (conflict of interest concern)

- Technology transfer office
- Industrial liaison office

But, internal generated start-ups occur (Stanford medical school) without transfer mechanisms.

- With maturity of Silicon Valley's firms, lateral interactions were reduced.
- New collaborative formats to support culture of free exchange

= Hackathons, code camps, meet-ups
= New dynamic start-ups culture

*Efflorescent phase* (phase 4, p.16)

- Innovative clusters are crosscutting and hybridizing different technological fields at different growth stages and is unparalleled in scope elsewhere.
- Chemical fields, DNA re-engineering as new fields
- Multiple technological paradigms are in development feeding innovative clusters and the region. (Semiconductor & electronic advances microwave, biotechnology)
- Parallel developments mean both emergence and decline of technological fields.
- Venture capitalists were growing due to success of technology platforms.
- Bio-tech industry - Teerman's chemistry research advancement, PhD and faculty members collaboration, VC funded new biotech industry, government supported fundamental research/articles and firm formation, Stanford's TTO's marketing of industrial potential. (p.17)
- Threat of losing semiconductor industry to Japan in 1990s: development of JVSJ, triple helix regional organization - 'highly individualistic entrepreneurial ideology had to be overcome to pursue collective action' (Saxion, 1990 in Etz.)

= Shift of entrepreneurial region from individualistic oriented to renew inter-firm network and ties with government and academia; but 'centrifugal forces that hold the region together are still relatively weak, with little "top down" guidance, (exceptions are targeted federal Agency initiatives) (Youtie, 2010).

**Notes**:
Role of government essential; VC alone is not sufficient - clean tech example;
Government funded R&D with VC industry offer potential for new technological paradigms.

*Silicon Valley as knowledge society*

- Strong knowledge base crucial to (future) success
- Venture capital industry and triple helix governance part of economic development model
- Capacity to renew itself evident in biotechnology complex
- Attractor of international 'human, financial and intellectual capital' has downside of threat of loss of ability to regenerate itself; but there is a flow of exit and entrance of newcomers
- National representation agencies located in silicon valley to support/link home country universities and firms
- Venture capital as 'pull' factor
- Pool of managerial talent plus technical and business skills present but these are not exclusive to SV
- Other contenders
    - Bangalore but no 'Stanford' level research and training capabilities
    - San Diego and Linkoping with entrepreneurial research oriented universities contributing to knowledge based developments (sustainable high-tech growth) but limited scale (short gestation period)
    - Developing human capital focus is key element (sufficient resources is important)

*Silicon Valley risk*

- Dependent on foreign human capital and technological innovation
- 'Stickiness' of other region is threat for existing foreign human capital
- New immigrant entrepreneurs of silicon valley
    - Transnational entrepreneurs with offshoots in home country (cheap labour)

    - Possible return to country of origin if conditions improved (professional opportunities)
    - Incentives for return are emerging from countries; appeal to 'give back' to country (Taiwan)
- Development of specialized immigration law firms to facilitate inflow of foreign talent
- Neglect of developing local human resources base - upgrading and supporting local technical/high schools and graduates absent/limited

*Knowledge-based economic and social development risks*

- Supporting research as an end for itself
- Expensive buildings for high-tech firms as generative strategy
- Universities with high patents and publication records may remain as untapped potential

*Developing knowledge-based economic and social development*

- Universities to be incentivized to become entrepreneurial; or, create new ones

Creating human capital and R&D development strategies that are institutionally embedded in interacting and 'permeable' triple-helix

# 13. VALIDATING RESEARCH FINDINGS: KARLSTAD AND SILICON VALLEY CASE STUDIES

The case studies of Karlstad and Silicon Valley are described in the light of propositions on cluster developments that had emerged from the investigation on Energy Valley cluster. The propositions are presented in the table below.

| | |
|---|---|
| *P1* | *Cluster developments, connected to context and contextual changes, and driven by internal and external drivers of change, are becoming increasingly complex.* |
| *P2* | *Cluster developments are connected to their initial conditions of container, stakeholders and path dependent factors.* |
| *P3* | *Cluster dynamics are interconnected system responses to changes in its context; namely, attractors to new movements and changing stakeholder perceptions, fitness to landscape strategies to meet changing contextual challenges, using significant differences as a potential for new path creations.* |
| *P4* | *Cluster performance is visible in transforming interactions and contributes to macro level emergent systems patterns.* |
| *P5* | *Cluster developments are influenced by both top-down steering and self-organizing processes.* |
| *P6* | *Clusters are systems-in-systems connected to higher-level systems (national and EU) where parallel emerging patterns as well as tensions are present due to differences in systems at different levels.* |
| *P7* | *Clusters are embedded in related and overlapping systems interacting and influencing cluster developments.* |

The pilot study of Paper Province of Karlstad was revisited and as with Silicon Valley, the propositions were held to light. The two cases allowed more thorough exploration of Propositions 1-5 and these are described in the two cases below. The limited scope of these supplementary cases meant that Propositions 6 and 7 could only be discussed more generally and this has been done in the Discussion of the three cases in Appendix 14. Propositions are referred to as P1, P2, etc. as indicated in the table above.

## Karlstad re-visited

Paper Province, a cluster based on the paper and pulp industry in Karlstad and Region Värmland, is the first of two supplementary case studies. The Karlstad case study offered insights into cluster developments in a mature cluster, and of a different industry. The findings of the analysis served to enhance insights into cluster developments related to changing contexts, cluster conditions, cluster dynamics, cluster transformations, and organizing processes of the cluster.

In addition, the Karlstad study was also part of a European project that explored strategy for cluster developments and the document *Cluster Strategy Toolkit* has been included in Appendix 11. The 'Toolkit' policy brief and the original interviews were used in the extended analysis of this research. The underlying framework for the 'Toolkit' analysis and this research overlapped.

The following sub-sections describe the case study in the light of Propositions 1 – 5, and as such verify and, or qualify the propositions.

**Proposition 1**

*Cluster developments, connected to context and contextual changes and driven by internal and external drivers of change, are becoming increasingly complex.*

Paper Province, the paper and pulp industry of Karlstad, was faced with globalization whereby competition from Brazil and other emerging economies were changing the context of the cluster. There were however different perceptions and behaviours amongst stakeholders of these changing contexts. The dominant paper and pulp industry in Karlstad and the region acknowledged the growing threat but seemed to adopt a 'business as usual' attitude. There were other stakeholders, such as Karlstas Municipality (Karlstas is Karlstad in Swedish), regional government, university and businesses, who were concerned about these changes and were voicing the need to invest in research and development and education. The national government focussed on fundamental research and awarded large grants to prestigious academic universities that were not meeting the industry's needs. The education system was also inadequate in responding to changing contexts and the changing needs of industry. In addition, growing consumer demand for 'green' products and climate change meant new sustainability agendas needed to be addressed. The paper and pulp industry and the region needed to respond to the changing context.

Global competition and other factors saw closure of paper mills increasingly in the region. Paper Province as a cluster was doing well but there were challenges to be addressed. Different stakeholders were focussed on different needs that added to the complexity of the cluster. For example, changes in budgets meant that city council and regional government demanded efficiency by cluster organizations through closer collaborations amongst clusters; the cluster organization felt that the paper mills should be conserved for their valuable innovation spin-offs; citizens were focussed on aesthetics of their neighbourhoods even as they were dependent on the industry for jobs, etc.; 'green' and sustainable movements were demanding environmental friendly production processes; the cluster organization focussed on supporting its members but also felt that conserving the mills was important as they contributed expertise, innovations and spin-offs.

What was also evident in the Karlstad case was the presence of both internal and external drivers of change. The need for collaboration due to changes in funding policy was an example of an internal driver of change. As for external drivers of change, there was increasing need for small and medium sized businesses to collaborate to tender for complex projects, in part due to EU developments. There was also need to support Karlstad to counter the urban draw of large centres of Stockholm, Gothenburg and Oslo. There were environmental conservation pressures for more sustainable forestry practices. Globalization and increasing competition, technology developments and EU acknowledgment of Paper Province as a 'world class cluster' were all examples of external drivers of change in this cluster.

Insights from the Karlstad case offered similar insights into the relationship of clusters to their changing contexts and drivers of change. The differences in stakeholder perceptions of context and contextual changes and the interrelatedness of cluster developments to internal and external drivers of change reflected increasing complexity, as was the case in Energy Valley. The limited scope of the Karlstad case did not include explorations into differences of stakeholders due to regional differences, as was the case in Energy Valley. Nevertheless, Proposition 1 reflects Karlstad's cluster developments in relation to its contextual changes.

**Proposition 2**

*Cluster developments are connected to their initial conditions of container, stakeholders and path dependent factors.*

Paper Province, and the paper and pulp industry as a whole had a long history of a traditional caretaker's role of local communities since the 17th Century, providing jobs in Karlstad and the region. The industry had its own research and development capacities and had little need in the past for links with the local university. Past success had led to 'complacency' and the 'business as usual' attitudes as described earlier. The dominance of the paper mills in the local community and economy meant that existing structures were not challenged and fragmentation of knowledge and cluster developments resulted. This meant that the risk of lock-in was present and that inertia and resistance to change were important issues in Karlstad and Region Värmland.

Key stakeholders of clusters in Karlstad were closely connected due to the dominance and the historical and economic interconnectedness of the paper and pulp industry in the region. Initially, key stakeholders of Paper Province were the municipality, regional government, industry and supporting businesses, and the cluster organization. The municipality and the regional government were important to cluster developments in Karlstad due to a lack of national cluster policies. Local and regional governments play a significant role in cluster developments in Sweden. Lack of funding, absence of the national government interventions and weak university linkages were also important path dependent factors in cluster developments in Karlstad and region.

Paper Province's development generated new spin-off clusters but it remained closely connected to the paper and pulp industry and key stakeholders. The spin-off clusters were Steel and Engineering, Compare, an IT cluster and The Packing Arena. There was a tendency to be protective of human resource and knowledge assets between the different clusters even as they closely collaborated.

Different stakeholders had different interests and needs as discussed in the first proposition. The municipality, for example, was changing cluster containers by changing its funding policy to clusters whilst cluster members of Paper Province were also changing the container by demanding more services from its cluster organization. It was clear that changing contexts were influencing the role and expectations of the cluster organization.

Lock-in processes ('business as usual' attitudes, etc.) hampered change in the face of increasing contextual complexity, whilst the same factors of path dependency also contributed to cluster spin-offs both in the past and also at the time of the research; new developments emerging in the cluster, namely, bio-medicines developments, and is described in more detail below (P4).

The insights from the Karlstad case illustrated the significance of path dependency on cluster developments and how it also influenced its container and stakeholders. Cluster developments in Karlstad were therefore shaped by stakeholder behaviours and its impact on the container and vice versa, stakeholders were influenced by changes in the container. Proposition 2 therefore holds for the Karlstad case.

**Proposition 3**

*Cluster dynamics are interconnected system responses to changes in its context; namely, attractors to new movements and changing stakeholder perceptions, fitness to landscape strategies to meet changing contextual challenges, using significant differences as a potential for new path creations.*

There was a movement acknowledging that the closed value chain within the local paper and pulp industry was not sufficient and that there was a need to connect to 'outside' of their the own closed community. This need could be met through new collaborations to re-establish its position, gain new knowledge and efficiency, and possibly new markets, according to different stakeholders.

A movement towards sustainability was also present and this was to be achieved through resource efficiency. There was also a new understanding and recognition of the need to nurture the forest (key resource of the industry) to sustain both the environment and business. Environmentally friendly and sustainable practices were attractors in the cluster systems.

The municipality and regional governments were also seeking efficiency by coercing cluster organizations in the region to collaborate in the face of complacency, duplication of tasks, protective and isolated behaviours of individual clusters that were hampering further collaborations, inclusion and attraction of new businesses and business development. They were convinced that Karlstad needed to be competitive on existing strengths that included complete project management and production in niche markets that needed extensive collaborations. They too were concerned about optimizing scarce local resources and human capacities and the need for branding their 'specialized' knowledge and competences in the globalizing market place.

The attractors in Karlstad's cluster landscape were therefore related to the fitness to landscape strategies to meet challenges of the changing globalized context. These included competences for the future such as more technical skills and more creative people, and the need for new business models and scope of businesses. There were significant differences present in the region and amongst the clusters of Karlstad highlighted by stakeholders. Potential cross-cluster collaboration was one such strategy to leverage specialized knowledge and competences for enhanced product offers.

Research at Karlstad University offered different types of knowledge and competences compared to that of industry, and this was a significant difference that could be leveraged to enhance Karlstad's economic and cluster developments. The university had a leading service innovation research group that could support development of total business services concepts rather than individual production business models prevalent in industry. Other research centres in the region were also potential partners for businesses for new types of knowledge development.

The value of Karlstad University for local businesses and their cluster organizations, and the need for increased linkages between stakeholder groups reflect interconnectedness of fitness to landscape strategies and significant differences potential.

The interrelatedness of attractors, fitness to landscape and significant differences were clearly seen in the Karlstad case study. Changing contexts were driving changes in cluster systems responses evident in attractor movements, acknowledgements of the need for new fitness to landscape strategies that explored new collaborations in existing structures and significant differences as described in this sub-section.

The findings of Karlstad supported Proposition 3 related to cluster dynamics.

**Proposition 4**

*Cluster transformation is visible in transforming interactions and contributes to macro level emergent system patterns.*

The changing contexts of Karlstad region, including that of Paper Province and other clusters, showed shifting interaction and collaboration patterns. The Karlstas Municipality changed its role as funder to exert more influence on cluster efficiency and collaborations between the four clusters. Policy was an important driver of change and the aim was to forge more collective strategies, deepen collaborations, broaden competences, and promote more collective efforts to brand the region and its competences.

Region Värmland was involved in facilitating collaborations to boost innovation between the clusters and Karlstad University, where all stakeholders shared ownership, communication and development of the collaborations. This resulted in ten new professorships that focussed on ten niche areas identified and committed to by stakeholders from the university, clusters, Region Värmland and Karlstas Municipality. This five-year collaborative project expected research co-operations and projects to be developed that would result in a shift in collaboration patterns in Karlstad cluster and the region.

Another example of transforming interactions was the creation of the Grants and Innovation Office at Karlstad University that engaged an industry professional to foster better linkages between industry and university with the aim to acquire new research projects and funding. The university shifted to more outward looking interactions and collaborations. New projects offered researchers incentives to engage with the industry. In this way, the university intended to contribute more actively to regional innovation systems and developments. Supporting new networks with local industry was a shift in interactions and collaborations for Karlstad University and local businesses. Cluster organizations were also important in facilitating interactions between stakeholder groups.

Sustainability agendas, as a driver of change and a growing awareness of the need to nurture the forests, led to new developments that resulted in the bio-medicines business, a new emerging sector. Related to this, the 'sustainable fibre flow' concept was introduced in the paper and pulp industry to ensure that both resource efficiency and nurturing the forest, the 'double loop of sustainability', were prominent in future strategies. The 'giving back' to the forest strategy was expected to result in new service businesses to support Paper Province cluster. This new area of knowledge was not then present in the cluster and therefore connections to 'outside' stakeholders and businesses were expected to take place in the immediate future. The cluster when focussed on the 'sustainable fibre flow' strategy would bring together and accelerate existing initiatives in sustainable economies and ecologies. Spin-offs like this reinforce the added value of the mills for innovation and new emerging businesses and sectors. (Details of further developments in Paper Province are included in Appendix 11).

The industry in collaboration with Karlstas Municipality set-up a Karlstad Technology Center to ensure that skilled labour needs were met where the education system had failed to do so in Karlstad. This was an important response to changes in the context (see also Discussion of the cases, Appendix 14).

The paper and pulp industry was a traditional stronghold of men but the cluster manager was a woman. Bringing in women and new competences into Paper Province was slowly taking shape. Re-connecting the cluster to the local community and instilling pride in the mills and the industry were important steps to retain the mills in the face of external competition in the future.

Changing consumer behaviours, global competition and sustainability agendas had influenced cluster and regional developments in various ways. These included expanded scope and, or new collaborations, businesses, clusters and policy. The need to connect to 'outside' including new businesses, stakeholder groups, citizen groups, clusters and sectors was evident at the macro systems level.

There were also stronger links in the cluster system between stakeholders, specifically the triple-helix stakeholders. There were also more cross-sectoral and cross-cluster collaborations and more ownership for innovation agendas and projects supporting future developments for the region.

The urgency to attract, create and develop new businesses and business models, products and services and to include different competences and types of professionals and people were evident in its cluster transformations. These shifts in systems patterns were responses and results of drivers of change and contextual changes that reflected shifts in interactions and collaborations patterns, and emergent cluster transformations. Proposition 4 therefore also holds true for Karlstad's cluster transformations.

**Proposition 5**

*Cluster developments are influenced by both top-down steering and self-organizing processes.*

The national government's lack of cluster policy and its bias towards academic universities, which supported academic goals rather than industry goals meant that Sweden lacked a top-down steering policy for clusters. Instead, municipalities, regional governments and the innovation agency of Vinnova played an important role in cluster policy and practice, which promoted cluster focussed 'top-down' steering and initiatives

(Examples in Appendix 11). The Karlstas Municipality's changes in funding of cluster organizations indicated policy driven top-down steering in Karlstad.

Within the local community, a well-established hierarchical role of 'caretaker' by the paper and pulp industry had been established and was still prevalent in Karlstad. The Karlstad Technology Center initiated by the paper and pulp industry and other businesses was another example of the industry's strong influence on cluster developments. One could argue that industry initiated a 'bottom-up' project to meet its needs where educational systems failed although the dominance of the paper and pulp industry in the region could also be seen as a continued dominance of the industry rather than a bottom-up initiative.

The increasing demands of cluster members for more services and insisting more 'value for money' in Paper Province, as well as increasing green consumer demands were examples of bottom-up developments that influenced cluster developments.

However, new developments of collective efforts such as initiating ten professorships to meet future challenges meant that there was a shift in demarcations of clear top-down and bottom-up processes even as both processes were present in Karlstad's cluster developments.

Proposition 5 holds true in Karlstad case study even as different, more collective processes were emerging.

### Iconic Silicon Valley

The Silicon Valley case study was based on an extensive literature case by Etzkowitz (2012) 'Silicon Valley: The Sustainability of an Innovative Region', which offered a comprehensive overview of Silicon Valley's development of clusters in its broader context, meeting the needs of the research. The iconic status of Silicon Valley was an important reason for choosing the cluster. The case description by Etzkowitz provided thick descriptions that permitted a detailed exploration of Silicon Valley's developments in its contextual and historical context using the CAS framework. The analysis notes are found in Appendix 12. All quotations in this sub-section are indicated by page numbers only and are from the main article by Etzkowitz (2012), unless otherwise indicated. The next paragraph offers a short introduction to Etzkowitz's case study of Silicon Valley.

The case study of Silicon Valley by Etzkowitz spans a long history of the region that goes back to the 19th Century, which helps understand deeper historical developments that contributed to the 'innovative region' that it had become. The long historical perspective meant that the case provided a more extensive understanding of clusters and cluster development. Etzkowitz used a five-phase model to structure Silicon Valley's development, which included 'origin', 'aggregation', 'expansion', 'efflorescence' and 'renewal' phases. These terms are also used in the analysis to separate the different developmental phases of Silicon Valley. The success of Silicon Valley as an innovation hub was ascribed to its 'history of indigenous academic entrepreneurship and government-supported R&D, as well as importation and reinterpretation of ecosystem elements like the venture capital firm' (p. 2).

The rest of the sub-section describes the Silicon Valley case in the light of Propositions 1–5, which in turn, offers insights that support and, or qualify the propositions on cluster developments. Similar to the Karlstad case, Propositions 6 and 7 are also not discussed in this sub-section but are addressed in the discussion of all three cases in Appendix 14, and propositions are also indicated as P1, P2, etc.

#### Proposition 1

*Cluster developments, connected to context and contextual changes and driven by internal and external drivers of change, are becoming increasingly complex.*

Silicon Valley's context and development as described by Etzkowitz spanned five different phases of development and this meant that different drivers of change and changes in contexts prevailed.

Silicon Valley enjoyed a tradition of small firm networks, including inventor firms from early 19th Century, driven by autonomy, high levels of innovation and collaborative developments focussed on meeting challenges of the local industry in its need for long distance power and communications triggering new technological developments.

One of the most important drivers of change in Silicon Valley was Stanford University and its founders. The dominant role of the university and later other knowledge institutions in Silicon Valley offers a different example of cluster developments when compared to Karlstad with its dominant industry. Later in its development, other stakeholders take on significant roles but the initial dominance of Stanford is a key aspect of its cluster context.

The prevalence of government contracts as funder of academic research was an important aspect of Silicon Valley's expansion phase but austerity measures in its later stages meant that Stanford needed to seek private resources for its academic knowledge development and firm formation, which up to the 2000s was a driver of regional economic development through its firm formation spin-off of research. The waves of technology innovations meant that multiple firm and cluster formations profited from these developments but there was a danger of decline for Silicon Valley as a whole when technology innovations were not sustained. The introduction of venture capitalism into the Valley in its efflorescence phase also saw the rise of a new group of stakeholders, namely angel investors and venture capitalists, who played an important role in the Valley. These investment agencies influenced the choice of technologies they supported, thereby also influencing the container of Silicon Valley in later stages. Another group of stakeholders was large corporations dominant in its efflorescence phase of development (discussed in more detail in P3).

Silicon Valley also saw a large influx of talent, money, and innovation from all over the globe in its renewal phase, which made its context more complex due to interconnectedness to global developments (competition from other regions for talent and resources, home country incentives of Silicon Valley migrants, etc.).

The local educational developments were initially an internal driver of change for Silicon Valley but in the renewal phase, an increased dependence on foreign talent and innovation meant that external drivers were increasingly more important to the cluster's growth.

The Proposition on interrelatedness of contextual changes and cluster developments and the role of drivers of change hold true for the Silicon Valley case whereby the significance of internal and external drivers of change and the increasing complexity due to contextual changes have been described.

**Proposition 2**

*Cluster developments are connected to their initial conditions of container, stakeholders and path dependent factors.*

Silicon Valley had various path dependent factors that were relevant to the cluster going back to its origin and initial developments. The gold rush of the 19$^{th}$ and other developments at that time contributed to engineering capabilities that supported the need to transcend distances and technologies for mining. The initial hydroelectric industry that met the distance challenge contributed to long-distance power and radio wave transmission developments, and later, electronic technology developments. The 'transcending distance paradigm' (p. 4) was therefore an important impetus for later developments.

A lack of dominance of large corporations in the past meant that there was a need for new industry and firm formation to support development of new technologies. New firm formations continued the culture of small entrepreneurs organized in patterns of collaboration dating back to the 19$^{th}$ century. The space for autonomous development of their 'crafts' contributed to the inventor and technical entrepreneurship culture, as an important path dependent factor in Silicon Valley.

The Engineering School of Stanford originally trained professionals to operate electrical equipment imported from the East of US, but the founders of the university decided that a local industry was necessary to distinguish itself and initiated a strategy of firm and industry formation. The electronics technology cluster was the result of this strategy. The knowledge-based economy as a motor for regional growth was part of the Silicon Valley's container that grew from Stanford's ambition to excel.

Another important path dependent factor was the brainchild of Terman, the Dean of Engineering, whose academic development strategy, their container, created cross-boundary interactions. His strategies included connecting departments of science and technology, linking local science-based firms to academic departments, and focussing on key research fields that had potential academic and industry values. His vision, an adaptation of the triple-helix model from Boston, was also an important path dependent factor for Silicon Valley's container. Terman also brought with him not only the 'lessons' from the East but also committed personal resources to support initial industrial and firm formation.

The antecedent of land ownership by Stanford University was in itself a path dependent factor that allowed development of the science park that enabled closer industry-academic interactions and innovation developments.

Stanford University had chosen to expand its scope of activities from a teaching university to one that generated firm formations based on academic knowledge. The container included an entrepreneurial university that offered its knowledge base as a source of regional development; this commitment was connected to firm and industry formation. At a later stage, close connections to industry and a limited research focus led to development of niche research strands that were industry relevant, and this in turn, led to the development of fundamental research. The university expanded its container from a developer of human capital to a generator of knowledge-based firms and industry and a leading research institute securing government contracts.

The analysis shows how Silicon Valley's path dependent factors, stakeholders and container were all closely interconnected, with Stanford (and its key founders) being an important driver of change. In its later phases of development, new containers and new stakeholders added to Silicon Valley's development. One of the new containers dominant in the later stage was the 'whatever it takes' mentality stemming from an older practice of 'unlimited hours focused on research goals' that was transferred to the 'un-bounded hours of the start-up firm' (p. 11). Changes in Silicon Valley's developments also meant shifts in cluster conditions and, therefore shifts in cluster dynamics and transformations (see P3 and P4).

Developments in Silicon Valley reflected that Proposition 2 on cluster conditions held true and that cluster conditions changes as the cluster develops. It was also clear that in

Silicon Valley, the role of Stanford and federal funding played a significant role in cluster developments.

**Proposition 3**

*Cluster dynamics are interconnected system responses to changes in its context; namely, attractors to new movements and changing stakeholder perceptions, fitness to landscape strategies to meet changing contextual challenges, using significant differences as a potential for new path creations.*

'Silicon Valley took a proactive stance in creating industry to support academic development from its 1891 founding' (p. 2). Stanford was the motor for the knowledge-based economic development of the region. The university built linkages between the academic departments and industry, and between the departments and government. It also foresaw the need to create an industrial base to sustain its own academic developments and ambition to excel. The fitness to landscape strategies adopted by Stanford resulted in attractors of money, firms and talent, and later, new emergent fields. The following paragraphs give more details on these interconnected developments.

Early strategies at Stanford were based on the experience and insights of Terman and its founders, looking towards the 'East' (MIT, Boston). They realized that they needed to learn and compete with the developments of the East that was thriving on government contracts, and how academic research supported industrial growth. The need to 'fit' to changing contexts as represented by the East, and to ensure that government contracts and funding for research was available, Stanford Research Institute was founded in 1946. The Stanford Research focussed on a limited number of key themes to ensure both academic and practical value. These early developments resulted in formation of the electronics industry in Silicon Valley. The focussed research strategy at Stanford, the inclusion of student and faculty interactions with industry, research that supported industrial innovation, exposure of students to multidisciplinary and commercialization projects, linkages between science and technology departments in the university, and securing government contracts to support academic and industry relevant research were all part of Stanford's fitness to landscape strategies in the early phases of its developments (origin and aggregation phases).

The fitness to landscape strategies included adoption of what was later to be known as the triple-helix model of interactions from MIT, bringing together industry and academia and emergence of the Science Park as well as nurturing small-scale entrepreneurial network organization and its 'inventor haven' fame. These strategies continued into later phases of Silicon Valley's development. These strategies in turn, contributed to attractor movements of increasing new innovative firms, new talent, and resources, particularly in the form of venture capital. A precedent dynamic start-up culture that embraced splintering and regeneration of businesses also supported high numbers of firm formations (Etzkowitz, 2012; Jaruzelski *et al*, 2012). The attraction of 'like-minded' technology and innovation oriented professionals and start-ups willing to pursue collaborative developments, accelerated innovation. This in turn, resulted in multiple technology paradigms that eventually led to advances in new fields and clusters in its expansion and efflorescence phases of development, for example, semiconductor and electronic advances, microwave and biotechnology developments.

The description in the previous paragraphs of Silicon Valley's fitness to landscape strategies and attractors of new developments and stakeholder behaviour showed the interconnectedness of these aspects, and also of interconnectedness to its path dependent factors and key stakeholders. The descriptions above focussed mainly on the first three phases Silicon Valley's developments, namely, origin, aggregation and expansion phases.

The next part of the description focusses on the efflorescence and renewal phases of Silicon Valley's development in relation to its cluster dynamics. Some overlap occurs where connections to previous and continuing developments are included to capture more completely interconnected cluster dynamics developments.

An attractor in this phase was the integration of start-ups into larger corporations, be it home grown, like Google, or from older multinational corporations, like Siemens, who were located in the area. These corporations drew start-ups into their 'gravitational field' according to Etzkowitz (p. 15). There was a new wave of start-ups supported by a culture rooted in entrepreneurship and collaborative spirit. This led to a critical mass of start-ups that were supported and 'supervised' by the growing cadre of experienced entrepreneurs in the area. A growing institutionalization of 'matching activities' in Silicon Valley saw a movement that supported and invested in young start-ups.

Another attractor present was large corporations' buying-in of and investments in start-ups that fed the trend of migration of innovative firms and start-ups to the Valley. In addition, the history of in-house 'proto firms' within existing structures (university labs, research and development projects) breaking off to begin new firms, a tradition rooted in its origin and aggregation phases, also added to this process as did the supportive culture of friends, family, colleagues, mentors, professors, and government procurement contracts. The attractor of firm formation seemed to have accelerated in this phase of Silicon Valley's development.

The various parallel and supportive developments of firm formation contributed to an innovative ecosystem, which in itself was an attractor with a global outreach. Silicon Valley's success 'as an ecosystem' led to a new phase (efflorescence) that made it a global player attracting finance, talent, and innovation, but also, organizational intermediaries of foreign universities and industries seeking innovation, collaborations, and to be part of the success. It became, in Etzkowitz's term the 'entrepot-dok' of the world, attracting talent, resources and intellectual capacities that contributed to transforming interactions and developments in Silicon Valley (details in P4).

The changing landscape of Silicon in these developmental phases meant a change in Stanford's role and (fitness to landscape) strategies. Firm and cluster formation and acceleration were becoming independent; Stanford's initial driving force of firm and industry formation was overtaken by exogenous developments. Initial funding sources of Stanford's research-based firm formation declined due to declining state support and government contracts. Stanford however was faced with a new opportunity to support regional development due to developments in the semiconductor industry in the 1990s. Japan became an important competitor that threatened Silicon Valley's own successful semiconductor industry. An urgent renewal of Silicon Valley's technology knowledge base was needed. This crisis brought together major stakeholders in Silicon Valley to create a Joint Venture Silicon Valley (JVSV) platform. This innovative fitness to landscape strategy to counter growing knowledge-based competition globally resulted in an important attractor as becoming the home to venture capitalism. The attractor, Silicon Valley drawing in innovative technology firms in search of investment resources and business development support, was an important component of Silicon Valley's cluster dynamics and accelerated growth. Stanford's role supporting new knowledge developments to renew the industrial base of Silicon Valley was not only a shift in its role but also reflected a need to develop new competences to support regional transformations. The fitness to landscape strategy that resulted in the JVSV collaborative platform changed Stanford's dominant role as driver of change and cluster development to a broader joint ownership and participation of other stakeholders to drive change in Silicon Valley.

The 1990s crisis in Silicon Valley showed how changes in cluster context affected cluster dynamics through changes in fitness to landscape strategies, which in turn, influenced cluster conditions of stakeholders and their roles, and subsequently, influenced emergent cluster developments.

Another aspect of change in cluster dynamics was the change in the role of government in its renewal phase. There were shifts in the national government's role from being a catalyst of economic development (funder of public research, offering large government contracts and investor in public infrastructure) to a conservative spender of public finances. The shift towards austerity and minimizing the caretaker role was in part due to a change in political paradigms, namely, more conservative.

Silicon Valley also became an attractor, an 'entrepot-dok' where international 'human, financial and intellectual capital' landed (pp. 17-18). The large inflow of resources and new firms, however, also resulted in a reliance on imported talent and resources leading to (fitness to landscape) strategies that accommodated and built on this attractor. Venture capitalism, an innovation of Silicon Valley, attracted new talent and resources to the Valley, contributing to an escalating pattern of success and potential risk (more details in P5 and Appendix 12).

Silicon Valley's success also saw a different movement whereby not only did it attract novice entrepreneurs but also 'world class entrepreneurs, technologies and business ideas' making the Valley more diffuse and more individualistic (p. 18). A surge of upscale neighbourhoods and excessive private wealth contrasted to a backdrop of diminished public education spending and risks related to lack of investment in longer-term development of local human capital.

Attractor movements in Silicon Valley in its renewal phase were success and international allure drawing in the best resources to replenish and renew its growth but also an underlying process of decreasing local capital development (more in P4 and in Appendix 12).

To summarize, throughout Silicon Valley's development, its fitness to landscape strategies were focussed on research development and knowledge-based firm formations, availability of funding for research and for start-up formations and, later, for attracting international firms, talent and intellectual capital. Development of human capital was also an important part of Stanford's fitness to landscape strategies to support local industries and formation of new industries. Acquisition of government contracts and research funding in the Valley were important strategies that led to the formation of semiconductor, aeronautics and space industries. Even when public funding was reduced, federal government contributed up to 30% of Stanford's budget of 3.8 billion in 2010-11 (p. 10), which reflected the significance of public funding in Silicon Valley's developments throughout its history.

Attractors in Silicon Valley were visible in terms of success in firm and industry formation throughout its development; the academic, technology-based start-up culture, the interacting academic-business cultures and presence of like-minded inventor and entrepreneurial networks; collaborative innovative cultures and the resulting presence of collective and multiple technological paradigms; emergence of new industry and large corporations investing in start-ups and innovation; venture capitalism and experienced managers mentoring start-ups; 'entrepot-dok' role with global outreach; international network of innovative firms and organizations; various interconnected attractors and developments pushing Silicon Valley's developments towards escalating processes of success (with new risks and threats inherent).

In order to understand Silicon Valley's cluster dynamics more completely, understanding how significant differences were leveraged offered deeper insights into its cluster developments. In its origin phase, huge distances between the East and West and the different economic contexts of these parts of the US in the 19th century, contributed to significant differences of imbalances in government support, industrial development and innovation focussed on the West. These developments played a crucial role in Silicon Valley's need to develop and lead its own industrial innovations to meet the need for long distance water, power and later, radio transmissions. Stanford's role as an important force of local development helped correct imbalances of government funding and technology innovations between East and West (described in P1 and P2). The next four paragraphs describe significant differences that were dominant in the later developments.

A recurrent significant difference leveraged throughout its developments was the academic-industry linkages. The added value of Stanford's connection to local industry and firm formation through academically driven entrepreneurship were important to Silicon Valley's success. The potential value of research to solve industrial needs and create new industries was recognized early by Stanford's founders and this recognition transformed into strategies and action. In addition, differences between industries and knowledge fields were also significant differences contributing to creating new knowledge fields and industries such as electronics, biotechnology and networking technologies. The 'double helix' discovery of technology and chemistry developments was another example of parallel developments and leveraging of significant differences, as was development of common technology platforms leveraging multiple technology developments and paradigms in the Valley. Accelerated innovations and firm formations that generated critical mass supported further technological advances and new industry developments. Stanford's contribution to strong interactions between research and businesses through development of its Science Park on its grounds was a decision to capitalize its property and the need for proximity to research labs and knowledge developments of innovative entrepreneurs. These examples illustrate how academic-industry and inherent differences within these groups were leveraged resulting in new cluster dynamics and developments.

Similarly, academia-government linkages also contributed to Silicon Valley's success. Imbalance of government funding between the West and East as described earlier was an initial significant difference that resulted in Stanford Research Institute's strategy to accrue federal government contracts and funding by targeting government's needs for knowledge capacities. Even with decreased public expenditure, government contracts contributed about 30% of Stanford's research budgets in 2010. The presence of government contracts in turn attracted innovative entrepreneurial firms to the Valley in search of funding for their innovation and business developments. However, the reverse was also evident. In its renewal phase, decreased role of government support in human capital development and public funded research coupled with reduced large corporation research, meant that Silicon Valley's funding and human capital prospects were less significant, which in turn meant Silicon Valley's attraction for innovative entrepreneurs was weakened.

Other examples of significant differences contributing to new developments in Silicon Valley's were presence of networks of small entrepreneurs collaborating for technology innovations seeking complementary knowledge; spin-off of academic-based entrepreneurs leveraging both worlds; spin-offs and the university or large corporations; convergence of different capital (financial, social, human capital intellectual) that provided a dense web of social capital; this web spurred a 'spiral of innovations' supported by friends and family endowed by knowledge and capital; and managerial mentors/angel investors and venture capitalists and novice entrepreneurs. Significant differences in resources, competences and interests, transfer of academic practice of 'un-bounded hours' to become the 'whatever it takes' mentality amongst start-ups and entrepreneurs in the Valley fed entrepreneurial and innovation successes (p. 11).

A different example of how significant differences were leveraged in Silicon Valley was related to organizational structures and processes. Both the Technology Transfer Office and Industrial Liaison Programmes had been set-up to leverage potential differences of capacities and needs of academia and industry. The Joint Venture Silicon Valley was a similar strategy that rallied key stakeholders to initiate a local innovation fund to stimulate and support innovations in the face of the 1990s crises.

The four types of significant differences supported innovations and new path creations in the cluster's system were described above: academia and entrepreneurship/industry, government and academia, different types of collaborations and symbioses building on differences in resources, needs, capabilities and work ethos and attitudes, and organizational platforms and structures.

The analysis has shown how various significant differences contributed as leverage points towards cluster dynamics of a successful Silicon Valley, also reflected in fitness to landscape strategies and attractors. The interconnectedness of these different aspects of cluster dynamics, and their interconnectedness to path dependent factors and initial cluster conditions were also described. In addition, changes in cluster dynamics were connected to contextual changes and ensuing shifts in stakeholder perceptions and attractor developments. The study of Silicon Valley, in part due to the long history and comprehensive coverage of the cluster's developments, also clearly illustrated interconnectedness of cluster dynamics, cluster conditions and context.

Silicon Valley's developments therefore supported and strengthened the proposition related to cluster dynamics.

**Proposition 4**

*Cluster transformation is visible in transforming interactions and contributes to macro level emergent system patterns.*

This part of the analysis provides an overview of key transforming interactions and underlying processes, and description of emerging systems patterns in Silicon Valley.

Important visible results in Silicon Valley were successful technology advances and firm formations starting with the Federal Telegraphic Corporation (1911), the subsequent emergent industries of electronic technologies (1930s), the creation of the Science Park (1950s), and later, the development of parallel and multiple technological paradigms and knowledge fields that resulted in the emergence of biotechnology firms and industry (2011). These visible examples were all results of transforming interactions. To understand these developments, some of the related underlying processes and mechanisms need to be described.

Related to Stanford's research driven firm-formation strategy was the changing patterns of interactions that were part of Stanford's arrangements of collaborations with industry and government stakeholders. These arrangements included the offer of 'neutral ground' at the university for pre-competitive research collaborations as part of start-up dynamics (p. 10); the creation of 'proto firm' in research projects (p. 12); and support by technical and managerial skilled supervisors that included training programmes. However, there was also a different development that extended beyond the university-firm interaction patterns. The spin-off start-ups from research labs formed interactive clusters of start-ups that when highly successful broke off to become integrated corporations like Intel but returned to their original clusters and academic sources 'to renew ties and acquire start-ups and advance academic knowledge to improve their product lines and reinvigorate their knowledge bases' (p. 12). There were also examples of how successful firms, like Sun Microsystems with successful products (workstations) became out-dated but were acquired for their staff and product lines. This last example reflected the rise and fall of firms in the Valley that continued to build on previous competences. It could be seen that expansion and renewal of firms were not limited only to the original academia-industry linkage that produced most start-ups in Silicon Valley's expansion and aggregation phases but also extended to spin-offs from interactive clusters to form integrated corporations, acquisition of less successful firms for their products and production lines and staff. Large corporation buy-ins and angel investor linkages with start-ups were also examples of new developments in Silicon Valley supporting business renewal and development.

Another example of the shift from the original university's collaborative arrangement was seen in the example of Apple computers. The presence of different technological innovative components such as the mouse combined with new user-friendly paradigms created Apple's innovative products. This last example also captured the shift of innovation from industrial processes and government projects to the realm of users and consumers.

Another example of transforming interactions was Google's search engine development in which 'agglomeration of social, intellectual and financial capital' took place (p. 11); Google originated from a government defence project collaborating with Stanford's Computer Science department with contributions from the computer science department's entrepreneurial 'university angel', and its Office of Technology Licensing (p. 11).

Silicon Valley's 'collaborative pursuit of innovation… [had] created a web of ties over time that became the source for collaborators in future projects in an escalating spiral of innovation' (p. 8) but changed as firms matured and more individualistic focusses emerged. However, a resurgence of dynamic start-up culture 'with its own collaborative formats of Hackathons, code camps and meet-ups' arose that supplemented an older tradition of informal networking at coffee houses and bars characteristic of Silicon Valley in earlier phases (p. 15). The strong start-up culture and informal sharing of new innovation ideas and collaborations were still present albeit changing, reflecting the changing contexts of Silicon Valley's innovative milieu.

In addition, new mechanisms were created such as the Technology Transfer Office and the Industrial Liaison Programmes, to counter a lack of firm-formation incubators in research labs, and as part of the Joint Venture Silicon Valley platform in the 1990s. Whilst the medical school at Stanford had internal start-ups without such external mechanisms, the creation of such organizational structures seemed to indicate a more formal culture of collaboration and firm-formation was emerging.

The development of Silicon Valley 'from a local generator of new technologies and industries into the key node of a global network, with multi-national firms, countries, regions and universities maintaining outposts to markets or source advanced technologies' (p. 2) helped understand the emergence of more formal structures of collaborations, which in fact reflected contextual changes and system responses.

The new global scope of Silicon Valley's interactions and collaborations, and subsequent dependence on international resources, was visible in an emergent 'innovation eco-system' (p. 14) of specialized legal, financial and headhunting firms, business angels and venture capitalists seeking to generate start-ups from international aspirant entrepreneurs for their intellectual capitals. Potential risks of this new development are addressed in the concluding paragraphs of the Silicon Valley case, and in Appendix 12.

The changing patterns of interactions and collaborations in Silicon Valley as described above also reflected macro-level systems changes, the emerging systems patterns. The following paragraphs describe changing systems patterns of Silicon Valley.

Accelerated growth of research-based firms, innovations and industry supported by double and triple-helix collaborations were important emergent systems patterns in Silicon Valley in all phases of its developments. Similarly, the dominance of parallel technological paradigms interacting to produce new innovations and industry was also an important emergent systems pattern throughout its history.

Supportive start-up culture, initially within Stanford and its Science Park was later prevalent throughout Silicon Valley (entrepreneurial supervision; business angel and venture capital resources; friends, family and university mentors and entrepreneurs; government contracts and research funding; etc.). Free flow of information and ideas, part of an entrepreneurial and innovative culture, later took on new forms and types of supportive culture seen in Hackathons, code camps, etc. Emerging systems patterns capturing this culture of collaboration and support can be described as the emergence and prevalence of supportive innovation eco-systems.

Availability of funding, initially from government contracts and research funding, and later through private, large corporation research projects and emergence of regional venture capitalism funding, was an important emergent systems pattern in Silicon that fed research and technology driven innovations and regional clusters. The systems pattern of increasing financial capital, together with another emergent systems pattern, splintering and regenerating of firms, contributed to rise and decline of new firms and

clusters of firms, which, together with development of multiple technology paradigms, saw the emergence of new industries (electronics, biotechnology industries, etc.).
Other emergent systems patterns included maturing firms, availability of experienced managers, private finances and new institutionalized matching and mentoring activities drawing in new international talent and aspiring entrepreneurs. Silicon Valley with a global scope of interactions, collaborations and networks paralleled by its unprecedented scope of 'crosscutting and hybridizing various technological fields' at different growth stages (p. 16) showed emerging systems patterns of a global leader of regional innovation and cutting-edge innovations.

Convergence of financial, intellectual, social and public capital, first on a regional and national scale but later on a global scale, was an overarching emerging systems pattern of interacting of various systems patterns throughout its developments that fed Silicon Valley's success.

As mentioned before, an important change in systems pattern was the role, engagement and influence of key stakeholders in Silicon Valley's development. The changes in Silicon Valley's stakeholders were as follows: initially, Stanford and government funding were leading change, but later, large corporations were an emergent influence on developments; and afterwards, the rise of venture capitalists and private wealth (business angels) were a driving force; and within this last development and subsequent developments, international players were increasingly shaping Silicon Valley's global and iconic success. Silicon Valley's systems patterns related to stakeholder engagements and influence emerged throughout its developments.

Silicon Valley had developed at an accelerated pace thriving on global resources and interests in its renewal phase building on successes that had a long history of successive and parallel developments, and a culture of entrepreneurial and knowledge-driven systems.

This part of the analysis also offered insights into sensemaking processes leading to changing behaviours of stakeholders and patterns of interactions and collaborations. In addition, Silicon Valley's developments could be traced back to dominant systems patterns in different phases of its development that emerged as a result of (new) transforming interactions responding to contextual changes. Therefore, Silicon Valley's cluster transformations supported the proposition and offered detailed insights into such processes. More discussion on this aspect is found in the discussion of the cases (Appendix 14).

**Proposition 5**

*Cluster developments are influenced by both top-down steering and self-organizing processes.*

One of the cornerstones of Silicon Valley's core culture was the presence of small entrepreneurial networks collaborating for innovation. There was a strong spirit of autonomous craftsmanship where technical work was organized in specialized firms in the 19th and early 20th centuries, illustrated by the telegraphy industry. The autonomous culture and spirit of Silicon Valley remained an important part of its later developments. The 'inventor haven' of the 19th century emerged due to the absence of large corporations in Silicon Valley, and the 'inventor haven' lure continued to be a dominant feature in Silicon Valley. This is illustrated by Shockley's choice to establish Shockley Semiconductor in Silicon Valley when he left Bell Labs, and later, the Varian brothers also set-up Hewlett and Packard for the same reason: lack of large corporation and room to develop work autonomously. The dominance of start-ups and networking cultures in Silicon Valley continued the tradition of autonomous and collaborative technology and entrepreneurial developments reflecting self-organizing processes influencing cluster developments.

Nonetheless, Silicon Valley also had a strong top-down steering process in its history, particularly in the aggregation and expansion phases due to dominance of Stanford and flow of government research funding and contracts. This top-down influence of Stanford was however countered by its firm and industry formation strategies. Stanford's strategy therefore contributed to both policy driven developments as well as a dynamic start-up culture that was self-organized and contributing to accelerated innovation in the Valley.

The presence of large corporations and development of the Joint Venture Silicon Valley Corporation diffused Stanford's dominance and influence on Silicon Valley's developments even as Stanford remained an important player in Silicon Valley.

In the expansion and efflorescence phases, self-organizing processes contributed to accelerated technological advances through collaborations, financing, buy-ins, etc.

rooted in the growth of multiple innovative clusters (of start-ups and new enterprise), splintering of successful firms that developed into integrated multinational corporations (Intel), and growth of successful multinationals (Hewlett Packard, SUN Microsystems, Google, Apple, etc.) These processes were also dominant in Silicon Valley's later phases.

The decreasing role of federal government in terms of public expenditure for infrastructure, including education and research funding, and reduced government contracts, meant that there was also a diminishing top-down support and orchestration of innovation and economic developments. On the other hand, a growing share of international resources, talent and networks meant that Silicon Valley's developments were increasingly dependent on exogenous drivers of change, plugging into global developments, availability and competition of resources. The threat for Silicon Valley in its renewal phase was the strong dependence on international inflows of resources and a neglect of local human capital development.

The initial growth of Silicon Valley attributed to university human capital production and research-based firm and industry formation backed by government and large corporation research funding had shifted to increased private resources in its later phases. The lack of top-down processes was a concern for its future as Silicon Valley also faced successful global competitors, such as Linkoping, San Diego, Merced, Norrkoping, and potentially, Taiwan and Bangalore. In addition, the nature of entrepreneurship in the Valley had changed to become more individualistic and the growing dependence on international talent and finances, and a neglect of local talent developments contributed to concern about Silicon Valley's future.

The analysis of Silicon Valley reflected strongly the need for both top-down and bottom-up processes to strengthen regional and cluster developments in the face of increased global competition and acknowledging the benefits of diverse, parallel developments in technology, firm and industry formations.

# 14. DISCUSSION OF CASE STUDIES

This analysis looks at the findings of the case studies in relation to cluster context, condition, dynamics and transformations, and the broader systemic developments. The analysis discusses the initial propositions in the light of all three cases and draws conclusions on the different aspects of cluster developments.

The first aspect of cluster developments addressed was the interconnectedness of clusters with respect to changes in their regional and larger contexts, which resulted in complex and urgent challenges. The next three paragraphs discuss this aspect of cluster development in each of the cases.

Karlstad's developments were tied to the paper and pulp industry and the clusters that had emerged from it. New competitors from emerging economies were an issue for the paper and pulp industry but the urgency of this development for the local industry and economy and the corresponding responses were varied. Local and regional governments were seeking efficiency and new economic pathways. The paper and pulp industry was aware of this but 'business as usual' seemed to be the dominant response. The national government focussed on supporting academic universities and research but the local clusters were not linked to university for their search of new knowledge-based catalysts. Local education system was lagging in meeting labour needs. Different stakeholders seemed to be focussed on different needs, interests and time scales. Other drivers of change contributing to changing contexts were both internal and external to cluster development and the region. The external drivers included climate change and sustainability agendas, resources depletion, urban sprawl (threat to engulf Karlstad) and urban migration (brain drain), and need for keeping ahead of technological advances. Internal drivers were changes in funding, dependence on paper and pulp industry, forest depletion concerns, and need for competitive advantage. The interconnectedness of context and developments of the region and clusters reflected the increasing complexity of cluster developments in the Karlstad case study.

Similarly, Silicon Valley's developments in the 1990s with the rise of Japanese semiconductor industry reflected how external drivers of change were important to its development. The reduction of government expenditure and contracts became an important challenge for regional and cluster developments. Growing competition from other regions in the renewal phase posed a problem for the cluster. The most important internal driver of change in Silicon Valley up to its efflorescent phase was Stanford's vision and commitment to leading research, which was driving local firm and industry formation. The introduction of venture capitalism and growth of private wealth became an important driver of change in Silicon Valley in the 2000s. In the efflorescent and renewal phases, Silicon Valley's success became its most important driver of change that attracted global resources and interactions. The developments of Silicon Valley were closely tied to those of its context, which were regional, national and global, but Silicon Valley was also contributing to contextual changes when it became a national contender for government contracts, and a hotspot for inventors and investors, and yet later, also as a global player, replicating its historical 'gold rush' era that brought diverse new players to the region. The complexity of keeping up its own success and keeping up with global developments were part of the new challenges faced by Silicon Valley.

The complexity and interconnectedness of clusters and their regions to their context were reflected in Energy Valley's case study whereby energy transition developments, EU internal market and energy market developments, climate change and sustainability push, depletion of fossil fuels, geo-political shifts, changing business and social landscapes and globalization were some of the factors contributing towards this. In addition, diversity of stakeholder perceptions and responses to changing contexts due to differences of interests, needs, resources and engagement also increased the complexity in Energy Valley.

The three cases showed how cluster developments were intertwined with contextual changes and interconnected issues fed by both internal and external drivers. In addition, stakeholder perceptions, interests, engagement and influences were also important aspects of the complexity of challenges facing clusters and regional developments. The proposition on this aspect of cluster development was adapted to capture these insights:

*Cluster developments are interconnected to developments in the region and the larger context, and become increasingly complex due to internal and external drivers of change, and different responses of stakeholders.*

The three cases showed interconnectedness of cluster conditions that defined the 'initial' cluster. The following paragraphs highlight some of the key insights from the cases.

Karlstad and Region Värmland were dominated by the paper and pulp industry. Although new spin-off clusters had emerged in the past, the risk of lock-in was present. This was mainly due to limited links to external (university) knowledge developments, limited national funding for research and efficiency demands of municipality. The absence of a national cluster policy also contributed to an internally oriented container by Karlstad's stakeholders. In addition, being part of small communities also contributed to closely-knit and interdependent cultures that strengthened the internal dynamics. However, strong ties to the Karlstad University were absent in the container due to the dominant and self-sufficient nature of the paper mills in the past whereby the mills were important sources of innovation and new cluster formations.

Silicon Valley was also marked by the dominance of one stakeholder in the initial phases, namely, Stanford, and indirectly the federal government through contracts and funding obtained by Stanford. Silicon Valley's container however included firm and industry formation with research driven innovations due to Stanford's dominant position and ambitions, which in turn, resulted in new stakeholders in later phases of its developments. However, the dynamic craftsmanship driven mentality stemming from the 19$^{th}$ Century of networks of specialized entrepreneurs was part also part of Silicon Valley's container. Other elements of its container were collaborations focussed on cross-disciplinary, academic-industry and academic-government linkages. Innovative developments such as 'proto firm', practice of splintering and regeneration of firms, triple-helix interactions, creation of the Science Park and mentoring and supportive culture of start-ups were also important elements of Silicon Valley's early cluster conditions. In its later phases, its container included various technological innovations and common technology platforms, venture capitalism and private funding, and the 'entrepot-dok' status for global innovation development. Silicon Valley's long history meant insights into different development stages and shifts in its initial cluster condition for the next phase of its development.

Energy Valley was not only dominated by its gas sector but also by national government due to the significance of gas revenues for the Treasury. The national container of 'BV NL' of the Dutch government played an important role in Energy Valley's cluster developments. The risk of a lock-in in cluster developments was caused by gas and national interests dominance in the cluster's initial conditions. Key stakeholders included energy corporations, national government and regional governments and to a lesser extent the academic stakeholders. Energy Valley's stakeholders had three dominant frames, namely, 'economic', 'energy transition' and 'regional' that influenced their perceptions and strategies for cluster and regional developments. Diversity of stakeholders reflected diffused container definitions related to Energy Valley in its initial cluster condition. The cluster Energy Valley was initiated by stakeholders in the region in the face of EU and energy market developments but differences remained.

The lessons learnt from the three cases on cluster conditions showed how factors related to a cluster's path dependency, stakeholders and container were interconnected and that inherent risks were also present. The dominance of an industry, or as in the case of Silicon Valley, one stakeholder, impacted the cluster's stakeholders and container and therefore its developments. The dominance of an industry with weak links to university and external research developments as was the case in Karlstad and Energy Valley combined with an absence of national cluster policies and adequate national funding, increased the risk of lock-in path developments. There was a tendency to focus inward, and to neglect, underestimate or respond inadequately to external developments. A dominance of differences in cluster could also lead to 'diffused' cluster container as seen in Energy Valley where three different 'frames' of references ('economic', 'energy transition', 'regional') were present, representing stakeholder interests, perceptions and behaviour. Silicon Valley had also a dominant player, Stanford, which determined the cluster's initial container, which in turn, became part of the cluster's path dependent factors shaping later developments. The strong technology-based innovation and start-up culture with supportive and boundary-crossing interactions in the cluster were initiated by Stanford's vision of regional development, Silicon Valley's container. Government funding, and capital in general, were also part of this container, which was an important stimulus of technology driven innovations, firm and industry formation and renewal. The breakdown of borders continued in Silicon Valley's expansion of its regional and national scope to a global one.

The three cases showed how cluster developments were closely tied to their original cluster conditions of path dependent factors, stakeholders and container, which were in turn, closely connected to each other. Key stakeholders with their dominant 'frames' often defined and shaped cluster container, whilst a cluster's container also determined which stakeholders were engaged in the cluster. Both stakeholders and container were closely linked to path dependent factors, which had a risk of inward and lock-in path developments if external links were absent:

*Initial conditions of container, stakeholders and path dependent factors are important in determining subsequent cluster developments whereby dominance of one or more stakeholders or path dependent factor could increase risks of lock-in where limited external linkages are present, or if there are too many differences, a risk of diffused cluster developments exists.*

Cluster developments in response to contextual changes were described in the three cases to understand its cluster dynamics. The three cases showed different cluster dynamics due to their unique cluster conditions and contextual changes. The next five paragraphs highlight key insights of this aspect of cluster developments.

Karlstad's paper and pulp industry and its related clusters needed to address developments such as new global competitors, demands of sustainability and resource efficiency, urbanization and lagging education. These developments showed interconnectedness between drivers of change and attractors to these movements and these in turn, were influential in Karlstad's regional and cluster developments. The deeply rooted industrial developments to its regional economy meant that fitness to landscape strategies needed to break the 'lock-in' and closed value chain trends of the paper and pulp industry that had dominated its past. Leveraging significant differences such as Karlstad's University's knowledge base and industries' needs, the knowledge base and competences of the different clusters, building on whole project specializations and services by combined offers of different clusters and businesses, forest regeneration with new industry formation as part of cross-sectoral business developments, were all part of Karlstad's fitness to landscape strategies. Region Värmland and Karlstad's city municipality played an important role in supporting such developments, as did Karlstad University with its own outreach to industry strategy. Cluster and regional interests were closely tied and therefore responses were also intertwined; Karlstad's systems dynamics showed how new stakeholders were responding to drivers of change and cluster dynamics. Attractors, fitness to landscape strategies and leveraging significant differences, aspects of cluster dynamics were therefore closely related and overlapping regional systems dynamics.

Silicon Valley's significant fitness to landscape strategies were its research driven firm and industry formation and regeneration, with supportive collaborative arrangements and conditions, and availability of financial capital. These strategies, connected to path dependent factors of 'inventor haven', autonomy due to large corporations (initially) contributed to its continued success, which in itself became an important attractor. Attractor movements in Silicon Valley saw accelerated growth of innovations and technological advances, availability of social, intellectual, financial and human capitals, and growing size, scope and influence of its firms, industry and of Silicon Valley itself. These interconnected and interacting attractor movements were important in their role in transforming Silicon Valley from a cluster of regional and national significance to one with a global status, building on new cluster dynamics that brought in new stakeholders, financial, intellectual and human capital, and entwined in global networks and global developments. Much of this success was attributed to successful leveraging of significant differences in the cluster's systems that stemmed from its early origins and continued to be present throughout its developments. The most significant of these differences were the 'permeable boundaries' between entrepreneurial, academic and governmental realms connected by shared vision (container) of knowledge driven innovation. Silicon Valley's interconnected cluster dynamics were also connected to its path dependency, stakeholders and containers. Like Karlstad, cluster and regional developments were closely tied to each other in Silicon Valley, and spin-off cluster developments were also dominant throughout its developments building on cross-boundary interactions.

Energy Valley's cluster dynamics were characterized by increasing diversity and complexity of the energy cluster. Shifts in energy landscapes due to external and internal contextual changes saw attractor movements to major changes, from re-positioning of gas and emergence of decentralized systems and new energy sources to engagement and inclusion of grassroots movements and sustainability and resources efficiency agendas. The increasing diversification, expansion of scope and levels of energy systems meant that Energy Valley's capacity to deal with these attractor movements needed to be addressed. One attractor movement, connecting to 'outside' the cluster within and outside of the Netherlands, posed a risk of 'cluster drain' when the region did not benefit from such connections. Similarly, enlargement of the energy sector posed a risk of a lack of collective vision in the cluster and energy transition. However, significant differences, differences in resources, competences, markets, networks, socio-economic structures, developments and priorities present in Energy Valley supported opportunities for new collaborations and path creations to deal with the increasing complexity of regional and energy developments. These opportunities were reflected in fitness to landscape strategies expressed by stakeholders that indicated a need to expand existing strategies, scope of activities and collaborations. This shift in stakeholder perceptions was an important attractor in Energy Valley's cluster dynamics. Key strategies needed to support Energy Valley's future developments were identified as the need for new institutions and innovation spaces that supported cross-sector, multidisciplinary business and value chain innovations; the need for focus on systems and societal transitions; the need for varying scales and scope to support diversity of challenges even as more collective vision and developments were needed; growing trust issues due to conflicting roles of government and large corporations versus public safety and local welfare; and the risk of energy transition challenges becoming secondary to dominant national and regional growth agendas. The growing complexity and interconnectedness of challenges and developments in Energy Valley were reflected in its cluster dynamics. Key issues underlying cluster and regional developments in Energy Valley were coherence, lack of close collaborations and agreement of priorities, trust, and accountability for cluster and energy transition challenges. However, these issues also offered diversity as potential for innovation and new path creations for Energy Valley.

The three cases reflected how clusters and regions were closely connected and how cluster dynamics were interconnected. The clusters had different cluster dynamics and challenges given their different initial conditions and cluster dynamics. Karlstad and Energy Valley were limited in their knowledge and financial resources as opposed to Silicon Valley. On the other hand, Energy Valley and Silicon Valley were faced with increasing number of new stakeholders and new developments in the sector whilst Karlstad was less responsive due to the dominance of and its dependence on the paper and pulp industries. Potential for changes in Karlstad lay in closer collaborations between industry and university and supporting new inter-cluster and cross sectoral collaborations, and creating specialized services and niche segments. In Silicon Valley, cluster dynamics was closely connected to its cluster conditions that encouraged strong triple-helix interactions and firm formations and availability of capital. In Energy Valley, the changing cluster contexts of increasing complexity was an important driver of its cluster dynamics together with its cluster conditions of a dominant gas sector, resulting in energy transition and regional development competing with national interests.

To summarize, the findings of the cases helped understand cluster dynamics and the interrelatedness of the different aspects of attractors, fitness to landscape and significant differences, and how these were connected to other aspects of cluster developments. Attractors in the cluster included shifts in stakeholder perceptions. Examples of this in Energy Valley and Karlstad were acknowledgement of changing contexts, growing complexity and a need for new solutions, often 'outside' existing practice. The potential of significant differences to deal with new challenges were often reflected in fitness to landscape strategies identified. The cases also reiterated the interconnected nature of different aspects of cluster developments, whereby cluster dynamics was influenced by cluster conditions and new complexities due to contextual changes (and their drivers of change), and these in turn, influenced cluster dynamics and cluster transformations. Insights from the three cases on cluster dynamics is formulated as follows:

> *Cluster dynamics, reflected in attractors, fitness to landscape strategies and significant differences leveraged for new path creations, are responses to contextual changes, which in turn, contribute to cluster transformations.*

Cluster transformations are the next aspect of cluster developments to be discussed. This aspect has two parts, namely, transforming interactions and emerging systems patterns. The term 'cluster transformations' replaced the original concept of cluster performance as the former captures more accurately the nature of changes in complex cluster developments. Each of the cases is highlighted in the next paragraphs in terms of their transforming interactions and emerging systems patterns.

Karlstad and Region Värmland were concerned about competitiveness of their current and future clusters. Local governments used funding policies to support new types of collaborations. Region Värmland initiated ten new professorships strengthening university-industry linkages, whilst Karlstas Municipality used funding policy to promote deeper inter-cluster collaborations. Local government policy was therefore instrumental to new collaboration patterns. Establishing a new Grants and Innovation Office at Karlstad University was another visible shift that facilitated university-business linkages. In addition, new fields such as bio-medicines were emerging due to shifts towards sustainable forest resources (attractor movements). These developments meant that new knowledge and partners were needed and as such, new business and research developments were expected in the future. The need for new labour pools skilled in new technologies resulted in an industry driven technology skills centre. Expansion of scope and activities of clusters and existing industry (connecting to 'outside'), new business developments, and sustainability focus were visible macro level shifts in Karlstad's developments. The role of policy and stronger industry-government-academia collaborations in Karlstad were important visible systems shifts of its cluster and regional developments.

Silicon Valley's cluster developments of transforming interactions were most visible when Stanford's strategy of firm and industry formation took off. However, early developments in the mid-nineteenth century already showed how organizing patterns of small entrepreneurial firms resulted in engineering innovations bridging long distances for water, and later power and radio waves. Stanford's success with the Federal Telegraphic Corporation was the start of 'waves' and 'spirals' of innovation in technology, and later, in financial and mentoring support for start-ups. New firms, clusters of firms, new industries and combination of industries and sectors were all part of visible transforming interactions and collaborations throughout Silicon Valley's developmental phases. The breaking down of boundaries between different 'realms' resulted in innovations such as double and triple helix arrangements, the Science Park, 'proto firm' and 'pre-competitive' cultures of free knowledge flows, venture capitalism for regional growth and transformation (Technology Transfer Office, Industrial Liaison Programmes), and later, in new forms of transformative collaborations such as Hackathons, code camps, matching events, etc. Silicon Valley's cumulative convergence of social ties, networks, technological advances, technology and entrepreneurial paradigms contributed to its spiralling success that transformed the cluster into a global 'entrepot-dok' that brought with it new international networks, financial, intellectual and human capitals. The various transforming interactions and resulting patterns of collaboration contributed to emerging systems patterns in Silicon Valley's different stages of development. Stanford, followed by other stakeholders, pursued a pattern of connecting to, and often, committing to Silicon Valley's regional growth. Strong social and knowledge development ties were also important emergent patterns in the cluster's development. The commitment, belief and strategies in research and technology driven innovation and dynamics of start-up as basis for firm and industrial developments were examples of emergent systems patterns. Other examples were establishment of innovative ecosystems with supporting processes of technology and financial development; shifting entrepreneurial nature and culture; parallel developments of fundamental knowledge and technology innovation coupled with bridging and cross-border developments; institutionalization of 'matching' activities and mentoring by venture capitalists and business angels; and the shift from regional motors of innovation and cluster developments to exogenous (global) motors of growth and development. There were however concerns related to Silicon Valley's emergent systems patterns of diminished focus on indigenous human capital development, over-reliance on international assets, reduced government expenditure and growing individualistic entrepreneurship cultures. These developments were contrary to Silicon Valley's past successes that had been built on regional developments drives. Silicon Valley's future path developments were not without risks due to its reliance on strongly interconnected global ties and developments. The interconnectedness and complexity of cluster developments related to internal dynamics and contextual changes were shown in Silicon Valley's developments.

Energy Valley's visible results of its transforming interactions and emerging systems patterns were seen in the formation of new institutions and innovation spaces for energy transition challenges in the form of Energy Academy Europe and EnTranCe at the cluster level, and at the regional level, examples are North Holland's Energy Board and Drents Energy and Climate Change Platform. These innovation spaces focussed on energy, facilitated academic and industry linkages to resolve energy transition challenges. New collaborations across disciplines and economic sectors were also evident in the search for new energy sources and applications, examples being bio-fuels, biomass for power plants and gas, blue energy and e-mobility. Other examples of transforming interactions and new collaborations on energy were trans-regional initiatives with Northern Germany and the North Sea region. There were also new connections in energy that crossed boundaries, examples being between gas and electricity, and between fossil and renewables, whereby new grid infrastructure developments were central to these interactions. EnTranCe was specifically set-up to help support industry prepare for future infrastructure demands in the sector. New interactions and collaborations between new energy stakeholders, traditional energy and regional development agencies were also visible, and formed part of Energy Valley's strategic developments. However, other developments arose outside these formal developments and were embraced by Energy Valley Foundation. Digital theme based communities were facilitated by the cluster organization to meet the growing diversity and numbers of such communities. New initiatives, communities and stakeholders in Energy Valley included local citizen and consumer movements, energy transition parks, NGOs, farmers, etc. New interactions were also seen in changing relations between citizens, businesses and energy corporations whereby the producer-consumer, 'prosumer', was an example. Growing local and regional energy initiatives and grassroots movements were new interaction and collaboration patterns emerging outside of traditional market developments. The liberalization of energy markets gave consumers more choice and resulted in competitive pricing and more sustainable energy offers (demand-driven market developments). This last development supported the rise of decentralized energy sources and infrastructure developments, partly fuelled by growing concerns about energy security and affordability and related needs for autonomy. A shift in perceptions of citizens of the government's caretaker role was evident due to earthquake damages, ensuing risks, and inadequate responses by the energy corporations and the national government. The issue of trust was therefore important in the cluster. Latent distrust of the national government prevailed, due to its peripheral disadvantaged position in national priorities, fuelled by the earthquake affair. Local and provincial governments were closer to citizens and were deemed to be trustworthier than the national government. Another shift in interaction patterns was that there were more intensive and joint efforts related to energy and energy transitions within and between knowledge institutes, and between energy knowledge institutes and industry. Similarly, joint and integrated policy vision and collaborations between the four provinces were also results of transforming interactions to meet energy transition and regional development challenges. Energy Valley therefore saw diverse initiatives of both public and private initiatives that resulted in new interactions and collaborations, which were reflected in its systems patterns. Emerging systems patterns of Energy Valley reflected increasing complexity due to increased number of new interactions and initiatives and growing interconnectedness of energy sources and infrastructure. In addition, more consistent attempts to facilitate and develop 'ecosystems' for knowledge-based innovations were also new systems patterns as a result of policy efforts to develop joint and integrated vision on supporting innovations on energy transition and improved quality of life for its citizens. Energy Academy Europe and EnTranCe were such examples as mentioned earlier. Moreover, EnTranCe focussed on value chain and whole systems developments to promote shared sustainable energy transition strategies. These systemic and cumulative developments in Energy Valley were also communicated and connected to national energy agendas. Broadening energy and regional developments agendas to more issue-based, cross-sectoral themes, seen in 'Bio-based economy' developments, were also emerging systems patterns in Energy Valley. Another emerging pattern was shifts in the cluster's scope and scales. The cluster saw a shift from regional focussed scale to include enlarged scales (trans-border, EU) and local scales (citizen initiatives, farm-scaled bio-gas developments). This acknowledgement and room for small and local scales, and for large and more trans-regional and European scales, were important shifts in its cluster systems developments. Energy Valley's shift from a regional initiative to maintain its energy expertise to a strategic partner of the

Dutch government on energy transition developments and partner in North Sea Region to develop the region into a EU Region of Excellence reflected enhanced scope, visibility and ambitions of the cluster. Other emergent systems patterns included the rise of self-organized initiatives, different policies of the Provinces, and emergence of new sub-clusters and energy communities. These patterns showed Energy Valley's transformation from a gas-dominated, centrally driven cluster to a complex, interconnected system of diverse stakeholders and developments, seeking collective answers in the face of urgent challenges by private and public stakeholders.

The three cases showed how cluster developments were intertwined with regional and external developments, and interactions of key stakeholders were crucial to their developments. In this, national and regional government's role and degree of support were also shown to be significant to clusters developments. Growing complexity in cluster developments through expansion of cluster scope, scale and strategy, and contextual changes, showed emerging developments of new systems patterns of sub-cluster formations and closer interactions between academia and industry, and linkages beyond the cluster. In the case of Energy Valley, local self-organized citizen initiatives were also becoming a part of the energy cluster where new 'prosumer' developments and need for autonomy and self-sufficiency were present. Although cluster systems developments are directly linked to transforming interactions, these developments were also directly linked to cluster dynamics and contextual changes that preceded transforming patterns of interactions. The original proposition based on Energy Valley's finding was therefore enhanced to include these insights based on the three cases:

> *Transforming interactions in cluster developments, as a result of changing cluster dynamics often include shifting sensemaking processes of stakeholders, resulting in emergent systems patterns of shifts in scope and scale of activities, and roles of stakeholders, increased cross-over collaborations in knowledge and industry developments, and emerging sub and new cluster formations, which cumulatively reflect increased interconnectedness and complexity in macro level systems patterns.*

Insight into cluster transformations reinforces the proposition on related overlapping and related systems developments in acknowledging the interconnected nature of systems developments.

*Clusters are embedded in related and overlapping systems interacting and influencing cluster developments.*

The three cases showed how cluster developments were interconnected to developments between/amongst sectors and region; region and nation; local, regional, national, (European) and global levels, namely, interconnectedness of multi-level and overlapping developments of sectors, technologies, regions, etc. In the light of previous discussions and evidence, this 'insight' into related and overlapping systems is therefore not discussed further and is taken as it stands.

Similarly, the next proposition on top-down and bottom-up processes has also been mentioned in discussions of other aspects of cluster development and is therefore only discussed briefly here. The role of policy and centralized steering as opposed to self-organizing processes in cluster developments was present in all three cases. Energy Valley and Karlstad showed how policy interventions played an active part in cluster developments through funding and joint policy initiatives, whilst in Silicon Valley, the government's role was indirect but significant due to the large public contracts and funding of research projects driving Silicon Valley's success up to its renewal phase. Contextual changes and ensuing challenges triggered self-organized processes and initiatives in both Silicon Valley and Energy Valley. In Karlstad, spin-off cluster developments and developments in new fields of research seemed to also indicate self-organized developments although more data would be needed to draw any conclusions. In both Silicon Valley and Energy Valley, strong presence of both top-down and bottom-up processes were present as a result of growing complexity and scope of their developments even as these processes contributed to these developments. This insight did not change the original proposition and is captured as follows:

*Cluster developments are influenced by both top-down steering and self-organizing processes.*

The final Lesson from Energy Valley was the systems-in-systems parallels of cluster developments. The cases of Karlstad and Silicon Valley did not provide specific insights into such developments but the original proposition has been adopted with the proviso that this needs further verification in future studies.

*Clusters reflect systems-in-systems developments such that parallel and differing emerging patterns prevail due to similarities and differences in the different systems levels.*

**Overview of the 'insights into cluster systems developments'**

(Also in main thesis)

| *Cluster aspect* | *Insight into cluster systems developments* |
|---|---|
| *Changing context* | *Cluster developments are interconnected to developments in the region and the larger context, and become increasingly complex due to internal and external drivers of change, and different responses of stakeholders.* |
| *Cluster condition* | *Initial conditions of container, stakeholders and path dependent factors are important in determining subsequent cluster developments whereby dominance of one or more stakeholders or path dependent factor could increase risks of lock-in where limited external linkages are present, or if there are too many differences, a risk of diffused cluster developments exists.* |
| *Cluster dynamics* | *Cluster systems respond to changes in the context, reflected in attractors, fitness to landscape strategies and significant differences leveraged for new path creations, which in turn, contribute to cluster transformations.* |
| *Cluster transformations* | *Transforming interactions in cluster developments, as a result of changing cluster dynamics often include shifting sensemaking processes of stakeholders, resulting in emergent systems patterns of shifts in scope and scale of activities, and roles of stakeholders, increased cross-over collaborations in knowledge and industry developments, and emerging sub and new cluster formations, which cumulatively reflect increased interconnectedness and complexity in macro level systems patterns.* |
| *Organizing processes* | *Cluster developments are influenced by both top-down steering and self-organizing processes.* |
| *Related (horizontal) systems* | *Clusters are embedded in related and overlapping systems that interact and influence cluster developments.* |
| *Embedded systems (systems-in-systems)* | *Clusters reflect systems-in-systems developments such that parallel and differing emerging patterns prevail due to similarities and differences in the different systems levels.* |

# 15.OVERVIEW OF PRESENTATIONS AND PUBLICATIONS

| Presentation of Research | | |
|---|---|---|
| **Presentations – LSBU Summer School** | **Title** | **Year** |
| Paper | Energy Valley Cluster and Internationalisation | 2010 |
| Poster | Five Approaches to Cluster Theory | 2010 |
| Paper | Drivers of Change and Cluster Dynamics | 2012 |
| Poster [2nd Prize awarded] | Exploring Drivers of Change and Cluster Dynamics: Case Study of Energy Valley | 2012 |
| Paper | Cluster dynamics and drivers of change: a case study of Energy Valley | 2013 |
| Poster | Clusters as Complex Adaptive Systems: what strategy in Energy Valley | 2013 |
| Paper | Dynamics of Cluster Development: Lessons from Energy Valley Cluster | 2014 |
| Poster | Cluster Development: Insights from Energy Valley Case Study | 2014 |
| Paper | Local Energy Systems – Lessons from Energy Valley, Netherlands | 2015 |
| Poster | What is Changing in Energy Valley Cluster & How is This Influencing its Developments | 2015 |
| **External Presentations** | **Title** | **Year** |
| Policy officials, Kuala Lumpur, Malaysia | Dutch Energy Cluster: How 'wicked' is it? | 2010 |
| SIRIM, Kuala Lumpur, Malaysia | Energy Valley – Cluster Development: Strategy Development | 2010 |
| Hanse Reinvented Conference, Netherlands (co-presentor) | International Business Networks & Northern Europe: Emerging New Perspectives | 2010 |
| Policy officials, Ministry KeTTha, Kuala Lumpur, Malaysia | Collaborative Approaches to Energy and Greening Initiatives | 2011 |
| Energy sector stakeholders & Policy officials, Kuala Lumpur, Malaysia | Expert Session on Future of Energy in Malaysia: How Different is it from Dutch & EU Developments and what Lessons to be Learnt? | 2013 |
| Policy officials, Ministry KeTTha, Kuala Lumpur, Malaysia | Developments in Energy Valley, the Netherlands & EU | 2013 |
| 4th year Bachelor students | (Action) Research: Wicked Problems | 2013 |
| Joint Annual North Sea Conference, Halmstad, Sweden | Clusters and how to make it work: Toolkit for a cluster strategy | 2013 |

| | | |
|---|---|---|
| Europe Regional Conference, Amsterdam | Cluster Toolkit | 2013 |
| RSA-UCLA Joint Conference, Los Angeles | Energy Cluster as 'Wicked' and Complex – Insights from Dutch Energy Valley Case Study | 2013 |
| Hanze Knowledge Café – Energy, Groningen | Dynamics of Energy Clusters – Energy Valley: Region and Energy Transition – Shifting Landscapes | 2014 |
| RSA Conference, Izmir, Turkey | Dynamics of Cluster Development: Lessons from Energy Valley Cluster | 2014 |
| Women4Energy Conference, Stuttgart, Germany | Energy Clusters in Context – Complex Adaptive (Innovation) Systems | 2015 |
| **Publications** | **Title** | **Year** |
| Chapter in *Results Opening Up Report 2011-2014,* Hanze Publication | Clusters and How to Make It Work: Cluster Strategy Toolkit (co-author) | 2014 |
| Chapter in *Results Opening Up Report,* Hanze Publication | Using Social Media to Support Cluster Development (Working Paper, co-author) | 2014 |
| Chapter in *A New Take on Energy*, Hanze Publication | Contextual and Systemic Forces in Energy Valley, The Netherlands | 2015 |
| Chapter in *New Economic Realities* | The Complexity Challenge: A New Strategy Approach in an Unpredictable World (in development, co-author) | Expected 2017 |

## Anu Manickam

Anu Manickam explored the increasing complexity of cluster developments through the detailed case study of Energy Valley and two supplementary cases of Paper Province and Silicon Valley. The research describes how clusters are interconnected to broader contextual developments at local, regional, national, European and global levels. The research brings together insights from Regional Innovation Systems, Evolutionary Economic Geography and Complex Adaptive Systems scholarships to develop a whole systems approach to understanding cluster dynamics and related systems. The doctoral thesis offers 'lessons' from Energy Valley that includes understanding cluster and energy transition developments as part of broader interconnected systems developments.

Hanze
University of Applied Sciences
Groningen

HANZE-17_1414