Handling the Crowd

An Explorative Study on the Implications of Prosumer-Consumer Communities on the Value Creation in the future Electricity Network

Dissertation

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Mit der Annahme einer Dissertation beabsichtigt die Wirtschafts- und Sozialwissenschaftliche Fakultät der Universität nicht zu darin enthaltenen wissenschaftlichen Meinungen der Verfassers Stellung zu nehmen. (Fakultätsbeschluss vom 23. Januar 1990

„You never change things by fighting the existing reality. To change something, build a new model that makes the existing model obsolete.”

\- R. Buckminister Fuller -

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Fribourg, July 2016

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List of Abbreviations

AC	Alternating currency
ADA	Advanced distribution automation
AMI	Advanced Metering Infrastructure
CE	Crowd Energy
CHF	Confederation Helvetica Franc
CHP	Combined Heat and Power
CO_2	Carbon Dioxide
CPP	Critical Peak Pricing
DC	Direct currency
DER	Distributed Energy Resources
DG	Decentralised Generation
DMS	Distributed Management System
DNI	Direct Normal Irradiance
DR	Demand Response
DRM	Demand Response Management
DS	Decentralised Storage
DSM	Demand Side Management
DSO	Distribution System Operators
EDF	Électricité De France
EEG	Erneuerbare-Energien-Gesetz
EEX	European energy exchange
GDP	Gross Domestic Production
GHG	Green House Gas
GWH	Giga Watt per Hour
ICT	Information and Communication Technology
iGSL	Intelligent Generation-Storage-Load
KEV	Kostendeckende Einspeisevergütung
kW	Kilo Watt

kWh	Kilo Watt per hour
kW/y	Kilo Watt per year
LP	Linear Programming
LPL	Linear Programming Language
M	Mean
MAS	Multi-agent system
M&S	Modelling and Simulation
MCF	Minimum Cost Flow
MIP	Mixed Integer Programming
MLP	Multi-level Perspective
NaS	Sodium sulphur
NVA	Network Value Analysis
PV	Photovoltaic
RES	Renewable Energy Sources
RTP	Real Time Pricing
SA	Smart Applications
SCM	Supply Chain Management
SD	Standard Deviation
SGAM	Smart Grid Architecture Model
SLP	Standard Load Profile
SNA	Social Network Analysis
STS	Socio-technological System
TOU	Time of Use
TP	Time Points
TSO	Transmission System Operators
TSP	Travel Salesman Problem
UK	United Kingdom
VAT	Value added taxes

1 Introduction

„*We can do everything – even 100%*" (Janzing, 2011) is a manifestation to accept challenges of unrestrained and unsustainable handling of electricity in society. The manifestation demonstrates a terrestrial project, the energy turnaround, intending to re-design an entire industry on economic, political, and social levels. The transition was nudged by environmental pollution or nuclear accidents in Fukushima questioning sustainability of electricity networks. The growing public awareness of electricity production and consumption starts to modify the acceptance of climate damaging production units as nuclear or thermal power plants are increasingly in the spotlight of critics. Recent undertaken efforts like the last climate conference in Paris in 2015 are signals and reinforcements to reduce CO_2 emissions or to abolish energy forms (i.e. nuclear exit). These efforts are not solely concessions on paper which show the example of economic disinvestments initiative in coal (Henn & Dubois, 2015), respectively announcement of Allianz (Esser, Hua, & Morawietz, 2015). Big challenges are ahead due to decades of neglected care and attention.

The challenges cause ramifications on existing electricity industry and current vivid discussions demonstrate the need for a vision of future network as well to perform transition to the next stage. For that purpose, stakeholders define the concept of a Smart Grid. In general, it describes a synchronised production and consumption of electricity through advanced metering and digital information and communication technologies. The concept plans a vast scope of actions and for example intends a reconfiguration of the macro level (Verbong & Geels, 2010). Leaving electricity industry pretty much unchanged, on a micro level – mainly demand side contribution – experiences a radical change and is important to achieve strategic objectives (BFE, 2013). Thereby, the major objective is the integration of the black box "consumption" to build a holistic and continuous value network. To this end, technical connection and information exchange are central topics for sustainability, reliability, and performance. Initial ideas tackle integration by introduction load management programs to peak, fill, or shift demand and balance with production capacities (Bellarmine, 2000). However, load management is a single aspect and further views must be added.

The addressed 100% refers to a total electricity production from renewables redefining the regional value creation. This requires more advanced concept of micro-grids and implies a re-decentralisation and promotion of on-site production. With cellular structuring, a profound integration is expected and simultaneously promotes dramatic implications in the low-voltage network. The result is a complex, interconnected, interactive, and adaptive network. An essential driver is a recognisable decentralisation trend supported by internal technological developments in the electricity sector, e.g. photovoltaic, and external influx of information and communication technologies (ICT). The latter one introduces new possibilities of value creation but also implicate different mind-sets for innovation. Furthermore, value capturing opportunities expands to other participants e.g. communities (Nürnberger, 2015). Such novel factors implicate a commotion in the current electricity system causing a transition pathway of de- and re-align the supply chain (Verbong & Geels, 2010); thereby the de-alignment expresses the disengagement of traditional concepts and mind-sets. This kind of socio-technological transition is a continuously incremental approach rather an upfront planned schedule. In the emerging uncertainty, struggles for power is common and influence transition as stakeholders act in favour of own interests. An authoritative part has the suppliers' and distributors' side (later called also called electricity provider or only provider) defending their existing revenue stream of selling quantity. The opposing attitude of providers to the Smart Grid concept brings controversial contributes to discussions. Providers accelerate load management objectives to reduce electricity waste keeping influence of demand side under control. Simultaneously, an improved consumption behaviour cuts of lucrative stream and would throttle own profit. The willingness of profound alterations from provider side must be questioned.

Consequentially, present disputes are predetermined and lack on a sufficient consideration of future consumer role and accompanied duties and rights. The technological decentralisation entails that consumer strengthen their position in the value network by investments in production and storage equipment. By becoming a prosumer, temporary independency diminishes claims from the overall grid (Teufel & Teufel, 2014). Such an individual independency is greatly feared, but will undoubtedly occur. It would also be folly to state that there will be at one side independent individuals and at the other side the overall grid. It is likely that centralised and decentralised elements exist and incorporate for a sustainable network. Nevertheless, the appearance of prosumers permanently modifies the network and especially value creation because of a different behaviour contrary to business driven counterparts. New relationships and decision making patterns emerge and sharing of electricity and information reshape traditional constructs. Meanwhile, the dominance of intangibles, e.g. knowledge or internal structure, modifies value creation and stakeholders depend upon the connectivity to and among demand side. Thus, research from a prosumer perspective is highly recommendable.

For that reason, this dissertation elaborates on the new research field of Crowd Energy (Teufel & Teufel, 2014). Crowd Energy takes the micro-grid concept further and investigates upon so called intelligent generation-storage-load cells (iGSL) (Teufel & Teufel, 2014). These three cell functionalities provide a range for actions in regard to produce electricity surpluses and hence to sustain own demand or support neighbouring cells through delivering electricity. By pooling functionalities of several houses, collective effort creates a virtual crowd. This provides several advantages. First, a crowd approach improves resource allocation between surplus and shortage locations but also allocation through time. Furthermore, the local to local principle shortens the transportation distance and hence the losses for transformation. Secondly, the local flexibility of exchange provides reliability for the overall grid. In case of black outs, crowds can preserve availability through self-produced electricity. Additionally, crowd resources can provide storage space to balance load. These arguments proclaim an advanced technical, automated integration similar to the crowd sourcing methods but extend these approaches by including social related subjects. A last advantage of Crowd Energy is the consideration of human behaviour to influence cell functionalities and consequential the dynamics of a crowd. Subjects like sharing behaviour, decision making patterns or trust and commitments, are decisive for creating and maintaining crowd structures as well for completing successful demand side integration.

The bottom up approach of a Crowd Energy is a new research field and requires investigations to answer basic questions. A major area is designing the future electricity value network under a Crowd Energy paradigm. Important points are of peculiar interest: role description of prosumers, position in the value network, types of relationships and value creation through prosumers respectively crowds. Latter point contains several significances due to value creation through tangible and non-tangible assets and hence related quality of outcomes. Another question is potential outcome of crowds in terms of electricity production. There are several simulations of micro-grid contributions, mostly in the light of top-down views (Baños et al., 2011), but the crowd-based concept focuses on optimal exchange among members. So, the potential of exchange considers minimisation of transportation and is an indicator for independency of the crowd in the value network.

1.1 Research Methodology

Investigations in design, strength, and potential of crowd-based value networks require pioneer work to introduce a new perspective on the electricity industry. The new concept applies and integrates various aspects like technical (e.g. micro-grid structure), social (e.g. sharing), and processual (e.g. crowd sourcing). The combination of these aspects permits to elaborate a different understanding of future electricity production and consumption with a central focus on a local production-consumption principle. Along with this new research field, many research questions occur that require immediate attention. The amount of questions and directions tempt to start randomly and the familiarity of research subjects misleads to do it without considerations. A professional research strategy to gain insights is hence beneficial.

The object under study is Crowd Energy, which does not exist yet, and implies that implementation and behaviour of a community in a system are uncertain or ambiguous. In particular, the idea of communities alters value network design defining new technical integration, information exchange routines, and responsibility of individuals. Such a temporarily involvement through customisation is already known in practice and literature, but a permanent integration of the prosumer role shifts value creation process beyond recognised concepts. For example, prosumers provide production and distribution for themselves and simultaneously are responsible for functioning of a larger infrastructure – the crowd. Prosumers are located between individualism and community thinking. This controversy affects decision making of self-produced electricity: keep it or share it. Those choices will also be based on business but social factors. Research can follow certain theories to define and explain Crowd Energy, however, a profound picture of the situation is missing as well as directions for future needs to be uncovered. Such a research problem proclaims an explorative research design and this dissertation investigates Crowd Energy from a community perspective.

An exploratory research design applies on research problems with few or no earlier studies for referencing or undertaken when concepts are in a preliminary stage (Cooper & Schindler, 2008). Preliminary stage includes that theories and concept are not established. The exploratory idea has inherent characteristics (Cooper & Schindler, 2008). Research objectives are among others familiarity to gain background information on a particular topic, provide further research questions and directions, addresses research questions of all types (what, why, how), and to define new terms and clarify existing concepts. On the contrary, exploratory studies utilise small sample sizes and hence results cannot be generalised. Additionally, the explorative nature provides firsts insights in fields and inhibits to make definitive conclusions about results. A certain freedom and flexibility underpins the process causing often to an unstructured methodology. This leads to tentative results which has limited validity. In comparison, descriptive research, where a clear formalised standard exists, forces to define hypothesis or investigative questions, verify them, methods for gathering data, and analysis (Cooper & Schindler, 2008). Thus, it is necessary to secure research quality of explorative studies by clarifying the procedure in detail.

The dissertation follows a deductive approach which is the process of reasoning from one or more statements to reach a logically certain conclusion (Snieder & Larner, 2009, p. 16). Reasoning is from top to down starting with a theory and leading to new hypothesis or investigative questions. On this regard, deductive approach for an explorative study relies on a profound description of the underlying situation, reference to future scenarios or trends, and statement of shortcomings in the current discussions. Furthermore, the background must provide the object of study (i.e. the new concept Crowd Energy) and the research perspective for further investigations. The outcome of the background is requirements for the framework and later on discussions. Thereafter, research questions are deduced from the background and are formulated in operational terms. Operational refers to provide arguments for research importance. The verification of questions lies in the discussion of future trends and the examination of secondary data.

A next step involves exploring known literature to explain characteristics, interrelationships, and behaviour of the research object. This is done as exploratory provide new insights but do not necessarily must develop new theory (Thornberg, 2012). In other words, the new concept alters profoundly existing knowledge rather replacing it entirely (Thornberg, 2012). Further argument is that the object under study does not exist in a vacuum and close related general theories are a starting point for establishing insights (Thornberg, 2012). So far, used language is descriptive meaning that reasoning describes the actual, sometimes unconscious rules of existence.

From the gained knowledge of background and general theories, a framework is established and outlines variables for further statistical investigating. The language becomes prescriptive defining future goals and purposes of the object under study – how it should be. Arguments and requirements are deduced from background and theories. The proposed factors are tested by applying relevant quantitative or qualitative method(s). Generally, exploratory studies are often classified as qualitative research according to the way of gathering information (e.g. secondary data analysis, experiences surveys, or focus groups) (Cooper & Schindler, 2008, p. 146). Subjectiveness, non-representativeness, and non-systematic design produce biased results and minimise quality of outcomes. Criteria for quality depends on designing and executing research, but also quantitative techniques can additionally reduce biases by using statistics and more structured techniques.

The above mentioned scientific process is related to real phenomena and hence follows the critical rationalism approach (Popper, 2002). Rationalism emphasises theoretical thinking whereas critical indicates the ability to falsify statements. The critical rationalism is a synthesis of rationalism (i.e. insights are gained by deduction based on rational premises) and empiricism (i.e. insights are gained by induction through observations).

Figure 1: Scientific research approach of this dissertation

Despite regarding different sources of knowledge, both approaches have similarities and the idea of exclusive deduction or induction is outdated (Kornmeier, 2011). The results of a critical rationalism process concern with the real phenomena and involve practical applicable results. As a consequence, the dissertation follows the tradition of Schmalenbach (Schmalenbach, 1911/1912) rather Rieger's position of a strictly theoretical science (Rieger, 1984). The tradition defines empirical facts is translated in practical normative recommendations. Both, scientific process and results, requires being coherent. A synthesis of critical rationalism and normative recommendations is proposed by (Brodbeck, 2007) and defines descriptive-empirical approach resulting in normative recommendations for action. The dissertation follows this approach and is summarised in Figure 1.

1.2 Aims and Objectives

The perspective of a community defines an in-between position of individuals and traditional roles of electricity producer or distributors. Finding conclusions about crowd-based networks have to investigate in two directions. First, a value network view describes general relationships of community with the rest of the value network. This includes structure of the future value network defining the roles, relationships, and exchange types. The second view focuses on internal features of a community. In particular, two main features can be noticed a) cooperation among members (i.e. strength of communities) and b) exchange of electricity to become independent from external linkages (i.e. potential of communities). Strength is the possibility of prosumers to convert tangible and intangible assets into deliverables whereas potential states produced, stored, and exchanged electricity of crowd members. The latter is important to support leverage of communities in the value network in the light of future electricity strategies according to (BFE, 2013). Therefore, aims of this dissertation can be summarised in three main and several sub-questions:

1) What does the design of the new value network in a Crowd Energy paradigm look like?
    a) How is a community interrelated with other roles?
    b) What values are exchanged between roles?
2) How does a prosumer define the conversion of tangible and intangible assets into deliverables?
    a) What are the factors for assessing asset conversion?
    b) How does a prosumer evaluate the conversion of assets?
3) What is the potential of Crowd Energy?
    a) Which production and storage potential can a crowd achieve?
    b) What is the effective electricity exchange rate within a community?

The above aims will be accomplished by fulfilling the following research objectives:

- Review literature elaborating requirements for future electricity by describing current market situation, trends in the industry, and the shortcomings in discussions.
- Provide a description of the Crowd Energy concept and arguments for research questions.
- Formulate theoretical background explaining activities for an integrated value network management philosophy.
- Establish a crowd-based value network framework by considering requirements and theories. The first contribution is a holistic value network including description of roles, types of value exchanges, and behaviour. The second contribution focuses on strength of a crowd (i.e. coherency of a crowd) and defines factors assessing prosumer's conversion of tangible and intangible values into deliverables. The last contribution describes factors for the potential electricity exchange among crowd members.
- Investigate in perceptions and attitudes to assess crowd strength from prosumers perspective by using statistics. Answers are given to factors like storage management, willingness to be part of a crowd, decision patterns for storing or sharing of self-production, value and price of self-produced electricity, and challenges for crowd participation.
- Calculating electricity production and storage as well as optimising exchange based on real consumption and production data. Comparing current and future scenario. The scenarios involve winter, summer, and transition periods.
- Drawing conclusion about a Crowd Energy value network and provide recommendations for further research in the field of Crowd Energy.

1.2.1 Outline of the Thesis

The outline of the dissertation addresses research design requirements as well as aims and objectives. The chapters address different scientific research steps (see Figure 1) and hence an interlinked outline emerges. An overview of the thesis structure is summarised in Figure 2 and will be discussed in the following paragraphs.

Chapter 2 introduces to the field of research by describing the current electricity markets in Europe and highlights the current characteristic of the industry. Based on these features, the chapter discusses the next evolutionary step of Smart Grids and the implications for the low voltage layer transition to create a sustainable electricity network. Especially, the concept of micro-grids has tremendous implications by bundling a clear defined local area of consumption and production loads to a single controllable entity. This creates a more complex, interconnected, interactive, and adaptive network and causes a realignment of the supply chain. Present disputes about the concept of micro-grids are flawed and a need for further investigation is necessary by the reasons of insufficient consideration of the future consumer role, value creation from tangible and non-tangible assets, and the level of decentralisation.

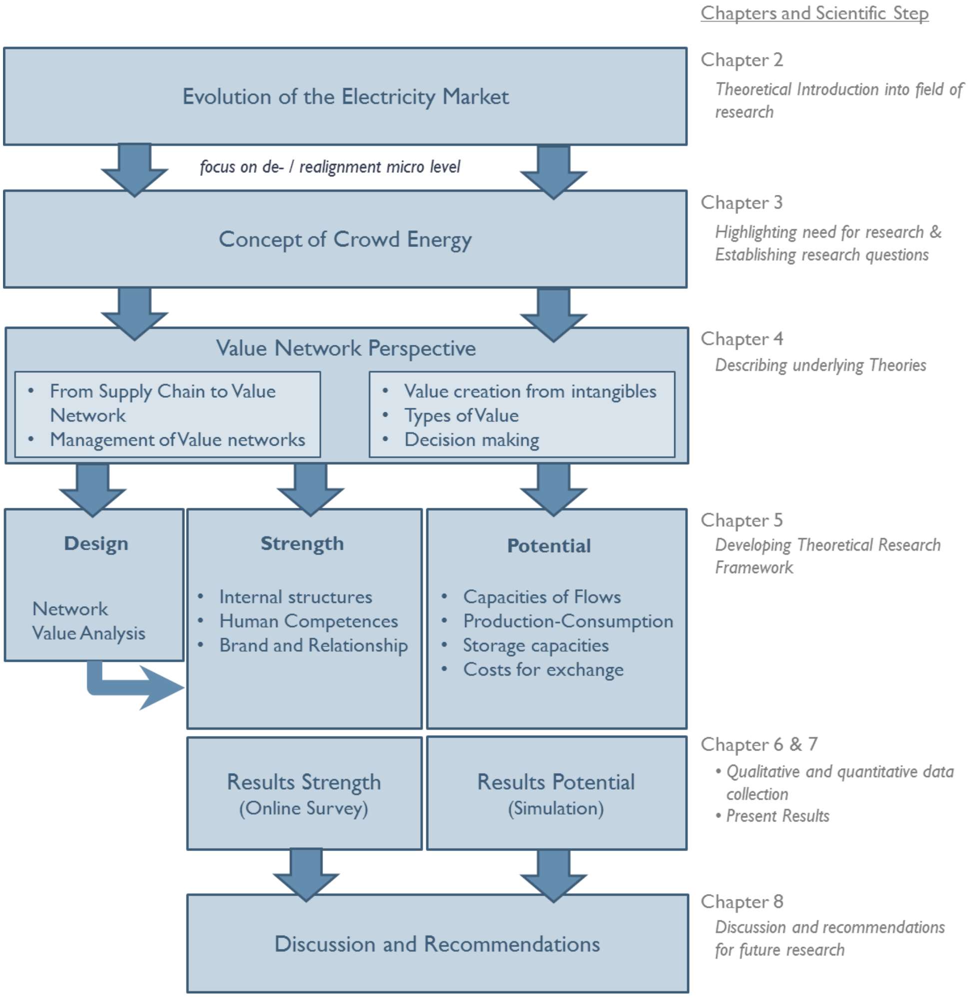

Figure 2: Outline of dissertation chapters according to scientific approach

Chapter 3 introduces the Crowd Energy concept as a possible solution for eliminating the shortcomings addressed. Crowd Energy is a new and interdisciplinary research field. The chapter elaborates on the basic idea of Crowd Energy and the intelligent generation-storage-load (iGSL) structure, and the emerging prosumer role that produces and stores electricity. The need for research is highlighted in this chapter by discussing the effects on a value network. In particular effects are discussed on the overall design of a crowd-based value network including value creation, and the strength and potential of a crowd. As a result, the chapter ends with a list of important research questions addressing a) design of the future value network and b) the strength and potential of a crowd generated by electricity exchange among members. These research areas are described separately due to the different theories and methods used.

Chapter 4 describes the underlying and essential theories which support the framework. The chapter starts with development from a supply chain to a value network approach to highlight crowd-based value network characteristics and management principles. Subsequently, this chapter elaborates on value networks by discussing both elements separately – value and network design. This involves among other things, a description of roles and connections, context for exchange, and changing exchange content by adding new types of value. In particular, the chapter turns its focus to the social roles of the prosumer and value conversion from tangible and intangible assets to deliverables; therefore the decision making process is a crucial element.

Chapter 5 builds upon the theoretical backgrounds and establishes a framework for further investigations. The stated framework is the conceptual contribution to the field of research. The absent of crowd structures in the electricity industry does not permit to study the object under real environment. Thus, the prescriptive language of network value analysis (NVA) supports to describe a possible future situation of roles and types of linkages according to established background and theories. The chapter develops a conceptual Crowd Energy value network to provide a context in which a crowd structure acts. The outlined value network is a possible scenario and a verification of the new value network design is not further supported by a research method. Nevertheless, the crowd-based network provides the context for investigation into strength and potential. The chapter defines factors for strength which is the ability to create value from tangible and intangible assets. Strength is a prosumer perspective and an assessment requires the adaption of the strategic conversion model respectively the inherent factors internal structure, human competence, brand and relationship, and financial assets. The last part of the framework concerns with the potential of crowds and refers to the asset electricity. Potential describes the capability of exchange self-produced electricity among crowd members and simultaneously reduce dependency from external suppliers. Thus, the chapter formulises appropriate factors like capacity of different flows, production performance, generated surplus, and capacity to store electricity. The described factors are applied, analysed, and discussed in the following chapters.

Chapter 6 deals with the crowd strength. The chapter starts with a description of the online survey concerning with creation of questionnaire, response strategy, and integration to a holistic self-guided survey. Eventually, the results and findings of crowd strength are presented.

Chapter 7 illustrates the crowd potential. The chapter starts with a description of the abstract model for optimising transportation costs of electricity. Furthermore, the chapter presents the necessary input, parameters, and constants of the model. Eventually, the results and findings are presented. For that purpose, a simulation experiment with the minimum cost flow model of a transformer station in Spiez was executed.

Finally, chapter 8 opens up the discussion of results and conciliate both streams to generate a general picture of Crowd Energy value network. The goal is to present findings and by doing so to answer the proposed research questions. The chapter provides an outlook for further research.

1.3 Publications

During research at the iimt, several papers related to the topic of crowd energy are published.

Aldabas, M., Gstrein, M., & Teufel, S. (2015). Changing Energy Consumption Behaviour: Individuals' Responsibility and Government Role. *Journal of Electronic Science and Technology*, *13*(4), 343–348. doi:10.11989/JEST.1674-862X.505263

Craven, J., Derevyanko, E., Gstrein, M., & Teufel, B. (2015). Influence of Taxation on Supply and Demand in Tomorrow's Crowd Energy Paradigm. *Journal of Electronic Science and Technology*, *13*(3), 237–245. doi:10.11989/JEST.1674-862X.505011

Egger, S., Gstrein, M., & Teufel, S. (2015). Impact of Business Practices on Individual Energy Consumption. *Journal of Electronic Science and Technology*, *13*(4), 349–354. doi:10.11989/JEST.1674-862X.505242

Gstrein, M., & Teufel, S. (2014). The changing decision patterns of the consumer in a decentralized smart grid. In *11th International Conference on the European Energy Market (EEM)* (pp. 1–5). doi:10.1109/EEM.2014.6861216

Gstrein, M., & Teufel, S. (2015). Crowd Energy Management: New Paradigm for the Electricity Market. *Journal of Electronic Science and Technology*, *13*(3), 165–205. doi:10.11989/JEST.1674-862X.505091

Vereshchagina, V., Gstrein, M., & Teufel, B. (2015). Analysis of the Stakeholder Engagement in the Deployment of Renewables and Smart Grid Technologies. *Journal of Electronic Science and Technology*, *13*(3), 221–228. doi:10.11989/JEST.1674-862X.505121

2 The Evolution of the Electricity Market

This chapter describes the current situation and the development of European electricity markets. Both, the initial situation and the impact of development, outlines the shortcomings in recent discussions and highlights the arguments for a Crowd Energy value network. This chapter represents the environment of this research (see Figure 2).

The current situation of the European electricity industry in chapter 2.1 elaborates the characteristics of the electricity value chain and the three areas of production, distribution and consumption. It will be shown that European markets follow a top down approach and attach little importance to integrate demand side. Please note that a European perspective is chosen due to provide the largest maximum of electricity industry characteristics. A common definition is a difficult task due to the variety of electricity networks configurations in Europe. To ensure a certain amount of objectivity, the general features of an electricity market including the value chain, will be described according to the Swiss electricity market; thereby this market becomes a reference point. Any derivations from this reference point configuration in other European electricity markets will be outlined within the text.

The next evolutionary step of Smart Grids is descried in chapter 2.2 and highlights the implications for the low voltage layer to create a sustainable electricity network. In particular, the micro-grid concept transforms the perspective on decentralised production resources and the chapter outlines the critical factors for successful implementation and management.

The effects of micro-grids on the value network electricity is the integration of demand side in operations of load, however, the chapter 2.3 shows that shortages of discussions concerning subjects like degree of decentralisation, the new prosumer role, value creation, and address social and individual behaviour.

2.1 The Electricity Network Today

The electricity market is infrastructure based following the concept of building up infrastructure to handle capacities. By capacity, it is meant the existing demand. Thus, the development of demand is tightly connected with the size of the infrastructure. A current electricity infrastructure represents the result of a continuous and interminable process. Largely the infrastructure evolved in following steps (see Figure 3). Initially, the infrastructure contained so called single closed structures of “Block-/Stadtzentralen” each local centre supplies nearby collateral buildings with electricity, e.g. lighting of the city

Lausanne in 1882 (Haemmerle, 2001). Around the 19th century production and consumption was separated due to accessing more promising production locations, e.g. in mountain regions, to cover the increasing demand. By doing so, the development of a distribution network was initiated allowing short transports.

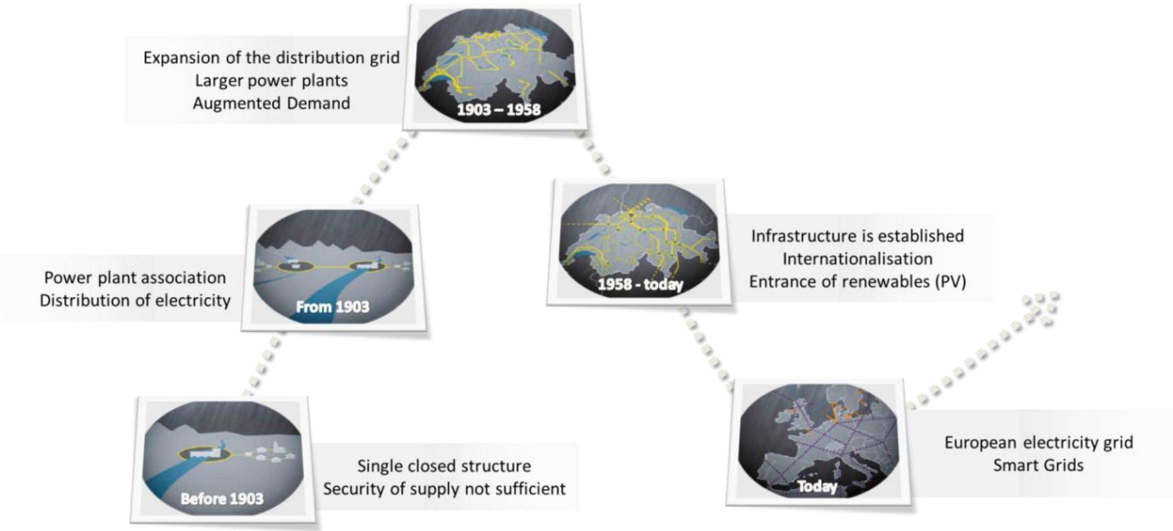

Figure 3: History of the Swiss electricity industry (adapted from Infel AG, 2010)

The expansion of the distribution network continued to keep abreast with demand several significant events happened which led to features of industry. The distribution network introduced higher national power lines capacities, so called transmission lines, with a current of 220 kV, respectively 380 kV (Haemmerle, 2001). The distinction between transmission and distribution is still made, especially at discussion of responsibilities for the specific network layer. The transmission lines guaranteed the flow of electricity within a nation and simultaneously initiated cooperation beyond a nation’s border. A milestone of internationalisation was a coalition of the 220 kV networks of France, Germany, and Switzerland in Laufenburg in 1958 creating the business of electricity import and export (Haemmerle, 2001; SwissGrid, 2010). The internationalisation of networks provided access to additional production units as well demand – foreign markets. The growing demand and the access to foreign markets forced production to increase outcome and was achieved by introducing the first nuclear power stations, e.g. in Beznau (Switzerland), Kahl (Germany), or Marcoule (France) (IAEA, 2016). A further event in the internationalisation phase was the establishing of trading at stock markets like the European Energy Exchange (EEX) in the late 80s.

Today the electricity industry is at the point of a new development step which is the implementation of a European electricity network including the establishing of a Smart Grid. The development represents organic rather physical growth and a change in principles of the market. Before explaining the Smart Grid concept, a more in-depth discussion of the current market principles will help to understand obstacles and possibilities of future direction or solutions.

By the end of the 1970s the electricity infrastructure (power lines, power plants, etc.) was mostly established (Infel AG, 2010). The physical growth potential of the electricity network from an infrastructural point of view had slowly reached its maximum. So, it can be said that infrastructure has been maintained for more or less 50 years. During this long period, processes, roles, behaviour, and mind-sets have been established, specifying the unique characteristics of the value chain. Infrastructure is designed to operate at maximum consumption, although this is usually only necessary at a single time point. Every other aspect of the electricity network is influenced by capacity thinking. Profitability is achieved by utilising as much capacity as possible for as long as possible. Hence, capacity sets the limits of revenue. Any shortage due to capacity limitation is removed through investments, but only if long-term profitability is guaranteed by that capacity being utilised. Furthermore, progressive transformation of the system is always carried out with considerations of how to handle various vulnerabilities. This consists of: superior management of security criteria technology (e.g. adverse behaviour of protective devices), natural forces (e.g. extreme weather conditions), people (e.g. human failure), or system maintenance and development (e.g. construction work) (Zio & Aven, 2011). Any adaptations to the electrical system, reducing vulnerabilities and enhancing output or capacity utilisation, require an evolution of priorities – mostly, they are business-driven but adapt with the maturation of the grid. In general, the priorities of the system can be summarised as: reliability, controllability, profitability, and scalability (Arnold, Rui, & Wellssow, 2011). The latter defines its ability to adapt to changes in basic settings in the long term, e.g. infrastructure provision and improvements. The motivations for change are immanent, but deliberately established.

2.1.1 The Electricity Value Chain

The central roles in this value chain are producers, grid operators, and consumers. The roles are strictly separated and each has specific purposes. To add to the picture, IT companies or manufacturers providing components for production or distribution, as well as the government, are also part of an extended value chain, but they will not be described further here (see Figure 4). The linkage between the major roles is straightforward. Any demand at a specific location extracts electricity from the network which is fed in by production from a different location. The grid operators “settle” differences by transporting electricity and transforming voltage gradually. In the process, grid operators plan ahead in order to balance input and output. The simple schema below demonstrates a dominant principle of this system: “production follows demand”.

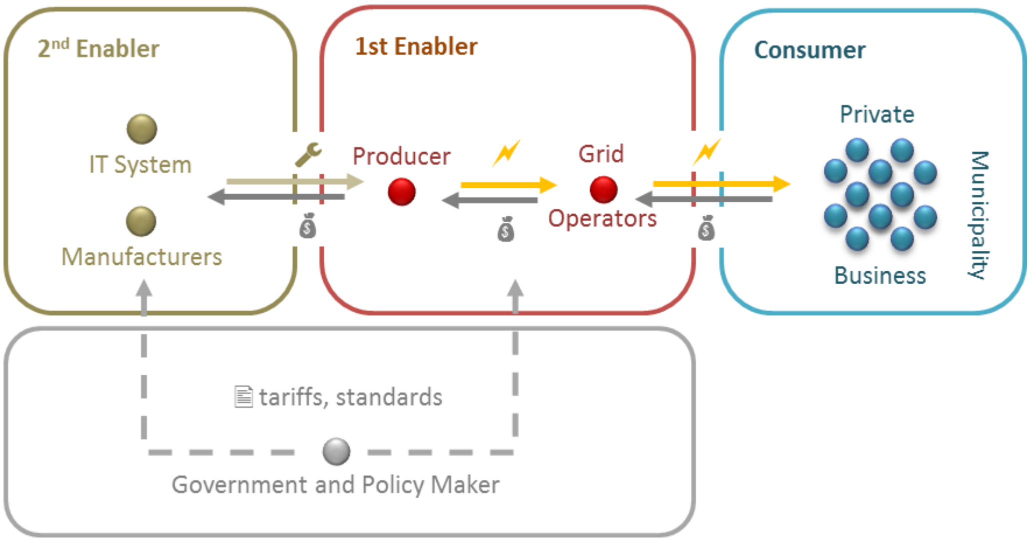

Figure 4: The current electricity value chain

In Europe, the Swiss electricity market, with around 8.3 million inhabitants (BfS, 2015b), is small and comprises around 250’000 kilometres of power lines (VSE, 2016a) and is a fraction of the size of one of the biggest markets, Germany with around 81 million inhabitants (Destatis, 2016) and 1,679,000 kilometres of power lines (BMWI, 2015). Despite its small size, Switzerland has a highly heterogeneous and fragmented market with around 730 electricity companies (VSE, 2016a) – Germany has more than 1,100 electricity suppliers (BDEW, 2013). Moreover, territorial monopoles characterise the structure and six electricity companies dominate the market providing 80% of the production capacity. Furthermore, players are vertical and horizontal integrated (Becker, Wichmann, & Bader, 2012) and can be roughly distinguished, according to VSE, in 15% pure production, 53% grid operators and 28% mixed (includes production, transmission, distribution, and trade) (VSE, 2016b). By contrast, numerous small and local producers and operators have different goals focusing on local areas. For the most part, they are pure retailers and administrate by cities or communities (Flatt, 2010). Their intentions are locally orientated and often their provision of electricity is just one of several other community tasks – “not-their-core-business” behaviour. This fragmentation of a small market with distinct players does not allow for a unified energy strategy and actions that might result from this. Thus, some experts believe that the first step towards a more efficient, lower-cost future electricity network is consolidation (Schellekens, McDonnell, Battaglini, Lilliestam, & Patt, 2013).

The Swiss market is partly liberalised meaning that the majority of consumers (below a consumption of 100 MWh/y) cannot choose their electricity providers and represents an intermediate stage of liberalisation degrees. The other markets are totally liberalised like the Germany market allowing consumers to choose from around 102 electricity suppliers (BDEW, 2013). A non-liberalised market exists in France with one privatised company namely Électricité De France (EDF) (EDF, 2015). Other markets define them as liberalised, however, the example of Austria shows that "…*electricity business […] is still characterised by a heavily federal structure of the providers, owners and markets …*" (Hofbauer, 2006). In other words, the markets are liberal but "…*marked by the powerful dominance of the respective companies in their old provider areas*." (Hofbauer, 2006).

An explanation for the state of liberalisation and possible obstacles to change current position derives from the composition of prices. The price structure indicates the flow of revenues and the level influences from the regulatory side. For that purpose, the final prices for the end-consumer becomes an important instrument and creates certain behaviour in developing the electricity industry. Generally, a final electricity price is composed of four elements: network tariff, energy tariff, taxes for communities, and taxes to support renewable energy (ElCom, 2015). The latter is either defined as a separate share like Erneuerbare-Energien-Gesetz (EEG) in Germany or Kostendeckende Einspeisevergütung (KEV) in Switzerland. Otherwise renewables are subsidised by regular taxes, e.g. United Kingdom (UK) or Austria. Each of these parts is designed to nurture financial support for administration, maintenance, new investments, and revenues. For example, the network tariff is split up between grid operators whereas the energy tariff is the commission for electricity producers.

In Switzerland the a rule of thumb is that a price is comprised of around 50% network tariffs (transmission 7%, distribution 43%) and around 45% energy tariffs. Taxes for communities make up only 3%, and taxes for renewables 2% (SwissGrid AG, 2015c). The majority of the revenue goes to electricity providers (producers and distributors). The minor share of taxes and levies indicates that the responsibility for investment is delegated to electricity providers. This is manifested in regulations such as the Swiss "Stromversorgungsgesetz" (StromVG) based on the "Stromversorgungsverordnung" (StromVV). The same concept can be seen in the UK. Figure 5 presents a comparison of electricity price composition for households lower than 1,000 kWh per year. The figure shows that another concept exists in the European markets. The majority of revenue is directed to governmental institutes through increased taxes and levies. For example, the final price for the end-consumer in Germany is divided as follows: 21.4% for electricity, 24.6% for transportation, and 54.0% for taxes and levies (BDEW, 2016a). The situation is similar in Austria with 31.5% of the price paid for the electricity 27.3% for transportation and 41.1% for taxes and levies (E-Control, 2016). With the augmented share, taxes are used to subsidise but simultaneously reduce the investment in the industry. Furthermore, the greater participation of regulative institutions is obligatory and increases the complexity of finding a consensus.

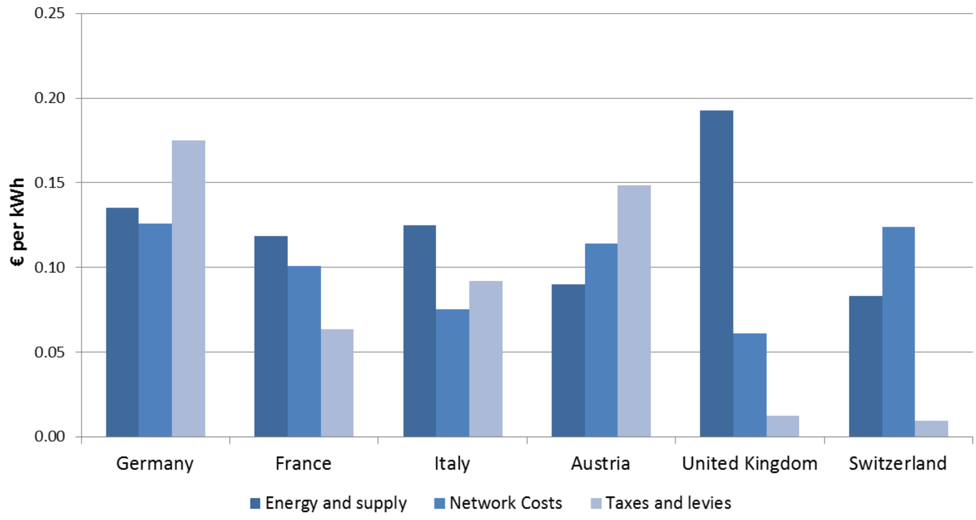

Figure 5: Composition of electricity prices in selected European countries (Eurostat, 2016)

A further characterisation of the value chain is price creation and dynamics between the price components. Price creation in Switzerland or in markets labelled as “liberalised” is dominated by electricity suppliers whereas markets (e.g. Germany) with a competitive pricing mechanism represent an exception rather than a majority. Thus, to speak of a general and sophisticated pricing strategy from electricity providers would be an exaggeration. In fact, pricing depends on the “cost-by-cause” principle allowing shifting costs to the next participant in the chain rather than managing sophisticated product portfolios including price segmentations. A passing on costs without limit to the end-consumer is impossible as any price determination or adjustments is regulated by law using regulations such as the “Stromversorgungsgesetz” and is supervised by the independent state supervisory authority (see ElCom, 2015) which monitors tariffs and intervenes if price increases get out of hand. Similar institutes carrying out the same tasks have been established in European electricity markets, for example ElCom in Switzerland, Bundesnetzagentur in Germany, E-Control in Austria, or Commission de régulation de l'énergie in France. Ceiling prices and supervision of changes increases pressure on electricity suppliers which already receive a small portion of the final electricity price. To ameliorate benefit-cost ratio, electricity providers are focused on cost minimisation as well as looking for more profitable foreign markets.

In European, electricity prices are in range of approximately 11 to 33 Euro-cents per kWh where Switzerland’s prices are roughly average (Eurostat, 2016). The price differential among countries creates a preference of exporting electricity to countries with a higher price level. For example, for Switzerland direct neighbours as Germany and Austria have higher prices (Eurostat, 2016). This increases attractiveness for Swiss suppliers to export electricity. The expansion of the transmission power lines becomes urgent (SwissGrid AG, 2015a). On the other hand, the potential of exports and revenues is limited and so electricity providers rely also on domestic market price development. The ceiling of domestic prices by regulators shifts the focus to discuss the distribution of shares. The support of necessary expansion project in the networks leads to increase network tariffs at the expense of energy tariffs (BDEW, 2016a, p. 39; ElCom, 2015, p. 25). The alteration intensifies conflicts between stakeholders. Additional conflicts emerge from outside the value chain as a country is generally interested in lower electricity prices. However, the increasing demand requires investments which are capture by lower final prices extending the break-even point for amortisation further into the future. The current discussions of the disastrous prices situation indicate that this is insufficient to guarantee profitability; value capturing is unsatisfactory (BFE, 2011b). The industry even speaks of price collapse leading to decommission on completion of new power plants (ElCom, 2015). Nevertheless, price development directly shapes alterations in the value chain and a challenge is a balance between necessary raises and compliance with policies (ElCom, 2015).

As a summary the European electricity markets have a common value chain structure with various configurations creating a kaleidoscope of market settings. A major characteristic factor of electricity markets is the different liberalisation levels and the related prices. In particular, the ability to create prices and the dynamics between price components defines the scope of investments and hence activities of a market. Another strong influence on the underlying market structure and hence price development has the assimilation of different European electricity markets (Atukeren, Busch, & Simmons-Süer, 2011; Meister, 2008). Overall, the electricity industry evolves into a competition-based market (ElCom, 2015). Based on offer and demand, prices are dynamically created and calculations of profit require different skills. Additionally, flexibility to adjust capacity to volatile market situations is decisive for competition. By contrast, open market includes accessibility for end-consumer meaning that they are allowed to choose from a range of offerings. This implies demand side integration on price sensitivity and contradicts current price and market policy.

The changes in structure, as well in price constellation, have different effects on the three areas of production, distribution, and consumption. Therefore, in order to gain adequate understanding of the research issue, it will be appropriate to investigate the assigned roles within the value chain process, dealing with alterations and the inherent potential of each area.

2.1.2 Production

Currently, 1,200 Swiss power plants are responsible for electricity production and the portfolio has certain notable features. It has a high share of renewables, with 58.6% hydro power plants and 3.8% other renewables (sun, wind, biogas, etc.) (BFE, 2014a, p. 3). Residual electricity production comes from nuclear plants (37.9%) and conventional thermic plants (1.9%) (BFE, 2014a, p. 3). In comparison with other European countries, only Norway and Austria produce more electricity through renewables (see Figure 6).

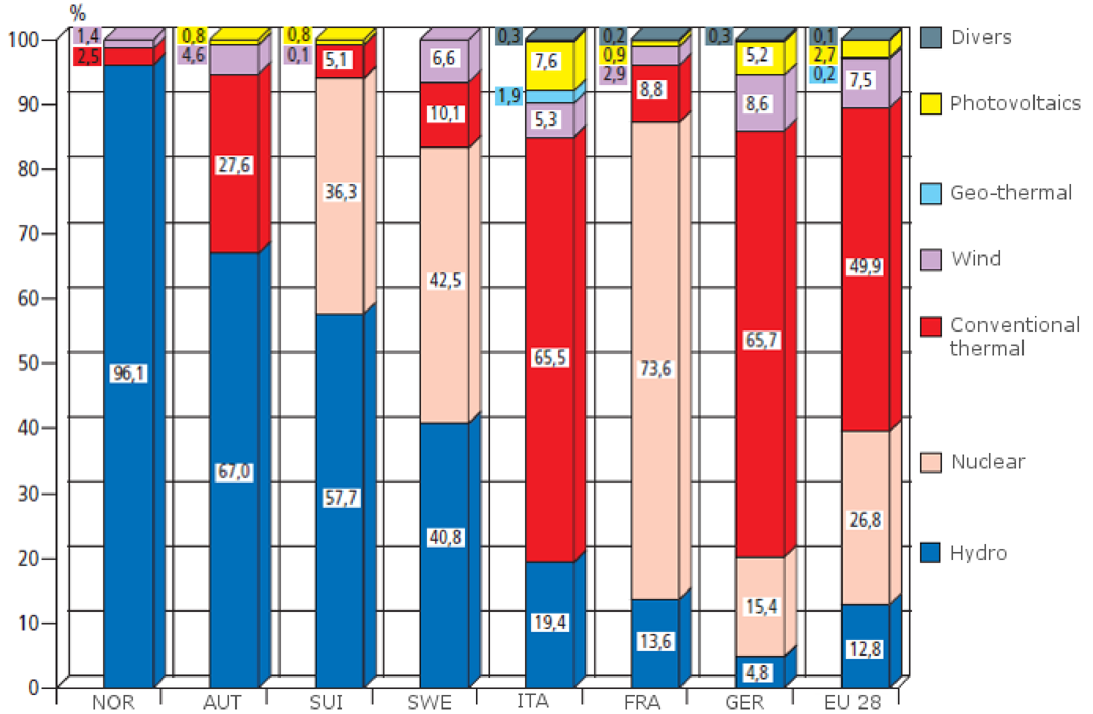

Figure 6: The electricity production, per type, of selected European countries in 2014 (BFE, 2014a)

On the other hand Sweden, France, Italy, and Germany define the general picture of production in Europe where 60% and more of electricity is produced through non-renewable sources. Consequential, Switzerland, Norway, and Austria are strongly independent of international oil and coal prices. In general, the production structure of European countries has a pyramid form where numerous small and medium performant units build up foundations and a few high performant units are at the peak. For example, Swiss production relies on 186 big power plants which are responsible for 90% of total GWH: vast facilities with considerable capacities. In terms of numbers, five nuclear power plants contribute 40% and show a beneficial performance per unit ratio. The 99 river power plants produce 22% of the total and besides nuclear, they are predominantly responsible for band energy. With a 29% contribution, storage power plants represent the last major production area, mostly providing peak energy. A further feature, besides renewability, is flexibility – responding to demand variations. For example, hydro production has small start-up costs, maximum change and ramp time compared to other production forms (NEA & OECD, 2012).

The current production portfolio of Norway and Austria provides quite a good foundation for meeting future objectives of the energy strategy 2050. Therefore, the strategy for essential alterations is the expansion in renewables and improvements of existing production forms. A different strategy pursues countries which have to replace a larger portion of non-renewables units. For example, Switzerland fosters domestic production on large and small scale as well as investing in production in foreign locations. The domestic production capacities are increased by private owned new renewables, like sun, wind, and biogas. This area has grown sharply in the last three years (Kaufmann, 2015, p. 7) and two policy instruments, “Kostendeckende Einspeisevergütung” (KEV) and “Eigenverbrauchsvergütung” (BFE, 2014b), nurture small hydro and photovoltaic facilities encompassing around 1,060,590m^2 of photovoltaic surface area and feeding in around 841,570 MWh (Hostettler, 2015, p. 12).

On a bigger scale, Swiss energy suppliers invest in renewables and put together investment strategies of around 9.7 billion Swiss francs (Windisch, Friedrich, Wanner, & Wüstenhagen, 2011). These investments focus heavily on foreign locations due to limited available locations in Switzerland, better physical conditions (e.g. sun radiation), and easier approval procedures (Windisch et al., 2011). If the renewable sources strategy is successfully implemented, the industry will cover an additional 17.8% of consumption by 2020 (Windisch et al., 2011), expanding an already renewable-orientated production portfolio. The subsidisation of constant production behaviour through more volatile production profiles will bring challenges in terms of balancing. Thus, the creation of additional storage power plants shows the importance of hydro in the Swiss production portfolio (Alpiq AG, 2011; Axpo Power AG, 2013; BFE, 2011a). In summary, the alteration of production portfolio depends strongly on the exploration and exploitation of domestic and foreign production locations, e.g. Germany with wind offshore in the East/Nord Sea or Spain with photovoltaic facilities. Furthermore, volatile production forms entail the implementation of stable production forms.

A different strategy for increased production capacities is non-infrastructural and comprises enhanced trading and import/export activities. The latter is already an important production factor as despite the high performance of its power plants, for example

Switzerland still depends on imported electricity for five to six months per year – mainly because of water restrictions in winter periods (BFE, 2014a; Meister, 2008). The trading, on the other hand, follows economic principles and different marginal costs of power plants in the various countries. Thus, it can be more beneficial to import electricity rather creating a new power plant. Furthermore, countries like Germany and France are main exporters of electricity within Europe, but rely heavily on non-renewables. Adjustments in the portfolio and possible shortages would lead to a reduced export. Either way, a stronger dependency on the production strategies of the country's neighbours is developing (Meister, 2008) and creating transnational competition as well as lending transnational influence to foreign policy decisions, e.g. the energy transition in Germany and the exploding availability of renewable energy (Meister, 2014).

With a changing production portfolio, revenue streams and profitability change too, raising questions for production planning, in particular: "at what time-point should specific sources be activated to deliver electricity with the lowest marginal costs?" In general, the cost-shifting paradigm dictates that compensation is based on different production costs or marginal costs. As a rule of thumb, nuclear, hydro, and solar have lower marginal costs whereas thermal and storage have higher marginal costs. Additionally, decisions based on marginal costs are leveraged due to priority feed-in of renewables which mean that they receive preferential treatment regardless of cost. In small quantities, renewables have tolerable prices, but saturation of electricity in low-voltage grids can cause temporary overproduction and lead to negative prices (IASS, 2015). Furthermore, subsidies support renewables and lead to a distortion of the market. Electricity companies want this distortion to be removed and for remuneration rates to be adjusted accordingly (BFE, 2014b) so that decentralised production units are compensated according to current market prices (BFE, 2015). Despite doubts that renewables can cover shortages (Meister, 2008), the increase of private ownership forces profitability discussions as non-economic behaviour and decision-making enter the value network.

Consequential, a competition among production types, even among renewables, on bases of minimised production costs occurs (Forster, 2015) challenging production side to create a portfolio that is competitive, sustainable, secure, and provides necessary flexibility. Players may depart from traditional mind-set of "dictating prices" and adopting a waiting attitude might have an adverse impact (Schicht et al., 2012).

2.1.3 Transmission and Distribution

The transportation of electricity involves absorbing electricity capacity from power sources and allocating it to end-consumers. Therefore, the size of a grid is defined by these two parameters. Naturally, it is common to speak of a network, however, a closer look at the outline of the system reveals a hierarchical structure with four distinct grids and three transformation layers (see Figure 7). The layering originates from voltage discrepancy between the source and the point of consumption. Improvements in the performance of production sources favour production at the higher layers. As the majority of consumers are located on the lower level (BfS, 2015a), a vertical flow from top to down and a strong interconnection between the layers is incentivised. Depending on the size of the grids and the involved business create various environments. For example, there are 671 grid operators managing 250,000 km in Switzerland (ElCom, 2015, p. 15), 930 grid operators in Germany handling 1,679,000 km. In any case, the networks are highly organised meaning that an allocation of responsibilities for infrastructure in balancing and maintenance to keep the pressure at a constant level of 50 MHz (Neidhöfer, 2008) is given.

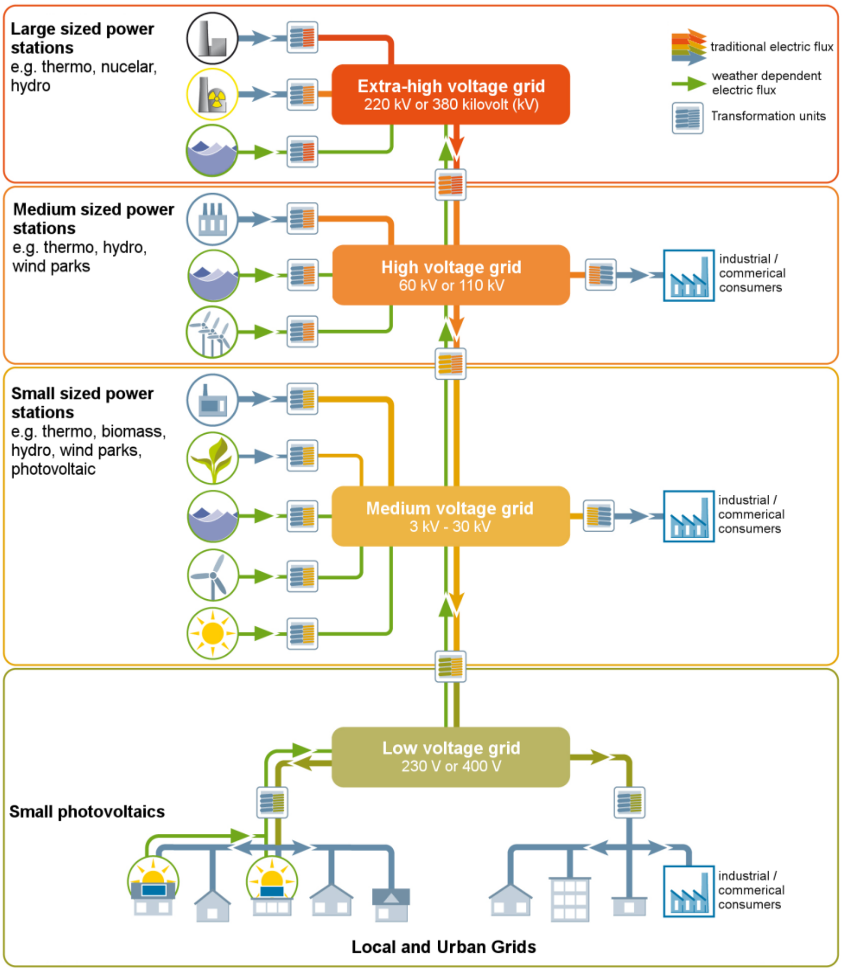

Figure 7: Schemata of the Swiss electricity network (adapted from AEE, 2015)

Grid operators handle load by defining supply and demand in advance (balance groups). The flow of electricity is executed according to these schedules and any asymmetries are corrected by activating or deactivating sources temporarily. Any derivation from the reference value causes different network conditions (Vaterlaus & Wild, 2001) – secure, endangered, deranged, or critical – which affects either the entire grid or small areas thereof. Hence, the top priorities of the network are reliability and sustainability, including an obligatory management of 24 hours for 365 days a year. To deal with complexity, the physical electricity network is separated into transmission and distribution power lines with different duties assigned.

Transmission power lines are responsible for transferring large bulks of energy over a long distance, acting as the "motorways" of the electrical network. It implies that large power stations feed-in and transmission power lines distribute the electricity to lower levels or to other transmission lines. At the transmission layers no end-consumers like business or households exist. These power lines refer to the top layers – 380 kilovolts (kV) or 220kV – containing a small share in the overall length of the network (e.g. 6,700 km in Switzerland or 77,000 km in Germany) (BMWI, 2015; SwissGrid AG, 2015b). Mostly, the power lines are installed above the surface due to cost efficiency (SwissGrid AG, 2015b). The primary task is to handle asynchronous national production according to current demand by load management. Controlling load entails establishing enhanced base load and peak load capabilities, with safety and fault tolerance margins. Load management proceeds normally through an advanced build schedule which gathers all the information about supply and demand from all balance groups. Any deviation from the schedule, due to unexpected events or miscalculations, leads to the regulation or shutdown of generation sources or storage capacities (mostly hydro storage power plants) (Vaterlaus & Wild, 2001). Weather-dependent renewables which do not achieve calculated performances have an increasing influence on variation.

To ensure safe and predictable operation, a comprehensive information technology (IT) infrastructure creates a real-time control system and a small network like the Swiss transmission grid already involves 40,000 data points of which 10,000 are refreshed every 20 seconds (SwissGrid AG, 2015b). This results in a vast amount of data which is processed for management or decision-making. The processing is done by automated management systems and creates an intelligent complex environment. The automated system is responsible for the management of national and of transnational activities involving other European states. National management is an own field of responsibility, however, Switzerland, and other countries, experiences an increasing involvement with load handling with European asynchronous grids (SwissGrid AG, 2015b).

This involvement is growing as the European Union exerts leverage on countries, demanding an "… *establishment of the internal market in the electricity sector [which] must favour the interconnection and interoperability of systems*" (Richtlinie 96/92/EG des

Europäischen Parlaments und des Rates). A first step is the agreement to form transnational synchronised transmission grids (see Figure 8) (Kreusel, 2015) to follow these rulings in order to have access to European electricity sources and customers (Meister, 2008). In particular Switzerland depends on the connectivity to other countries because of the future hub position and hence grid operators are initiating network projects to transport electricity from north to south as well as from west to east (SwissGrid AG, 2015a); Switzerland's location marks it out as a "switchboard" in the emerging European electricity network, providing a link between remote production locations and end-consumers. Eventually, the transmission layer, and hence the entire Swiss electricity grid, will become progressively involved with macro-level problems and challenges.

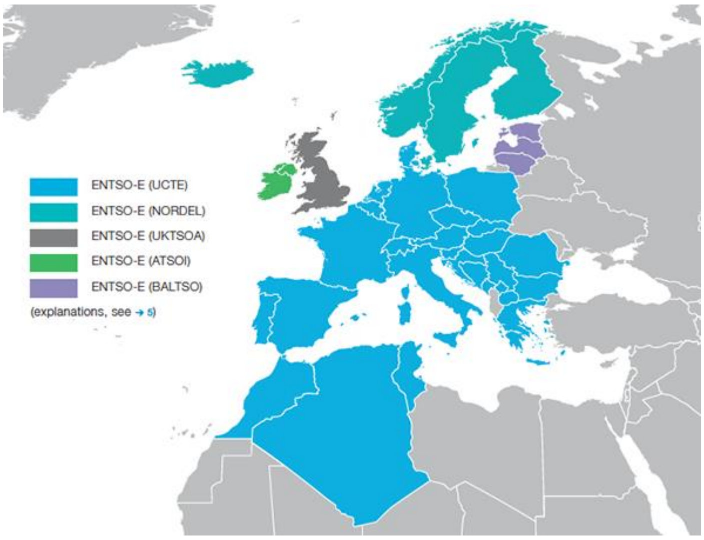

Figure 8: The main synchronous grids of Europe (Kreusel, 2015)

This European transmission "super-grid" is still in its early stages, but the intention to create a transnational grid is clear. Before this is possible, however, several details must be addressed. Making agreements for the unimpeded flow of electricity between high-voltage grids is an immense task. Striking such a deal at the negotiation table is difficult because the physical flow of electricity is not straightforward and controllable. Its grid-boundedness means that, from the north, electricity may flow over several different paths to the south. For example, recent problems in handling the capacity of large offshore wind facilities in the Baltic Sea impacted not only Germany's but also Poland's transmission grid, acting as a pressure compensating valve (Uken, 2011). In compensating for Germany's overproduction, the Polish grid endangers national supply security. Consequently, risk and insufficiency are transferred, creating conflict between national and European interests.

Another detail that must be addressed is value capture in a European context. Any transmission grid is funded according to different national guidelines and funding is ring-fenced, e.g. in Switzerland 40% must go towards capital costs and more than 40% to operational costs (ElCom, 2015, p. 17). However, transferring electricity from the Baltic Sea to Spain requires transfer through several grid operators, each of which would like to have their share. As more players enter the game, transportation costs increase and economic efficiency becomes questionable.

Closely related to capture is the design of organisational structure, as a European transmission grid entails a diffusion of leverage between players. In Switzerland, the transmission grid is in the hand of SwissGrid whose only purpose is to unbundle generation, transmission, and distribution and avoid any discrimination, cross-subsidisation, or distortion of competition. SwissGrid AG is a conglomeration of all Swiss suppliers and distributors (SwissGrid AG, 2015b). In contrast, France's transmission grid is similar but in the hands of the French state, which holds more than 84.9% of the shares (EDF, 2015). The German situation is more complex with four transmission operators (BMWI, 2015). Notwithstanding, transmission grid operators are obligated by law to secure the transfer of electricity, so diversity of institutions (companies, states, or associations) as well as their inherent purposes (profit or non-profit) create a formidable challenge on a macro level. Which solutions prove best for the reconfiguration process remains to be seen, but the issue is decisive for access to national distribution grids and to corresponding foreign markets.

Distribution grids have the same essential function as transmission grids: regulating pressure on the system by scheduling input and output. However, their purpose and structure are different from the extra high-voltage grid. The purpose of each layer is either to pass electricity to the next level down or to keep it within the same layer without changing the voltage. A vertical and horizontal distribution emerges due to the necessity of providing different voltages for various consumers. The direct linkage to consumers brings another perspective for management. The difference compared to other industries is that future consumption is calculated through forecasting or concluded agreements – mostly with larger purchasers. The integration of consumers is based on a hierarchical outline of high-, medium-, and low-voltage grids and the reach of the specific network layer decreases with a descending sequence of national, regional, and local geographical coverage. Within this outline, several grid operators are established, claiming ownership of grids. There is no sharing of organisational rights and duties, e.g. responsibility for maintenance. Hence, numerous organisations are involved, from big national players to small, locally based grid operators. Therefore, absorbing capacity and transporting electricity require considerations of other levels as well as production units on the same level.

In recent years, the complexity of load management has changed progressively with negative effects on the accuracy of scheduling, modifying coordination efforts for a stable network, and making a stronger interconnection. Firstly, the driver for distribution is external and depends on the number of new production and consumption units. For example, in 2013 around 50,000 new apartments required a connection to the grid (BfS, 2015a). Secondly, the increase in smaller production sources (e.g. photovoltaics, wind) on the low voltage grids causes a lower demand from higher levels – sometimes even changing the direction of load flux(IASS, 2015). Finally, the mode of dealing with small units already altered from feed in to local consumption, e.g. Eigenverbrauchsvergütung (BFE, 2014b), initiating discussions about transport distances and the doctrine of top-down. A de- and realignment of the supply chain is occurring, which in turn initiates an alteration of the changing revenue stream.

A major change to the revenue stream is the reduced distribution quantities as a result of the increasing number of small and private production facilities. A lower distribution quota affects revenue as grid operators can claim less money for the transportation of electricity. Infrastructure becomes less profitable requiring rethinking of business models. A similar development has happened in the telecommunications sector. Reductions in profit from infrastructure can be immense, for example in Switzerland where 43% of the final price is designated for transportation. Other European distributors face losses too; a maximum of a third of the final price. The reduction of revenue causes fear of the availability of sophisticated infrastructure leading to disputes over adequate taxation to adjust prices to cover rising costs. Arguments for an increase in taxation include: a) necessary investments that must be made in the grid (mostly transmission); b) higher costs for service systems (e.g. maintenance of power lines); c) liberalisation costs (according to European general agreements); and d) grid integration of renewable energy (BFE, 2011b, p. 23). The latter argument acknowledges problems on lower grid levels, especially private PV owners require less electricity. These demand adaptations are dynamic and, in the short term, pressurise operators as the flexibility of price adjustments implies “longer-term” discussions with the regulator. Absorbing this discrepancy is a challenge for the future supply chain on a distribution level and is tightly connected with the understanding of consumers.

2.1.4 Consumption

Consumption represents the end of the supply chain and is the starting point for capacity thinking and the principle of "production follows demand". Generally, consumption varies with the time of day and season, making it uncontrollable and unpredictable (Strbac, 2008). This causes uncertainty and suppliers as well as providers define capacity according to the maximum peak of demand (Strbac, 2008). Starting from maximum, a rough assessment, defined by factors like weather, season, and number of buildings, is sufficient. Accessibility of data is guaranteed and small derivations can be absorbed by back-up capacity. In 2014, Switzerland consumed 57.4 billion MWh, with the following distribution of recipients: 31.8% private households, 31.4% industry, 27.0% services, 8.1% transport, and 1.7% agriculture (see Figure 9) (BFE, 2014a, p. 4). Switzerland has a similar distribution according to sectors as the EU-27. Furthermore, the forecast of consumption for the year 2020 assumes an increase in the services and households sector and a slight reduction in the industry sector (Kearney, 2016).

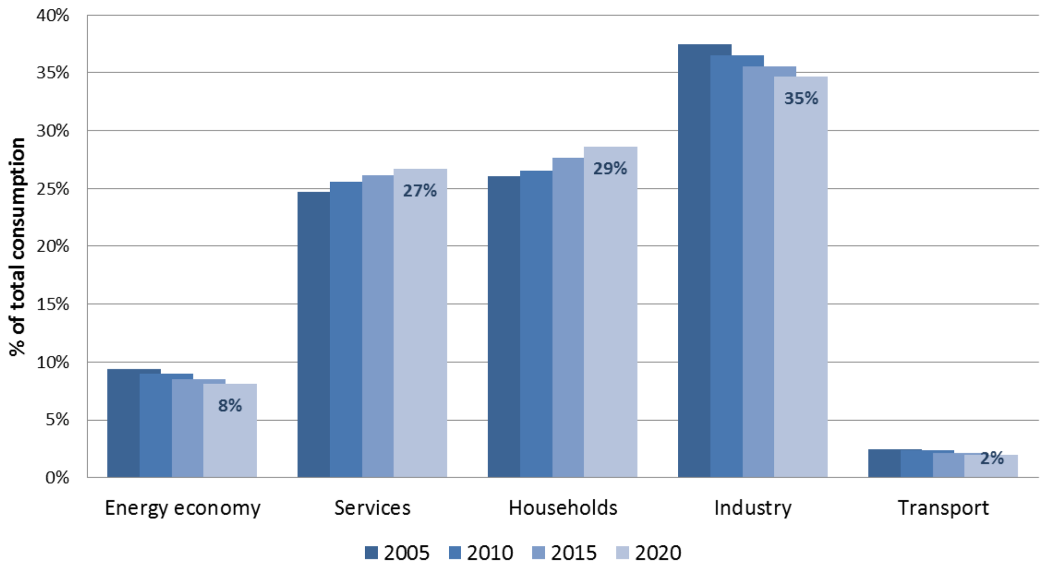

Figure 9: Electricity consumption of EU-27 according to sectors (Kearney, 2016)

The principal usage categories are: process and drives, process heat, climate and air conditioning, and lighting (Kemmler et al., 2014, p. 22). Overall, total demand has increased since 1990 and is mostly influenced by the size of the population and economy, both of which have grown steadily (Capros, Mantzos, Tasios, Vita, & Kouvaritakis, 2010; DOE/EIA, 2015). It is widely assumed that the upward trend for electricity demand will continue (Abhari, Andersson, Banfi, Bébié, & Boulouchos, 2012).

This trend is accompanied by an alteration in usage characteristics, which show complex and heterogeneous patterns. These patterns, in turn, are strongly influenced by social developments like individual lifestyles, increased mobility, shared economy, or urban farming. Meanwhile, the new value of sustainability is becoming a central driver in society. This starts with “green” electricity products and extends to a sustainable value chain questioning the efficiency of consumption but also production types, e.g. nuclear phase-out or CO_2 certifications for thermal power plants (Abhari, Andersson, Banfi, Bébié, & Boulouchos, 2012; Keith, Jackson, Napoleon, Comings, & Ramey, 2012). Simultaneously, electricity is substituting other energy forms: for example, hybrid or electrical cars are promoted on the basis of sustainable consumption. Additionally, the upwards trend intensifies as electrification increases the availability of previously non-electrical appliances like e-bikes. These new possibilities for consumption increase the complexity of prediction beyond currently known areas and define various time-points, amounts, and reasons (Abhari et al., 2012).

Currently, the accuracy of daily consumption prediction is very high, thanks to the skills and experience of electricity providers. For decades, electricity providers have minimised demand considerations, limiting calculation to an annual reading of mechanical meters. Further information exchange with consumers is limited to yearly consumption figures and an address for billing. Even integration of private PV facilities has had no effect on this behaviour, with consumers still considered consumers, with tiny add-ons to the vast capacities of the grid. The demand side has evolved into a black box and – a fact that is unthinkable in other industries – electricity providers are barely aware of consumers’ preferences. It is no wonder that the electricity network is struggling more and more to define demand and hence outline capacity for the supply chain. Nevertheless, the changes in demand characteristics, including the role of the demand side, are realigning the underlying processes and creating an electricity network that functions more cooperatively, responsively and organically (UVEK, 2015). The evolution of the demand side is tightly connected to the maturation of a Smart Grid and vice versa.

With the consumption, the description of the today’s electricity network characteristics ends. The following paragraphs describe the development of the electricity network to Smart Grid initiative, with particular focus on the micro-grid concept, and its impact on the current low voltage network. The characteristics of a future network provide the foundation for the discussion of the Crowd Energy in chapter 3.

2.2 The Smart Grid Initiative

The term “Smart Grid” stands for the next evolutionary step of the electricity network and combines tangible and non-tangible benefits to society to create more complex, interconnected, interactive, and adaptive networks. There are various triggers for the initiative and inherent energy turnaround, consisting of different environmental change types, e.g. regular, hyper turbulence, or avalanches, varying in their impacts (Suarez & Olivia, 2005). For the energy turnaround, events like external shocks (e.g. accidents), policy and regulations (e.g. energy efficiency, reduction of CO_2 emissions, nuclear exit), internal industrial development (e.g. sectorial requests for more flexible energy allocation), and innovation developments in other industries (e.g. ICT, photovoltaics) define the scope of development directions (IEA, 2011). Hence, drivers involve technological, sociological, economic, environmental, and political factors (Openshaw, Strbac, & Ault, 2011). In general, a Smart Grid is an electrical system including metering and digital ICT to ensure the efficient exchange of electricity between sources and consumers (UVEK, 2015). In other words, the network integrates intelligently "… *the actions of all users connected to it – generators, consumers and those that do both – in order to efficiently deliver sustainable, economic and secure electricity supplies*" (ETP SmartGrids, 2016). Eventually, such a system can account for the needs of all market participants (BFE, 2010).

These definitions leave ample scope for various objectives, and different ones may be emphasised depending on the stakeholder in question; additionally, definitions of objectives are influenced by stakeholders and are constantly reshaped. However, several main objectives arise repeatedly in discussions and can be summarised as follows (see Table 1) (EPRI, 2014; ETP SmartGrids, 2006). First, the optimisation of electricity management, including streamlining electricity allocation throughout the value chain, is being contemplated by grid operators in order to secure supply and reliability. The process commands a high degree of automation, featuring advanced monitoring and control elements.

Objective	Key tasks
Optimisation of electricity management	• Improvement of grid cooperation between Transmission System Operators (TSOs), Distribution System Operators (DSOs), Measuring point operators, Measuring service providers, Energy marketplace operators, and other players. • Improvement of grid monitoring and control for automation. • Integration of power flow management, balance and contingencies analysis of the distribution systems and lower levels. • Optimisation of grid topologies and implementation of smart systems to the grid.

Increasing transport capacity	• New infrastructure projects – mostly at the transmission level – to optimise infrastructures. • Introducing new technology developments, e.g. superconducting.
Integration of intermittent sources	• Improved grid responsiveness to transport the energy generated by volatile renewables, e.g. wind and photovoltaic. • Improving grid responsiveness to energy storage systems.
Advanced information & communication management	• Development of secure and flexible communication infrastructures. • Standardisation of data types and protocols. • Architecture for information security. • Distribution of bi-directional interface devices between participants.
Optimisation of market	• New market models for active demand integration. • Generating sophisticated service offerings including quicker problem identification and faster service restoration. • Encouraging interplay between new entrants and existing players.
Engaging consumers	• Spreading information on energy saving and energy efficiency. • Provision of incentives for behaviour change.

Table 1: Main objectives and the required tasks for a Smart Grid (EPRI, 2014)

A second focus of the European Smart Grid concept is augmented transport capacity, the ability to transfer unfettered electricity. Another objective is the integration of intermittent resources like photovoltaics (PV) or wind. This involves balancing volatility using resources like storage, and raises challenges for electricity management and the optimisation of processes. Additional communication is also necessary and requires an advanced ICT infrastructure. Therefore, ICT must be an adaptive infrastructure which reacts to variance in the electricity network. A crucial point is the communication and interaction between buildings and humans, which implies new topics such as the architecture of information security and standardisation of protocols. A further objective concerns emerging market structure and active demand integration. Key tasks include real-time price-setting. This involves a restructuring of the value chain due to new entrants, and changing the focus of value creation. A servitisation of the industry is dominant and reacts to decreasing quantity sales. Servitisation is "[a]*ny strategy that seeks to change the way in which a product functionality is delivered to its markets* (Lewis, Portioli Staudacher, & Slack, 2004) [by a]*dding extra service components to core products* (Verstrepen, Deschoolmeester, & van den Berg, Roelof J., 1999) [and to create a]*n integrated bundle of both goods and services*" (Robinson, Clarke-Hill, & Clarkson, 2010). The final objective which is repeatedly mentioned relates to the engagement of consumers with the value chain process. Currently, this involves spreading information on electricity efficiency through feedback and visualisation based on advanced ICT. Additionally, more deliberate points include behaviour change and consequently the control of demand through incentives. It is for these reasons that the industry is experiencing an influx of social topics, e.g. changing routines, the accountability of electricity, and decision-making processes.

This richness of objectives points towards two main kinds of development, namely macro and micro, in the evolution of a Smart Grid. It is important to define the perspective which is preferred, since the macro and micro orientations have both complementary and divergent points for the direction of evolution. Furthermore, a clearly defined approach allows for the characteristics of transition pathways – and hence the ramifications on the current electricity network – to be defined (Geels, 2004).

Macro development is primarily concerned with the reconfiguration of the socio-technological system (STS) (Geels, 2004), i.e. suppliers build up capacities and expand the infrastructure towards a European Grid (ETP SmartGrids, 2006). By recognising user-centric and distributed elements, and tasks to manage distributed energy resources (DER), the main vision and strategy concentrate on the interoperability of European electricity networks, politics and regulatory aspects, and liberalised markets (ETP SmartGrids, 2006; IEA, 2011). This favours existing capacity thinking and improving marginal cost by increasing scale, e.g. transmission network expansion in Germany and Switzerland to improve transfer (Sterner, 2015; SwissGrid AG, 2015a). It also points towards new solutions for stabilisation provided by hydro pump storage power plants. Initially, these power plants were regarded as a major factor for energy transition, but due to developments at the micro level, changes in network tariffs, and the drying-up of the revenue stream, profitability is lower and a rethinking of investments is underway (Asendorpf, 2013; Meister, 2011). Nevertheless, the macro perspective adheres to traditional business remuneration philosophy – allocating large quantities – sustaining profitability and the paradigm of "production follows demand". It also reinforces the centralised network structure in which big power plants are responsible for supply.

Micro development relies on local elements like decentralised generation (DG), storage (DS), and demand side management (DSM) to achieve its objectives, i.e. building a cellular system including DER and user-centric methods like demand response (DR)

(ETP SmartGrids, 2006; IEA, 2011). Its major goal is the integration of the demand side in the production process. Micro development follows a de-/re-alignment transition pathway and includes fundamental adaptations due to DER growth (Verbong & Geels, 2010). Based on cellular structures, so called micro-grids, the electricity network locates production closer to the point of consumption, causing a decentralisation and a reduction of dependency on centralised units; micro-grid roadmaps represent a supplement to the centralised system rather than a replacement of it (ETP SmartGrids, 2006; IEA, 2011). A de-alignment initially deconstructs the existing centrally focused supply chain, and then realigns processes including decentralised components; the constitutional complexity of this is characteristic of a network rather a chain. The modified, interconnected network creates value differently and contradicts the macro business philosophy through a reduction of transportation and centralised production. A more decentralised structure answers calls for sustainability by using renewable generation sources. So, the benefits of DER are reduction of emissions, higher efficiency, improved human health, and conservation of electricity despite increased demand (Akorede, Hizam, & Pouresmaeil, 2010; Driesen & Katiraei, 2008). Such a transition pathway profoundly alters the characteristics of the industry and has many implications for system innovation (Verbong & Geels, 2010). Further, willingness to undergo transition is fostered by the possibility of new, profitable revenue streams for both existing and new participants (Giordano & Fulli, 2012).

Macro and micro developments are happening simultaneously, being complementary and divergent on certain points. Nevertheless, immediate micro development has a promising potential and is worthy of further investigation.

2.3 De- and Re-alignment of the Low Voltage Grid through Micro-Grids

Micro-grids represent a way to re-decentralise the electricity industry and invigorate decentralised concepts of single-side generation, backup, or emergency constructs (see Figure 10), the latter two representing particularly strong advantages. In contrast to former decentralised structures, micro-grids entail the clustering of numerous generation, load and storage sources to project outwardly a controllable entity (Lasseter, 2001). It represents a modification of traditional mind-sets because it involves incorporating electricity exchange at the distribution level by including consumers and making them part of operation optimisation in the process (Lasseter, 2001). For a cluster to qualify as a micro-grid, however, it requires the ability to operate in both grid-connected and island modes, a smooth transition between un-/intentional mode switches without load interruptions, relaying and protection, and assurance of power quality (Sapar, Gan, Ramani, & Shamshiri, 2014; Xu, Li, & Tolbert, 2012; Zhichun, Jian, Kaipei, & Wei, 2011). Thus, "[a] *micro-grid is a group of interconnected loads and distributed energy resources within clearly defined electrical boundaries that acts as a single controllable entity with respect to the grid and that connects and disconnects from such grid to enable it to operate in both grid-connected or 'island' mode*" (DOE, 2011). Furthermore, management of micro-grids requires internal organisation among the members of a cluster but also orchestrate between separate micro-grids to build a sustainable network.

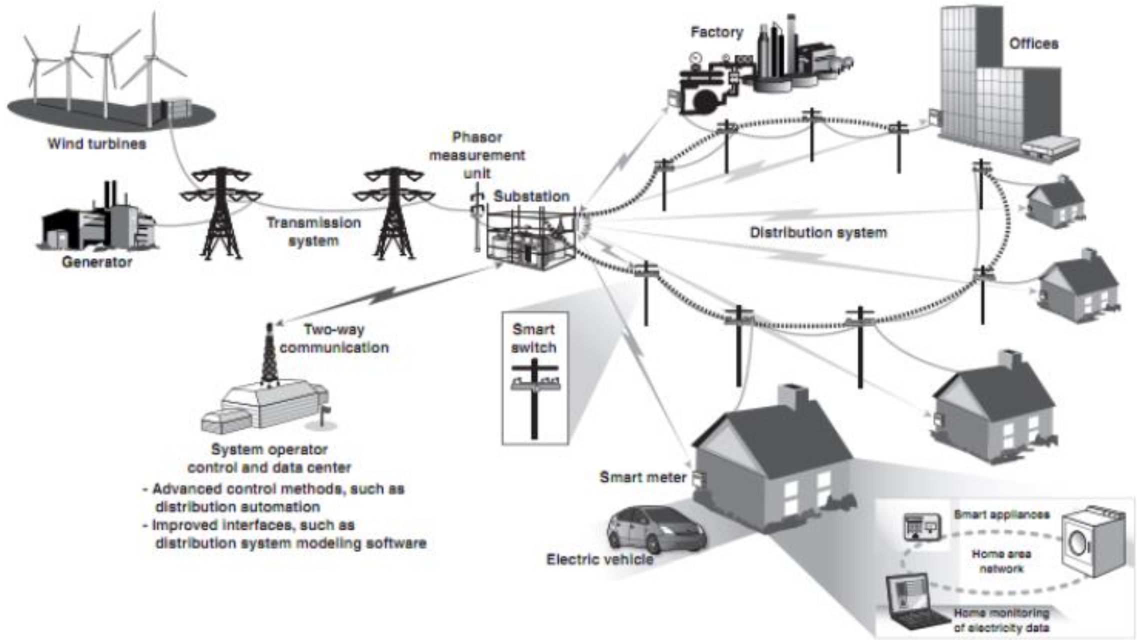

Figure 10: Conceptual layout of micro-grids in Smart Grids (Leonardo ENERGY, 2016)

The description of micro-grids still indicates a traditional architecture from a top down view to serve industrial, commercial, or residential customers. Possible architecture types include utility (urban networks, rural feeders), single or multi-facility industrial/commercial, and remote micro-grids (see Table 2) (Driesen & Katiraei, 2008). The characterisation depends on application according to geographically or infrastructural dependent areas, the main drivers for installation, and load types that emerge within micro-grids (Driesen & Katiraei, 2008). An urban network, in this case, consists of a district in a city utilising numerous renewable sources to avoid the interruption impacts inherent in the main grid. Ancillary services comprise a local supply of reactive power and premium power quality. However, industrial and commercial micro-grids are more vulnerable to interruptions and demand a higher degree of reliability. Therefore, management strategies include distributed control and automation to reduce the influence of the main grid or other micro-grid users. Another case is the remote micro-grid, which refers to the electrification of distinct areas and a simultaneous shift away from fuel dependency. The aim is to change the system and provides a stable single network, rather than integrating into the residual network. In each type of micro-grids a connection to another system, such as heating, exists and shows the necessity to think beyond electricity.

	Utility	Industrial /Commercial	Remote
Application	- Downtown areas (urban networks) - Planned islanding (rural feeders)	- Multi-facility: Industrial parks, university campus, shopping centres - Single Facility: Commercial and residential building	Remote communities and geographical island
Main Drivers	- Outage management, - Renewable energy sources (RES) integration	- Power quality enhancement, reliability and energy efficiency	- Electrification of remote areas and reduction of fuel consumption
Benefits	- Greenhouse gas (GHG) reduction - Supply mix - Congestion management - Upgrade deferral - Ancillary services	- Premium power quality - Service differentiation (reliability levels) - Combined heat and power (CHP) integration - Demand response management (DRM)	- Supply availability - RES integration - GHG reduction - DRM (Demand Response Management)
Operating modes	- Dependent - Independent and autonomous - Isolated	- Dependent - Independent and autonomous - Isolated	- Isolated

Table 2: Micro-grid architectures (adapted from Driesen & Katiraei, 2008)

All named micro-grids applications commonly employ distributed energy resource methods to orchestrate DG and DS as well as a more efficient electricity allocation (Driesen & Katiraei, 2008). This entails a physical integration of devices into existing electricity management. Thus, it is assumed that devices have the capabilities necessary for power sharing, utilisation of well-sized storage, and load control and prioritisation. The optimal micro-grid – seen from the perspective of grid-operators – is an external control of input variables. For example, a higher PV penetration would be dangerous and corrective actions would be either a reduction of PV penetration or the activation of storage to compensate surpluses. Customer integration and participation in micro-grids is reflected in DR methods, emphasising the benefits of load customisation (Driesen & Katiraei, 2008). In other words, individual units respond to given instructions (price- or event-dependent) from external supervisors, e.g. grid operators, to reduce net load or to provide sources to other micro-grids (Shariatzadeh, Mandal, & Srivastava, 2015). Hence, demand response management (DRM) is an integrative framework handling demand response at the building or micro-grid level, adding to the functional requirements of distributed energy resources (Shariatzadeh et al., 2015).

2.3.1 Functionalities of an intelligent DER

An intelligent DER has a cellular structure that masters micro-grid- and network-specific functionalities. A variety of functionalities exists and can be categorised into four groups: visualisation, forecasting, interoperability, and distributed intelligence methods (Wakefield, 2011). The level of performance in each of these four categories defines the intelligence of the micro-grid and consequently the Smart Grid (Wakefield, 2011).

Visualisation involves the “slicing and dicing” of data levels from an aggregate to a substation unit, and improves the comprehensibility of the distributed system. Furthermore, visual representations are the intersection between customer and system allowing changing undesired habits through feedback and learning (Mezirow, 1990). Visualisation should support meaning to be created through the information received (Mezirow, 1990). Thereby, the “horizon of expectations” broadens and “… *significantly affect*[s] *the activities of perceiving, comprehending, and remembering meaning within the context of communication*” (Mezirow, 1990).

Forecasting encompasses functionalities that predict consumption and production (Wakefield, 2011). The latter employs well-established methods from the domain of weather forecasting. By contrast, consumption, especially in the private household domain, is a more significant challenge, as it entails predicting minutely detailed based patterns which are dependent not only on technological factors (e.g. types of device) but even more on segmentation according to socio-demographic and lifestyle factors (Asare-Bediako, Kling, & Ribeiro, 2014; Fischer, Härtl, & Wille-Haussmann, 2015; Hayn, Bertsch, & Fichtner, 2014; Seo & Hong, 2014). Currently, small-scale consumers or businesses are subject to standardised load profiles (SLP) (BDEW, 2016b).

Interoperability is the ability of components, applications, devices or even several micro-grids to communicate with each other through a managing system; to exchange and to process information for pursuing load, infrastructure, and error handling (Wakefield, 2011). The interchange of information may proceed securely and effectively (Wakefield, 2011).

The visualisation has a significant impact on interoperability between human and machine communication. It becomes the Achilles' heel for the quality and smartness of the micro-grid as the variety of data requires sophisticated data management, comprising tasks such as metering, monitoring, and analysis (Barenghi, Bertoni, Breveglieri, Fugini, & Pelosi, 2011; Kaufmann, Koller, Kurchkina, & Stoffel, 2013).

Finally, distributed intelligence functionality is the ability to process data and make decisions on individual and system-based levels to deliver electricity at the right place and the right time (Wakefield, 2011). The purpose of real distributed intelligence is the optimised planning of capacities with "… *typically no centralised control dictating the behaviour of the individuals, local interactions among the individuals often caus*[ing] *a global pattern to emerge*" (Engelbrecht, Li, Middendorf, & Gambardella, 2009). A case in point is swarm intelligence (Meng, Dong, & Qiao, 2013) or the crowdsourcing approach (Gstrein & Teufel, 2015; Teufel & Teufel, 2014). The benefit of distributed intelligence lies in improved failure modes as it is less disruptive (Wakefield, 2011) requiring new mind-sets, advanced methods and tools for management (Teufel & Teufel, 2014). Despite DER models still being in an early stage of development, the distributed system is regarded as a driving force for an integrated grid, enabling better coordination between utility projects, and improving cooperation between various service providers (EPRI, 2014). DER development is, however, reliant on advanced information and communication technology (ICT) infrastructure transforming the energy sector in the 21st century (Teufel & Teufel, 2014).

2.3.2 A Reference Model for Micro-Grids

A corresponding reference model for managing functionalities is an interdisciplinary model between the domains of electrical process and structural zones (see Figure 11) (Biester, 2012). Structural zones are hierarchical levels of electricity management whereas electrical process refers to the electrical supply chain. On top of those two dimensions, five layers address interoperability between different systems from basic connectivity components to economic and regulatory policy (Biester, 2012). The interoperability categories are organisational, informational and technical aspects (The GridWise Architecture Council, 2008). The business layer combines two points, namely business objectives and policy, to map the business model, portfolio, capabilities, market structure and/or regulatory situation. The function layer identifies the architectural design of functions and services including relationships. The information layer describes the information usage of functions, services, and components and focuses on the relevant business context and semantic understanding topics to enable interoperable information exchange through communication. The communication layer describes technical aspects of protocols and mechanisms to support information exchange and describes syntactic and network interoperability. The last layer, the component layer, is concerned with all the components which are necessary for physical distribution. By merging all three dimensions into one framework, cross-cutting topics can be addressed and tackled on different layers. Such a structure implies various possible smart network implementations and it is no wonder that European Smart Grid initiatives vary as greatly as do accompanying research agendas (El-hawary, 2014; Hübner & Prüggler, 2011).

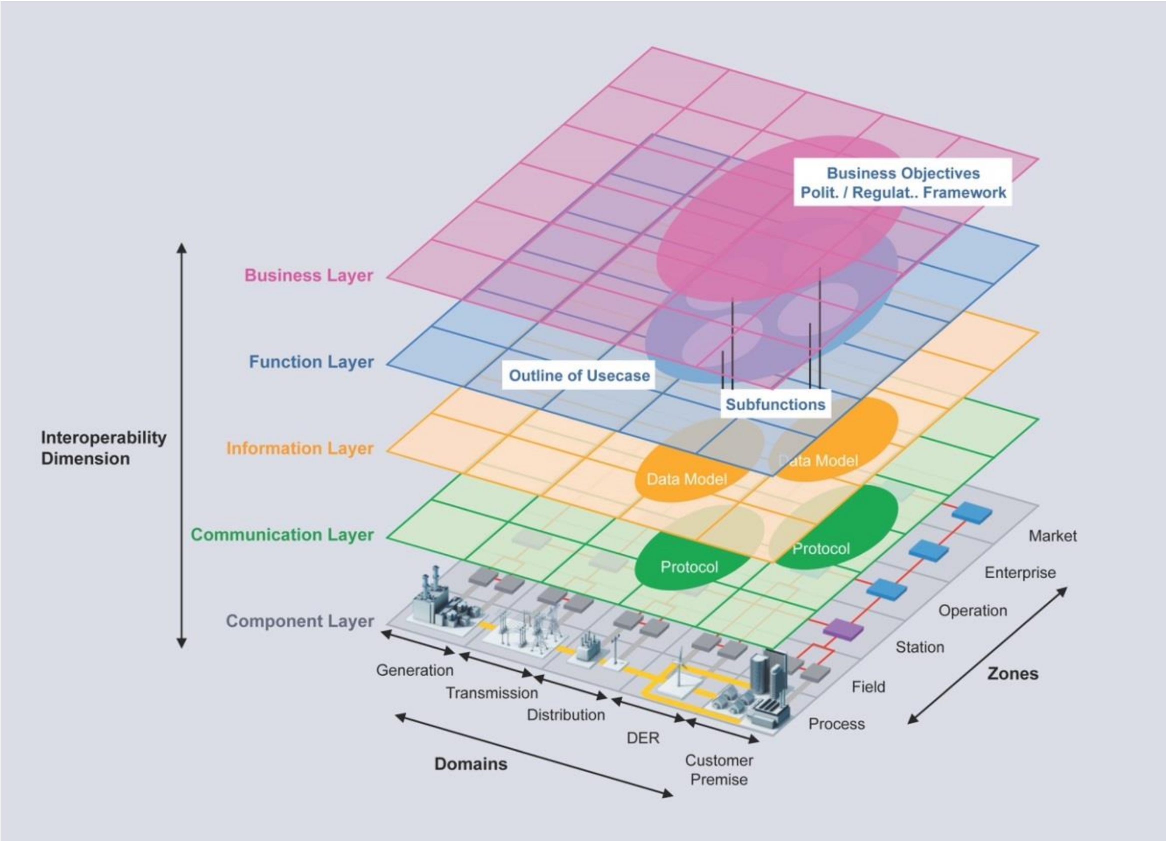

Figure 11: The Smart Grid Architecture Model (SGAM) (Biester, 2012)

The reference model increases horizontal and vertical complexity for management and especially processing of information for the value network and value creation. ICT becomes the key for smartness as it is central to technical implementation and shapes functionalities and the scope of actions. A heterogeneous ICT architecture across vertical layers (Zaballos, Vallejo, & Selga, 2011) provides a *"… two-way communication network for sensing, monitoring, and dispersion of information on energy consumption*" (Bari, Jiang, Saad, & Jaekel, 2014).

This demands high standards of corresponding architecture, reliability, robustness, availability, scalability, and service quality (Gungor et al., 2011; Kuzlu, Pipattanasomporn, & Rahman, 2014). Such standards make computation and communication in real-time possible, allowing for a near-instantaneous allocation of electricity between various units. As well as shortening the time scale, the ICT system may also consider localised decision priorities, in some cases, to be autonomous, at the same time applying centralised control decisions. Furthermore, the needs of stakeholders are changing as the nature of transmission and distribution and the role of local system operators evolve. New roles are also emerging, such as measuring point operator, measuring service provider, energy marketplace operator, or end-customer (Kießling & Khattabi, 2011). It is mentioned that the customer will be integrated in the process, however, integration is based on technology and automation rather than on personal responsibility of consumers. Crucial for interconnection and eventually stability is the degree of standardisation and current progress in this area is strong (Basso, Hambrick, & DeBlasio, 2012). On the other side, interconnection means also the capability of scalability to integrate numerous elements in the grid (Gungor et al., 2011). A smooth extension capability is the ability to grow in size and fit in seamlessly through adequate configuration. Additionally, good service quality allows communication behaviour between elements to be specified. Questions of average delay, jitter, and connection outage probability are central to the sensing and monitoring of units as well as to the interplay among them (Gungor et al., 2011). Minimised outages assure the operation-readiness of elements and determine the performance of the ICT.

These standards rely on information exchange, and the large number of different access points within the ICT infrastructure gives rise to growing security concerns (Gungor et al., 2011; Teufel & Teufel, 2015). Security management is becoming increasingly essential as data leakages can cause a disruption of energy network operations (Egozcue, Rodríguez, Ortiz, Villar, & Tarrafeta, 2012). Technical implementations of authentication, encryption, or malware removal tools ensure smooth operation (Bari et al., 2014) but also create new challenges in terms of information management, e.g. which information may be shared and which is private (Teufel & Teufel, 2015). This very question of security defines the accessibility of information and the creation of knowledge. In turn, generating knowledge from information created by diverse components offers further space for innovations in big infrastructures (Nightingale, 2003).

Big infrastructures contain an inherent incentive to minimise deficits and improve collaboration between intangible services and tangible manufacturing (Nightingale, 2003).

In other words, time constraints on service delivery force technologies to synthesise, leading to an interwoven, integrative structure in order to achieve distributed intelligence. The advanced distribution automation (ADA) copes with the variety of decisions to make under new network priorities. The requirements on ADA arouse attention to automation technology and especially to algorithm implementation. Control through algorithm excellence provides an advantage for the grid and for single players similar to a high-frequency trading system (Gomber, Arndt, Lutat, & Uhle, 2011). Therefore, it is the centrepiece of the architecture and steers ICT infrastructure. Additionally, elimination of failures triggers a constant adaptation and innovation cycle and the pace is derived from the ICT industry. Substitutions of ICT technologies advance in shorter circles remoulding technology portfolio constantly. On the other hand, ICT represents an entry point for additional, as yet unknown areas and social trends like the sharing economy (Hamari & Ukkonen, 2013) to gradually enter and present challenges. Therefore, experts have noted the need for the alignment of technology with the objectives which are in place, in order to avoid unintended developments within the value network (UVEK, 2015, p. 43).

2.3.3 A proposed Value Network Design

De- and realignment through the micro-grid creates new underlying market settings and a new value creation process. The fundamental shifts in environment redefine the main features of the market in a similar way to recent transitions in the telecommunications domain (Peppard & Rylander, 2006). New characteristics must be established to cope with the challenges ahead: in a nutshell, what is required is a shift away from infrastructure thinking towards product and service offerings (Figure 12).

Characteristic	Monopoly		Competition
Core Competencies	Infrastructure	→	Products/Services
Performance Measure	MWh	→	Revenue/customer
Competitive Advantage	Economy of scale	→	Economy of excellence
Pricing	Cost recovery	→	Market driven
Production Process	Single Point	→	Integrated
Investments	Cash flow	→	Market value
Intelligence	Central	→	Peripheral
Information	Non-transparent	→	Transparent

Figure 12: Shifts of characteristics in the electricity industry (adapted from Peppard & Rylander, 2006)

Of course, infrastructure remains important, but profit will be generated via customisation and benefits created through additional offerings besides the single product of electricity. New services will include the management of electricity to support comfort for consumers and simultaneously improve efficiency. To achieve this, a customer-centric approach is inevitable and to assure quality, an economics of excellence will be crucial in order to guarantee competitive advantage. Furthermore, this customer-centric approach will permit the integration of the consumer into the production process. Cooperation between business-driven and non-profit units will be a necessary consequence as the intelligence of the process becomes peripheral. Hence, valuable information will increasingly be produced at the local level and must be exchanged in a transparent and simple way.

The effect on the value creation process is to cause an extension from a “direct” to an “ultimate” supply chain (see Figure 13) (Mentzer et al., 2001, pp. 4–5). All participants are included in upstream and downstream flows of electricity and system-relevant services. In addition, the entire network may synchronise capabilities and this fosters an integrative philosophy. Thus, tasks like capacity and security management move downstream to the demand side through outage management and demand response. Furthermore, activities such as sharing information, sharing risks and rewards, and long-term relationship building are consistent with this philosophy (Mentzer et al., 2001). Meanwhile, new business activities arising from the existence of micro-grids establish a market-driven approach at the lower network level and force adjustments to the business modelling mind-set as well as product and service portfolios (Blaschke, Suhrer, & Engel, 2013). A new value creation process enables new revenue streams.

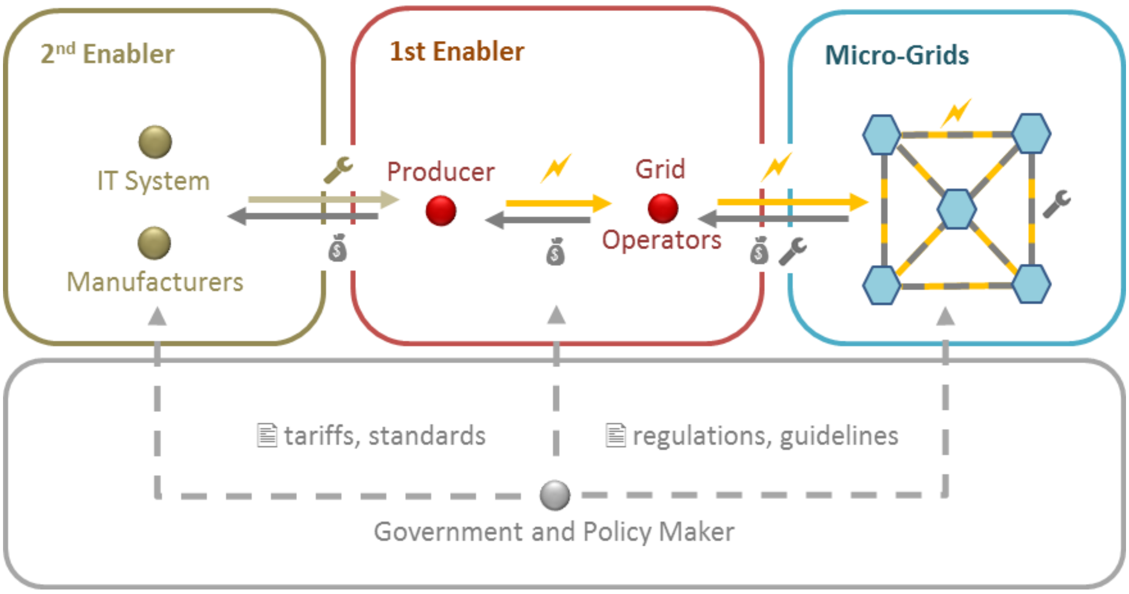

Figure 13: The new Value Chain Design based on Micro-Grid Structures

The traditional value stream of selling electricity still exists, but four new revenue streams are created which support the economic feasibility of micro-grid implementation. First, demand response programs manipulate the capacity of consumption in a region (Shariatzadeh et al., 2015). Implemented Regarded price-based or event-based programs offer the possibility of defining specific rates for specific time frames, e.g. Time-of-Use (TOU) rates, Critical Peak Pricing (CPP) and Real-Time Pricing (RTP) (Shariatzadeh et al., 2015). Flexibility influences load allocation but also makes it possible to play with margins generated between buying and selling. The second revenue stream emerges from the consumers' desire for resilience against outages. Beneficial behaviour from the consumer to avoid outages is incentivised or supplier can provide premiums to guarantee supply (Willis & Garrod, 1997).

The first two revenue streams show a variation on already existing management tasks which is tightly linked to the micro-grid idea. An additional revenue stream originates from additional DG and opportunities to export power back to the overall grid; micro-grids evolve to a production capacity (Stadler et al., 2015). The micro-grid institution (operator) negotiates with utility companies on the same level. Value creation is captured through a variety of agreements under export conditions and feed-in tariffs. This stream is highly situation-dependent (Stadler et al., 2015). Another notable feature of this stream is that within it, tariffs are subject to negotiation for the first time.

The export of electricity to other micro-grids (excluding electricity providers) is also possible, and represents the final revenue stream: the emergence of local energy markets. The primary idea is to trade electricity between micro-grids. This minimises costs for transportation and electricity losses. Local exchange also provides a mechanism for coping with a rise in renewable penetration rates. Local trading includes several streams and hence investigations are vigorously carried out in order to define instruments under demand-supply market rules (Rosen & Madlener, 2013). A common stream is the potential for cost savings on final electricity bills (Maity & Rao, 2010), but even further-reaching potential lies in auction-based market design (Rosen & Madlener, 2013). With consecutive bidding, clearing, and pricing procedure (Marzband, Sumper, Ruiz-Álvarez, Domínguez-García, & Tomoiagă, 2013), revenues are generated by skilful buying and selling capabilities. It is a replication of the European Energy Exchange (EEX), only on a smaller scale. How well trading works is a question of time and the establishment of micro-grids.

Eventually, these streams consolidate the technical integration of micro-grids in the overall process. This also supports a reduction of distance between generation and demand through decentralisation. Current design discussions led by traditional suppliers and distributors show a promising direction of movement towards a sustainable network, but seem to be influenced by traditional mind-sets. Hence, the occurrences of particular situations are predetermined and particular results are anticipated.

2.3.4 Beyond the Micro-Grid Value Network

The characteristics of the new, competitive industry described above provide sufficient reasons to create more far-reaching solutions than those currently discussed under the supplier-dominant top-down view. The proposed designs mainly lack more radical discussions of decentralisation, the role of the consumer, and value creation from intangibles. These shortcomings require a reconditioning for a value network that better incorporates crowdsourcing.

The first inadequacy of decentralisation concerns the autonomy of single units of the demand side. From a micro-grid perspective the unit refers to a building and current discussions focus on top-down structure and management practice. It is assumed that a centralised system offers a steady connection for supply, control, and information. There are no doubts as to the need for top-level units and interaction with bottom-level units, but there is value in going beyond this. First, the implementation of a decentralised subsystem promotes further decentralisation and strengthens the development of Smart Homes (Alanne & Saari, 2006; Bohn, 2005). Secondly, decentralisation entails a relocation of electricity generation closer to the point of consumption and hence a shortening of allocation distances (Alanne & Saari, 2006). The shortest transportation distances are realised by buildings which are self-supportive and require no interconnections among themselves or to the public network, a principle it can already be seen at work in hospitals which depend on security of supply at all times. This implies that the entire electricity supply chain be integrated into a building (Dunn, 2002). Lastly, buildings extend their functionality for electricity management by adding decentralised storage (DS). The potential of DS is to break off maximum peaks by buffering surplus and releasing it when needed. It can be achieved through optimal charging and discharging times, balancing the sharp ramp time of PV (Alam, Muttaqi, & Sutanto, 2013). Thus, a building takes responsibility for the emergency and backup roles assigned in micro-grid management. Nonetheless, this still raises the essential question: is it more beneficial for the network to calibrate an individual building's consumption, production, and storage before considering these functionalities for the network? The importance of each individual building makes it a preferable level for investigation, which therefore favours a bottom-up approach, investigating the building's potential and then grouping in order to minimise transportation. It should be mentioned that factors of scale and efficiency of electricity allocation provide a definite answer to this question and research on, for example, central batteries (ABB, 2012) or plug-in hybrid electric vehicles (Galus, Koch, & Andersson, 2011) are moving in promising directions.

The centrality of buildings in micro-grid concept means that the existing role of the consumer changes from a passive receiver of services to an active participant. By making individual investment decisions, consumers develop into “prosumers” (Teufel & Teufel, 2014). Managing prosumers from within the supplier’s integrative philosophy means dispensing output through solely technically focused implementations. The prosumer’s contribution is to support load or error management by handing over ownership of electricity or sometimes (temporarily) facilities. However, the prosumer also claims ownership of self-produced electricity and the electricity industry must be able to adapt to the individual’s decision to “keep” it or share it (Gstrein & Teufel, 2014), the latter option entailing providing electricity to the micro-grid. Community behaviour evolves and cooperation between micro-grid members creates a system with its own dynamics. This has extensive effects on the fundamental understanding of roles, relationships and value exchange.

Current disputes assume that socio-political and market acceptance (Wüstenhagen, Wolsink, & Bürer, 2007) is sufficient to explain the willingness of prosumers. In reality, this is simply how they have to act in order to achieve, for example, maximisation of profit. This also applies to micro-grids. Existing arguments short-sightedly neglect the community aspect and hence the third dimension of social acceptance (Wüstenhagen et al., 2007). The motives for community behaviour can also be non-technical and non-economic (Wüstenhagen et al., 2007). The inherent dynamics of a community are less market-orientated and loyalty is achieved by respectful behaviour. Elements like trust, commitment, and procedural and distributional justice become central to participation (Wüstenhagen et al., 2007). Community-based research is a human-centric approach which studies behaviour and engagement of the demand side rather than a purely technical micro-grid view (EPRI, 2014). More adequate methods and processes address individual bad habits affecting trust and commitment in communities (Aldabas, Gstrein, & Teufel, 2015; Egger, Gstrein, & Teufel, 2015).

Furthermore, community acceptance increases awareness of the perceived value of electricity. With production in people’s “back yard” and a highly visible electricity value chain process, a better understanding is easily obtained. Similar phenomena are observable in the food industry, where consumers now have an enhanced awareness of ecological and sustainable food production (Smith, 2006). Hence, both extrinsic and intrinsic values are important for community dynamics, although intrinsic ones are crucial for participation as they have a stronger integrative potential (Ryan & Deci, 2000) as the purely financial factors (Abrahamse, Steg, Vlek, & Rothengatter, 2005; Almeida, Fonseca, Schlomann, & Feilberg, 2011).

The integration of the demand side requires extensive information and an economy of excellence requires a sophisticated management of social and business driven participants within a layer. Thereby, the importance of information grows, creating a knowledge-based industry and modifying the nature of value and consequentially of value creation (Davis & Botkin, 1999). Competitive advantage is achieved by acquiring more knowledge and translating it into new offerings. Internal mechanisms become essential, including a dynamical learning cycle to continually increase agent's knowledge base (Davis & Botkin, 1999). Eventually, value creation increasingly happens via intangible assets and affects content as well as exchange philosophies (Allee, 2008). At present, discussions are restricted to top-down information management, e.g. cost savings on electricity bills (Maity & Rao, 2010) or trading according to an auction-based market design (Rosen & Madlener, 2013). By assuming unlimited availability of information, suppliers and distributors underestimate barriers deriving from the demand side. Electricity provider imposes voluntarily information exchange without concerning privacy matters (Teufel & Teufel, 2015). The availability is influenced by the willingness of the demand side to share information and hence becomes an object for exchange. A top-down imposition of information exchange might be contradictive for willingness. On the other side, the demand side cannot withhold information as the efficiency of the network depends upon it. A sophisticated information management is necessary to ensure interests of all stakeholders. The influence of availability and exchange-willingness of information adjusts the value creation behaviour in the value network. There is an increasing need for an analysis of value creation and insights must be gained in the fields of which role generates value, which types of values are necessary the quality of value outputs, the constraints on value creation, and adequate resource deployment for output.

These existing debates concerning the degree of decentralisation, consumer roles, and value creation, demonstrate the need for a concept which refines the level of demand side integration, addresses social and individual behaviour, and simultaneously constructs micro-grid structures with optimised distribution. The Crowd Energy concept provides the possibility to address the new requirements on the future electricity network. This dissertation refers to the Crowd Energy concept and hence the next chapter will describe the concept and highlights important research questions which will be answered at the end of the dissertation.

3 Crowd Energy, the new Paradigm in the Electricity Market

After the theoretical introduction in the research field of electricity market and the establishing of the shortcomings in discussions, this chapter highlights the research need for a Crowd Energy network (see Figure 2, page 9). Crowd Energy (CE) is based upon the micro-grid idea and is a sophisticated concept of a future electricity network and provides a solution for the extensive integration of all stakeholders to create value. This chapter objective is to define the foundation for the research questions stated in chapter 1.2.

Chapter 3.1 elaborates on CE concept defining a collaborative community based on integrated processes, cooperation, shared goals and values, and mutuality in rewards and risk sharing. A socio-technological approach is the core of the CE concept. The iGSL (intelligent generation-storage-load) structure in chapter 3.2 describes the underlying functionalities of a building. These functionalities can be pooled together with other buildings and consequently creates a crowd. Please note that buildings refer to a specific address and hence can inherit several end-consumers. Also, the terms cell or object are synonyms for a building. The last chapter 3.3 describes the impact of CE concept on the current value network. In particular, the chapter highlights major adaptations of involved roles, relationships between roles, and the value creation context.

3.1 The Idea of the Crowd Energy Concept

CE is based on the previously described concept of micro-grids and the SGAM framework, new building standards (Kylili & Fokaides, 2015), technological solutions to integrate consumers through Smart Homes (Chan, Campo, Estève, & Fourniols, 2009), or advanced data processing and management to handle the increase in coordination efforts (Felden, 2013). The significant difference with other concepts is the change in perspective; from a top-down to a bottom-up view (Teufel & Teufel, 2014). The bottom-up view has an integrative character, avoiding separation of parts in the electricity network or avoiding excluding specific stakeholders in a value network to increase efficiency and sustainability of resources, this works best when the entire value network is included. The value network must have an integrative philosophy and involves integrated processes, cooperation, shared goals and values, and mutuality in rewards and risk sharing (Gstrein & Teufel, 2015). This all becomes even more important in light of the new Smart Cities development. Incipient stages of integration exist in concepts such as the shared economy or crowd sourcing, however, these concepts lack of profound integration. For example, crowd sourcing partially integrates a community in the process just for a specific phase or for single tasks (Howe, 2009). The shared economy is defined by sharing resources within a specific time period (Botsman & Rogers, 2010). Both approaches are partially reflected in CE, however, the CE concept involves more profound and sustainable integration and cooperation among members of a community.

The CE concept promotes a crowdsourced electricity network where crowdsourcing is defined as “the collective effort of individuals or profit or non-profit organisations, or both, pooling their resources through online information and communication technology-applications (ICT applications)” (Teufel & Teufel, 2014). The collective efforts, made by members of a crowd, rely on cooperation and willingness to achieve energy strategies and visions. Therefore the CE concept is one of the main drivers of energy transition (Teufel & Teufel, 2014). Sustainable cooperation among all stakeholders means that the current paradigm of the electricity industry must be altered from “TO-YOU” to “WITH-YOU” (Teufel & Teufel, 2014).

The paradigm change induces an extended understanding of electricity beyond the tradeable good aspect (Hertig & Teufel, 2016). The CE includes further aspects of electricity which are strategic means, ecological sources, social imperative, and interpersonal construct. The latter characterises the cooperative behaviour within a crowd based on a local production, storage, distribution, and consumption of electricity among members. To ensure cooperation in CE, the concept is based on the intelligent generation-storage-load’s (iGSL) cellular structure which will be elaborated on in the next paragraph.

3.2 iGSL Structure

Crowd Energy is founded on a cellular structure. A cell refers to a building, and each cell has three functions: generation, storage, and load (iGSL cell) (Teufel & Teufel, 2014). All three functions are performed via a sophisticated information and technology infrastructure to ensure communication and security of supply (see Figure 14). At this level, individual cells are profiled according to patterns of consumption, PV production profile, and storage size, allowing them to be tailored for specific management activities. The optimisation of individual buildings is an important preliminary step for the creation of a micro-grid, because producing or saving enough electricity reduces load balancing efforts. By pooling iGSL cells and their functions, a sustainable network is created and this establishes a local production-consumption principle.

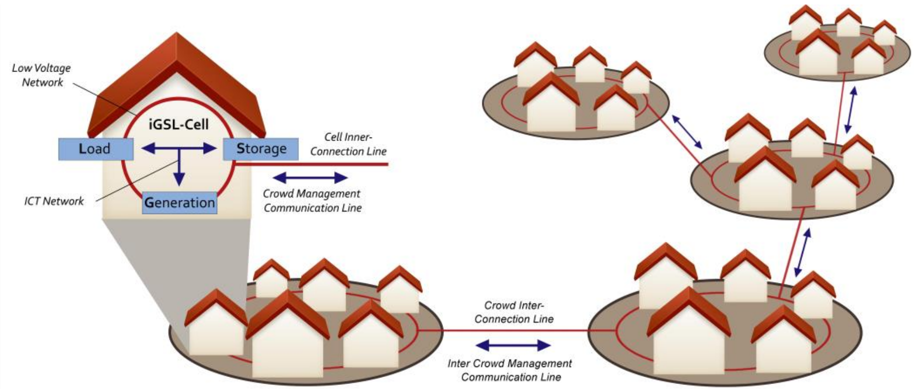

Figure 14: Crowd Energy based on an iGSL cell (adapted from Teufel & Teufel, 2014)

The local production-consumption principle implies that the load management tasks required for balancing and allocation need to be redefined. Within the crowd, the allocation of electricity to shortage locations and surplus locations, in the short as well the long term, generates an independent micro-grid and relieves higher network levels. Furthermore, cooperation improves stability by spreading load balancing issues, e.g. the sharp ramp time of PV production, between several cells. Load balancing can also be achieved by pooling production or storage capacity, for example, using a neighbour's storage capacity when one's own storage is not available reduces production loss and provides operation scope. In other words, production and/or storage capacities are installed in optimum locations, economically and technically speaking, to improve the smartness of electricity allocation.

Such a building-level perspective enables a bottom-up network in which crowdsourcing activities apply complementary actions defined by the top-down approaches. Crowd Energy's local production-consumption principle moves beyond the current characterisation of micro-grids as purely technical counter-measures for unwanted incidents. In Crowd Energy thinking local areas support each other, leading to transportation distance to be reduced. Short distance allocation dominates and shorter distances to travel reduce transportation costs for electricity. The exchange of electricity in a local network affects electricity price and it will decrease but this also means that the transmission and distribution revenue will decrease significantly. The reduced final price of electricity leads to questions being asked on how maintenance of the transmission and distribution networks will be secured in the future. Those networks need to be maintained as transmission and distribution grids are the backbone. At the same time, CE is a good way of introducing a smarter way of distributing electricity locally postulating optimisation solutions for exchange rather than solutions involving artificial intelligence. It illustrates a way of "working with what we have already" rather than implementing extensive network expansion policies. In a Crowd Energy model, distribution is decentralised and the low-voltage grid relieves higher network layers by allocating electricity horizontally. All of this renders investments in high-voltage network expansion projects questionable.

Eventually, the iGSL structure described provides benefits for the electricity network but also requires changes to be made to the value network structure, value creation and the management of the value network.

3.3 The Impact of Crowd Energy on the Current Value Chain

The iGSL structure leads to a further differentiation of the low voltage layer and describes two domains: a building, which has individual characteristics, and a crowd, which has the characteristics of a community. Both domains have specific requirements and they need to be respected. Furthermore, the new role of the prosumer defines and influences both domains and eventually alters the value network. In general, prosumers and their iGSL system are the backbone of a crowd. This includes the utilisation of the iGSL system for individual and community purposes. It should be remarked that not all end-consumers turn into a prosumers who produce and store electricity, however, there are a certain number of prosumers in the network leading to changes in the value network. The following paragraphs highlight the critical points for further research from a value network perspective.

To define a crowd in a value network, two main characteristics exists. The crowd potential refers to the ability of the crowd to produce surpluses for sharing. The crowd strength is the ability of the crowd to work together through sharing. The potential is a technical related supply chain subject which incorporates a local production and consumption network and the optimal allocation of electricity among those units to create independence from external supply. The strength of a crowd relies on cooperation which is the conversion of tangible and intangible assets into deliverables. The conversion involves social and psychological aspects. For example, providing value to the crowd requires, amongst other things, the willingness to share electricity. The willingness of prosumers is based on rational and irrational factors like moral values creating various individual personalities. The willingness for sharing also concerns information and assets, storage in particular, which is needed for the functionality of a crowd. Nevertheless, willingness is essential for the construction of a crowd, otherwise a prosumer is acting as an individual. Consequentially, Crowd Energy considers individuals and community interests, both must be addressed, and it also demands nurturing the relationship between prosumers and a crowd. Both characteristics of a crowd, strength and potential, are interrelated and together determine how cohesive a crowd is and the relationship with other stakeholders in the value network.

The crowd's ability to create cohesion causes a shift to a more leading position among the current roles of producer, transmission and distributors, 2nd enabler, reshaping the basic structure and relationships. In the future network, a crowd will be involved earlier in the value creation process which means it has to carry out load management tasks. For example, the availability of self-produced electricity within a crowd must be allocated. This will reduce the need to buy electricity from commercial suppliers. At the same time, the crowd requires infrastructure and management systems to allocate electricity which is furnished by ICT and facilities' manufacturers of small decentralised solutions. The quality of crowd functionality depends on provided decentralised equipment and hence a closer interaction will be pursued to ensure that innovation is fostered and consequently a crowd's potential is improved.

Nevertheless, management of a crowd, and its members, requires load balancing skills and capabilities which create a window of opportunity for business. Providing services for a crowd creates a new role within the value network. The role of a service provider is distinguished it from the traditional producers and distributors by focusing on the sophisticated management of electricity which implies further factors such as comfort or efficiency. The quality of a service provider, which can be expressed in business excellence, will be crucial for the relationship between a crowd and the rest of the value network. Sophisticated business excellence is repaid with loyalty by the crowd and a tight interrelationship between Service Provider and crowd emerges. The closeness between the roles permits to speak of an extended crowd perspective. Besides roles and relationships, the emerging prosumer changes value creation, in particular exchange and content (Lepak, Smith, & Taylor, 2007), by adding new tradeable value types.

The new types of values emerge as a result of enhanced cooperation and the recently created social role of the prosumer. First, cooperation leads to more exchanges of information; thereby information become valuable and an object for exchange itself. In other words, information is the content for value creation and obtains an equivalent value. The social role of prosumers, on the other hand, acts differently as existing business driven stakeholders of the network and introduces intangible values like commitment, trust, loyalty, or sense for community. These intangible values are necessary for cooperation among crowd members and crucial for conversion of tangible and intangible assets into deliverables. Eventually, the complexity of value creation is increasing and creates challenges for enhanced electricity management (Gstrein & Teufel, 2015).

The previous paragraphs addressed some emerging issues which require further investigation. In particular, research is needed into the overall design of crowd-based value networks including value creation, and the strength and potential of a crowd. These three subjects are the objectives of this study and are expressed as the research questions stated in chapter 1.2. The proposed questions require a theoretical foundation before a conceptual framework of a crowd-based value network can be presented.

4 The Value Network: the Theoretical Background for the Electricity Industry of the Future

This literature chapter describes the underlying and essential theoretical background for the defined research field (see Figure 2, page 9). A theoretical description of a crowd-based value network concerns with following subject areas: a) design and dynamics of networks, b) value creation process, and c) the influence of roles on value creation. All three areas describe the quality of a value network, i.e. the achievement of value network goals. The objective of this chapter is to provide foundations for the Crowd Energy framework (see chapter 5) defining an overall value network design, and crowd strength and potential.

Chapter 4.1 provides a value network perspective and starts with the development from a supply chain to a value network approach highlighting necessary crowd-based value network characteristics and management principles. Subsequently, this chapter elaborates on design of value networks discussing involved roles and relationships. From a general value network description the chapter investigates in the specific area of value creation. In particular, the chapter 4.2 turns its focus to the social role of the prosumer and their strategy to convert tangible and intangible assets to deliverables. Besides that, prosumer introduce new types of value and altering context for exchange. Additionally, a theoretical description of decision making should highlight arguments in favour of sharing or storing electricity.

4.1 From Supply Chain to Value Network

The concept of a supply chain has been well known in the field of economics for several decades and is commonly mentioned in the literature; the idea was first discussed in the domain of logistics management. The economics behind this initial mind-set entails the optimisation of planning, implementing, and controlling of efficient and cost-effective flows (Cooper, Lambert, & Pagh, 1997). The traditional and more mechanical approach requires defining the considered stakeholders corresponding to the upstream and downstream in the chain. The specified scope determines the degree of supply chain complexity. There are three types of supply chain complexity which can be identified: direct, extended, and ultimate supply chains (Mentzer et al., 2001, pp. 4–5). A direct supply chain has the smallest complexity, consisting of a supplier, business, and customer relationship. An extended chain includes the suppliers of suppliers and if the customer is an intermediary, their customers. An ultimate supply chain represents the highest degree of complexity by considering all players involved in the flows of products, services, finance, and information.

The delivery of products and services in the current electricity system requires the integration of several players and hence can be described as an ultimate supply chain. The complexity of an ultimate chain illustrates that many functions enable a variety of supply chain configurations. Another development concerns the redirection of flows. In recent years, suppliers have been dedicating production steps to the end-consumer and have consequently been offering customised products and services. Both impacts lead to a more appropriate definition: a supply chain is "… *a set of three or more* [independent] *entities (organizations or individuals) directly involved in the upstream and downstream flows of products, services, finances, and/or information from a source to a customer…*" (Mentzer et al., 2001). The enforced management within the supply chain is intentional as the quality of the outcome is tightly related to it (Mentzer et al., 2001). Thus, supply chain management (SCM) can be seen as a deliberate effort to handle activities and relationships.

4.1.1 Supply Chain Management

This emerging complexity renders outdated the traditional, purely operational, mechanical view of SCM; more integrative management positively affects performance (Cox, 1999). Hence, SCM is the sum of management activities undertaken for orientation (Mentzer et al., 2001). Supply chain orientation is a type of management philosophy recognising the strategic or systematic implications of the various upstream and downstream flows (Mentzer et al., 2001). In this paper, SCM refers in a broader sense to both streams and is specified as "…*the systemic, strategic coordination of the traditional business functions and the tactics across these business functions within a particular company and across businesses within the supply chain, for the purposes of improving the long-term performance of the individual companies and the supply chain as a whole* …" (Mentzer et al., 2001). The corresponding set of management activities express a more connected view. It implies an integrated behaviour and mind-set, mutually shared information, mutually shared risks and rewards, cooperation on several levels, defining the same goal and the same focus on serving the customer, and a physically integrated process. The establishment of these management activities requires time and hence are only executed under a long-term partnership maxim.

To create a complete model of SCM, the framework must consider the antecedents and the consequences of the SCM and supply chain orientation (see Figure 15)

(Mentzer et al., 2001). These elements are necessary for steering the performance and alignment of activities. The antecedents shape the orientation and consist of several factors (Mentzer et al., 2001). The willingness to address questions of trust and commitment is the basic ground for cooperation: this is crucial to overcoming difficulties (Morgan & Hunt, 1994). Moreover, it involves the handling of influential positive as well as negative factors. The acknowledgement of interdependency defines the willingness to negotiate about functional transfer for operational planning (Bowresox, Closs, & Stank, 2003). The function's transfer scope relates to traditional businesses of marketing, sales, research and development, forecasting, production, procurement, logistics, information technology, and finance (Cooper et al., 1997).

Figure 15: Antecedents and Consequences of Supply Chain Management (adapted from Mentzer et al., 2001)

An inter-functional coordination evolves and requires an internal and external perspective to streamline the flows. This encompasses organisational decision-making based on a defined supply chain identity and a willingness to coordinate between corporations. Organisational compatibility is an important pre-condition: players must have complementary objectives, operational philosophies, and cultures (Bucklin & Sengupta, 1993). Additionally, a common agreement on vision and on key processes improves the competitive strength of the supply chain (Grant & Lambert, 2006). The final factor is support through top management, as this drives the organisation's value, orientation, and direction (Mentzer et al., 2001). Thus, the accomplishment of successful SCM relies on the alignment of top management. Results may include system-related outcomes, e.g. lower costs and competitive advantage, or customer-related outcomes, e.g. higher value and improved satisfaction. Finally, a sophisticated supply chain management model has at its core inter-functional and inter-corporate coordinated business processes aligning supply chain flows to produce supply chain- and customer-related outcomes (see Figure 16).

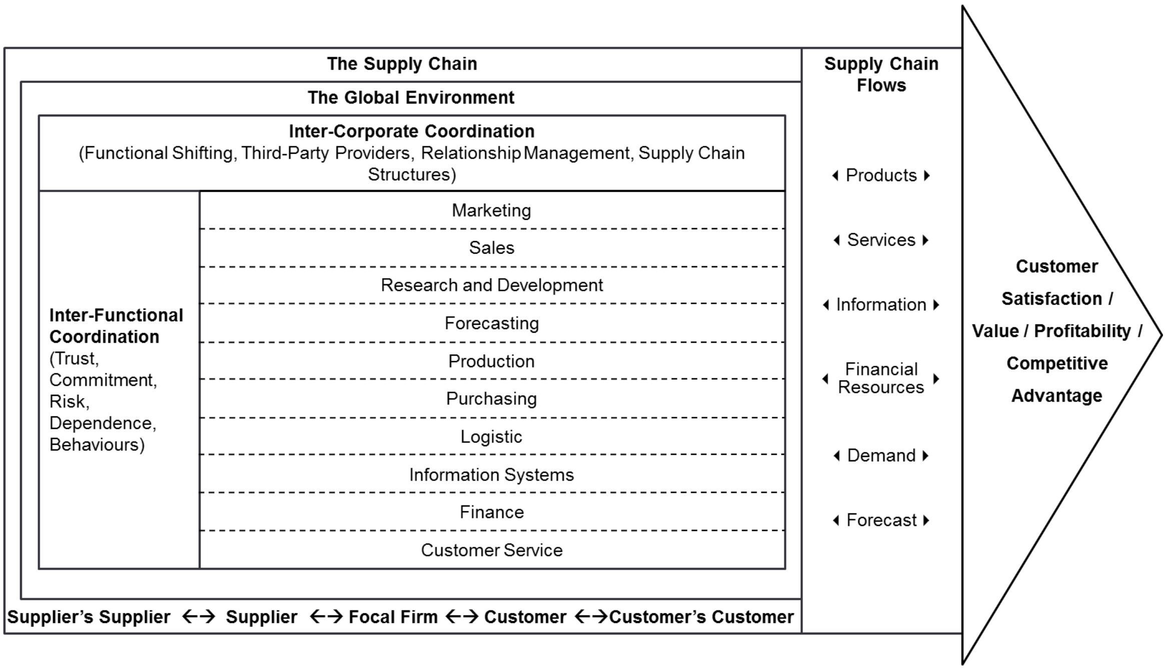

Figure 16: A supply chain management model (Mentzer et al., 2001)

The chain is nested in a global socio-technological environment (including policy, regulations, and industry settings), influencing the configuration of individual players and the organisational scope of SCM. The organisational scope involves strategic partnerships or alliances (Cooper et al., 1997) erecting complex, multifaceted organisational structures (Webster, 1992). At this point, the chain approach shows limitation and a network perspective is more appropriate.

4.1.2 A Value Network Perspective

Parallel to the supply view, a value view exists and defines the flow of revenue; in general it defines the up-stream from the end-consumer to the supplier (Cox, 1999). An appropriate value is determined for each particular supply chain resource and these are combined into a final price for the customer or a sales price for a partner. Both perspectives are interrelated and a specific supply chain functions yields specific values (Cox, 1999). For example, supply chain functions are defined according to operational excellence and so functions (or activities) are constantly evaluated through key performance indicators (Tsiakis & Papageorgiou, 2008). Thus, efficiency from supply chain discussions influences value formation. The crucial twist of view is that a value perspective focuses on the validation of the quality of outcome made by the customer. Eventually, the customer's request becomes the source of all actions and influences supply chain key performance indicators (Ramsay, 2005). This complementary value approach is now well established in research literature and represents a process view on a business unit level as well as illustrating a way of carrying out activities (Porter, 1985).

Value chain activities (which generate value and hence profit) can be either primary or secondary. Porter (1985) defines primary activities as logistics, operations, marketing and sales, and services to generate value. Secondary activities have a supportive character and consist of activities in the fields of firm infrastructure, human resource management, technology, and procurement (Porter, 1985). Clearly, the value chain follows the same logic of transferring products from supply to demand by focusing on essential business processes. The difference with regard to the supply chain, however, is in the coordinated chain of activities adding more value to the outcome than the single activities can produce (Porter, 1985). Thus, competitive advantage derives from discrete activities designed to produce a final value, but also allows each activity to be a source of differentiation (Porter, 1985). The firm's activities are part of a larger construct and the stream of activities is called an industry value chain or value system (Porter, 1985). A value system identifies and dictates the required activities by focusing on the value of the customer and how the customer creates value (Normann & Ramirez, 2000).

The value system forces an alignment of all necessary activities to generate sophisticated offerings respectively the inherent value; this creates new ways of sharing and of co-production, including customer participation and extended offer customisation (Normann & Ramirez, 2000). Thus, a customer's value-creation logic dictates the constellation and hence a constellation does not exist in a vacuum (Normann & Ramirez, 2000). Successful companies will understand the implications of this and shift strategic analysis onto the value-creating system itself rather than onto the company or even the industry. A mutual influence emerges and enhances the firm's produced value as well as the value creation process. Moreover, the value-creating system involves many actors. Norman et al. (2000) postulate that the focus should go beyond the direct customer or supplier. The system develops an analysis scope on an all-embracing level as the system mobilises value creation through constant improvement and reconfiguration cycles of roles, skills, and relationships. Involved stakeholders consider the health of the system and of individual partners equal to their own (Iansiti & Levien, 2004). Thereby, the quality of value quality is subject to a benchmark of performance which is achieved by a sophisticated management of business processes and by coordination between them. In doing so, the same principles of supply chain management are applied including antecedents, philosophy, and activities (Katsamakas, 2014). The difficulty now lies in the management of a constellation rather than a simple chain.

The concept of a constellation develops from the idea of a limited linear flow to that of an interwoven web in which flows are bi-directional and a management of activities has an integrative, flexible, and long-term character (Ramsay, 2005; Soliman & Sherer, 2005). Eventually, a constellation can be referred to as a value network – also known as a business network (Ford, Gadde, Hakansson, & Snehota, 2011), strategic network (Gulati, Nohria, & Zaheer, 2000), value web (Tapscott, Lowy, & Ticoll, 2000) or business ecosystem (Iansiti & Levien, 2004). An example of this new logic is illustrated by IKEA, which mobilises customers to create their own value from the company's various offerings (Normann & Ramirez, 2000), moving beyond pure consumption and marketing thinking. All steps involved in interior design are reflected by activity-based products and service offerings. Even the handover of some activities to the customer, e.g. the manufacturing step of reassembling furniture, or transport to the home, is covered in a straightforward manner. The mobilisation of customers to create value is a key factor and under this logic, it is offerings, more than companies, that are in direct competition (Normann & Ramirez, 2000). Hence, offerings, and their included values, set high quality expectations and the management of activities in the network must be sophisticated.

A remarkable influence on the development of high quality value networks has been exerted by the information and communication industry. Information and communication technology (ICT) supports the coordination of activities between players and have gained significantly in importance in the last decade. This influx of ICT is leading to a redesign of processes and flows, especially of information, and primarily serves to fulfil customer needs (Soliman & Sherer, 2005). This induces a sequential mode and a linear emphasis (Soliman & Sherer, 2005); however, ICT has the ability to integrate the value network and produce sophisticated value beyond customer needs. Furthermore, ICT complements the integration of other networks, particularly social and technical, to deal with socio-technical requirements.

Thus, when speaking of a value network, this dissertation in fact imply the interaction of several networks, which partly overlap, extend, or supplement each other in certain areas, to produce value for individuals, businesses, government, and society in general. In other words, a value network is an abstract and superficial description of structure and relationships drawing on underlying networks. To counter this abstraction, the following chapters describe the characteristics of networks, the types of value exchange, and the possibility of value creation from tangible and intangible assets.

4.1.3 The Networks Involved and their Purposes

The value network theory emphasises values and defines the corresponding network according to the participants and linkages who contributes to it. This is sufficient from a business perspective, however, the CE value network is more complex and demands a refinement of the term network within a CE. In particular, it is necessary to investigate in social networks to highlight their influences on value creation.

The network approach investigates the structure and patterns of interconnected elements in varying categories such as social, technology, or information (Newman, 2003). In each case, the network theory analyses single small graphs and their properties as well as large-scale ones, towards which there has been a shift in popularity in recent years, driven by the availability of ICT (Newman, 2003). In general, a network is a set of vertices (nodes or actors) connected through edges (links or ties) (Newman, 2003). These links can be either directed, meaning the orientation between edges is in a specific direction, or undirected, meaning the orientation is possible in either direction (Newman, 2003). Any structure of edges and vertices has a set of properties which defines the degree of links, degree of distribution, clustering of nodes, level of resilience to vertex removals, or diameter of a network by calculating the length of the longest geodesic path (Newman, 2003). According to these properties an examination of the structure and behaviour of real-world networks can be done which are non-random and use a certain mechanism (Newman, 2003). Additionally, networks are dynamic systems which include dynamic linkages which can carry multiple types of value. These statistical properties grant a characterisation and a prediction of behaviour (though only in combination with local rules governing vertices) (Newman, 2003). Given the non-randomness of the networks, the purpose of incorporation is to help distinguish network types and characteristics, and to understand the purpose of their existence, namely the exchange of value.

Three networks of incorporation can be recognised in a socio-technical environment: technological, social, and information (Newman, 2003). A technological network is constituted by the distribution of commodities like electricity and, in return, money. Such networks imply a connection between physical components and present an outline of the fundamental system. By contrast, a social network is a connection among people or groups of people based on affiliation factors. Individuals within a group have the same context and the quality of communities is measured by strength of connections (i.e. measurements of distance or exchange frequency between nodes (Newman, 2003). According to these parameters, several subsystems emerge in an ecosystem.

Predominately, affiliation factors are social structures (e.g. friendships, family or business relationships), commonalities (e.g. interests, preferences, or lifestyle), or common collaboration objectives (Newman, 2003). Collaboration is especially apt to generate stable communities by giving people common objectives that they can achieve by working together. Moreover, the community structures flourish through social trends like the sharing economy (Botsman & Rogers, 2010). Technological and social networks rely on the exchange of data and hence information features prominently in the value network.

From the information exchange conclusions about social and technological structures can be drawn and hence distribution, centres, availability and interlinking of information exchange allow making statements about the technological usage and social engagement of individuals. Broadly speaking, an information network refers commonly to web-based information exchange between several entities, mostly ICT components (Newman, 2003). In an electricity grid, ICT components dictate the design and, likewise, the exchange relationships, as information is fundamental to control and decision-making. The applied ICT components describe information creation points and limitation or possibilities is determined by the technological system. Information is also created by the interaction of actors with the physical system, and this generates profiles of consequential preferences indicating the strength of likes and dislikes. Besides people-to-object linkages, these preference profiles are influenced by non-related system information like lifestyle. Non-related information contributes to the amount of information in the system and adds additional perspectives beyond the commodities of electricity production or consumption. The availability of electricity-related and non-related information makes it possible for actors within the network to gain further knowledge and hence supports an evolution towards a knowledge network (Davis & Botkin, 1999). This knowledge launches a dynamic cycle of learning, continually increasing actors' knowledge bases (Davis & Botkin, 1999). The consequences of this include a higher customisation of offerings, real-time activities, and short-cycled developments (Davis & Botkin, 1999). In such a knowledge-based value network a deconstruction of existing structures and the formation of hyperarchical forms is likely (Evans B. & Wurster S., 1999) accompanied by the dis-/re-aggregation of values (Davis & Botkin, 1999). A critical factor for knowledge-based systems is the availability of information and the restriction of access by the provider of information.

The accessibility (and hence the availability) of information is determined by the behaviour of actors, which defines the existence and intensity of edges. From a social exchange theory point of view, actors possess the ability to negotiate and to create any value from exchange, but always act within a structured situation (Cook, Cheshire, Rice, &

Nakagawa, 2013). At the same time, it implies that the consequences and conditions of their actions are influenced by larger, non-controlled relationships (Cook et al., 2013). The formation of structures defines the scope of actions, but the vitality of the network depends on the potential of actions to convert value (Allee, 2008). On the other hand, the conversion of value in a knowledge-based network depends on the ability to use intangible values, like information, to create negotiable offerings (Allee, 2008).

Eventually, the behaviour of actors, and their ability to convert value, are critical and lead to reformulate the previously stated value network definition to *"…any set of roles and interactions in which people engage both tangible and intangible exchanges to achieve economic or social good*" (Allee, 2008). A summary is that an increased influence of social roles in a CE value network has two implications. First, the main assets in the electricity industry shift towards intangibles and change the nature of value. Secondly, social roles introduce different methods of conversion strategy.

4.2 Value Creation from Intangibles

Value creation is commonly defined as the *raison d'être* for any business and includes all necessary actions that provide "better value" for others. Improved value creation manifests itself in the form of tangible (e.g. products) and/or intangible outcomes (e.g. services) and improvements are attained via innovation (Teece, 2010). This understanding is propagated in organisational theory or strategic management, and in recent years, the value creation of services has been gaining more attention as the servitisation of industries introduces a shift in the design of offerings (Baines, Lightfoot, Benedettini, & Kay, 2009). This requires, on the one hand, more elaborate processing capabilities, but on the other hand, the ability to convert these intangibles into deliverables (Allee, 2008). In order to convert intangibles, a medium for exchange, e.g. money or credit items, is required in order to define a value of deliverables (Allee, 2008). A common unit of measure for intangibles is advantageous but the conversion of every intangible type creates the extreme of "micro-credits for ideas" (Allee, 2008). Thus, some intangibles are not converted at all or are exchanged within the intangible realm.

The conversion and utilisation of intangible assets is becoming an important challenge for future electricity markets. A central issue lies in the inherent value experiences of customers, which can generate a discrepancy between potential and realised value (Ramsay, 2005). Increasingly, value creation originates not only at the organisational collective level but also from individuals. The resultant non-profit orientation creates specific social roles and assigned capabilities, building in further antecedent factors for the management of value creation. Therefore, an explanation of new value creation must begin with individuals (Teppo & Hesterly, 2007). These changes in the nature of outcomes imply that the concept of value creation, in particular content and exchange, alters as well as the understanding of roles and their utilisation of assets.

4.2.1 Types of Value

To begin the investigation into value creation, two concepts must be defined: content and exchange. Value content is "… *the specific quality of a new* […] *product or service as perceived by users in relation to their needs* …" (Lepak et al., 2007). This implies that experienced value is subjective and individual (Bowman & Ambrosini, 2000). On the other hand, experienced value can at least be interpreted as the user's willingness to exchange one relative value for another value (Lepak et al., 2007). The willingness to exchange on the part of both producer and user is generally dependent on two conditions. First, the value in return must exceed the producer's costs, and secondly, the monetary amount spent by the user for the new service received must be lower than that of the next alternative (Lepak et al., 2007). The creation of value is an emergent property of two participants and shaped by the design and functioning of the value network (Allee, 2008).

Such context-specific offerings require an agreement on the deliverables, i.e. they must include all contracted, mandated or expected deliveries (Allee, 2008). In this regard, delivery streams beyond the final product and/or service emerge, and a refinement of deliverables according to the perspective of negotiable value becomes more suitable (Allee, 2008). This form of value is created by the conversion of tangible and intangible assets into a deliverable which enters the market. The exchange of deliverables requires a medium of exchange (conventionally, money) (Allee, 2008). This mainstream mind-set has prevailed for a long time in research, but other forms, such as alternative currencies (e.g. air miles), knowledge, or favours prompt a rethink of classes of exchange medium (Allee, 2008). To this end, three currencies can be distinguished as shown in Figure 17.

The conventional stream (the green line) represents the exchange of products and services for money, e.g. electricity for money. The second intangible stream emerges from the novelty and appropriateness of subjective value and strongly depends on the distribution of knowledge. The particular role of knowledge is crucial for deciding to participate in an exchange and has three conditions (Amabile, 1996). Firstly, the user must have knowledge of all options and their inherent value. Secondly, the user must be capable of understanding the meaning of all the options. Lastly, the choice of an option depends on the social and cultural context into which the new value is introduced. A critical aspect is the information asymmetry between participants, which makes it doubtful that individuals will make the optimal decision (Greenwald & Stiglitz, 1986). The value gained in return consists of information about the user using further to provide personalised offers. Thus, source and user agree on the necessary information for strategy, planning, process, technical know-how, design, and policy which surrounds the core product as well as existing in the value network (Allee, 2000). This would imply that within CE value network information like service offerings or utilisation of devices are exchanged.

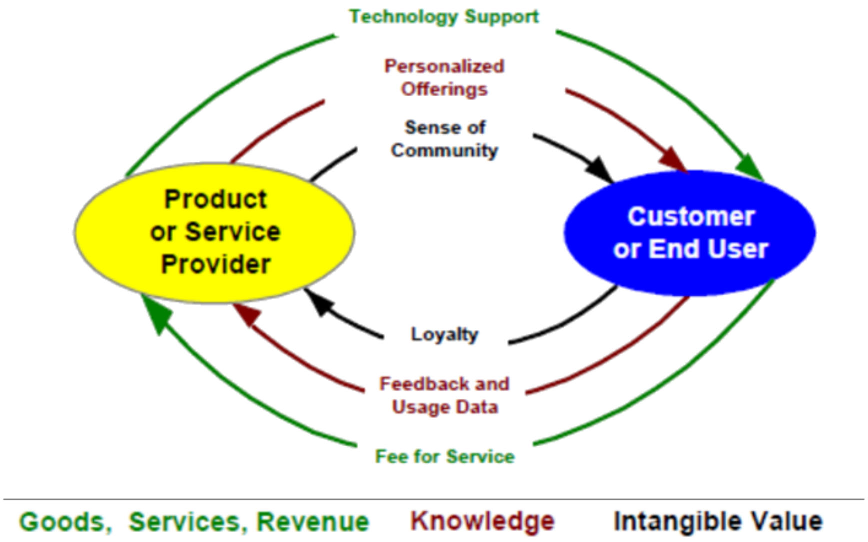

Figure 17: Mapping the value exchange (Allee, 2000)

The third intangible stream goes beyond services and knowledge, and eludes traditional financial measures (Allee, 2000); it is comprised of intrinsic motivations or social values such as a sense of community which are paid in return for the customer’s loyalty. Additionally, intangible values can be used in an exchange, e.g. provide electricity for the community and in return obtain commitment and trust, but even more, intangible values are an indicator of willingness to participate in an exchange. The absent of trust or commitment would peril the exchange of electricity. In summary, intangible values are exchanged among each other, are used as a counter value for other value streams, or disrupts exchange in the lack of absent.

These different types of value exceed the traditional agreement of content value and willingness to exchange in the crowd-based value network. Moreover, the subjective and context-specific nature of value creation results in competing views on valuable options among various stakeholders. To consider all three value types is necessary for explaining new deliverables from the emerging role of prosumer and exchanges based on nonrational or non-economic behaviour. Eventually, types of value can be used to recognise social roles and in knowledge of a different asset conversion into deliverables.

4.2.2 Roles and their Relevance of Value Exchange

The ability of a network to convert assets into value is heavily dependent on the role producing deliverables from tangible and intangible assets (see Figure 18). Tangible assets refer to all system relevant technology to produce, store, and consume electricity. This includes technologies which are interlinked direct or indirect, e.g. mobiles to show statistics, with the production and management of electricity. On the other side, intangible assets define skills and abilities to apply tangible assets to produce deliverables. In general, assets can be private and/or public resources and are categorised in four main groups: financial assets, human competences, brand and relationships, and internal structure (Allee, 2008). In more detail, financial assets refer to the investment potential in a system, human competences are skills, capabilities and knowledge, brand and relationship defines the self-awareness of a role and their relationships, and internal structure mainly refers to tangible assets. Such a strict distinction might not be possible. For example, internal structure also inherits certain knowledge about usage. This knowledge is bound to the internal structures, however, could be assigned to human competences.

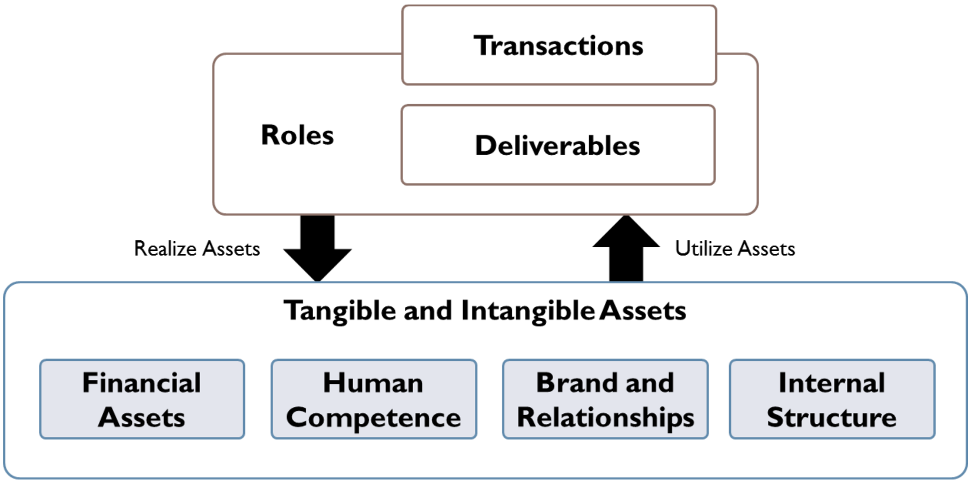

Figure 18: Value conversion strategy model (Allee, 2008, p. 10)

The implementation and execution of value conversion from assets is strongly characterised by the type of role, namely organisation, society or individual (Lepak et al., 2007). Organisational roles generate new value and thus create competitive advantage by being innovative – finding new approaches, materials, or technologies (Tidd & Bessant, 2013); they also allow organisations to acquire new skills and the ability to organise internal knowledge of value delivery (Teece, 2010). A strong orientation towards customers emerges and becomes part of value creation, e.g. business modelling of customers' "pains and gains" (Osterwalder, Pigneur, & Clark, 2010). Thus, organisations are capable of finding, developing, and combining information to generate knowledge for the exploration and exploitation of opportunities (Smith, Collins, & Clark, 2005). Compensation is either of a financial nature or delivered through intense cooperation in an increasingly intangible value network. Finding equal value for intangible exchange depends on the utilisation of openings to improve competitiveness.

Meanwhile, society as a role for value creation employ different tangible and intangible assets and is less business driven, maybe more altruistic (Lepak et al., 2007). This means that the production of deliverables occurs simultaneously with the activities of organisational and individual roles. Furthermore, these deliverables serve the purpose of improving value conversion for both of the other roles. Hence, society receives success or failure feedback and stimulates inherent capabilities, skills and knowledge. Such roles are on higher collective levels and can be either institutionalised in governments or defined as society in general. Both, convert assets differently and also deliver different values. For example, institutional deliverables are regulative rules considering the welfare of all participants within and outside the value network (Scott, 2014). They describe all types of formal rules, laws, sanctions, incentive structures, cost structures, power systems, standards, and protocols. Societal deliverables are normative rules and are morally governed (Scott, 2014). Hence, deliverables of values, norms, role expectations, systems of authority, a sense of duty, and codes of conduct, are produced and begin to interact with existing regulative rules. The overall objective is the stimulation of the internal value creation cycle. Thereafter, organisations and individuals may begin to consider objectives such as sustainability deriving from normative rules (Breuer & Lüdecke-Freund, 2014).

Individuals are increasingly sources for value creation, developing novel and appropriate tasks and processes to pursue personal interests. Achieving individual objectives is distinguished from the organisation-centric, more economic theory-based view in its acknowledgement of social relationships and their philosophy of exchange with their environment (Cook et al., 2013). Applying social exchange theory provides an economic metaphor for these social relationships. In social exchange situations, individuals assess value and the resulting exchange happens in accordance with the two central properties of self-interest and interdependence (Lawler, 2001). Self-interest defines individuals' motivation to maximise rewards and to avoid potential costs (McDonell, Strom-Gottfried, & Burton, 2006). So it is assumed that individuals are rational and engaged in weighting options to finally make a decision. In recognising self-interest as an entity, individuals are motivated to fulfil basic needs through the improvement of interactions between several individuals. In other words, individuals seek relationships to promote both own and others' needs through mutually beneficial behaviour. Individuals or groups of individuals show a high level of goal-orientation. Furthermore, exchanges happen in a non-competitive system and that kind of collaboration requires different forms of interdependency like reciprocal control or punishment (Andreoni, Harbaugh, & Vesterlund, 2003). To this end, participants establish mutual and complementary arrangements built on fairness, emotion, trust, and commitment (Baxter & Braithwaite, 2008; Cook, Cheshire, Rice, & Nakagawa, 2013). Such social exchanges are more flexible and rarely involve explicit bargaining (Baxter & Braithwaite, 2008). The value in return may come in the form of recognition or status rather than just money (Amabile, 1996).

The main determiner of social exchange, however, is still the decision of whether or not to exchange according to cost and reward, and in which quantity (Lawler, 2001). Eventually, the decision-making process, and the risk-averse or risk-seeking behaviour involved, determine to a large extent how dynamic and lively exchange will be.

4.2.3 The Decision Making of Individuals

A common theory for economic reasoning is Bernoulli's expected utility model (Bernoulli, 1954). The mathematical expression of each possible outcome weighted by its probability expresses, in terms of numbers, a difference in preferences and finally provides a scope for actions (Bernoulli, 1954). In other words, rationality hinges on the ability to describe benefits and costs in monetary terms. Moreover, preferences can be represented as utility functions, implying a mathematical optimisation towards an objective. This central point of the theory has helped to establish it in political (Petracca, 1991), sociological (Hechter & Kanazawa, 1997), and economic (Simon, 1979) science due to its simple handling of a complex situation.

Later, the emergence of the concept of value expectation in decisions altered the mathematical model to a moral expectation model (Bernoulli, 1954), which recognises that individuals' benefits and costs can go beyond financial assets and involve expectations on various levels, e.g. comfort or sense of time. Expected utility theory still assumes optimal decision-making between risk; however, the normative interpretation fails to explain derivations in the adaption of individuals' decision-making. Individuals often adapt their choices and violate the rational choice axiom raising doubt of the intelligence of "rational" economic agents (Kahneman, 2012). In particular, the fact that irrationality can originate from perceptions, habits, beliefs, and desires, is barely even considered in this theory (Boudon, 1998).

Kahneman's prospect theory attempts to improve the accuracy of decision-making behaviour modelling (Kahneman, 2012). Based on the gambling metaphor, the theory enriches the elementary axiom of rationality by allocating risk-averse and risk-seeking choices to a matrix of the prospect of changes and the probability of occurrence (see Figure 19) (Kahneman, 2012). The emerging fourfold pattern extends expected utility theory and emphasises the prospect of change and the evaluation of positive or negative change in comparison with a reference point (Kahneman, 2012).

	GAINS	LOSSES
HIGH PROBABILITY Certainty effect	**Risk Averse** *e.g. Bet on the sure thing* Fear of disappointment Accept unfavorable settlement	**Risk Seeking** *e.g. Gamble between bad options* Hope to avoid loss Reject favorable settlement
LOW PROBABILITY Possibility effect	**Risk Seeking** *e.g. Lottery* Hope to large gain Reject favorable settlement	**Risk Averse** *e.g. Insurance* Fear of large loss Accept unfavorable settlement

Figure 19: A prospect theory matrix (Kahneman, 2012)

Contrary to Bernoulli's assumed equality of individuals' preconditions, Kahneman notes that individuals have different starting points and consider choices with reference to their current situation and the expected impact of the change on their future situation (Kahneman, 2012). For example, the prospect of increasing electricity production by 1,000 kW per year (kW/y) is not perceived in the same way by a prosumer, with a yearly production of 5,000 kW/y, and a prosumer, with a yearly production of 15,000 kW/y. Furthermore, the expected response to gains is generally weaker than that for losses, meaning that people normally exhibit loss aversion and are willing to fight harder when facing the prospect of a loss (Kahneman, 2012). This asymmetry is in a ratio of about 1:2 (Kahneman, 2012). Additionally, the endowment effect influences the prospect of changes by creating variation in tastes: people apply the "thinking like a trader" concept if the reference point is higher (Kahneman, 2012). For example, prosumers with a higher reference point (i.e. higher surpluses) perceive higher losses if selling at a lower price than expected. Thus, the current market price matters and may drive prosumers to spend more time selling their surplus. Meanwhile, people with lower reference points are indifferent to trading habits, but their choices are between different losses. No endowment effect occurs and any treatment of expenses is considered a loss.

The dimension of probability of occurrence encompasses both an assessment of the likelihood of events and their expected impact (Kahneman, 2012). Familiar events are easier to weight as experience and knowledge are sufficient for assessing the impact of the event; people tend to risk more in such situations (Kahneman, 2012). In contrast, rare events are much more difficult to predict, e.g. outages of supply through nuclear melt-down, and individuals tend to worry about their ability to deal with the consequences. If rare events seize individuals' attention, it is likely that they will exaggerate their probability (Kahneman, 2012). This habit derives from flawed, limited knowledge, and is beyond the realm of normal expectations. The Black Swan metaphor characterises this problem (Taleb, 2008). However, estimates of probability of occurrence are also affected by the "possibility" (low probability) effect and the "certainty" (high probability) effect. Normally, one would expect the effect of a 5% change to the probability of increasing electricity production to be equal regardless of whether the probability increased from 0% to 5% or from 95% to 100%. But, as shown by (Kahneman, 2012, p. 314), the decision weights are disproportional to the probability of change and hence do not depend solely on quantitative probabilities.

The prospect of unlikely outcomes is weighted excessively highly (Kahneman, 2012). This possibility effect explains insurances and lotteries in which people pay higher prices for a small chance to avoid losses or to win a large prize. In an electricity industry context, this would mean that individuals would pay maintenance services for rare events such as storage or photovoltaic outages. On the other hand, the certainty effect causes lower decision weights than the probability justifies (Kahneman, 2012). This is attributed to the fact that people are risk-averse when facing the prospect of certain gain (Bernoulli's expected utility) and accept lower risk in order to avoid disappointment. For example, the certainty of producing electricity indicates that the fear of disappointment, which is not benefiting from the surplus, leads to storing electricity. The option to sell and to have a financial benefit from surplus would also be plausible, but the disappointment caused by the current electricity prices is much higher. By contrast, in "certain loss" situations, deciding between bad options, a risk-seeking behaviour occurs in a bid to avoid losses. The negative prospect of a sure loss is less desirable than the gamble. Such certain loss situations occur when the benefit of self-produced surpluses diminishes, e.g. production is offline or storage level is low. To avoid losses less beneficial options, e.g. buying from external sources, are considered in the decision making.

The strength of prospect theory lies in its explanation of decision-making using a reference point, which opens up possible outcome areas (see Figure 19). In the light of prospect and probability dimensions, the fourfolded pattern explains underlying fears and hopes of prosumers to deal with decisions about self-produced electricity. For this reason, Kahneman’s approach might be closer to reality for decision-making of social roles in a crowd-based value network than the rational choice theorem. However, prospect theory cannot explain all influential factors which alter choices. It is also to note that the prospect theory frames choices according to risk definition. Other framing approaches, like attribute or goal framing, may produce different outcomes (Levin, Schneider, & Gaeth, 1998). The complexity of the decision-making process is immense and prospect theory does not claim to provide a complete understanding of it.

4.3 Summary of Literature Review

The literature review presented the theoretical background for defining a Crowd Energy value network. The review started with outlining the basic management principles of a value network, i.e. integrated process, sharing risk and rewards, cooperation, by describing supply chain theory. Most of today’s understanding of value networks derives from the supply chain approach, however, differences between theoretical concepts were addressed by highlighting the value perspective and the existence of different networks to create value. In particular, ICT contributed to the development of a value network and enhanced the exchange of information. Thus, information gained importance as a type of value for exchange. Additionally, the review characterised the prosumer as a social role with different perspectives on value and value creation. The value perspective of a prosumer introduces a new type of value – intangible values (e.g. sense of community, loyalty or commitment).

The literature review also provided the theory for prosumer value creation depending on the value conversion model, whereby tangible and intangible assets are converted into deliverables. Intangible assets, in particular are crucial for conversion and include the prosumer (human) competences of decision making on self-produced electricity and the asset of internal structure to utilise storage. The above assets describe the strength of a crowd. The factors involved in crowd potential in the review state that potential refers to traditional supply chain optimisation tasks. The subordinate treatment was deliberate as optimisation requires the supply chain to be defined, e.g. production, storage and consumption units or network, these depend on the design of the network. As a Crowd

Energy value network has not been defined yet, the factors for assessing potential will be described by the model and the objective of optimisation. In the case of Crowd Energy, this refers to the optimal flow of electricity within and between buildings. A description of factors in the model will be provided in the next chapters. Nevertheless, the theoretical insights of this chapter allow a Crowd Energy framework to be created.

5 A Research Framework for a Crowd-Based Value Network

This chapter defines a Crowd Energy framework based upon the highlighted research need in chapter 3 and the theoretical foundation in chapter 4 (see Figure 2, page 9). The chapter's objective is to develop a conceptual framework for analysing and interpreting crowd's coherency, namely strength and potential, and the effects on a value network (see chapters 5.2.1and 5.2.2).

To do so, chapter 5.1 develops a general Crowd Energy value network according to value network principles outlined in the literature chapter 4. In particular, the value network design includes the specification of network objectives, roles, relationships and deliverables. Therefore, an achievement of this chapter is that it has provided a value network design. The proposed design builds the context in which discussions of crowd strength and potential will take place. Chapter 5.2.1 presents crowd strength factors according to the value conversion model, discussed in chapter 4.2.2. Strength, i.e. working together as a community, includes factors without limitations, such as willingness to work within a crowd and decision to share or to keep self-produced electricity. The crowd potential can be summarised as the ability to create and sustain crowd independence from external electricity suppliers through a high availability of self-produced electricity. Thus, chapter 5.2.2 describes supply flow factors like electricity production, consumption, sharing, and storage capacities.

5.1 The Crowd Value Network Design

A powerful tool for creating Crowd Energy value network is the network value analysis (NVA) which builds on social network analysis (SNA) (Pinheiro, 2011) and social exchange theory (Cook et al., 2013). NVA allows representing a value network's complexity by using a non-financial and non-linear taxonomy meaning that it assesses participants' capabilities for value creation and hence business modelling beyond monetary factors (Allee, 2008). Furthermore, NVA analysis a value network on a business level and the investigation of value creation linkages with strategic partners and other stakeholders. Besides outlining the design, NVA provides the possibility to discover new types of business relationships, structural gaps or bottlenecks. Defining the structure including critical or new situations, capture and increases the understanding of beneficial or supportive elements in a value network. This goes beyond traditional business transactions and includes intangible values as they are key to creating trust. It also provides opportunities for innovation (Allee, 2008).

So, a careful elaboration produces valuable insights and answers the basic questions rising in a Crowd Energy value network:

1. What is the position of crowds, prosumer, and consumer in the value network?
2. How do relationships alter due to changes in the nature of value?
3. Which value types are decisive for value exchange?
4. What are the underlying business logics for different stakeholders (depending on their roles in the new network)?
5. What roles (or groups of players) are benefiting most in the new configuration?

The outcome of NVA is a network map showing flows, bottlenecks, and the importance of roles or relationships. The creation of the map is an incremental procedure and comprise following stages:

1. Define network and objectives
2. Identify network entities and map network influences
3. Define the value each entity perceives from being a network member
4. Analyse and shape

The above stages are explained in detail in the following chapters.

5.1.1 Define Network and Objectives

The comprehensive description starts with a definition of the focal and setting analysis boundaries. The focal is a crowd structured network and defines virtual geographical areas containing both prosumers and consumers. Theses crowds act independently but must align with overall network premises. This means there is interdependence between a crowd and the network and they both determine various (and maybe divergent) goals.

Traditionally, an electricity network, inclusive of crowds, accomplishes five objectives: economic performance, safety, technological performance, being environmentally friendly, and product quality (Rui, Arnold, & Wellssow, 2012). The relationships between these goals can be supportive, neutral or contradictory. In general, it can be said that not all objectives can be fully achieved simultaneously, hence some are favoured and are attained at the expense of others. Therefore, it is necessary to prioritise objective(s) for all participants at value network level. For example, being environmentally friendly postulates sustainable production initiatives based on more volatile renewables and requisites enhanced balance efforts to secure supply.

In a traditional sense, electricity network objectives dictate a crowd's behaviour and define measurements according to crowd characteristics and level. For example, wasteful behaviour is considered as heedless lighting or leaving devices in standby mode but eco-friendly behaviour requires these inefficiencies to be reduced. The crowd's sphere of actions describes all measurements at a low-voltage level and related factors referring to life-style, mind-set, and patterns. These are community-based factors providing guidance and describe the priorities of a crowd. The liberty to set priorities distinguishes crowds and one crowd could emphasise environmental friendliness whereas another would prefers technological security. In this study it is assumed that a crowd's highest priorities are security of supply and economic viability (see Figure 20). These two objectives play a major role in the conventional value stream and are subject to both risk averse and risk seeking decision making.

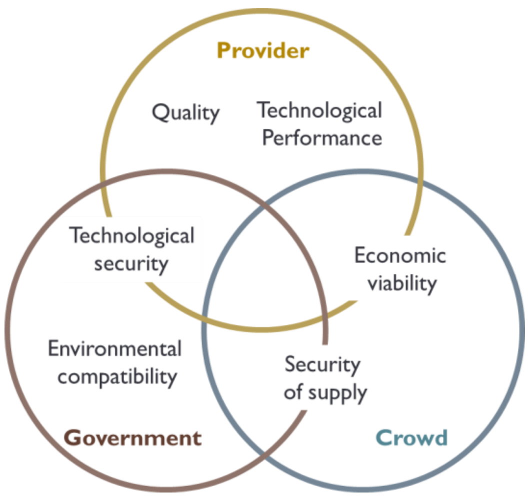

Figure 20: Objectives assigned to electricity network participants

The introduction of crowd-based objectives implies that there is a certain strategy of independence and all activities are aligned to it. Thereby, collective effort derives from individuals and their trust in and commitment to the community (Gstrein & Teufel, 2015). A community's strength lies in the management of various forms of altruism and egoism (Hunt & Beister, 1992). One difficulty is to determine a balance between altruism and egoism, which coexist in any case, and implies that a balance needs to be struck between individual and collective objectives. It should be noted that individuals might have different goals but require aligning to a community. Nevertheless, appropriate measurements to deal with negative individual behaviour are necessary. How difficult this is shows storing behaviour of cells. Considering it on a community level, others would require the stored electricity and it would be egoistic. But with this bad behaviour, the cell creates independency and would not require any assistance, at a later time-period, from the community. To deal with that all crowds define additional goals and values, which are accepted by the participants (Gstrein & Teufel, 2015). These goals and values differ from traditional values in the supply chain, e.g. the introduction of the principles of the sharing economy (Botsman & Rogers, 2010; Hamari & Ukkonen, 2013).

From the description above a crowd is conflicted when trying to satisfy members of the community as well as obey network rules. This conflict of objectives characterises behaviour, relationships, and position in the value network. To understand how they work it is necessary to investigate a crowd's scope of actions which can be determined according to two dimensions: the goals that are pursued and who are contributing to attain them.

In a crowd, tasks can be distinguished as being subjective or functional. These tasks achieve certain objectives and hence goals can be distinguished as being subjective and functional. Functional refers to necessary tasks to be performed to create a stable network, e.g. load balancing whereas subjective comprises tasks that support individual objectives, e.g. selling electricity at a certain price. This assumes that crowd members formulate objectives which might not be achieved in all cases. A strict line between subjective and functional cannot be drawn as each crowd sets priorities differently, in addition subjective and functional objectives can match. Eventually, competition between subjective and functional objectives emerges. The other dimension specifies how objectives are achieved by considering contributions from all (aggregated) or a part (filtered) of members. Aggregation consists of each member's contribution to execute a task. On the other hand, filtering defines a subset of a member's contribution. In the intersection of those two dimensions four areas emerge and each segment has its own characteristics (see Figure 21).

The left hand side of Figure 21 illustrates crowd dominated objectives and can be divided in two main areas. The bottom left corner represents objectives which are important for functionality of the crowd electricity networks, e.g. load balancing, and involves all crowd members. A separation into micro tasks distributes the burden evenly. Any appeals from crowd members are ignored and contradictive actions are punished. The top left area is less interfering in control mechanism as it requires all members to contribute by satisfying individual's objectives. The challenge lies in the creation of alternatives of attaining goals. For example, individual pricing preferences entails certain schedule to execute them.

Raising conflicts between these preferences means either to adjust individual preferences or to reschedule execution.

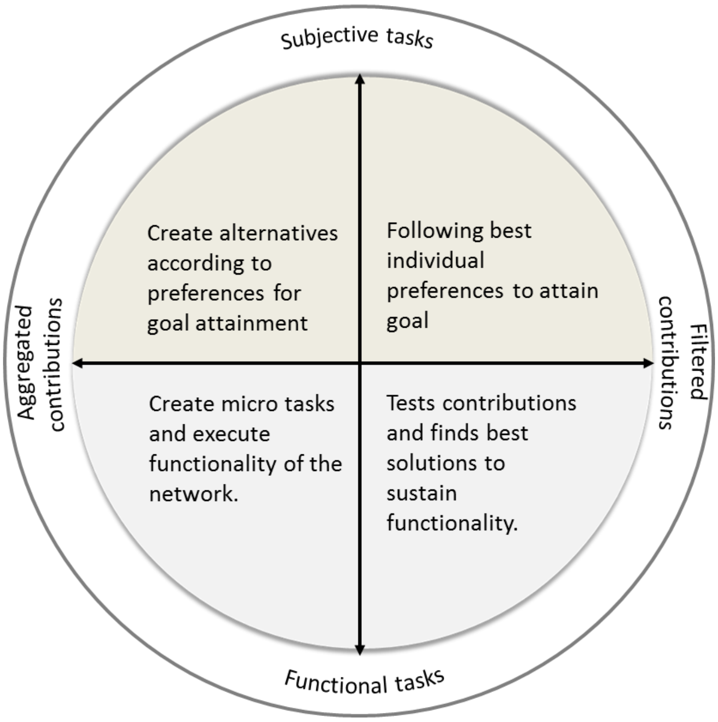

Figure 21: Crowd Energy objective matrix

The right side of the figure illustrates the decision making among preferences to attain objectives from individuals. The filtration of contributions creates competition among preferences and implies an adjustment to less preferable ones. Preferences compete according to the criteria for choices of preference and the difference is represented by the top right and the bottom right areas. The top right corner distinguishes choices according to the composition of preferences between members. The set of preferences can have high conformity or a high heterogeneity. The reality is somewhere in between those two extremes, however, the likelihood that a preference is considered increases if a single preference fits in the composition to attain objectives, mostly crowd specific ones. The bottom right corner disagrees with the similarity of preferences to functionality of the crowd. In other words, a crowd selects convergent individual preferences to the overall objectives before others.

5.1.2 Identify Network Entities and Map Network Influences

The next step identifies all participants, influencing the value for end-consumers, starting from the focal objectives and characteristics of a crowd. Starting from the focal, it is important to describe all actors, communities, and organisations according to their characteristics and functionality within the network. Besides role description, this step includes identifying the type of linkages between actors. The outcome is a preliminarily value network map (see Figure 22). The following paragraphs synthesise with the description of the chapter 3 and hence restate the main characteristics of the crowd and will elaborate more on the extended value network.

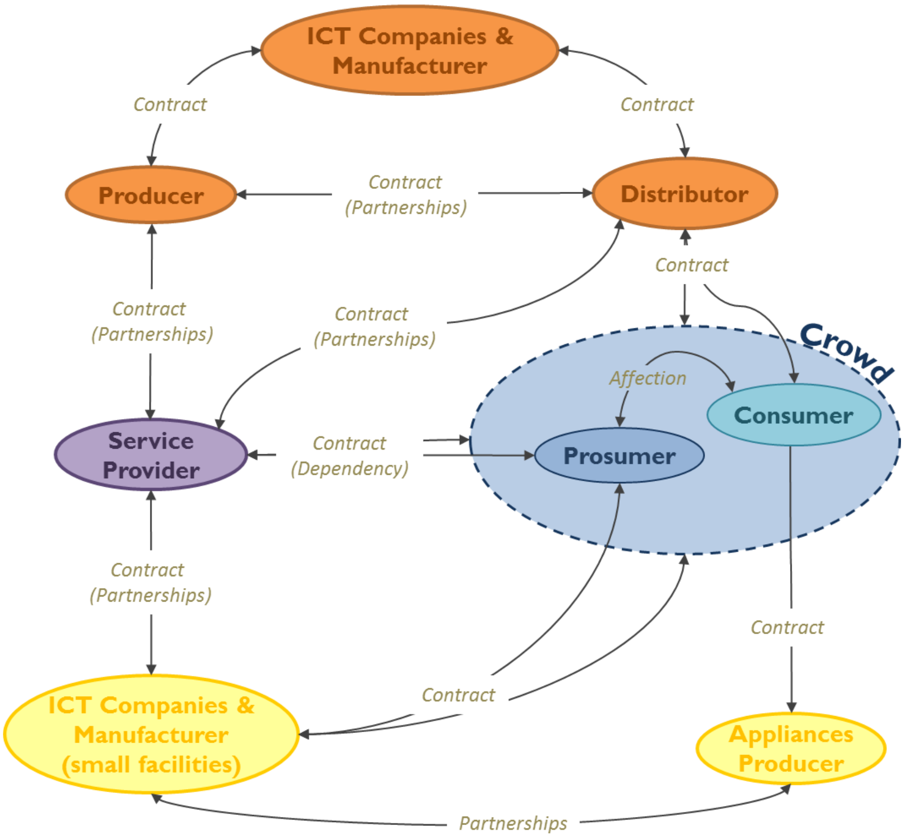

Figure 22: Future electricity value network with roles and relationships

The iGSL cellular structure allows allocating of electricity between local production and consumption locations. A crowd becomes the provider and receiver of electricity simultaneously. The duality of provider and receiver derives from prosumers by supplying new production and storage capabilities, allowing them to temporarily acquire the role of electricity suppliers. Success rests, in particular, on prosumers' willingness to share electricity and sharing includes that prosumers relinquish some-independence for others. Nevertheless, the relationships between prosumers-consumers (or prosumers-prosumers) are defined by the role type which can be either private individuals, business (they have no core competences in electricity business), or municipals. The relationships are marked by social, economic, and regulatory aspects and exchanges happen according to the traditional value stream electricity for money. This includes mainly temporary contracting. On the other hand, relationships also become more emotional due to the fact that roles participate voluntarily or show commitment to a community. These are non-business based relationships and include social and psychological factors. Eventually, the relationship can be defined as affectional. The characteristic of a crowd has some influences on the extended supply chain perspective and roles outside the crowd are redefined, reinforced, or created.

The future electricity industry expects traditional roles, orange fields in Figure 22, to comply with the electricity value chain flow. It redefines traditional roles to have a backbone functionality and supply and distribute electricity throughout the market. This definition has a distinctive impact on the producer and distributor stakeholders. General, load management tasks are still a responsibility of producers and distributors, however, both stakeholders are pushed back from the central location of events. The consequence is that relationships with other roles including the crowd are mainly based on temporary purchasing contracts, e.g. buying and ordering electricity. Additionally, traditional roles might pursue more long-term contracts like partnership with service provider. Its purposes can be development of new products, to secure market shares, or to create long-term ventures.

Besides traditional, supportive roles already work in the industry and, through technological upgrades, on the demand side, i.e. Smart Home, they have reinforced their leverage in the value network. These players are ICT companies, manufacturers of small electricity facilities, and appliance producers originating from other industry settings. They introduce or enhance certain functions, like flexibility of portfolio, shorter innovation cycles, service excellence, or customer-orientation. Such functions are beneficial for reinforcing linkages and locating them closer to the end-consumer as they provide devices to carry out daily tasks, such as cooking or washing. These supportive roles are essential for crowd performance as they define how well a crowd is equipped. Linkage between supportive roles and crowds is based on temporary contracting (e.g. buying appliances). Between supportive roles, (e.g. PV manufacturer and ICT business), partnerships may develop to synthesise capabilities for defining sophisticated solutions. The collaboration has an indirect linkage to electricity providers and generates competition for access to consumers and prosumers.

The newly created role of a service provider plays a central role in the value network. The role unifies traditional and new business characteristics as the major task is to manage electricity for crowds and their members. The hallmark of service providers is a high level of customer orientation, capabilities to deal with information and skills to convert intangibles to deliverables (i.e. services and/or knowledge). Service providers rely on ICT infrastructure, flexibility to adjust service portfolio (offering and pricing), and short innovation cycles to respond to new requirements. This description applies to players which have been working with real time systems for a long time and it is not surprising that telecommunication companies can catch up quickly, e.g. Swisscom Energy Solution (Millischer, 2012).

The room for manoeuvre is determined by network rules for service providers, however, the linkage to crowd or members provides windows of opportunity for creating business. A significant characteristic of linkages are dependencies and the willingness of crowds and their members to share information (Gstrein & Teufel, 2015). This has a direct influence on the quality of service offerings. At the same time, offerings are contracted by crowd and sophisticated services require information. Competition between contracting and dependency emerges and the availability of information is defined by the necessity for security of supply and economic viability. At any level of availability, a service provider becomes a hotspot for information and knowledge related to electricity management. Service providers have a central position and define linkages to almost every other role. The linkage to traditional electricity providers is contractual or partnership like (vertical integration) due to the regulative environment of the industry. A tight relationship with distributors emerges due to the influence on load management – this is the realm of electricity providers. Towards supportive roles, linkages are basically contractual through exchanging services, infrastructure or knowledge. However, services for electricity management are complementary offers (same with electricity providers) and hence promote partnership linkages, e.g. alliances or vertical integration.

Before identifying the value dimensions, a short remark to regulatory roles must be made. The NVA ignores regulatory roles as they exert influence at multiple levels and in different forms, e.g. subvention of PV (e.g. KEV), smart meter regulation, or supervision of prices. Regulation, in this dissertation, is seen that the government attend to create benefits for all players and to create a sustainable Smart Grid.

5.1.3 Identifying Value Dimensions of the Network Participants

The layout of the future electricity network construct in Figure 22 demonstrates the basic requirements for creating value. The next step adds details to the layout by defining value types (can also be called value dimensions) which are desired by roles. The objective of this chapter is to capture the perceived values of linkages. The perception of values implies reasons for being in a network and inherent opinions that guide behaviour (Flint, Woodruff, & Gardial, 1997). For example, a trigger event of a new supply channel through a service provider changes the perception of value – customers evaluate new values – leading to an alteration in customer satisfaction and retention. Furthermore, perception of values provides reasoning for hibernating or missing values (Gstrein & Teufel, 2015). Another insight of value dimensions is the planning and prioritising of the value abundance. The result is that the value delivery strategy and priorities are aligned with network objectives. Besides strategy, a subsequent analysis allows us to look at how a role adds value, e.g. conversion of intangibles. Last but not least, tracking any changes in values or improvements and how to deliver them are opportunities for innovation and subject to business modelling.

The focal of a crowd implies a collaborative environment, including information sharing (Gstrein & Teufel, 2015). Collaboration is an inherent characteristic throughout the network to achieve sustainability. Thus, identifying values of participants concerns all values that are involved in security of supply and economic viability. To satisfy the reasons for being in a network, the framework applies to the three currencies of values investigating beyond the traditional value streams (see chapter 4.2). Additionally, the description of “intangibles” currency is necessary to explain the conversion of them. The following paragraphs focus on the focal crowd and describe linkages between:

- prosumer and consumer (creating a crowd)
- crowd and external roles (supportive, traditional, and service provider),
- individual external roles (supportive, traditional, and service provider)

For simplification, the analysis bellow assumes a crowd with a prosumer and a consumer dummy.

Linkage: Prosumer and Consumer

The collaboration between prosumer and consumer describes the core of any crowd-based structure. The inner circle of currencies (see Figure 23) consists of essential exchanges, i.e. electricity for money, to incarnate a crowd. The traditional exchange proves existence and expresses a regular value stream of a localised market. Between prosumers, exchange can be based solely on electricity, meaning to provide electricity and receive the same amount later like a bank account. Distributors remedy any deficiencies in the crowd. The gathering of the prosumers’ supply and the consumer’s demand assumes willingness to share information in the second stream. Prosumers provide information about current electricity availability meaning current production and storage depletion. They also provide technical information regarding infrastructure. Other information that can be provided covers amongst over things, consumption preferences and decision-making for sharing. In addition, consumers share information about preferences. This includes range of purchasing prices, technical information about appliances, consumption patterns, and information closely related to usage. In particular, pattern recognition draws a blurred line between vitally and trivial data about electricity management. For example, data concerning usage of appliances is required for load management but also for profiling customer preferences. The definition of data type and quantity to be exchanged is closely linked to predefined crowd objectives and moral values.

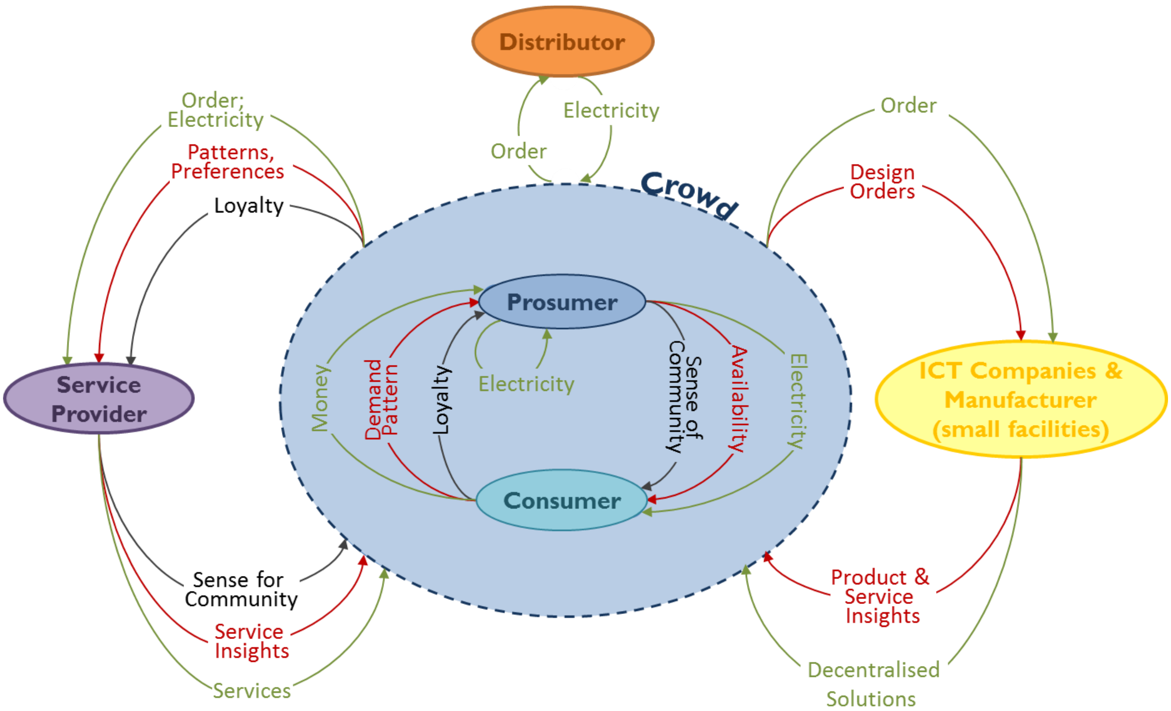

Figure 23: Internal and external currencies between crowd and external roles

Among these roles the third stream of value is mainly used and intangible values represent the lubrication oil for collaboration and nurture engagements (Gstrein & Teufel, 2015). Trust and commitment are the key factors and management involves rewarding positive behaviour whereas negative behaviour is penalised (Morgan & Hunt, 1994). A prosumer shows a sense of community by providing electricity for a crowd rather than selling it externally. To do that, independence is relinquished in favour of community welfare. This generates a certain leverage position as prosumers are the source of sustainability. So, the benefit must be noticeable for prosumers but they must not abuse the system otherwise consumers would leave. If prosumers are trustworthy and committed the consumers will remain loyal. Furthermore, consumer's signals loyalty by adapting a sustainable behaviour and mind-set. This calls for actions which are aligned with the set of crowd objectives, e.g. contribution to reduce waste.

Linkage: crowd and external roles (supportive, traditional and service provider)

The performance of the inner circle determines the quality of linkages to a service provider and supportive roles (see Figure 23). A crowd manifests itself as an association or institute which represents the interests of a collective. As a representative, a crowd buys services for managing electricity from service provider. The traditional business relationship comprises offerings to support load management including ordering electricity (delivered by distributors). Additional services comprise administrative tasks such as billing, business intelligence i.e. pattern recognition, and customer relationship management, including consulting or reward system. Furthermore, services entail optimising consumption, production and storage functionalities to deal with the functional tasks in the Crowd Energy objective matrix (see Figure 21).

Services are the carrier for information and mutual learning. For instance, the crowd gains insight into the possibilities of dealing with load as well as how the system works overall. Through this improvements and optimisation through learning is possible. Meanwhile, the service provider gains knowledge about collective demand, production, storage and transaction patterns. Additional information about collective preferences allows crowd to be characterised. A service provider evolves into an information hotspot. This knowledge is a critical input for load management.

The existence of intangible values between crowd and service provider depends on the closeness of relationship. Closeness is related to location of management. It can be inside or outside a crowd. Inside management leads to a sense of community which is repaid with a certain amount of loyalty (see Figure 24). At this point a service provider can be seen as an extended crowd. Outside management also requires a sense of community which must be proven, however, it is less intense compared to an inside management as the relationship is based on business excellence. So, crowd’s loyalty is replied by brand awareness and unwillingness to change provider.

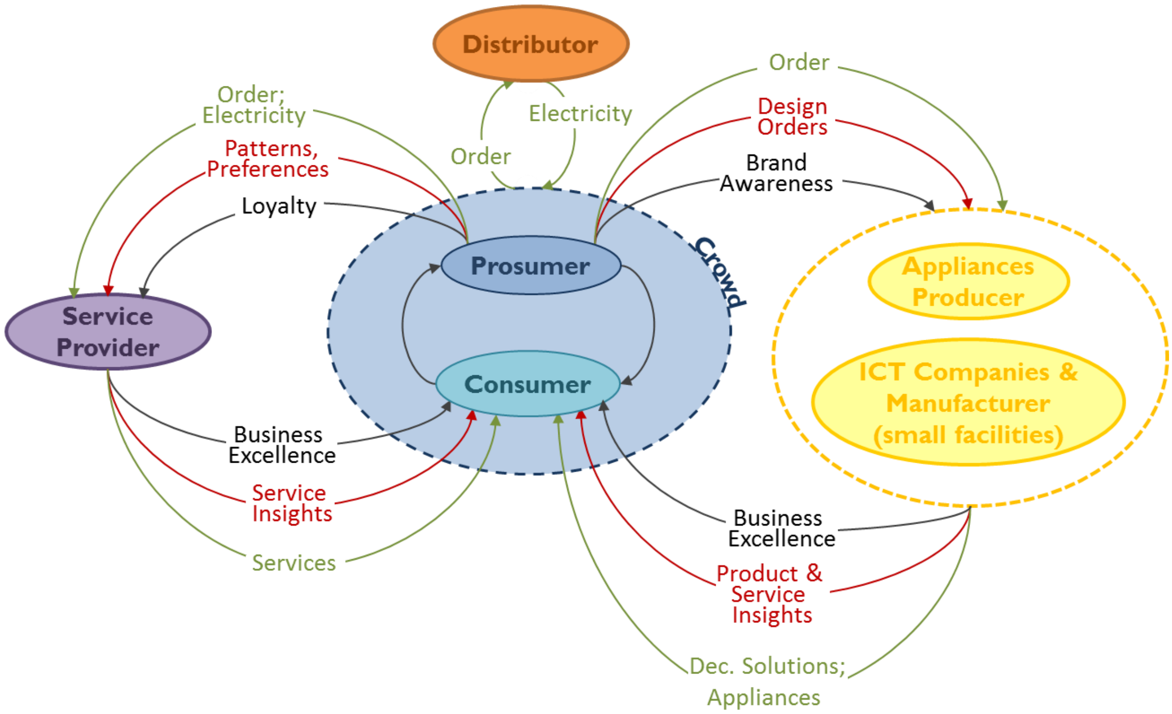

Figure 24: Internal and external currencies between individuals and external roles

The linkage to a supportive role, which offers decentralised solutions, is based on business objectives allowing for independence on the one hand and increasing market share by selling products and maintenance services on the other. Corresponding information about product design and functionalities are provided by the supportive role. By utilising devices, supportive roles gain knowledge and carry out innovation to provide more sophisticated products and services. This fosters mutual learning and innovation.

5.1.4 Shape and Analysis

The previous chapter provided insights into crowd related value dimensions. It is now beneficial to open up the perspective and form a value map to provide an overview of the entire network. An analysis of value creation in the entire value network entails drawing conclusions regarding design and the effects of discrete events on the network. Figure 25 shows the value dimensions of all participants and outlines dependency between roles and is the basis for discussion. Before starting, it is assumed that the role of a service provider is quite influential on flows and in regard to the analysis it is considered as independent in business terms as well as in taking actions. This might be different due to regulatory interventions on delivery of all electricity related information to distribution system operators (DSO).

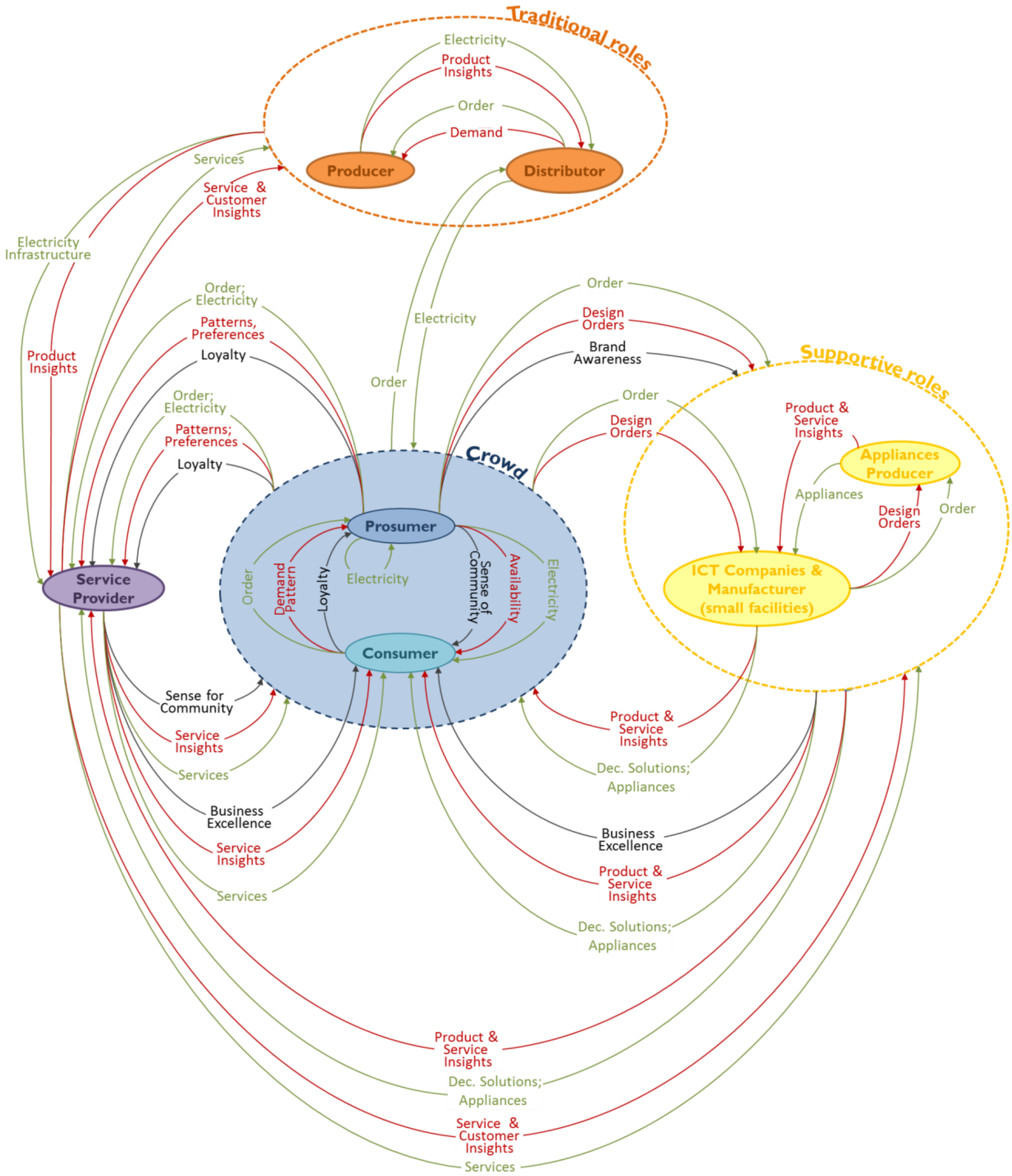

Figure 25: Network value map of a crowd-based electricity industry

A quality of the network value map is the investigation of how well it is defined. For that reason, a coherent logic and flow of values throughout the system must be discussed. A crowd-based value network considers a flow of electricity according to existing infrastructure. As mentioned, it is possible that orders of electricity can occur between crowd and service provider, the real exchange, however, happens through distributors. The traditional paths are integral and no parallel infrastructure exists. Meanwhile, the flow of information might take other paths. The major stream exists between crowd, and its members, and service providers identifying the crowd as the source. There are additional knowledge flows to support and traditional roles. The first flow is caused by the increasing importance of technological and decentralisation development. The second one satisfies traditional planning processes as the electricity system requires certain stability in forecasting. This might be influenced by some real-time adjustments through unexpected events, such as more sun radiation than expected or a lower consumption pattern than expected. Service providers are capable of immediately reacting in accordance with information management. In addition, service providers satisfy different end-customer types as well as different preference settings without disturbing security of supply.

Successful business in the value network means understanding crowd’s and their member’s expectations which are not network related subjects like the complex decentralised systems, distribution networks or revenue sharing agreements between stakeholders. Expectations are rather possibilities of choices, service quality, relevance to lifestyle, ease of use, fair and easy to understand pricing, as well as good support. The delivery of service offerings which addresses these expectations becomes profitable and must occur within a specific timeframe – mostly real time. Thereby, the service provider produces knowledge through business intelligence. This becomes valuable for other players in the network too. Such knowledge increases the portfolio of content and services and hence drives revenue growth.

Meanwhile, service sophistication indicates coordinating between external roles. Service providers address partnerships in traditional and supportive roles producing holistic solutions and in return distribute knowledge. Nevertheless, alignment of upstream processes and conversion of emotional values, e.g. sense of community or loyalty, improves time-to-market of new offerings. Service providers, as well as other players expand their business portfolio for crowd segments and reach a break-even-point. Eventually, service offerings are crucial for success rather infrastructure and hence a conclusion can be drawn that service provider benefits at the expense of traditional roles.

The translation of crowd expectation into service offerings flourishes the value network and also the quality of translation dynamic in the value network. The quality of translation, however, depends upon the skills and capability of stakeholders to produce the adequate deliverables and also the crowd’s coherence. The crowd’s coherence and high internal strength indicates a strong community and little dependence on external support. Limited services from outside are required and help is just needed for basic tasks such as allocation or optimisation of electricity. This affects less traditional business processes – apart from profitability reduction – as this is business as usual. On the other hand, a crowd's strong coherency flourishes internal flows and all internal value dimensions. Any disruption from outside is disadvantageous and crowds are vigilant in protecting flows and all involved values. These values are the foundation of crowd existence. For the residual network, this implies that accessibility of values is reduced and limits value creation of others. Eventually, the importance of service provider to translate expectations into services and the coherency of a crowd defines the intersection between both parties as the bottleneck of the value network.

5.2 Assessment of Crowd's coherency

The crowd's coherency, defined by strength and potential, implies dependency (or independency) to external stakeholders. The assessment of both characteristics allows drawing conclusions about the dynamic within the value network. Thus, the first part of this chapter illustrates factors for crowd strength which are based upon the value conversion model defined in the literature review. This includes factors without limitation decision making about self-produced electricity, storage management, or willingness to work within a crowd. The second part defines crowd potential which concerns with supply chain parameters like production capacities, storage capacities and flows for optimisation. These factors are based upon the design of the crowd which refers to the network of iGSL cells.

5.2.1 Factors of Crowd Strength

The quality of conversion can be identified by the value conversion strategy model and constitutes four areas: internal structure, human competences, brand and relationships, and financial. The model is generally used in a business-orientated environment, however, in this chapter factors for these areas are defined and described according to the prosumer's perspective. Thus, the factors evolve in the light of a crowd-based structure and iGSL structure. The following paragraphs provide factors for evaluation and discussions are lead in relation to an integrated philosophy of supply chain management. A summary of factors to identify crowd strength can be found in Table 3.

The first asset of internal structure relates to the iGSL, namely generation, storage, and load, and defines the concept of prosumer management these functionalities. It is necessary to understand the importance of producing and storing electricity. These two functions are new in contrast to the demand side's initial inherent purpose of consuming.

Asset	Factors
Internal Structure	• Importance of iGSL • Storage management • Electricity Management
Human Competence	• Individual value of self-produced electricity • Price of self-produced electricity • Decision Making (storing or sharing)
Brand and Relationship (to a crowd)	• Willingness • Size of a crowd • Conditions for participation • Characteristic for an ideal community
Financial Assets	• Budget to invest in iGSL infrastructure • Budget for maintenance

Table 3: Factors for evaluating crowd strength

In particular, storage management has potential for self-sustainability of the prosumer and the crowd. Capacities utilised only for self-preservation entails no conversion efforts, but sharing of stored electricity requires management principles for conversion. The corresponding storage management must address subjects like minimum capacity of storage, importance of filling storage to 100%, compensation to provide capacities for external usage and type of compensation, or efforts at a certain depletion level. Another factor is the orchestration of iGSL and the electricity management involved, this is a question of whether prosumers prefer automation or self-management. This affects integration in a crowd. Self-managed buildings can be seen as seclusion whereas automation requires a responsible authority to manage the iGSL system. Furthermore, the most important challenges of electricity management define the critical functionalities of integrating a crowd-based structure.

The human competences of prosumers rely on making decisions about self-produced electricity and the capability to define individual value and price for self-production. Prosumers have to first develop an understanding of individual value and price for self-produced electricity to assess different options. This new skill requires differences between self-produced and external electricity to be determined. Individual value refers to personal preferences, rather than monetary aspects, and becomes an obstacle when misapplied by external roles. On the other hand, price finding by prosumers is influenced by storage and the ability to transfer cheap electricity over time. Any dynamic adaptation of perceptions during charging and extracting is important for the electricity market as prosumer prices are in competition with market prices.

An established awareness of value and price is necessary for decisions concerning any surplus generated. As highlighted in the literature review, decisions are made between two options, a risk averse option, i.e. charging storage or consuming, or a risk seeking option, i.e. sharing or considering other options. Both options occur at surplus situation, otherwise any production is used for covering own demand. This implies that decisions depend upon the production and consumption profiles. Any made choice, storing or sharing, alters the status quo of a prosumer which can be defined as the capability to cover demand through own production. The status quo refers to the future possibility to continue production and hence depends upon the weather forecast. So, a surplus will be evaluated against the need for self-sustainability.

The illustrated situation occurs numerous and for simplification of decision making behaviour, the dissertation applies the concept of (Gstrein & Teufel, 2014) illustrating the linkage between production profile and dominant decision making behaviour (see Figure 26). The basic assumption is that all prosumers would prefer saving electricity – showing risk averse behaviour – when production is at maximum which is in the case for PV production during lunch time. On the other hand, risk seeking behaviour would occur when the option of having a surplus is not available meaning during production offline. Expectation of sunny weather allows for continuous production whereas bad weather would lead to an interruption. Consequentially, as a result of bad weather forecasts prosumers commonly favour more restrictive sharing than in sunny weather.

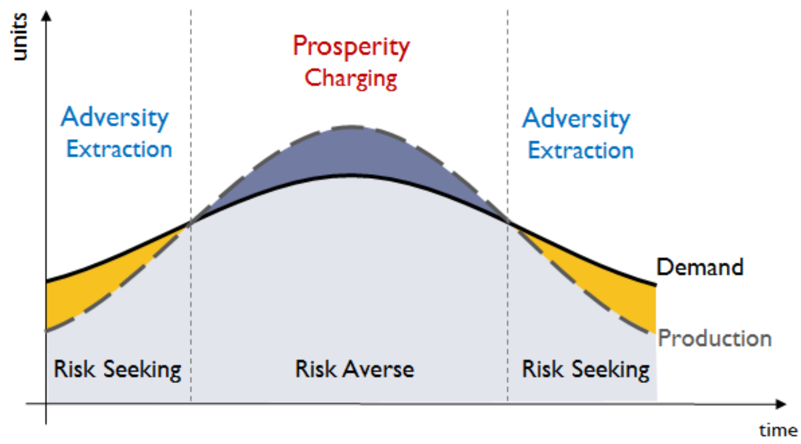

Figure 26: Linkage between production profile and dominant decision making behaviour

A prosumer utilises brand and relationship assets to define contributions in a crowd and evaluates their acceptance of a crowd-based network to share electricity by defining roles and under what conditions exchanges happen. This involves additional non-technical and non-economic perspectives (Gstrein & Teufel, 2015). The brand refers to a prosumer´s personality and will not be further considered as a variety of personalities exists. Insights must be found in relationship perspectives and consist of several factors. The conviction to want to be part of and the willingness to contribute to a community is a critical factor for the crowd’s coherency. It is an overall statement and a prosumer’s positive perspective. Further factors which define the willingness are the size of a crowd, conditions for participation, and characteristics of an ideal community. The size sets the aims for a community where smaller groups have the advantage of mutual confidentially (Thelen, 1949). So, do prosumers like to act in a more anonymous or more familiar environment? Meanwhile, conditions for participation define overall aspects on how to relate to others. These requirements must be fulfilled before considering any exchange. On the other hand, the characteristic of ideal community describe arguments to stay in a relationship and hence the willingness to maintain a crowd.

Lastly, financial assets refer to private or business budgets for investing and maintaining iGSL infrastructure. The economic wealth of individuals and business determines whether technological developments are pursued and hence whether the infrastructure is up-to-date. It is important to mention that financial assets are described for completeness, but are not further investigated and for this discussion it is assumed that investments and maintenance are secured.

5.2.2 Factors of Crowd Potential

As mentioned in the beginning of this chapter, the potential of crowds defines the optimal flow within and between buildings. An extensive description of the Crowd Energy concept is provided in chapter 3, however, it is beneficial to summarise the basic elements of the supply chain (see Figure 27).

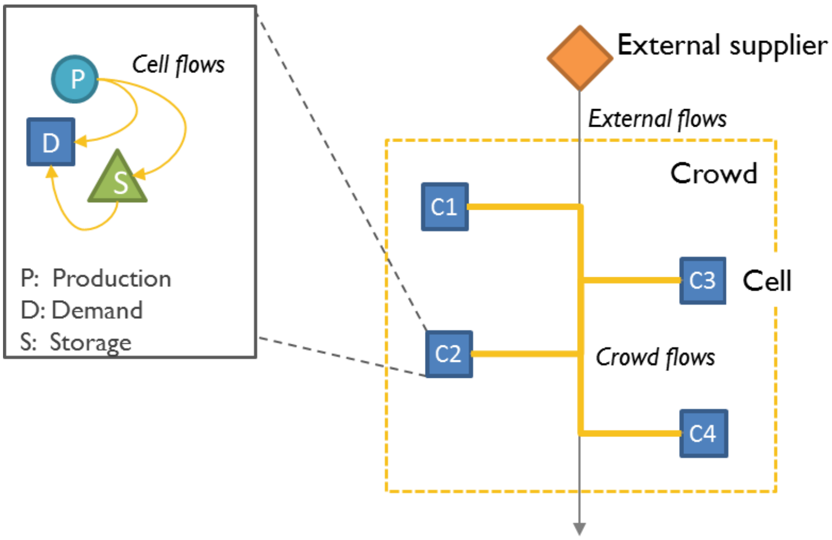

Figure 27: An abstract Crowd Energy model

The iGSL functionalities are the basic components which refer to the performance of production, the capacities of storage facilities and the level of demand. In general, a cell´s production is limited, i.e. sun radiation or wind, whereas storage depends on the amount of surplus generated, which is production minus consumption. Any adaptation in consumption of production influences capacities for storage. It is supposed that consumption is sustainable and necessary, and this framework leaves it to other research to investigate consumption efficiency programs. So, the supply chain is only influenced by production and storage and decisively determines building internal and crowd related flows. Based on that, the essential factors for the crowd potential and the necessary parameters for flow optimisation can be defined. A summary of potential factors is provided in Table 4 and will be elaborated in more detail.

	Factors
iGSL potential	• Missing flow and overflow • Ratio Production to Consumption • Generated surplus (kWh and no of time-points) • Storage capacity (kWh and no of time-points) • Flow quantity of internal exchange • Costs for internal exchange

Table 4: Factors for evaluating crowd potential

By generating a surplus, a crowd strengthens its internal competences and creates a local consumption-production paradigm which allocates individual capacities. Under the assumption that all members are sharing voluntarily, this requires the orchestration of electricity flows and a principal of this assumption is optimisation. Optimised flows between and within cells minimises the crowd’s expenditure leading to a reduction of consumption coverage from commercial electricity suppliers. A low value of these missing flows indicates that the ratio between production and consumption is close to 1:1. Higher ratios could lead to overflows, meaning that a crowd is capable of sustaining its own demand as well as feeding into the general electricity network.

Equal or high production-consumption ratios generate more of a surplus, higher storage capacities, and flourishing internal flow between cells. These effects are valuable factors needed to improve a crowd’s potential. The surplus produced defines the quantity needed for storing and sharing and suggests, on a superficial level, the potential a crowd has to cover demand. Besides quantity measures, generated surplus can be seen at time-points when surplus is available. More in-depth conclusions about potential can be drawn by setting the number of surplus time-points to the maximum time-points. Combined with quantity, the figure expresses the potential of building up independence.

From an hourly perspective, patterns of surplus generation can exist. The effect of storing electricity can be expressed in the factor of storage capacities and the related quantity of electricity held by the crowd or cells. In particular, sufficient capacity suggests sustainable coverage of demand, as well as in extreme situations, autarky. These capacities represent electricity for future references and in this regard, the number of time-points from which a cell discharges electricity creates more independence from external supply. By setting these time-points in relation to the maximum number of time-points, a degree of independence can be achieved.

The last effect of the production-consumption ratio is on the flow of electricity between cells. The quantity of internal flows represents the crowd’s value exchange and indicates the internal allocation between demand and supply locations. The factor of sharing quantities is one way but sharing potential can also be expressed as the coverage of consumption through sharing. By comparing sharing with consumption, the number defines the distribution of surplus and can be set in relation to other flows like storing. All of the aforementioned factors allow general conclusions to be drawn at crowd level, however, cell and time-point perspectives are necessary and applicable as cells define a crowd.

The final factor concerns with accruing costs of flows which should represent the holistic effort for sharing, storing, and buying. In general, costs represent financial compensation for using distribution lines but also network specific conditions like power losses or technical bottlenecks in the network. The Crowd Energy model contains three categories of flows: building internal, between members of a crowd and from members of a crowd to external electricity providers. The difference flows demands a variation in costs leading certain flows to be preferential over others. Besides flow categories, costs must consider the distance, i.e. the flow in a close range should be cheaper than in a wider range. So, the cost factor should consider categories and transport distance which will eventually be minimised. The difficulty for determining the total costs for a flow is to answer questions of how much costs a transport, what is the costs for losses, or what is the costs for a unit self-produced or external electricity. The variations for converting these questions into costs create a difficult and exhaustive task. Another way to build up a cost structure is to use a neutral unit and use it in a ratio starting from the costs for electricity exchange between houses.

A part of above factors, e.g. generated surplus or storage capacities, are the contribution of prosumers to the community. Besides determining the potential of a crowd, these factors can be used to categorise prosumer. The categorisation has advantages. First, a category provides a profile name for cells which allow summarising but even more defining similarities. In addition, a category includes an abstract description and hence increases the understanding of results. Another effect of categories is to provide a dimension to present results more sophisticated. Consequently, comparison between cells and between periods involves transition of cells from one category to another. In particular, it is necessary as consumption and production pattern of different periods influence decisively surplus situations. Lastly, the created categories are a refinement of the term prosumer.

For that purpose, the Crowd Energy framework introduces six categories: prosumer with reduced consumption, low or high temporary independent prosumers, and low or high autarkic prosumers. The categorisation also considers the group of consumers which are locations of electricity shortages and hence are receivers of electricity. Prosumer with reduced consumptions never achieve any surplus entailing that the cell has no flows to storage or flows to other cells. There is an immediately usage of production. They represent the lower end of the scale. Furthermore, they belong to the group of sharing receiver.

The group of temporary prosumers categorises all cells which generates certain surplus but cannot store enough to sustain offline periods. The group distinguishes in low and high temporary prosumers where low describes cells which have a production-consumption percentage below 50%. The low temporary also receive electricity from other cells but are not likely to supply other cells. The high temporary prosumers have a production-consumption percentage between 50% and 100%. This group are not yet autarkic but are close to the threshold of the 100% mark implying that a cell produces electricity exactly the amount of consumption. A small distinguishing of high temporary prosumer is made by stating cells with a plus which are supply electricity to other cells.

The group of high and low autarkic prosumer are beyond the production-consumption percentage of 100%. This means that all autarkic prosumers produce more electricity as they can consume. Again the group was separated in a low and high where low describes a production-consumption percentage between 100% and 150%. The high autarkic prosumer have a percentage above 150%. Both autarkic categories are self-sustainable and the main supplier for sharing. The provided criteria for categorisation are based on observation and qualitative judgment of the current scenario results.

5.3 Summary of Strength and Potential Factors

The previous paragraphs presented the step-by-step development of a conceptual Crowd Energy value network. The description highlighted roles, relationships and value dimensions. Furthermore, the chapter discussed characteristics of relationships between single roles and also the overall dynamics in the Crowd Energy value network. The resulting map is a possible future value network and provides a context for describing its strength, i.e. working together, and potential, i.e. producing surpluses for sharing in a crowd. Both strength and potential define the crowd’s coherency which is a measure of the position and relationship within the value network. Strong coherency indicates less dependence on other stakeholders.

Subsequently, the chapter elaborates on the factors used to assess strength according to the value conversion model. In particular, the human ability of decision making on self-produced electricity and the management of storage are key for defining strength. The potential of a crowd refers to the supply chain task of optimising flows. Thus, the factors are related to production, consumption and storage quantities. Furthermore, potential factors consider different flows, namely internal flows in buildings, flows between members (also known as sharing), and flows from external electricity suppliers. The flow differentiation allows applied cost structures to be minimised.

The presented strength and potential factors are taken for further investigation and bear the value network map in mind for later discussions. The analysis of crowd strength and potential pursue different objectives and to support readability, strength and potential are separately shown. Therefore, chapter 6 will show the results found for crowd strength and chapter 7 will show the results of crowd potential. This also allows describing the different research methods, namely survey and optimisation. The results of both chapters are synthesised in the discussion provided in chapter 8.

6 A Survey on Crowd Strength

The conceptual framework developed in chapter 5 provided the factors for analysing the crowd strength, this chapter presents now the empirical results (see Figure 2, page 9). The objective of this chapter is to elaborate on characteristics of value conversion from a prosumer perspective. The utilisation of tangible and intangible assets to generate deliverables depends upon individual preferences, opinions, and behaviour. Therefore, an online survey was chosen as the adequate research method to gather and measure data.

The development steps for an online survey in chapter 6.1. shows how data was collected and should support the quality of applying the research tool. The chapter describes in particular two main tasks: generating and structuring questions, and creating a screening process. The screening process was important to explain the unknown CE concept to respondents without influencing answers. Chapter 6.2. shows the results of 154 respondents. The analysis was made for the internal structure (chapter 6.2.2), human competences (chapter 6.2.4), and brand and relationship (chapter 0). Summaries of the most important results of each asset are stated at the end of each chapter.

6.1 Generating an Online Survey

This chapter provides a short discussion of the development process of the online survey for measuring crowd strength. The development follows the process according to (Cooper & Schindler, 2008) and included two main steps: structuring questions and creating a screening process. Such a process owns requirements for a survey like clarity in language, questions and explanatory notes are essential, providing simple and comprehensible terminology for non-experts. Functionality of visual aids during the questionnaire is desired to support clarity, however should not influence the respondents and hence measure biased answers. For respondents, the real purpose of a question should be obvious – these are undisguised questions. Accurate measuring of values requires that respondents are able to clearly define answers which will be ensured by using closed questions.

6.1.1 Basic Structure of Questionnaire

Considering these requirements, the survey for crowd strength must allow respondents to develop an opinion, especially, when the Crowd Energy value network is unknown yet. Thus, respondents must be familiar with iGSL functions and the possibility of generating a surplus before they can make a decision about it. Afterwards, respondents can be introduced to the principle of sharing with your neighbour including decision making for self-produced electricity. The logic of questions starts initially from a building internal perspective and adds then the view of a crowd. Eventually, the outline of the survey emerges following a strict order and contains three target question groups, namely the iGSL system, decision making, and crowd. The classification and administrative questions for the respondents finalise the outline which is summarised in Figure 28.

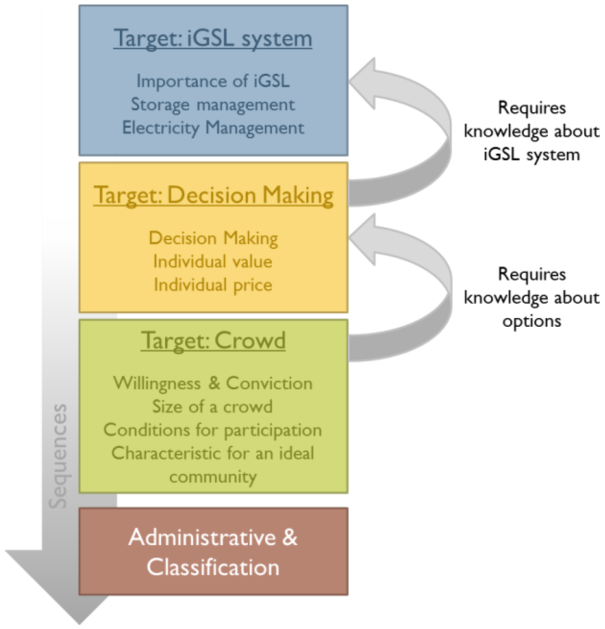

Figure 28: Inclusive factors in sequence of target categories

The sequence of target categories outlines the general flow of questions and requires questions to now be formulated so that they meet the objectives, encourage respondents to answer willingly and adequately. Bearing these points in mind the process started with developing initial questions, similar to a brain-storming session. The basic logic in each section goes from general (i.e. warm up, easy to answer) to more specific questions. In the second step, the purposefulness of questions was inquired. Incomplete or unfocused questions were discussed and either adapted or deleted from the catalogue. The catalogue generated included draft questions which were iterative so they were refined, combined, or deleted. An intra-category structure was established and similar questions were grouped together, they were also supported by visual aids. Eventually, 28 target and nine classification and administration questions were drafted for the survey. An example of the questions and responses can be found in Table 5 and the entire list is in appendix 10.1. Developing terminology regarding the Crowd Energy concept introduced as well as the iGSL system was challenging.

	Question	Answer	Notes
1	Which electricity has a higher value for you during the **surplus period**?	☐ self-generated ☐ from the electricity provider ☐ neither	G1 Max 1
2	Which price would you assign to the electricity in the storage during **surplus period**?	☐ Electricity price during the discharging of the storage ☐ Electricity price during the current surplus period ☐ Other value	G1 Max 1
3a	*Note: Storage allows creating an independency from the residual electricity network. We would like to know which basic decision approach would you prefer during the* ***surplus period****.* What would be your decision on your self-generated electricity, if you know in advance that the tomorrow weather will be sunny?	I play it safe and store any surplus I would feed in any surplus to the grid	G2
3b	What would be your decision on your self-generated electricity, if you know in advance that the tomorrow weather will be very bad and you could not charge your storage completely?	I play it safe and store any surplus I would feed in any surplus to the grid	G2
4	If you know that you have some storage space left (any surplus is left), would you buy electricity from the electricity provider?	☐ Yes, at any rate ☐ Yes, if financial advantageous ☐ Yes, if I cannot cover my requirements over night ☐ No, in any case	G2 Max 1

Table 5: Target questions and responses for Decision Making

The wording of the questions presented a challenge as words concerning crowd or intelligent generation-storage-load systems are not used in common language. Two points were important, explaining things in layman's terms and creating a common understanding of terminology. A further challenge was generating terms which have the same meaning in German, English and French. The choice of languages depended upon the coverage of DACH countries. Responding to this requirement, terms were either translated, e.g. crowd energy in a neighbouring system or explained with explanatory notes. Efforts were made to ensure terminology was accurate as well as to ensure general understanding and to receive opinions from a participant's perspective.

The response strategy in the online survey considers the investigative factors, desired conclusions and meaningful results by using dichotomous, multiple choice, paired comparison, checklists, and Likert type questions (Cooper & Schindler, 2008). The response strategy for the survey on crowd strength does not necessitate recall knowledge to be recalled (i.e. the respondent does not have to memorise previous answers or situations) and aims to ensure clear responses, e.g. statement of a maximum numbers of answers. The fixing of response types provides some clarity for drawing conclusions and defines adequate statistical measurements.

6.1.2 Finalising the Online Survey

The generated questionnaire is wrapped into a screening process, considering multiple steps such as questionnaire sequences, preparing explanatory notes, and testing (Cooper & Schindler, 2008). The screening process is the story board of the survey and the objective is a logical sequence where the process reveals sufficient information about current and forthcoming questions. It should make the respondents feel comfortable and remain motivated.

A critical point for Crowd Energy survey is the introduction to as respondent's judge survey quality and decide on their willingness to participate. Some important information must be provided: a) the main concept, i.e. Smart Grids: how would you decide as a consumer? b) the three objectives c) the survey objectives (see Figure 29). The survey started by introducing the little known iGSL system using an animation and additional notes on production, consumption, storage, electricity provider and metering. The animation is used throughout and will be explained in more detail later. Starting in this way allowed the respondent to take time to adjust and read about the study objectives before answering any questions.

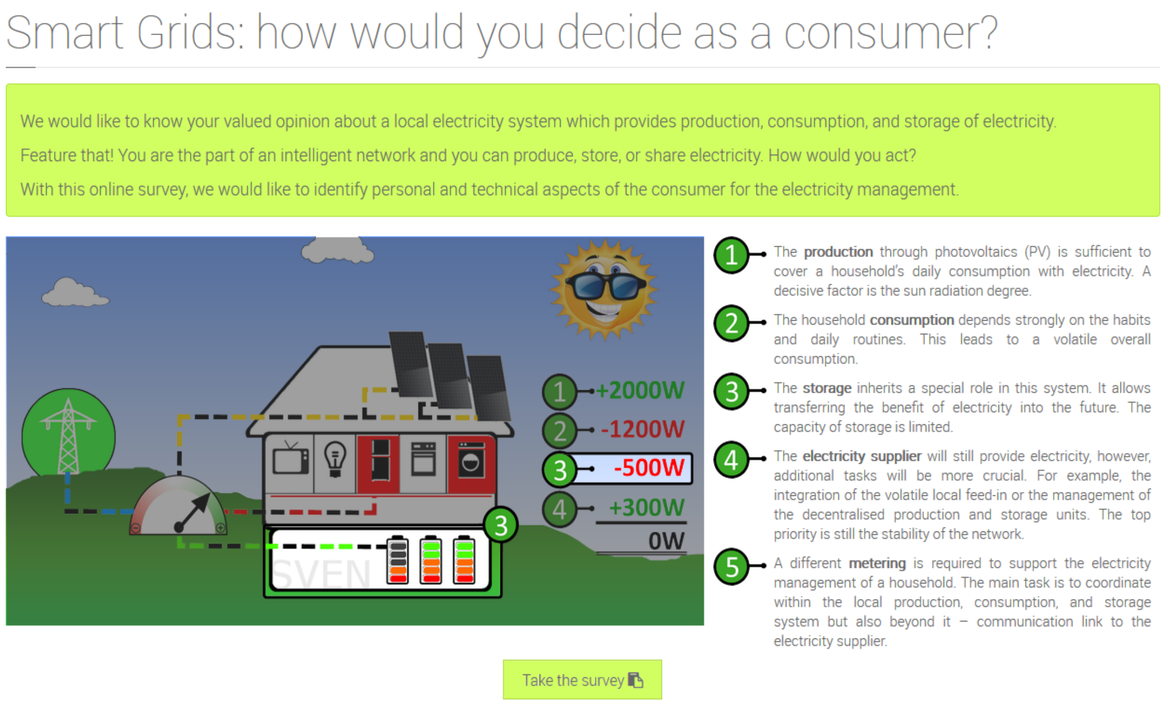

Figure 29: The beginning of the survey stating concept, objectives, and introduction to the field

The next step developed an internal sequence by identifying and establishing different groups. Moreover, sequencing ensures flow throughout by connecting the introduction and conclusion of a survey. The internal logic follows a general to specific paradigm allowing topics to be explained before reaching specific and sometimes difficult questions. Such an approach guarantees a smooth transition between groups. Furthermore, good logic ensures that respondents reach central questions quickly and keeps up concentration and motivation. A critical element for grouping was the balance between the number of questions per page (i.e. length of page) and the number of clicks between pages. Too many questions per page can be regarded as overwhelming and too many clicks result in slow progress and demotivate respondents so that they may not finish the survey. An additional difficulty was that skipping any questions was not permitted. Finally, seven groups were created to represent the internal logic (see Table 6).

Category	*Groups (headings in the survey)*
iGSL system	The decentralised electricity network – production, consumption and storage The decentralised electricity network – storage Decentralised electricity – metering
Decision Making	During the day - decision making and electricity value During the night - decision making and electricity value
Crowd	Crowd Energy Idea
Administration & classification	General Information (split in two pages)

Table 6: Categories and groups of the questionnaire

The advantage of groups is that they open up the possibility to create specific explanatory notes. Explanatory notes are made short and easy for two reasons: so that the respondent can understand things and they ensure that the answers are objective. The animation is an extra element and is used for reducing written text and especially to show movements of an intangible good (i.e. flow of electricity). It follows rules of objectivity. The animation's story book follows the sequence logic – from general picture to specific elements – and respondents do not have to memorise a lot of information. Special masks are utilised and elements are highlighted (see Figure 30). The pictures are simple drawings, such as a sketch of a house and connections which allow conclusions to be reached immediately, e.g. that metering is used to measure house's electricity status and connects to an external grid. The comic-like drawings should add a certain aspect of fun to explain serious matters without being ridiculous. The familiarity produced with the animation in the introduction helped people not to be distracted, as it was. a new and surprising element and helped them to spot differences immediately.

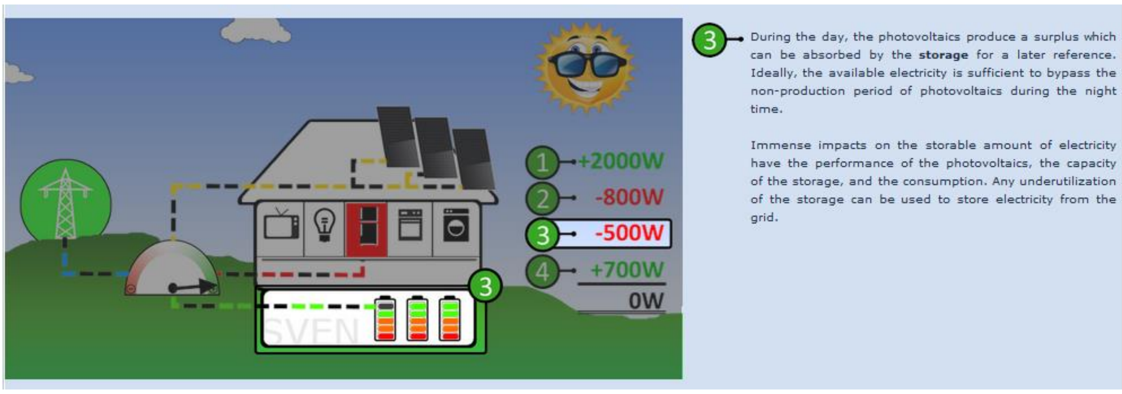

Figure 30: Explanatory notes and animation for storage related questions

The resulting layout of the online survey with explanatory area at the top and questions below (see Figure 31) was implemented in lime survey. Before mailing started, the survey was tested by five iimt employees and written feedback was received. As well as feedback for the survey, the cover letter addressing mail recipients was sent to testers. All comments were discussed and content and wording were adjusted when necessary. Moreover, the test entries in lime survey were verified and the expected values were recorded. The total time to answer the survey was 12 to 14 minutes on average. This represents an ideal duration as 77.6% of respondents are likely to complete a survey within 11 to 15 minutes (Cooper & Schindler, 2008, p. 350). Experience shows that the ideal survey length is five minutes or less but for this topic's complexity and scope of measurements this would not be realistic.

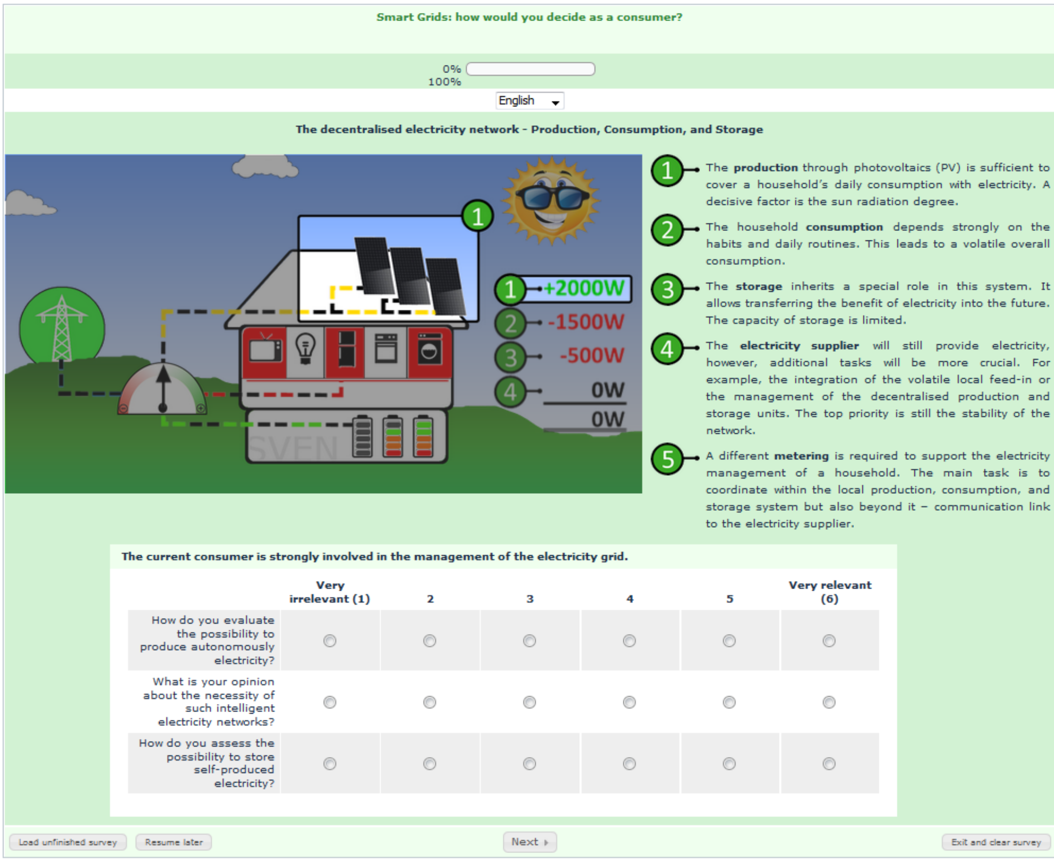

Figure 31: Layout for a set of questions for a specific group

The above description explained the process of implementing the online survey for recording opinions and preferences of individuals. The paragraphs should support the credibility of data collection for the results of the crowd strength.

6.2 Results of Crowd Strength

The result chapter is organised according to the structure of crowd strength assets, namely:

- Internal iGSL structure (chapter 6.2.2),
- Human competences of decision making and pricing of self-generated electricity (chapter 6.2.4)
- Brand and relationship with a crowd (chapter 6.2.6)

Each section provides detailed findings on opinions, behaviour, and relationships. Key findings are stated at the end of each chapter to help provide an overview of results. Before presenting the results, a short description of the online survey facts and sampling should facilitate understanding of the gathered and measured data.

6.2.1 Composition of Responses

The online survey was created and published using LimeSurvey. This web application displays questions and measures answers according to the created guideline. The respondents had to answer 37 questions in total, on the following topics: 11 on the iGSL system, 11 on human competences, and six on brand and relationship. Additionally, nine questions referred to administration and classification. A full description of questions and values measured can be found in appendix 10.1. The gathered data are exported, manipulated and analysed in IBM® SPSS® Statistics Version 22.

The initial recipients of the survey comprises around 1’350 contacts. The selected contacts are located in Switzerland, Germany and Austria. The survey was carried out over two months (May – June 2015). The only restriction for participation is that respondents must be aged eighteen or over. Contacts received a cover letter and a reminder was sent two weeks later. Despite having a recipients’ list, the survey was open and there was no tracking through personalised tokens. Further advertisements were placed in newsletters, on websites and on social media.

There were 294 responses in total to the survey divided into 191 complete and 103 uncomplete responses. The majority of uncomplete responses ($n = 89$) were registered on the first page but no answers were recorded for these responses. The procedure to start the survey by clicking on the button “Take the survey” favours such recordings. It is uncertain whether people stopped taking the survey or it was robots that registered. The set of complete responses consist of 154 for Switzerland, 30 for Germany, four for Austria, two for Ghana, and one for other (Question: In which country do you live?). A comparison between Germany, Austria, and Switzerland countries is not applicable due to insufficient answers and in the case of Germany due to a remarkable difference in response sizes. Therefore, further analysis only considers respondents living in Switzerland.

An 11.41% response rate for the Switzerland set allows speaking of a good survey quality (Sauermann & Roach, 2013). Furthermore, the 14 incomplete responses represent 6.83% of the total number of respondents who entered the survey (completion rate is 93.17%) showing a very good balanced between survey design and motivation to finish the survey (Nulty, 2008; Sánchez-Fernández, Muñoz-Leiva, & Montoro-Ríos, 2012).

The sample size was 154 responses, besides the respondents living in Switzerland, they had the following features. The sample contained responses from 135 males (75%) and 39 females (25%) this is not the same as the Swiss gender distribution of 49.5% to 50.5% (STATPOP, 2016). Recorded ages ranged from 22 to 79 years old and 67 participants were aged between 20 and 39 years old, 82 participants were aged between 40 and 64 years old and 5 participants were aged 65 and over (*m = 42.40; sd = 12.4*). There is no conformity with Swiss age distribution (STATPOP, 2016). 18.2% live in a one-person household, 31.8% in a two-person household, 16.9% in a three-person household, 22.7% in a four-person household, 9.1% in a five-person household, and 1.3% in six or more person household. The sample mainly included three-/four-person households and significantly underrepresented one-person households (see STATPOP, 2014).

	Obtain electricity PV facility		
	Yes	No	Total
Tenant	3	65	68
Apartment owner	2	10	12
House owner	21	53	74
Total	26	128	154

Table 7: Distribution property and obtain electricity from PV facility

An interesting classification parameter is the property situation, there were 68 tenants, 12 apartment owners and 74 house owners (see Table 7). It is of interest to see differences and similarities in house owners, who can invest in their property, and tenants, who lack this possibility. Another grouping parameter for further investigation is the procurement of self-produced electricity. 26 responses or 27.54% of total responses stated that they obtained self-produced electricity from a shared or owned PV facility. The perspective of obtaining electricity from a PV facility indicates that these respondents have some knowledge and experiences of producing electricity. In light of the investment required to buy a property, it is no wonder that the majority of people who obtain electricity from a PV facility are house owners.

6.2.2 Internal Structure Asset

The results on the internal structure focus in particular on a single production, consumption, and storage system. By emphasising the role of a consumer is more involved in the future electricity grid, each respondent was asked to assess acceptance of such iGSL systems, management of electricity, and management of storage.

The findings on the internal structure focus, in particular, on a single production, consumption and storage system. By emphasising the role of a consumer who will be more involved in the future electricity grid, each respondent was asked to assess acceptance of such iGSL systems, management of electricity, and management of storage.

Acceptance of iGSL Systems

A first result is that respondents assign high relevance to intelligent decentralised iGSL systems (*m = 5.24; sd = 0.98*). The frequency of responses supports this positive attitude towards a localised system (see Figure 32). With regards to the functionalities for producing and storing electricity, findings show that respondents consider both functionalities as relevant assets (*m = 4.97; sd = 1.30* and *m = 5.03; sd = 1.29*). Furthermore, in general respondents evaluate the intelligent system higher than a single functionality. This situation is also established in the groups of “living as” (i.e. tenants, owners) and obtaining electricity from a PV facility (i.e. yes or no).

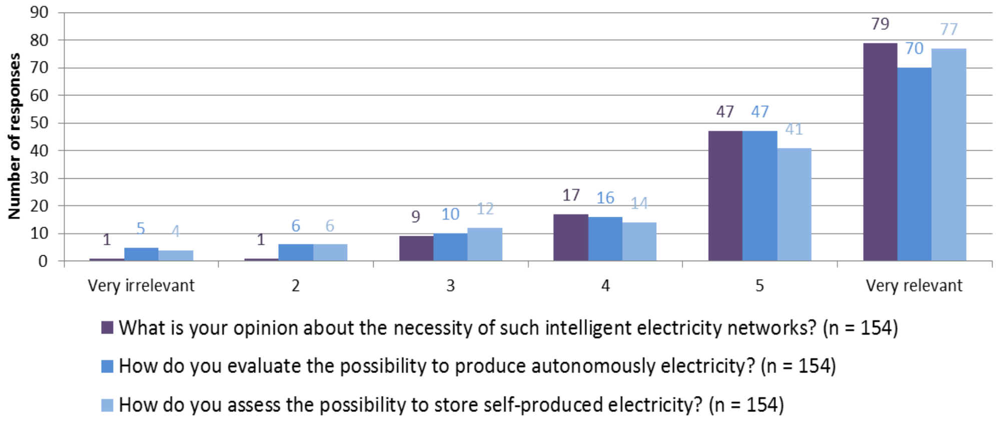

Figure 32: Relevance of an intelligent decentralised system

Storage Management

Storage is a new functionality for the electricity grid, along with capacity and management they can influence a crowd. A crucial factor is the size of storage which considers the minimum time period to cover demand by storage. The frequency of responses seems to be scattered but there are the highest numbers of responses for storage capacities is one day or one week (see Table 8). Findings show different views on capacity without a tendency towards the best option of one week. On average, the minimum capacity tends to be two days (*m = 4.15; sd = 1.48*) but house owners have slightly higher capacity requirements (*m = 4.28; sd = 1.49*) than tenants (*m = 4.04; sd = 1.50*).

Minimum storage capacity			*Fill-to-capacity* *(1) very irrelevant – (6) very relevant*
	N	%	Mean
For 6 hours	4	2.6%	4.50
One night	18	11.7%	3.50
One day	39	25.3%	3.90
Two days	24	15.6%	4.38
Three days	27	17.5%	4.26
One week	42	27.3%	4.40
Total	**154**	**100.0%**	**4.14**

Table 8: Minimum storage period and relevance to fill capacity

The importance of filling storage to capacity has an overall tendency to the middle of answer options (*m = 3.14; sd = 4.15*), but shows the increasing importance of only considering responses per group. Between minimum storage capacity and relevance to fill storage, a moderate positive Spearman's rho correlation of .227 exists (Bühner & Ziegler, 2009) and respondents with higher capacity requirements tend to have a more distinct need for storage to be filled to 100%.

Besides self-produced electricity, storage management includes the concept of providers using capacity for temporary storage. Leaving capacity for external custom is an abandonment of personal use. The willingness to share capacity exists among respondents and makes up around a half of the storage capacity per household (*m = 51.56%; sd = 23.44%*). The highest percentage of responses is at the 50% mark (n 54, 35.06%) where 35.71% favour capacity provision below the 50% mark and above

29.22%. The distribution and tendency to the 50% mark, however, suggests that findings should be regarded with care.

With respect to capacity provision, respondents were asked their preferred compensation type for providing capacity (see Figure 33). A 36% share of 260 responses (multiple answers) prefer a price reduction on electricity, this is an indirect financial reimbursement. Furthermore 31% favours direct financial reimbursement and together with indirect, financial compensation dominates. The result is hardly surprising as answers which could be chosen are made up of financial and non-financial options. A remarkable finding is that 29% of responses consider compensation with electricity to be acceptable. It implies that electricity is a potential tradeable object. A slightly different ranking exists in the two groups of people who obtain electricity from a PV. Price reduction is the most preferred method of compensation in both groups. But people, who obtain PV, prefer to receive the same amount of electricity (31.7%) over financial compensation (29.3%), whereas the non-obtaining PV group favour financial compensation (31.5%) over the same amount of electricity (27.9%).

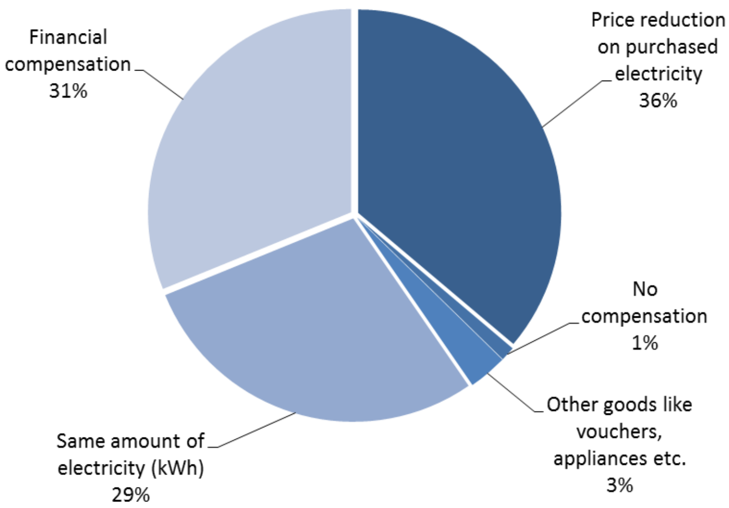

Figure 33: Incentives to provide storage capacity for external usage

Any leftover capacity can be used to fill up from external sources and it is interesting to know under what circumstances a prosumer would buy the electricity. Findings suggest that respondents would mainly fill residual capacity if it is financial advantageous (*n = 85*, 55.19% of 260 responses). The strong financial aspect supports more restraint when buying electricity. Furthermore, previously mentioned incentives emphasise that physical capacity is regarded as an instrument for financial reimbursement (see Figure 33). Around a third of the responses (*n = 46*, *29.87%*) mention security of supply as a reason for buying and electricity is bought when storage cannot cover demand overnight. These respondents evaluate buying for social factors rather financial ones, but it does not indicate unrestrained behaviour. Absolute decision making is expressed by the “yes, at any rate” option which only received 6.49% of answers (*n = 10*). Therefore the security of supply group considers other factors when making buying decisions. A small group of 13 respondents (8.44%) would not replenish electricity at all. The above results also show that minimum capacity does not have any links to buying circumstances and answers are well distributed. Eventually, it can be said that people with a higher need would not necessarily prefer to buy without less restrictions.

Besides fill-to-capacity, storage management includes extracting electricity these actions are taken, in particular, when storage runs low. Therefore, respondents were asked at which depletion level they are likely to reduce consumption or to buy electricity. The general findings suggest that respondents would reduce consumption (*m = 37.73%; sd = 23.31%*) before considering buying (*m = 21.88 %; sd = 20.63%*) from external resources (see Table 9). This implies people are self-supplying and they have a preference for using electricity from their own sources. Moreover, it reflects the fact that respondents are self-reflecting and are active (i.e. I do something) before taking the easy way out and buying electricity. House owners seem to take action at very low depletion levels (*m = 34.53%; m = 19.53%*) followed by tenants (*m = 40%*; *m = 23.16%*) and by apartment owners (*m = 45%; m = 27.27%*). Respondents, who obtain electricity from a PV, demonstrate more active behaviour and consider consumption reduction much earlier (*m = 39.42%*; *sd = 21.92%*) than when buying from external sources (*m = 18.27%; sd =16.05%*).

	Reduce consumption		*Buy electricity*	
	Mean %	*SD*	*Mean %*	*SD*
Tenant	40.00	21.30	23.16	20.89
House Owner	34.53	22.77	19.53	17.81
Apartment Owner	45.00	36.26	27.27	33.27
Total	**37.73**	**23.31**	**21.88**	**20.63**

Table 9: Average depletion levels at which respondents would reduce consumption or buy electricity

The challenges for using storage technology show a clear picture for improvements. From 360 measured responses (multiple answers, maximum of three options), the most important challenges are storage performance (*n = 123*), a better cost-benefit ratio (*n = 93*), and sufficient technical integration (*n = 68*). Subvention and tax rebates (*n = 43*) are financial support and stated in fourth place. The order of priority suggests that improvements are mainly technically and economically driven. Less activity is expected from the policy and regulation side and hence administrative challenges are positioned at the end of the list referring to sufficient legal regulations (*n = 10*) and reduced administrative efforts (*n = 23*). In short, the ranking demonstrates that storage technology is in a phase of early innovation before entering the mass market.

Electricity Management

The survey confronts respondents with the subject of enhanced electricity management as a result of the iGSL's functionalities. Competences and duties of managing electricity by the iGSL are primarily assigned from a general perspective to electricity providers (*n = 51*) followed by independent service providers (*n = 37*) and autonomous management (*n = 37*) (see Figure 34). Less trust to take responsibility exists in associations or clubs (*n = 29*). Nevertheless, assigned responsibilities vary between the groups of obtaining electricity from a PV. People obtaining electricity from a PV consider autonomous management and associations or clubs as a possible way of managing electricity. This is a stronger expression of a self-managing attitude and equivalent to the external responsible role of electricity providers. In contrast, the non-obtaining group respects external roles like service providers and electricity providers as more competent than self-management.

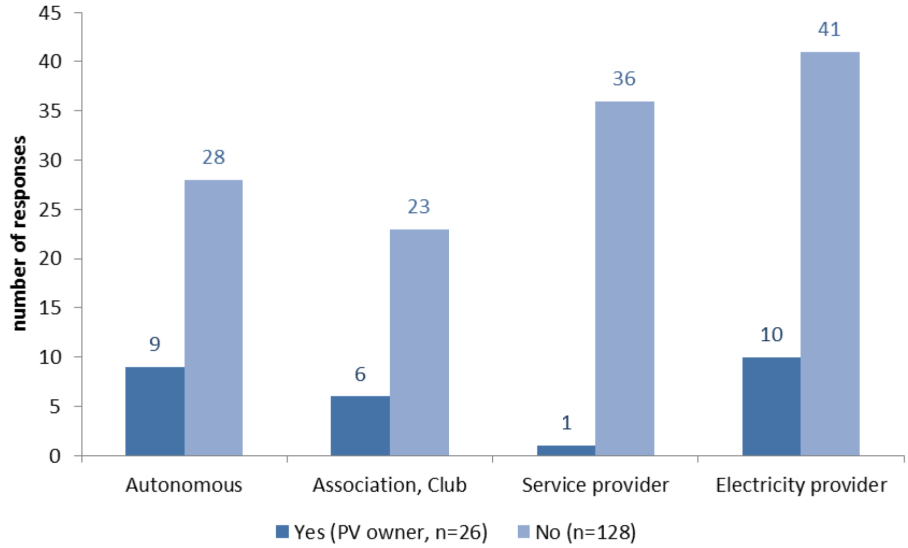

Figure 34: Assigned responsibility for electricity management

Any iGSL system requires a more sophisticated load balancing. As a result automated management and supporting coordination between the numerous units to secure the stability of the electricity grid is enhanced. One of the survey's findings suggests that automated management is essential (*m = 5.10; sd = 0.97*). The self-management view of the obtaining group manifests in less necessity for automation (*m = 4.88; sd = .99*) allowing one to conclude that experience shapes management expectations.

The challenge for automated management is, in general and within groups, transparency in electricity management (27.9% of 384 responses in total – multiple answers, maximum of three). Transparency allows gaining an overview of processes and exchange of information and is a precondition for developing trust and commitment (see Table 10). The challenges of constraints for individual decision making (also individual driven) and technical performance go head to head. Among the property groups, house owners regard technical performance (22.2%) as more important than constraints for individuals (18.4%). Apartment owners regard both options as equivalent (21.9%) whereas tenants see constraints of individual (20.4%) as a higher challenge than technical performance (16.8%). It is also the only group which considers technical handling of conflicts (19.8%) as a bigger challenge than performance. Another finding is that challenges, originating from individuals and technology, are by far more important than administration or legal regulations. They trail behind (at 8.6% and 7.8% respectively) and are placed least important.

	Tenant		*Apartment Owner*		*House Owner*		*Total*	
Challenges	*N*	*%*	*N*	*%*	*N*	*%*	*N*	*%*
Technical Performance	28	16.8	7	21.9	41	22.2	76	19.8
Handling of conflicts	33	19.8	4	12.5	26	14.1	63	16.4
Transparency of Mgmt.	47	28.1	11	34.4	49	26.5	107	27.9
Constraints for individuals	34	20.4	7	21.9	34	18.4	75	19.5
Administrative efforts	12	7.2	1	3.1	20	10.8	33	8.6
Legal regulations	13	7.8	2	6.3	15	8.1	30	7.8
Total	**167**		**32**		**185**		**384**	

Table 10: Challenges to electricity management according to property

Both the obtaining and non-obtaining groups consider transparency of management as to be a challenge to tackle, however, a slightly different ranking emerges. The obtaining group consider transparency and technical performance challenges as the most important challenges (each 23.4%) followed by constraints for individuals (20.3%). It seems that experience in producing electricity indicates a higher awareness of technical requirements. This is also supported by a higher rating for handling conflicts using technology from the obtaining group (18.8%) than from the non-obtaining (15.9%). The non-obtaining group evaluates, as described before, technical performance and constraints of individuals to be in second place behind transparency. Respondents also provided more specific challenges by using the “other” answer option. Entries showed sophisticated knowledge about the electricity network and answers mention abuse, optimisation of control to individual disadvantage, short durability of control systems and electrical components, lack of predictability, additional handling charges, clear separation between producer and distributor, data piracy and cyber-attacks, and data management.

6.2.3 Findings Internal Structure Asset

The following paragraphs describe the findings of the internal structure asset and are summarised in Table 11.

Internal Structure
A. High acceptance of production-storage systems exists.
B. A minimum storage capacity is not linked to the best option. If someone expresses a best option it means that there is a need to fill the storage to 100%.
C. Incentives for providing storage capacity to external roles refer primarily to financial compensation. Electricity also becomes an object for exchange.
D. Prosumer reduce consumption to prolong storage availability before buying electricity.
E. Electricity management is predominantly assigned to electricity suppliers.
F. Transparency in electricity management is the key challenge.

Table 11: Findings of internal structure asset

The expressed high relevance of iGSL systems indicates an established willingness to build up internal structure. Furthermore, the high acceptance of production and storage functionalities suggest that both functionalities are necessary elements of the system. In general, this means that installing internal structure for value conversion is well established among respondents.

The utilisation of the storage functionality shows some remarkable findings. A minimum storage capacity is not linked to the best option. This means that prosumers would tend to cover demand for two days in average. To fill the preferred storage capacity to 100% is moderately pursued. Higher capacities installed – as the two days – show that there is a stronger need to fill the storage to 100%. In conclusion, higher capacities indicate a more self-centric behaviour. On the other hand, self-centric behaviour indicates that these capacities are less likely to be provided for other purposes like temporary load balancing. Nevertheless, a sense of willingness to share capacities for external usage is expressed by prosumers. Related incentives for providing storage capacity to external roles refer primarily to financial compensation. This includes either direct compensation for losses of self-produced electricity or a reduction on the electricity bill. It is remarkable that electricity is regarded as compensation. Electricity becomes an object for exchange and introduces non-financial forms.

Another finding concerns the utilisation of storage capacity during the extraction of electricity, in particular the changes in behaviour if a certain depletion level emerges. Prosumers reduce consumption to prolong storage availability before buying electricity. This implies that a prosumer sustains the storage asset for as long as possible and relinquishes to consume electricity. Furthermore, prosumers regard storage management as a technology in an early innovation phase. Major challenges for storing are related to performance and cost-benefit ratio. Less challenge is seen in the area of administration and hence efforts must come from the manufacturer rather than from regulation.

A finding in the field of electricity management suggests that prosumers consider an automated management system as essential for an iGSL system. This indicates that automation becomes a key driver for establishing internal structure. A major challenge for electricity management is transparency defining traceability of process, decisions and information. Another challenge refers to constraints for individuals indicating negative implications of general management decisions on prosumers. Both transparency and constraints concern the relationship between management and prosumer.

Another finding is concerned with the responsibility for managing electricity. Prosumers predominantly assign responsibility to electricity suppliers. Further roles taking over responsibility can be the service provider or the prosumer him- or herself. This shows that prosumers are aware of their own competences but also accept other roles besides the traditional electricity providers for managing electricity.

6.2.4 Human Competences

Human competences refer to the ability to make decisions regarding self-produced electricity. Decision options involve sharing or storing electricity, this occurs at surplus time points. A correlation between production profile and decision making exists and despite a variety of personalities existing, competences rely on iGSL performance influenced by the specific characteristics of surplus and extraction phases.

On the other hand, decision making indicates that people need an understanding of the value and price of their self-produced electricity. Only then is a comparison between electricity types possible. The difference between value and price is that value refers to a personal evaluation whereas price is a monetary assessment. Value and price are influenced by the characteristics of surplus and extraction periods and evaluation of both factors can vary or change. To address the emerging complexity, the following sections discuss the findings on value, price and decision making factors and present results for both surplus and extraction periods.

Value of self-produced Electricity

The sample assigned a higher value to self-generated electricity during surplus periods (61.69%) rather than to electricity from suppliers (5.19%) (see Figure 35). On the other hand, around 33% of the sample could not decide which type of electricity has a higher value. The option “neither” is provided to show current decision capabilities of respondents and to avoid falsifying results by forcing a respondent to make a decision. The “neither” shows that respondents have trouble to define value. Reasons for this could be a general indifference to types of electricity, people are not aware of electricity, or it is difficult to distinguish between types. The latter reason could be a result of lack of experience and knowledge.

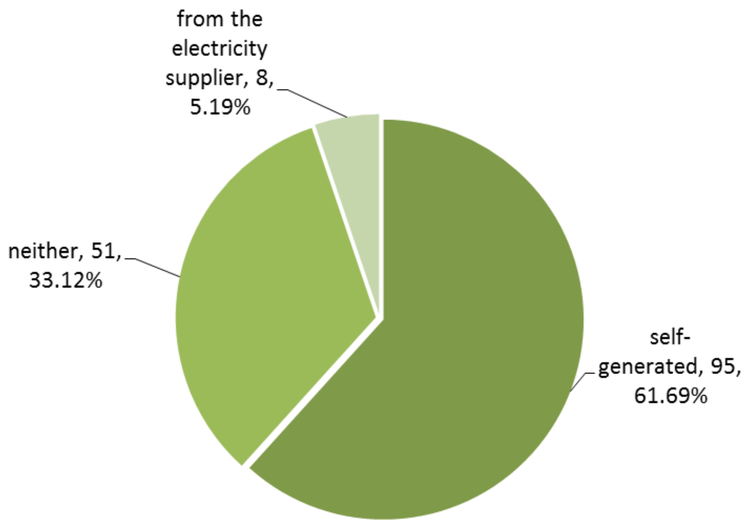

Figure 35: Perception of distribution of value during surplus periods

A more detailed investigation into "neither" and "self-generated" groups shows that experience and ownership positively influence capabilities and distinguish groups as well as respondents who tend towards the self-generation option (see Table 12). A remarkable result is that in the obtaining PV group the majority (84.62%) considers own electricity as more valuable. Likewise the house owner group (66.2%) favours self-generation more than tenants do (51.2%). Favouring of self-generation by the obtaining group and house owner group is a result of the fact that the majority of PV facilities are possessed by house owners. Table 12 suggests that groups of non-obtaining PV or tenants tend to value self-generated electricity but have a less clear idea of value.

	Living as				*Obtain PV electricity*			
	Tenant		House owner		Yes		No	
	N	%	N	%	N	%	N	%
self-generated	35	51.50	49	66.22	22	84.62	73	57.03
neither	29	42.60	22	29.70	4	15.38	47	36.72

Table 12: Value perceptions according to property and obtaining PV electricity

The value perception during the extraction phase demonstrates a marginally different picture. Results still show a 58.44% (*n = 90*) majority who prefer self-generated electricity, however, electricity from suppliers is slightly more popular (see Table 13). The size of "neither" group levels out at the same percentage. The majority retain their perspective on value whether they are in the obtaining or non-obtaining PV groups. Some respondents (*n = 20*) modify their opinions in a random pattern.

	Extraction phase			
Surplus phase	self-generated	supplier	neither	Total
self-generated	84	5	6	95
supplier	1	6	1	8
neither	5	1	45	51
Total	90	12	52	154

Table 13: Responses of value preferences in surplus and extraction phases

Price of self-produced Electricity

The results for price assignment are discussed under specific settings. The concept for evaluation consists of assigning a current or an expected price (i.e. it will be generated in the near future). There are various reasons for using this procedure for evaluation. The lack of knowledge on price per kWh provides no basis for comparison, meaning to state e.g. a 20% higher price in the future would require the respondent to know what the current price is. Also price varies throughout the day. Furthermore, there is a strong influence by price increase definitions, e.g. a 10% or 30% increase. Different price increase definitions could result in false interpretation and could lead to responses being falsified. Moreover, the survey forces people to decide a price for stored electricity by excluding the answer option "neither". This might have a drawback but the comparison between two options – without specific knowledge – is acceptable and executable. The results suggest a clear price picture (see Figure 36).

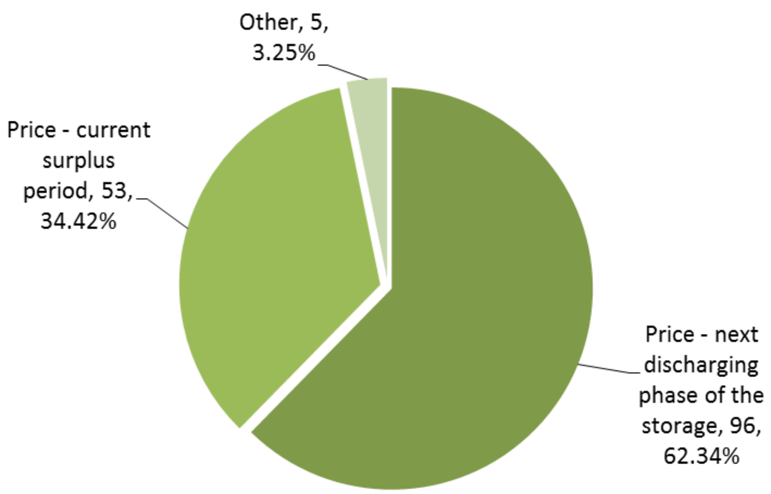

Figure 36: Distribution of price determination during surplus period

During a surplus period 62.34% (*n = 96*) of responses would assign the price which is expected to be charged in the next discharging phase of the storage (or extraction) period. Around 34% (*n = 53*) set electricity price at the current market price. Other suggestions for setting the price are according to the distribution fee or energy release. In any case, results imply that storage increases the range of prices at a specific time-point and shows that price discussions consider current situations but mainly future expectations. These results are also seen with tenants and house owners, as well as in the obtaining and non-obtaining PV groups.

The overall price perception in the extraction phase shows very different results. A majority of 81.82% (*n = 126*) would set the price of storage according to the current price in the extraction phase. A minority of 14.94% (*n = 23*) evaluates storage according to the price of the next surplus period. The popularity of current discharging prices is the consequence of price preference alterations (see Table 14). Regardless of phase, over half of all responses (53.25%, *n = 82*) always take price into account. In particular, tenants (57.35%) seem to have a more steady perception than house owners (48.65%).

	Extraction phase			
Surplus phase	Other	Current discharging	Next surplus	Total
Other	4	1	0	5
Next discharging	0	82	14	96
Current surplus	1	43	9	53
Total	5	126	23	154

Table 14: Responses of price preferences in surplus and extraction phase

Around 27.92% (*n = 43*) alter the price definition from current in the surplus to current in discharging period. Within these responses, a contrasting picture in the constant group emerges and it seems 31.08% of house owners and 26.47% of tenants would alter their price perceptions. It can be said that the group of shifting perception would do this once only. On the other hand, a small group of 9.09% (*n = 14*) would assign the prices of the next phase. In short, it seems that a majority defines prices according to the discharging of storage period.

Decision making for self-produced Electricity

Decision making for self-produced electricity includes the option of sharing or storing electricity at surplus time points. It is decisive to estimate the risk to secure the status quo of owning enough self-produced. This depends upon forecast of production (i.e. cover demand and/or refresh storage with electricity). Furthermore, it is necessary to show if there is dominant decision making behaviour for the surplus phase and if yes, does the behaviour differ in the extraction phase. The survey replicates the above risk estimation scenarios by asking the same question about decision making twice, once for sunny weather and once for bad weather expectations. These two questions were asked for once during a surplus period and once during an extraction period.

In a surplus period, the distribution between extremes, namely to play safe and keep electricity (1) or to feed in and to share electricity (6), shows distinct results for sunny and bad weather (see Figure 37). For sunny forecasts, respondents tend to be more in a sharing and risk seeking mind-set (*m = 4.12; sd = 1.34*). Whereas for bad weather forecasts, decisions are more risk averse (*m = 2.08; sd = 1.22*) and electricity is stored rather shared. Answers show slightly more conformity than when sunny weather is expected.

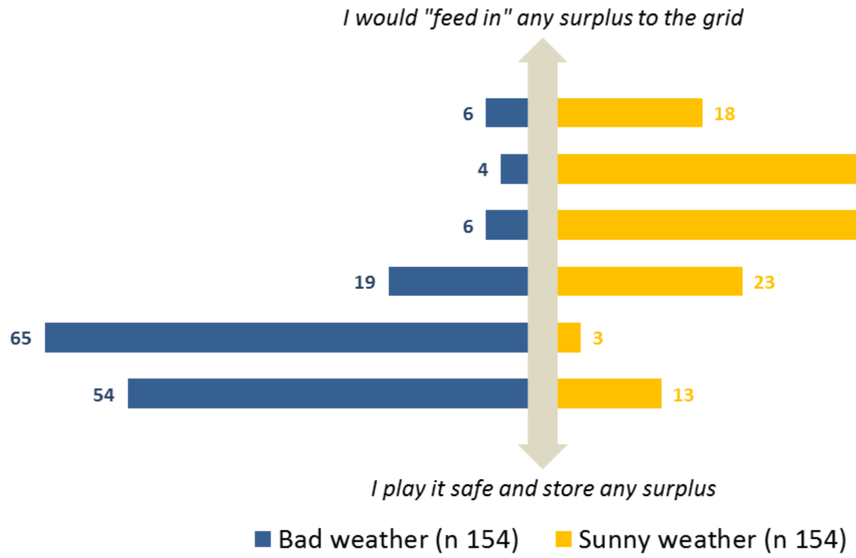

Figure 37: Surplus decisions on distribution for sunny and bad weather forecast

The distribution of both response sets indicates certain correlation and hence they are further analysed showing a moderate correlation of .258 according to Spearman (Bühner & Ziegler, 2009). Considering the responses measured, the correlation should be negative as the opposite behaviour is expected. Table 15 shows responses in a matrix and reveals two distinguishable groups. Group one shows indifferent adaptation behaviour and they are mostly risk averse (orange area). Group two adapts their choices more significantly and behaves according to the distribution in Figure 37. The boundary between answer options three and four determines answer values which tend to be more risk averse (i.e. values from one to three) and values which show more risk seeking behaviour (i.e. values from four to six).

The adaptive group contains 101 responses where the absolute (*n = 100*) shows a pattern of a risk seeking behaviour with sunny weather (*m = 4.64; sd = .76*) and risk averse behaviour with bad weather (*m = 1.87; sd = .72*). It is of further interest to know whether there is a correlation between the two response sets (sunny and bad) determining a pattern which applies to the adaptive group. There is no correlation (coefficient -.168 according to Spearman) within the adaptive group. The indifferent group contains 53 responses deciding on average between averse and risk seeking behaviour during sunny forecasts (*m = 3.13; sd =1.62*) and tend to take more risk averse decisions when bad weather is expected (*m = 2.49; sd = 1.77*). The response sets of the indifferent group shows a strong correlation in decision making behaviour (coefficient .748 according to Spearman) (Bühner & Ziegler, 2009). The calculations made allow some conclusions to be drawn, however, further investigation into specific quarters of the matrix in Table 15 should be beneficial for gaining more insight into decision making behaviour.

	Bad weather						
Sunny weather	play safe (1)	2	3	4	5	feed in (6)	**Total**
play safe (1)	9	2	1	0	1	0	**13**
2	2	1	0	0	0	0	**3**
3	13	6	4	0	0	0	**23**
4	11	25	7	3	0	0	**46**
5	12	29	5	2	3	0	**51**
feed in (6)	7	2	2	1	0	6	**18**
Total	**54**	**65**	**19**	**6**	**4**	**6**	**154**

Table 15: Sunny and bad weather response matrix for surplus period

The results for the adaptive group change slightly as the majority of the group is concentrated in the bottom left corner (see Table 15). Distinct risk seeking behaviour exists for sunny expectations (*m = 4.68* and *sd = .66*) and the group tend to make very risk averse decisions for bad weather expectations (*m = 1.84*; *sd = .64*). Still, there is no correlation between both response sets (coefficient of -.137) (Bühner & Ziegler, 2009). On the other hand, the allocation of the indifferent group shows that there are two sub categories where decision making behaviour is dominant regardless of the weather outlook. The only risk averse group (*n = 38*) is rigorously averse (*m = 1.50*; *sd = .93*) for bad weather forecasts and takes a less risk averse attitude (*m = 2.29*; *sd = .73*), when sunny weather is expected. The answers are stable, but vary more than in the adaptive group. The indifferent averse group shows no correlation between response sets with a coefficient of .184 (Bühner & Ziegler, 2009). The second indifferent group (*n = 15*) shows throughout a risk seeking behaviour by taking more risks during sunny weather (*m = 5.27; sd = .80*) than during bad weather (*m = 5.00; sd =. 93*). A strong correlation between response sets exists with a coefficient of .783 according to Spearman (Bühner & Ziegler, 2009). This group shows, as the only exception, a correlation between responses.

The survey asked the same questions twice, for the extraction period when production is offline. The aim is to define decision making behaviour for two extremes, namely to extract electricity from storage (1) or to buy electricity from a supplier (6). The extremes define again the risk assessment outcomes. Extracting from storage represents a risk averse behaviour whereas buying is risk seeking between varying options. Distribution also shows distinct results for sunny and bad weather (see Figure 38). For sunny forecasts, respondents are willing to extract (*m = 2.05; sd = 1.21*). When bad weather is expected, decisions tend to be more risk seeking (*m = 3.50; sd = 1.42*) and electricity is bought rather extracted. Answers show moderate conformity albeit less than for when sunny weather is expected.

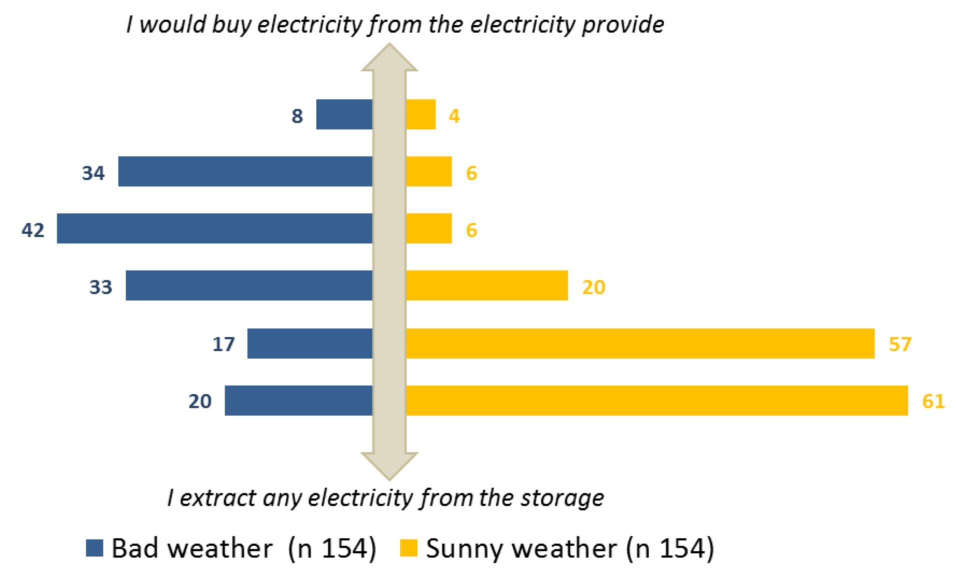

Figure 38: Distribution of decisions during extracting period for sunny and bad weather forecasts

The two response sets in Figure 38 show no correlation (coefficient .119 Spearman), however, further investigations have been conducted by splitting the set into indifferent and adaptive groups. This is possible because the risk assessment outcomes have been aligned with the extremes of the surplus period. The matrix, shown in Table 16, presents a more balanced distribution between the indifferent (n 74) and the adaptive (n 80) group. At the group level, indifferent members prefer extracting from storage without considering the weather, regardless of whether it is sunny (*m = 2.16; sd = 1.44*) or bad weather (*m = 2.55; sd = 1.27*). The strong correlation of .636 according to Spearman (Bühner & Ziegler, 2009) suggests that responses for sunny and bad weather sets are similar. So, the extraction phase seems to induce a more rigorous risk averse mind-set, just as during a surplus period. On the other hand, the adaptive group shows distinguishable decision behaviours for sunny (*m = 1.91; sd = .93*) and bad (*m = 4.37; sd = .89*) weather forecasts. Both averages are similar to the averages shown in the surplus period. Furthermore, it seems that both response sets are moderately correlated with a coefficient of -.445 (according to Spearman) (Bühner & Ziegler, 2009), supporting risk seeking behaviour in bad weather and risk averse behaviour for sunny weather forecasts. As previously shown in the surplus period results, further investigation into specific quarters of Table 16 should provide more insights into decision making behaviour.

	Bad weather						
Sunny weather	extract (1)	2	3	4	5	buy (6)	**Total**
extract (1)	17	7	11	11	10	5	**61**
2	0	3	10	23	21	0	**57**
3	2	4	10	4	0	0	**20**
4	0	2	1	3	0	0	**6**
5	1	1	1	1	2	0	**6**
buy (6)	0	0	0	0	1	3	**4**
Total	**20**	**17**	**33**	**42**	**34**	**8**	**154**

Table 16: Sunny and bad weather response matrix for extracting period

The allocation of responses for the adaptive group shows a majority in the top-right corner (*n = 74*) but seems less stringent as during surplus period (see Table 16). The small number of just six responses can be neglected for further investigation. Despite the dispersion, it seems that there is predominantly a pattern of deciding to extract during sunny weather in the adaptive group (*m = 1.70; sd = .57*) and buying (*m = 4.55; sd = .62*) when there is a bad weather forecast. Furthermore, a small correlation of -.255 (according to Spearman) between the response sets supports the pattern (Bühner & Ziegler, 2009).

It confirms the correlation found in the overall group. The indifferent group contains 80 responses in total, and a concentration of 64 responses exists in the top-left corner. The ten responses in the bottom-right area will not be considered further due to the small size of the group. The indifferent group is characterised by more risk averse behaviour and it decides to extract more when it is sunny ($m = 1.70$; $sd = .85$) and considers buying when bad ($m = 2.19$; $sd = .87$) weather is expected. Likewise in the overall indifferent group, a moderate correlation of .398 (according to Spearman) proves a relationship between the sunny and bad weather response sets (Bühner & Ziegler, 2009).

6.2.5 Findings Human Competence Asset

The following paragraphs describe the findings of the human competence asset and are summarised in Table 17.

Human Competences
A. Self-produced electricity is more prominent than externally produced electricity. However people have some difficulties assigning value to it.
B. The price for electricity in storage is the price paid during discharging.
C. A group of prosumers shows no adaptation of decision making behaviour. They act mainly in a risk averse manner.
D. A group of prosumers adapt decisions and prefer storing in the case of bad weather forecast and sharing when sunny weather is expected. The choice strategy is reversed when electricity is discharged from storage.

Table 17: Findings of human competence asset

A finding is that prosumers generally assign a higher value to self-produced electricity. Thus, prosumers distinguish between electricity types and show accountability for decision making. The finding does not indicate that this might be true for all prosumers as some had difficulties assigning value. It seems that some prosumers have not yet established a notion of value for electricity.

The notion of price definition of self-produced electricity is well established among prosumers. Prosumers define price for self-produced electricity according to the extraction period of the storage (during the night). Price definition does not change dynamically.

From an economic perspective, this implies that stored electricity has an advanced price expectation during the day and a current price expectation during the night. Consequently, the difference in price expectation between the prosumer and the market during the day can cause issues in dealing with loads. If the market price of electricity during the day converges with the price levels of the night, or even falls below that level, it is less beneficial to sell or buy for all stakeholders.

The human competence to make decisions about self-produced electricity, mainly whether to store it or share it, shows various patterns. Some prosumers will always act risk averse. Any decision made aims at securing the benefit from self-produced electricity regardless of the weather forecast or time period. Such prosumers will store any surplus to sustain personal interests. This implies that giving up electricity is tightly related to emotional rather than rational factors. Thus, compensation (financial or non-financial) for losses must outweigh personal interests.

The findings in human competences also reveal that some prosumers will adapt their decisions according to the weather forecast. The decision making strategy of prosumers in Figure 39 can be summarised as followed: in general, during surplus periods prosumers act more risk averse when the weather forecast is bad and more risk seeking when the weather will be sunny. A reverse behaviour emerges during offline production, i.e. extracting electricity from storage, meaning risk averse behaviour when weather will be sunny and risk seeking when bad weather is expected. The adaption of the behaviour confirms two things. First, weather forecast can be a factor in decision making. Second, the adaption proves that there is a linkage between production profile and dominant decision making behaviour.

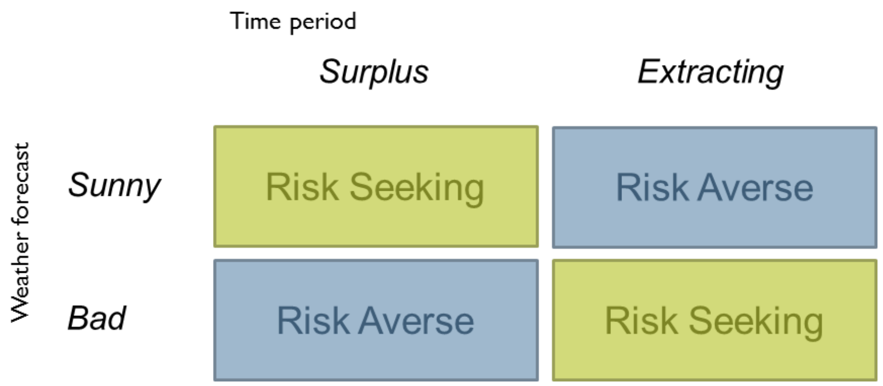

Figure 39: Decision making behaviour in prospect of weather forecast matrix

When the adaptive group shows risk averse behaviour, it is assumed that the same decision making strategy exists according to the non-adaptive group. Personal interests are prevailing and decisions are based upon more fear of disappointment or losses.

On the other hand, the risk seeking dominant periods show hope to large gain or hope to avoid losses. This implies that giving up electricity is tightly related to positive emotional factors. Any compensation (financial or non-financial) must fulfil the hope.

6.2.6 Brand and Relationships

The brand and relationships are assets which determine contributions in a crowd and evaluate the acceptance of crowd-based network structures. Sharing electricity is influenced by the prosumer's perspective on its own role, community, and under what conditions exchanges happen. It includes additional non-technical and non-economic perspectives defining willingness, size of a crowd, conditions for participation, and characteristics of an ideal community.

The starting point for assessment of a crowd-based network is how respondents are related to the concept of a crowd. The general results show that respondents assign high relevance (*m = 4.60; sd = 1.48*) to a local crowd network. Tenants (*m = 4.85; sd = 1.37*) and apartment owners (*m = 4.91; sd = 1.31*) rate local crowd networks as more relevant than house owners (*m = 4.32; sd = 1.56*) on average. The obtaining and non-obtaining PV groups shoes that people with experience of a PV regard local crowd networks as slightly more relevant (*m = 4.77; sd = 1.27*) than the non-obtaining set (*m = 4.57; sd = 1.52*), but the difference is marginal. The personal willingness to contribute to a crowd defines the relationship between prosumer and community.

The results show a moderately willingness is relevant for contributing to a crowd (*m = 4.21; sd = 1.56*). The relevance of personal willingness is higher rated by tenants (*m = 4.54; sd = 1.46*) and apartment owners (*m = 4.58; sd = 1.62*) than by house owners (*m = 3.85; sd = 1.58*). The obtaining PV group sees willingness for contributing to a crowd slightly more relevant (*m = 4.57; sd = 1.52*) than by non-obtaining group (*m = 4.20; sd = 1.58*). From the results in the house owner group, it seems that property possession reduces the relevance of working in and with a community.

The size of a crowd indicates community strength by allowing a large number of people to work together. It seems that respondents prefer to work in a more anonymous environment (see Figure 40). For more than a quarter of respondents the ideal crowd size is a block/suburb (*n = 65, 42.11%*), but they would accept larger villages and cities (*n = 52, 33.77%*) and counties (*n = 16, 10.39%*). In contrast only 9.09% (*n = 14*) would consider a street to be the ideal crowd size or with 4.55% (*n = 7*) direct neighbours. The statement implies that some kind of awareness of the specific size needed for a functional crowd seems to exist among the respondents. The results are uniform in the various groups of property possession and supply by PV. This increases strength and potential for production and storage in a crowd but also is more problematic for management. Thus, over two thirds (*n = 106, 68.83%*) think that management should be located inside a crowd rather outside (*n = 48, 31.17%*). Any solutions provided by external sources, e.g. electricity or independent service providers, require the challenge of defining highly localized and customised electricity management services to be met. This increases the complexity of service portfolios.

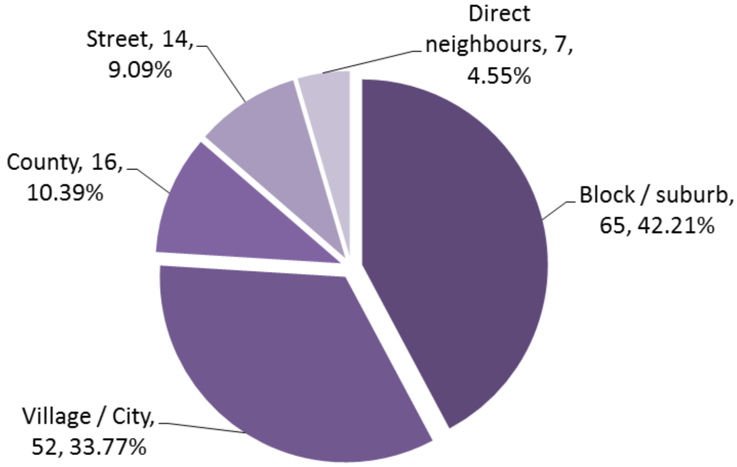

Figure 40: Considered preferences for crowd size

The survey includes an assessment of characteristics for an ideal crowd system. It states the factors which are important to run a system; a relationship with a crowd must be maintained. All 154 respondents evaluated each factor and the results (see Table 18) suggest that transparency in management (*m = 4.34; sd = 1.42*) is the most important characteristic, followed by quality (*m = 4.25; sd = 1.30*) and confidence/trust (*m = 4.21; sd = 1.34*). The averages are within a small range. It can be assumed that respondents have had difficulty assigning a value. This explains the higher standard deviation. Another reason can be that factors are equally important. Such a reason is supported by the fact that overall respondents assigned a moderate importance of characteristics. Furthermore, results show uniform and moderate importance regardless the property possession (house owner or tenant) and non-/obtaining PV groups.

Factors	Mean	SD
Quality	4.25	1.30
Performance	4.13	1.25
Security	4.06	1.38
Profitability	4.19	1.43
Confidence	4.21	1.34
Transparency	4.34	1.42

Table 18: Crowd characteristics and average importance

Another brand and relationship factor is defined by the conditions for participation. These points need to be addressed by the crowd in advance; a relationship is only created when pre-assets for participation are considered. The categories can include technical, managerial, economic or social aspects and multiple answers were allowed. In general, the findings give high importance to transparency in electricity management (*n = 91*), followed by a small gap for technical security (*n = 71*), automated systems (*n = 63*), and legal regulations (*n = 61*). The ranking of characteristics shows a mix and no preference for a specific category. Figure 41 shows the overall ranking and distribution between obtaining and non-obtaining groups.

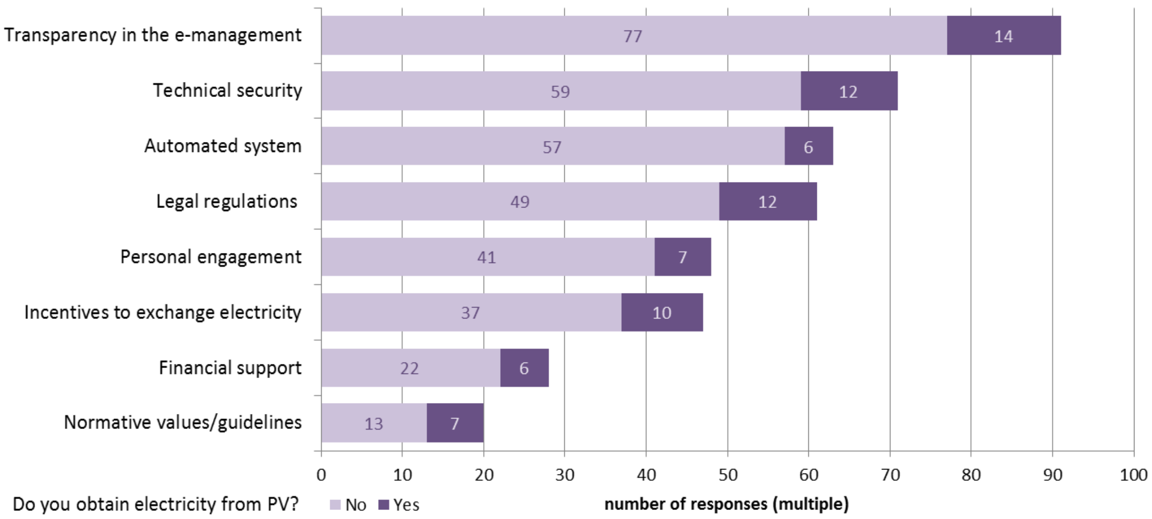

Figure 41: Factors for participation in a crowd-based network

The overall order of points can be applied to the non-obtaining group whereas there is a slightly different ranking for the obtaining group. This group gives priority to transparency, technical security, legal regulations and incentives to exchange electricity. Lower-rankings are given to automated systems, personal engagement, financial support and normative values. In summary, transparency is a major necessity for building and maintaining a relationship between individuals and crowds. Security seems to be a factor which is important for maintaining a relationship rather for creating one.

6.2.7 Findings Brand and Relationship Asset

The following paragraphs describe the findings of the brand and relationship asset and are summarised in Table 19.

Brand and Relationship
A. High acceptance of a crowd based network exists. B. The relevance of personal willingness indicates that prosumer introduce intangible values (e.g. emotions) C. The preferred size of a crowd is a block/suburb or village/city. D. The electricity management for a crowd is preferred inside a crowd. E. A transparent value network is important for participating in and sustaining a crowd.

Table 19: Finding of brand and relationship asset

The high acceptance of crowd based networks indicates that a positive relationship between a prosumer and a crowd exists. By accepting a crowd, prosumers share electricity or resources, like storage capacity. Additionally, it can be said that prosumers have an advance of trust in the CE concept. Another finding is that personal willingness is relevant in a crowd. Willingness expresses an emotional binding of the prosumer to the crowd and establishes linkages based upon intangible values. The finding suggests that intangible values become crucial for exchange: as a precondition to start an exchange and as an object of exchange.

The preferred size of a crowd, in which a prosumer would like to be, involves a decent number of buildings. The finding of a block/suburb crowd size suggests that prosumers consider a larger area as necessary to benefit from a community. Taking the second biggest share of a village/city, even larger crowds are acceptable. Therefore, crowds are not a clannish small group. It also seems that a certain anonymity is desired and thus leaving the level of intimate communities. The referred management of such crowd sizes should be inside a crowd. This finding indicates that the management of a crowd is close to the members. But also, it suggests that management focus is on a local area addressing specific requirements.

Transparency is the most important factor for participating and maintaining a relationship with a community. It is integral and covers many aspects like process or information. Furthermore, a transparent crowd network supports community acceptance and includes procedural and distributional justice, as well as building trust. Eventually, transparency stimulates intangibles values and influences the dynamic of exchanges. Other factors for participating and maintaining a relationship with a community are the technical requirements. The basic requirement of security expresses that there are still doubts and uncertainties regarding the crowd structure

7 Simulation of Crowd Potential

This chapter presents the empirical results of the crowd potential based on the factors developed in the conceptual framework in chapter 5 (see Figure 2, page 9). The objective of this chapter is to show the potentials of producing and sharing electricity of a crowd during different time periods (winter, transition, and summer). An assessment of potential relates to optimizing supply chain factors like production capacities and distribution of electricity. Therefore, the potential of crowds requires supply chain optimisation and the standard method is done through modelling and simulation.

The development of model for simulation is described in chapter 7.1 and shows how data was produced as well as should show the accuracy of applying the research tool. A mathematical model is formulated in chapter 7.1.1. and provides an understanding of the scope of model's functionalities. Furthermore, the model is optimised according to costs rather capacities. Hence the chapter introduces a cost structure for flows distinguishing three costs: cell internal flows, crowd flows (sharing), and flows from external suppliers. Chapter 7.1.2 explains the process to translate the abstract model into a computerised one. The chapter highlights the used software and programming languages for simulation.

The produced results from the simulation are presented in chapter 7.2. The chapter shows first the simulation for a current scenario of a transformer station in Spiez. A current scenario is used as a starting point. As the CE concept represents a future electricity network, a simulation with future production and consumption quantities should provide insights in the upcoming crowd potential. These results are presented in chapter 7.2.6. Before going to discuss strength and potential results (see chapter 8), the gained insights in the crowd potential are summarised in chapter 7.2.7.

7.1 Modelling and Simulation of Crowd Potential

A discussion about the potential of crowds, in regard to electricity distribution among members, necessitates modelling and simulation tasks. Simulations are used for different purposes, e.g. systems engineering support or training and education support, however, this dissertation applies simulation to analyse the potential in electricity exchange of crowds and to support the position crowds within a value network. This is a quantitative approach and input is known in advance by calculating production and consumption pattern. Therefore, the model can be classified as deterministic, dynamic, continuous and local. The absence of crowd structures (i.e. the absence of behaviour insights and data) and the objective of reaching potential conclusions require a deterministic model which provides sufficient valuable insights to explore the potential of the basic exchange idea. It is mentioned that future research should use stochastic modelling when insights are available.

Any modelling and simulation must secure good quality results and guarantee that this dissertation follows the simulation development process according to (Sargent, 2005). This includes certain procedural steps and related methods to show proof of accuracy. The steps are as follows:

1. Describe problem entity / situation (see chapter 3)
2. Formulate a conceptual model – Calibration (see chapter 7.1.1)
3. Translating the abstract to a computerised model – Verification (see chapter 7.1.2)
4. Running simulation (see chapter 7.2.4 and 7.2.6)

7.1.1 Formulate a Conceptual Model

The conceptual model represents a local network of buildings. Each building is represented by a node in the network and owns consumption, production, and storage capacities. A building can cover demand by production and/or storage. Any shortage of electricity of a building is covered by an external electricity provider. If demand is covered and surplus is produced, the node can store electricity up to a specific capacity, share electricity with other buildings or feed in to the external network. Electricity can directly be shared among all nodes within the crowd network. The cost of sharing electricity is defined according to a chain structure stringing up buildings and defining same length of linkages. Determining the costs of sharing between two buildings means to count the linkages between houses. The model is discretised implying that a building's capacities exist for a specific time-point. Only electricity in the storage is passed to the next time-period. The above description is outlined in Figure 42.

Let $G = (V, A)$ be a graph where V is a set of nodes and A is a set of arcs. We introduce the following nodes. The node z_t represents the external electricity supplier. The node v_t^r represents a building r in a time period t. Every node v_t^r contains obligatory demand $d_{v_t^r}$ for a specific time-point. Demand is covered by internal production and storage, or by external source z_t.

Furthermore, we introduce the following arcs. An arc (z_t, v_t^r) represents the electricity obtained from the external source by a building during a time period when a shortage of electricity occurs, also called missing flow. An arc (v_t^r, z_t) defines the electricity feed in to the general network by a building. Such a flow represents an overflow and implies that a building produces surpluses and storage is filled to capacity. An arc $(v_t^r, v_t^{r'})$ describes the sharing of electricity between two buildings within a crowd where $v_t^r \neq v_t^{r'}$. The node v_t^r is the supplier and $v_t^{r'}$ is the receiver of electricity.

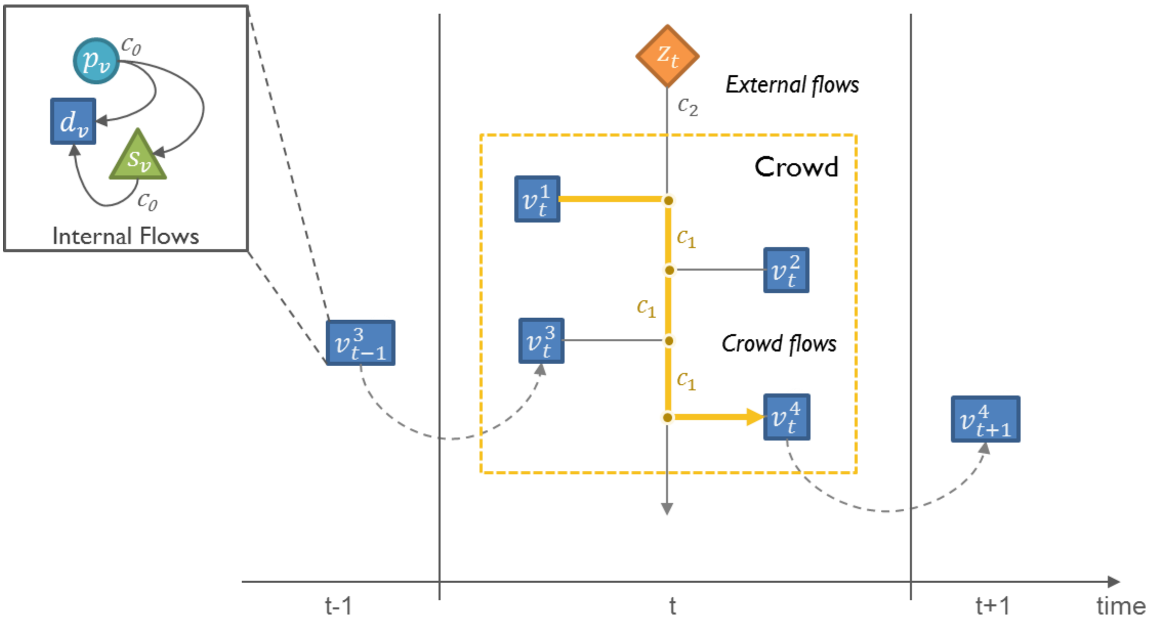

Figure 42: Abstract optimisation model of a crowd

The optimisation problem of the model consists in minimising total cost of flows within a crowd. For each arc $(v_t^r, v_t^{r'}) \in A$, we introduce a variable $x_{(v_t^r, v_t^{r'})}$, defining the units of electricity flow between two buildings, and has an unlimited capacity. The sharing between two houses induces costs including financial compensation for exchange, fee for power line or money for electricity, or losses occurring during exchange. Hence costs can be seen as the efforts for transportation. The determination of total costs is affected by distance and longer haul is more expensive. The model assumes that buildings are positioned in a line; houses have at least one neighbour and a maximum of two neighbours. This ordered collection of buildings can be expressed as a finite sequence of arcs $(v_t^1, v_t^2, \ldots v_t^{r_{i-1}}, v_t^{r_i})$. Consequentially, each arc can be assigned a cost value which in this model is a fixed cost c_1 (see Figure 42). The unit cost of an exchange can be determined as $C_{v_t^1 \rightarrow v_t^{r_i}} = (i-1)\, c_1$. For example, the unit cost for a flow from node v_t^1 to node v_t^4 (through node v_t^2 and v_t^3) can be represented as $C_{v_t^1 \rightarrow v_t^4} = (4-1)\, c_1$. Thus, the total cost of transporting $x_{(1,4)}$ units of flow is $3\, c_1\, x_{(1,4)}$.

For each arc $(z_t, v_t^r) \in A$, we introduce a variable $x_{(z_t,v_t^r)}$, defining the units of electricity flow to cover a shortage of a building through an external source (so called missing flow), and has an unlimited capacity. Also, for each arc $(v_t^r, z_t) \in A$, we introduce a variable $x_{(v_t^r,z_t)}$, defining the units of electricity flow sent by a building to an external source (so called overflow), with unlimited capacity. Both, missing flow and overflow are penalised as the objective is to calculate the maximum potential of crowd flows. Thus, every unit of transporting $x_{(z_t,v_t^r)}$ or $x_{(v_t^r,z_t)}$ has a fixed cost value c_2.

For simplification of the internal building flows, we introduce a variable $x_{v_t^r}$ representing the storage level of a node v_t^r at the end of a time period t. The storage level at the beginning of a time-period is $x_{v_{t-1}^r}$. Any storing has a fixed cost value c_0. The storage capacity of a node is limited by $k_{v_t^r}$.

All cost values are time-independent and remain constant. The optimisation is calculated for each time point where consumption and production numbers derive from input files.

By establishing the network and flow properties, the objective function of the minimisation problem can be stated as

$$\min c_0 \sum_{v \in V} x_{(v,v),t} + \sum_{(v,w) \in A} c_{v \to w}\, x_{(v,w),t} + c_2 \sum_{v \in V} (x_{(z,v),t} + x_{(v,z),t})$$

subject to

constraints of inwards and outwards flow of a cell to keep flow balance between arcs

$$\sum_{w \in V} x_{(w,v),t} + x_{(v,v),t-1} + x_{(z,v),t} = \sum_{v \in V} x_{(v,w),t} + x_{(v,v),t} + d_{v,t} + x_{(v,z),t}$$

Constraint of flows for the first period

$$x_{v_1^r} + \sum_{w \in V} x_{(w,v),1} + x_{(z,v),1} = \sum_{v \in V} x_{(v,w),1} + x_{(v,v),1} + d_{v,1} + x_{(v,z),1}$$

Constraint of storage capacity

$$x_{v_t^r} \le k_{v_t^r}$$

7.1.2 Translating the Abstract to a Computerised Model

The translation into a computer program contains several steps which are aligned with expected outputs. The process outputs produce files with hourly entries containing missing flows to and from external suppliers flows within a community, and storage capacity (see Figure 43). Output is achieved through the main steps: data preparation, modelling, and problem solving involving separate development environments.

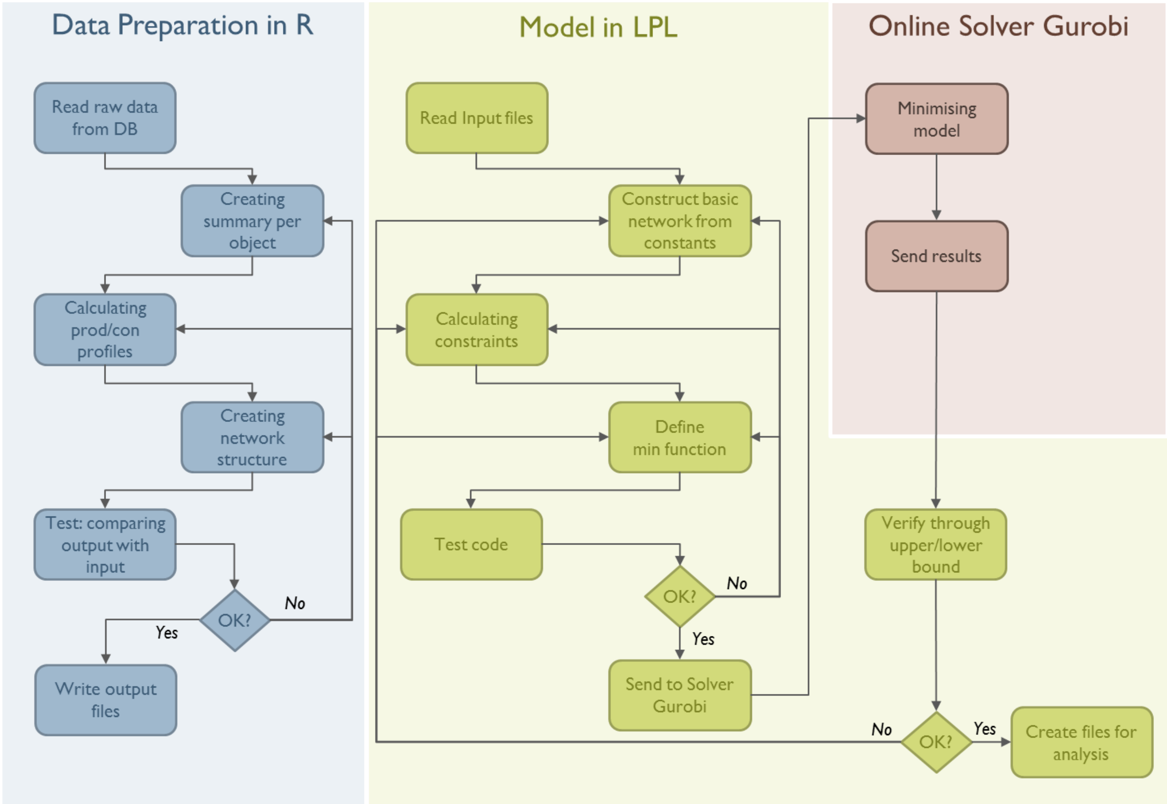

Figure 43: Process of creating a computerised model

The aim of data preparation is to generate input files for the model by manipulating the raw dataset supplied by an electricity provider. The dataset contains yearly consumption and production of single objects (buildings) which was translated into hourly production and consumption profiles through sun radiation and standard load profiles (SLP). Furthermore, the preparation tasks include the generation of a network structure as there was no access to such kind of data. This was achieved by using the travel sales problem (TSP) algorithm in R. The preparation tasks were implemented in R code and mysql. Verification of accuracy is achieved by comparing raw data with output or using established algorithm of R packages. The model, defined in Linear Programming Language (LPL), represents the core and describes the basic structure of the network, calculates constraints for the model, and contains the minimisation function. Verification of code is done by LPL and the model's functionality, by running the model with the dummy data from a smaller sample size. LPL is responsible for creating a model but not for problem solving. For minimising a function, online solver Gurobi is used, it takes a model provided, minimises it, and sends the solution back to LPL. A good solution is obtained when objective (upper and lower) bounds have the same value. All codes and log files can be found in appendix 10.2.3 and 10.2.4. A numeric test of the model is provided in appendix 10.2.5.

The modelling and simulation process does not compare different applications as performance questions are negligible and out of scope. The reasons for using these applications are based on recommendations rather than quantitative figures. All three applications are established in research. In particular, R has the advantage that it is able to manipulate large datasets, especially for matrices. The LPL program was applied in several optimisation environments including Swiss ice hockey schedule planning (Hürlimann & Hürlimann, 2016). Additionally, using LPL allows the broad expertise in the field of flow optimisation, as well as in linear programming, to be accessed. To this end, the choice of Gurobi is the result of experience as well as good connectivity between LPL and Gurobi.

7.2 Results of Crowd Potential

The experiment step, within the modelling & simulation process, involves running the model and simulating various scenarios to generate results and to provide a basis for discussion. Before presenting the results for crowd potential, the chapter provides an understanding of the general simulation parameters and variables. Furthermore, the beginning of this chapter provides an outline of the transformer station in Spiez and a short description of model variables related to framework factors. Subsequently, the chapter presents the results for a current scenario and a future scenario. The decision to present a current and future scenario was made as a current scenario would demonstrate the crowd potential which would be realised if a crowd was implemented. The future scenario should demonstrate technological development and the effects on crowd potential.

7.2.1 General Simulation Settings

The simulations were run for three regular weeks from Monday to Sunday without bank holidays (see Table 20). The weeks represent particular seasons (winter, transition, and summer period) and important due to volatile performance of PV production and difference in consumption patterns.

	Settings		
Time-points	24 h/day, for a week 168 in total		
Weeks	09.12. – 15.12.	08.04. – 14.04.	12.08. – 18.08.

Table 20: Simulation settings

The simulation requires further parameters to determine the potential and an overview is provided in Table 21. Each parameter is constant for each scenario and if there were any adjustments made for investigating a specific situation, they have been stated accordingly. Each cell has zero initial storage due to the objective of defining potential after a week in a particular season. Statements about the first time-points consider this fact. Also, each cell has unlimited storage capacity as the aim of this dissertation is to explore full electricity potential. Thus, storage is set to large capacity and is adjusted in specific cases to simulate more realistic storage behaviour. The new settings are stated at the relevant position in the text. The exchange cost c_1 between neighbouring cells is stated as one and hence the distance of cells in the chain determines the costs of exchange. This can be expressed as $|v - w| * c_1$.

The exchange cost between cells affects the other costs for installation, missing flow, overflow and storage. In general, costs are set into a ratio to support the definition of certain behaviour, i.e. the “first cell then crowd then external network” principle. Another argument for a ratio construct is the divergence of costs and the duration of simulation. Installation of a PV (40 m^2) costs around 20,000 to 30,000 CHF (Electrosuisse, 2015). Compared to compensation per kWh, which is 36.1 centimes Rappen/kWh (Electrosuisse, 2015), amortisation would be achieved within a decade/decades. The maximum simulated time period is a week and hence real costs would make discussion about installation obsolete and consequently electricity would not be shared. As a consequence, costs are normalised and set in relationship to each other.

Parameter	*Value*
Initial storage size	0 kW
Storage capacity	800 kWh
Installation costs for a PV	1,000 CHF
Costs for missing flow or overflow	100 CHF
Costs for flow to/from storage	0.01 CHF
Costs for exchange between cells	$\lvert v - w \rvert * c_1$ where $c_1 = 1$ CHF

Table 21: Parameters for simulation

The model designed can be applied to all location and considers different characteristics (e.g. sun radiation and number of buildings). However, the following results refer to a transformer station in Spiez. Please note that the original dataset was anonymised.

7.2.2 Description of Transformer Station

The transformer station is located near to Spiez main train station in Berner-Oberland (see Figure 44). The distribution of houses is scattered around the transformer and holds in total 91 objects. Each object has a specific address and summarises all measure points, deriving from flats, within a building. The majority are private households in the rural residential area, except one business which is a mixed-building (i.e. business with flats). The satellite map reveals that the single family house building category is dominant in the eastern, southern and western part. The northern part contains mainly multi-family houses (16 objects). This particular location was chosen as there is a mixture of buildings, it’s a rural environment, and current PV productions (marked with a flash in Figure 44) According to the original dataset, there are other locations with similar conditions but picking the presented transformer station was a personal choice.

Figure 44: Objects and network structure of transformer station

The assignment of buildings to a transformer is, contrary to general opinion, not straight forward. In other words, a transformer does not necessary connects entire streets or blocks according to landmarks. Additionally, transformers are randomly located. For example, transformer is positioned more or less in the centre (see Figure 44). Providing an explanation for the positioning transformer stations in a specific way concerns electricity distributors and cannot be explained here. To solve the issue of network design, a network was created according travel salesman algorithm. It should present an optimal path through the set of objects indicated as yellow line in Figure 44. This is the underlying electricity network with the buildings one and 91 representing each end of the chain. Any electricity exchange follows this tour.

A general description of the annual production and consumption of 2013 provides an idea of the situation concerning crowd's potential (see Table 22). Please note that there was no access to more up-to-date dataset, however, it can be assumed the dataset represents an adequate current situation as the total consumption of Switzerland in 2016 is slightly reduced. Furthermore, there have been any structural changes in the area. Currently eight buildings (yellow) have a PV facility installed and the figures represent their current performance. The randomly assignment of production potential to the residual buildings shows following picture. A good potential (green) is assigned to 20 buildings, medium potentials (blue) own 24 objects, and poor potential (red) are allocated to 22 buildings. The 17 entries marked in white have no production potential due to insufficient potential settings or lack of willingness to invest. In total, the production capacity of the crowd is in total 525,312 kWh/y and 7,099 kWh/y on average.

Object	Prod.	Cons.	Object	Prod.	Cons.	Object	Prod.	Cons.
1	4,800	13,913	31	-	390	61	4,800	2,337
2	4,800	11,898	32	6,975	4,295	62	-	897
3	4,800	4,101	33	6,975	4,720	63	6,975	6,894
4	-	9,787	34	4,800	7,563	64	4,800	10,430
5	7,935	26,918	35	9,600	20,151	65	12,500	18,922
6	4,800	12,666	36	-	3,391	66	9,600	17,186
7	9,600	9,245	37	6,975	7,735	67	9,600	11,547
8	6,975	17,279	38	6,975	4,083	68	9,600	22,984
9	4,911	21,954	39	6,975	8,751	69	4,031	12,933
10	4,800	1,292	40	4,800	3,421	70	-	12,288
11	4,800	12,025	41	-	2,660	71	-	6,934
12	1,834	4,009	42	9,600	4,818	72	14,712	22,142
13	9,600	4,960	43	10,028	11,420	73	4,800	5,209
14	6,975	11,386	44	4,800	3,893	74	4,800	21,060
15	4,800	11,628	45	4,800	4,015	75	-	17,621
16	6,975	7,061	46	9,600	7,712	76	-	1,483
17	6,975	5,597	47	6,975	6,642	77	9,600	22,533
18	9,600	6,420	48	-	4,278	78	4,800	13,562
19	9,600	7,500	49	4,800	6,933	79	-	3,466
20	9,600	16,217	50	9,600	3,529	80	6,975	15,119
21	6,975	7,981	51	6,975	4,163	81	9,600	12,756
22	6,975	46,112	52	6,975	8,122	82	6,975	9,850
23	4,361	24,550	53	9,600	3,970	83	-	13,854
24	9,600	9,410	54	-	5,298	84	4,800	9,638
25	6,975	24,381	55	-	3,068	85	6,975	17,838
26	9,600	7,742	56	9,600	4,927	86	6,975	16,008
27	6,975	4,080	57	-	2,817	87	-	13,541
28	4,800	6,229	58	4,800	4,231	88	4,800	12,220
29	-	46	59	6,975	3,841	89	6,975	8,385
30	4,800	15,294	60	9,600	4,847	90	6,975	8,988
						91	9,600	18,469

Table 22: Overview of annual production and consumption for all cells

Crowd consumption totalled 914,459 kWh/y (10,049 kWh/y on average) in 2013 and exceeded production by almost twice as much. Model designers might be tempted to fudge figures and add more potential to the crowd, however, the figures seem to describe a realistic situation. In more detail, object no. 22 has the maximum consumption of 46,112 kWh/y and together with object no. 5 (26,918 kWh/y). Both belong to a large group of 36 objects which consume more than 10,000 kWh/y. Multi-family houses in the northern part are members of this group, however, it seems that single-family houses constitute the majority and they are also at the top of the list. These observations come from satellite pictures. At the other end of the list, around a third (*n = 35*) consumes less than 6,500 kWh/y. In short, there is a wide range in annual consumption.

7.2.3 Meaning of Model Variables Related to Framework Factors

To support the understanding of findings, the following paragraph establishes names and relationships between model variables and how they are related to the framework. Some variables reflect framework factors and others are a combination of variables. Figure 45 provides an overview of the basic operating numbers, flows, corresponding names and dependencies. The variables can reflect a crowd or a cell but also can be discussed in total or for each single time-point. Moreover, the sum of all flows plus storage at the end of the week should be zero.

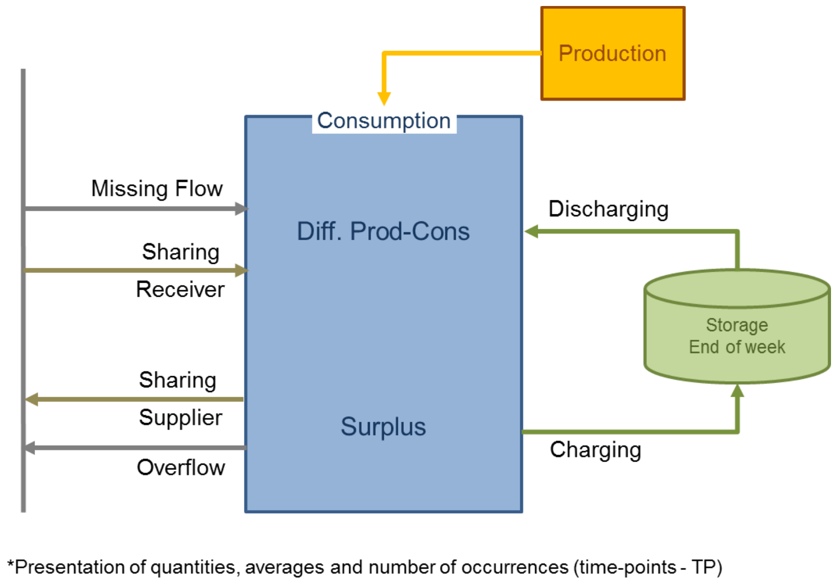

Figure 45: Overview of flows, names, and dependencies

The difference between production and consumption is the first key figure which reflects a crowd's or a cell's capability either to produce a surplus or to have shortage in the observed period. The difference is stated in total kilowatts (kW) or as a percentage where

100% implies that a cell produces exactly the same amount of electricity as is consumed. A negative difference must be covered and can be done using missing flows (from external suppliers), sharing activities, or discharging from the storage. The discharging figure is expressed in terms of how often (time-points) storage has positive entries. The total of kW in storage at the end of week defines overproduction left in the storage after the observed period.

The second important figure is the amount of surplus created. It represents all positive time-points where production is higher than consumption. A surplus is shared between corresponding flows and can either stay within a cell by charging storage or released by sharing activities or overflow. The sharing activities are represented as negative values. The single flows can be set in relation to production or consumption to illustrate shares. In this thesis, several percentages are presented: percentage of surplus from production, percentages of sharing activities and missing flow from total consumption, and percentage of time-points from the total time-points.

7.2.4 Current Scenario

The current scenario represents the year 2013 and is the initial situation for further scenarios. A full overview of results is given in the appendix 10.3.

Winter

The optimisation outcome of the winter period 09th to 15th December has an optimal solution and produces definite findings in which high missing flows, low storage activities, and few internal exchanges dominate. In other words, the potential for creating independence through self-sustainability barely exists. As a consequence, the dominance of missing flow raises total costs to 1,677,164.97 CHF.

The objects in this crowd have a total consumption of 20,121.6 kilowatt (kW) and produce around 3,350.5 kW (see Table 23). This leads to a total shortage of 16,771.0 kW. In more detail, the crowd has a shortage peaking at 11.7 kW whereas the 1.4 kW indicates that a small surplus is produced during the week. On average, the crowd has a shortage of 1.1 kW. The shortage is 83.35% of total consumption, in other words the crowd covers 16.65% of their consumption through their own production. A small surplus of 568.4 kW is produced which is 16.96% of total production. The available surplus is generated by 40 cells during 28 time-points (TP) on average. This is around 16.80% of all 168 time-points. On average the crowd creates a surplus of 14.2 kW and produces a maximum surplus of 41.1 kW, and a minimum of 0.3 kW.

Consumption	*20,121.6*				*(kW)*
Production	*3,350.5*				
	Total	Min	Max	Average	TP
Diff. Prod-Cons	- 16,771.0	- 11.7	1.4	- 1.1	-
Surplus	568.4	0.3	41.1	14.2	28
Flows	Total	Min	Max	Average	TP
Missing	16,771.0	0.001	11.7	1.2	147
Storage	565.3	0.0002	6.2	0.5	49
Sharing	3.1	0.4	0.5	0.005	7

Table 23: Total number of crowd flow winter

The specific characteristic of the winter week defines the flows. The missing flow is frequently used during 147 time-points (on average) and external suppliers deliver 1.2 kW on average and a maximum of 11.7 kW. The majority of the surplus, 565.3 kW in total or 99.46%, flows to individual storages and is fully utilised by the cell. On average, storage is charged with 0.5 kW and has positive capacity during 49 time-points (28.88% of total TPs). It seems that surplus allows cells to benefit from discharging electricity for longer than it takes to charge storage, yet there is no electricity left at the end of the week. A small share of 0.54% is exchanged during seven time-points. The sharing of 3.1 kW occurs solely between two objects and represents 0.02% of total consumption.

The winter week implies a distinct cell categorisation with a concentration on the lower end of the prosumer ranking (see Figure 46). The majority of productive buildings ($n = 65$) are categorised as either prosumer with reduced consumption ($n = 34$) or low temporary ($n = 31$). By adding the consumer category ($n = 17$), the vast majority of buildings wholly depend on or highly depend on the support of an electricity supplier. The figures also imply some individual self-sustainability through storage, however, this barely contributes to the community. More detailed results of categorisation and key figures are provided in appendix 10.3.

	Categories						Key Figures						
	Consumer	Pros. red. C.	Pros. Temp. L.	Pros. Temp. H. (+)	Pros. Aut. L.	Pros. Aut. H.	Prod-Cons	Cons-Missing	Cons-Sharing	Surplus to Storage	Sharing	% time surplus exists	% time storage positive
Total	17	34	31	8 (0)	1	-	16.65%	83.35%	0.02%	99.46%	0.54%	16.80%	28.88%

Figure 46: Crowd potential overview winter current scenario

The group of prosumers with reduced consumption consumes 12,438.0 kW on average and produces 1,442 kW leading to a deficit of 10,996.0 kW (see Table 24). On average, 87.41% of a cell's consumption is covered by missing flows defining a capacity of 10,992.9 kW during 168 time-points (or 323.4 kW on average per time-point). A member benefits from the sharing activities covering 0.64% of the cell's consumption.

		Consumer	*Pros. red. C.*	*Pros. Temp. L.*	*Pros. Temp. H.*	*Pros. Aut. L.*	*Pros. Aut. H.*
Diff.	Total	- 2,243.7	- 10,996.0	- 3,243.8	- 289.7	2.1	-
	Members	17	34	31	8	1	-
Surplus	Total kW	-	-	292.7	252.4	23.2	-
	Aver. kW	-	-	9.4	31.6	23.2	-
	TP	-	-	26	35	35	
Flows							
Missing	Total kW	2,243.7	10,992.9	3,243.8	289.7	1.0	-
	Aver. kW	132.0	323.3	104.6	36.2	1.0	-
	TP	168	168	131	89	9	
Storage	Total kW	-	-	292.7	252.4	20.1	-
	TP	-	-	37	79	152	-
Sharing (R)	Total kW	-	-	-	-	- 3.1	-
	TP	-	-	-	-	7	-
Sharing (S)	Total kW	-	3.1	-	-	-	-
	TP	-	7	-	-	-	-

Table 24: Flows according to cell categories in winter period

There is a total difference of 289.7 kW between consumption (91.5 kW) and production (55.1 kW) for the eight high temporary prosumers and they only require external support during 89 time-points, on average. As a result, the group reduces time-dependency for missing flows to 52.97% of all TPs. This leads to better performance of production which covers 38.98% of demand. Furthermore, the group generates a total surplus of 252.4 kW, on average 31.6 kW, and all of it is stored. Positive storage allows electricity to be discharged during 79 TPs on average. Object no. 50 achieves a maximum discharge at 111 or 66.07% of TPs. By comparing charging and discharging TPs, it can be said that a discrepancy between 35 (20.83%) charging TPs and 79 (46.65%) discharging TPs exists. The storage capacity of this group is 4.8 kW on average and has a maximum range of 2.6 kW to 6.2 kW.

The cell only requires assistance from missing flow during 9 TPs (3.34%). The total surplus of 23.2 kW is generated during 35 TPs on average, this implies that consumption plays a crucial role in the positive outcome as the high temporary group has a higher than average surplus. The charging flow contains 86.67% (20.1 kW) of the surplus and 13.33% (3.1 kW) is shared with the neighbouring object. The large amount of electricity for charging allows the cell to discharge during 90.48% or 152 time-points.

Transition period

The optimisation outcome of the transition period from 08th to 15th April has an optimal solution and shows more in storing and sharing activities. The increase in activity is attributed to higher production performance (more sun radiation) as well as more surpluses. In summary, the potential for creating independence through self-sustainability exists although it is not persistent throughout the week. Increased storage and sharing within the crowd reduces total costs to 547,562.53 CHF.

The crowd model has a reduced consumption of 18,066.4 kW and increased production of around 12,735.9 kW in total (see Table 25). The effect is that the crowd can sustain 70.50% of consumption with its own PV facilities. The shortage amounts to 5,330.5kW in total and the biggest shortage is of 9.3 kW. The maximum electricity of 2.9 kW indicates that a surplus is produced. The crowd produces a minuscule shortage of 0.3 kW on average. Moreover, a surplus of 5,084.8 kW is produced. This is almost 40% of total production. Compared to the winter period, a transition period has 10 times more surpluses available. The available surplus is generated by 68 cells during 66 TPs on average. This is in around 39% of total time-points. During these time-points, the crowd creates a surplus of 75.0 kW on average and there is a maximum of 193.1 kW and a minimum of 0.027 kW.

Consumption	18,066.4				*(kW)*
Production	12,735.9				
	Total	Min	Max	Average	TP
Diff. Prod-Cons	- 5,330.5	- 9.3	2.9	- 0.3	-
Surplus	5,084.8	0.027	193.1	75.0	66
Flows	Total	Min	Max	Average	TP
Missing	5,330.5	0.002	9.3	0.7	46
Storage	2,595.6	0.0014	23.1	3.5	106
Sharing	2,489.2	0.0012	15.2	0.6	43

Table 25: Total amount of crowd flow transition current scenario

The flows reflect the improved capacity of self-produced electricity. The missing flow has a capacity of 5,330.5 kW and is utilised during 46 TPs on average (27.38% of total TPs). External suppliers deliver 0.7 kW on average and have a maximum flow of 9.3 kW. The usable surplus is almost equally distributed between charging and storage at 2,595.6 kW (51.04%) and supplying to others at 2,489.2 kW (48.96%). Charging of storage happens using 3.5 kW on average and has a maximum flow of 23.1 kW. There is positive storage during 106 TPs (63.33% of total TPs) on average and it is clearly above the 50% threshold. Therefore the crowd benefits for much longer from discharging electricity than the time required to charge. A good charging-discharging ratio can be assumed. Although more electricity is available, the crowd has no electricity left in storage at the end of the week. The sharing activities cover 13.78% of demand and occur during a quarter of all time-points (43 TPs, 25.59%). On average, 0.6 kW flows between cells and reaches a maximum of 15.2 kW at any given time-point.

The situation affects cell categorisation distributing cells more evenly throughout the categories (see Figure 47). Remarkably is that cells are categorised in the upper two ranks, namely high (*n = 21*) and low (*n = 15*) prosumer autarkic, showing from their autarkic behaviour in their characteristics. This implies self-sustainability as well as that they support others by sharing electricity. Furthermore, the categorisation reveals an admirable number of temporary high prosumers with 22 objects from which 5 objects exhibit self-sustainability as well as sharing behaviour. In short, internal suppliers and receivers of electricity are 41 objects. It can be assumed that a community has been established. More detailed results of categorisation and key figures are provided in appendix 10.3.

	Categories						Key Figures							
	Consumer	Pros. red. C.	Pros. Temp. L.	Pros. Temp. H. (+)	Pros. Aut. L.	Pros. Aut. H.	Prod-Cons	Cons-Missing	Cons-External	Surplus to Storage	Surplus to External	% time surplus exists	% time storage positive
Total	17	6	10	22 (5)	15	21	70.50%	29.50%	13.78%	51.04%	48.96%	39.20%	63.33%

Figure 47: Crowd potential overview transition period current scenario

The group of prosumers with reduced consumption contains six members and the production performance of 871.8 kW reduces demand of 3,260.3 kW to an electricity shortage of 2,388.5 kW (see Table 26). The difference is covered by 87.41% of the missing flows defining a capacity of 1,831.6 kW or 305.3 kW on average during 133 time-points. The six members benefit from sharing activities to cover the residual electricity shortage (556.9 kW, 23.31%). This occurs during almost a third of TPs (53 TPs).

		Consumer	*Pros. red. C.*	*Pros. Temp. L.*	*Pros. Temp. H.*	*Pros. Aut. L.*	*Pros. Aut. H.*
Diff.	Total kW	- 2,012.2	- 2,388.5	- 1,508.8	- 1,835.5	377.3	2,037.1
	Members	17	6	10	22	15	21
Surplus	Total kW	-	-	8.0	872.5	1,331.2	2,873.1
	Aver. kW	-	-	0.8	39.7	88.7	136.8
	TP	-	-	11	61	84	84
Flows							
Missing	Total kW	1,471.5	1,831.6	1,083.8	877.4	35.6	30.6
	Aver. kW	86.6	305.3	108.4	39.9	2.4	1.5
	TP	80	133	104	36	6	6
Storage	Total kW	-	-	8.0	863.8	918.3	805.4
	TP	78	23	47	115	142	137
Sharing (R)	Total kW	540.6	556.9	425.0	966.7	-	-
	TP	57	53	39	31	-	-
Sharing (S)	Total kW	-	-	-	- 8.7	- 412.9	- 2,067.7
	TP	-	-	-	2	29	58

Table 26: Flows according to cell categories in transition period current scenario

The low temporary prosumers consume 2,759.3 kW and produce 1,250.5 kW in total resulting in a difference of 1,508.8 kW. Production covers 45.31% of total consumption. A small surplus of 8.0 kW produced during 11 TPs indicates that production performance mainly helps to reduce consumption. All member cells store to 100% resulting in a discharging duration of 47 TPs. The required storage capacity for the group ranges from 0.1 kW to 12.1 kW with around 3.5 kW on average. The charging-discharging ratio is impressive, however, it must be regarded with care. This group receives 425.0 kW in total and closer inspection shows that not every kW obtained is used immediately. The majority of the difference between production and consumption is covered by the missing flow of 1,083.8 kW (71.83%). External suppliers support during 104 TPs and supply in 108.4 kW on average.

The high temporary prosumer group comprises 22 cells of which 5 are marked with a plus indicating that these members are involved in sharing activities. The group produces 4,046.3 kW and consumes 5,881.8 kW within a week resulting in a negative difference of 1,835.5 kW. The difference is slightly higher than in the low temporary group but can be explained by the variance of group size. Production performance allows 71.32% of consumption to be covered and produces an additional surplus of 872.5 kW. Excess production occurs during 61 TPs on average and amounts to 39.7 kW. The vast majority (99.39% or 863.8 kW in total) is stored and discharging occurs during 115 TPs on average. Required storage capacity for the group ranges between 1.4 kW and 19.6 kW with around 10.6 kW on average. Only a fraction of the surplus (8.7 kW) is supplied to other cells. A characteristic of this group is the large share of receiving electricity, 966.7 kW. This positively affects storage availability. The increased share led to closer inspection of sharing activities showing that the group is bipartite. A subgroup of 13 cells requires marginal support of 51.7 kW from electricity suppliers. Consequently, the missing flow covers 1.58% of consumption. This is accounted for by the model's settings, cells start with no available electricity hence they require support in the first six time-points. The low dependence on the missing flow is not attributed to an improved production-consumption ratio (71.23%) but the cell receives the vast majority of kW shared, 958.8 kW in total during 40 TPs on average. The other 9 members barely benefit from sharing activities (91.47 kW in total) and requires to higher dependency on the missing flow with 825.7 kW in over 80 TPs on average. The larger and smaller subgroups have around 36% of time-points where surplus is generated (36.08% and 36.57%), however, another distinctive feature is in the time-points when there is positive storage. The 13 cells show a much higher average value of 79.72% (134 TPs) than the smaller group with 52.45%

(88 TPs). A final remark on the high temporary group is that it is the only group which receives and supplies electricity.

The next group, the low autarkic prosumers, contains 15 cells which have a total consumption of 2,213.3 kW and a total production of 2,590.6 kW. The group’s description specifies a range for the production-consumption ratio which is, on average, 120.28%. The difference is positive and totals in 377.3 kW. Furthermore, the group is capable of generating a surplus of 1,331.2 kW which is an average of 88.7 kW during 84 TPs. The missing flow of 35.6 kW is caused by the model’s design and hence the group is autarkic. The accrued surplus is unevenly distributed. The supply to other cells accounts for 31.16% (412.9 kW) whereas 68.84% (918.3 kW) is charged to the storage. The storage provides electricity during 142 TPs (84.52% of all TPs) on average and charged in 84 time-points (50%) on average. The required storage capacity for the group ranges between 16.4 kW and 5.3 kW with around 11.6 kW on average. Due to the difference between charging and discharging TPs and the lack of received electricity, it can be assumed that stored electricity is essential to independency.

The high autarkic prosumer group has 21 members which consume 1,939.6 kW and produce 3,976.67 kW in total. A positive difference of 2,037.1 kW exists and the group has the highest average production-consumption ratio allowing the group to cover demand by 221.52%. As a result, a missing flow only exists at the beginning of the simulation (30.6 kW). Furthermore, a surplus of 2,873.1 kW, 136.8 kW during 84 TPs on average, is generated and unequally distributed between charging storage and sharing. Less than a third (28.98% or 837 kW) is stored during 137 TPs on average. Extracting electricity from storage is possible in 81.26% of all time-points. The group has considerable storage capacity and average maximum storage size is 15.1 kW, ranging from 1.7 kW to 20.9 kW. Such quantities could still be handled by current flow or NaS storage solutions (Mahnke, Mühlenhoff, & Lieblang, 2014). The majority of the surplus (71.02% or 2,067.7 kW) is provided to other cells and makes autarkic prosumers the biggest supplier to the crowd. On average electricity is supplied during 58 TPs. There is no external support from other cells hence it can be said that this group is self-maintaining. In short, the label of high autarkic prosumer has been well chosen.

Consumers benefit from sharing activities receiving 540.6 kW in total during 57 TPs on average. The consequences are the installation of storage capacity. Of all members, only five cells do not store any electricity. The remaining 12 cells require storage capacity, on average 4.1 kW ranging from 0.1 kW to 7.3 kW. Capacity also leads to reduced dependence on missing flow and it is reduced to 1,471.5 kW. Six objects require support at the beginning of the simulation showing an average positive storage of 1.1 kW during 102 TPs (60.71% of all TPs). Eight objects require missing flow during 163 TPs on average, but three objects have a small storage capacity and discharge an average of 1.6 kW during 8 TPs.

The simulation shows further details about the behaviour of the model. First, the number of time-points when electricity is shared differs substantially between receivers (180 times) and suppliers (89 times) indicating that a single supplier provides electricity for more than one house at simultaneously. For example, object no. 3 delivered electricity on 08/04/2013 at the ninth time-point, 954.9 watts in total, to object no. 2 (145.1 watt) and no. 3 (809.8 watt).

Object No. 31 Prod: No *(all values in watt)*

Date	Time	Diff P-C	Missing	Storage	External (S)	External (R)
08/04/2013	0	- 27.0	27.0	-	-	-
08/04/2013	1	- 19.9	19.9	-	-	-
08/04/2013	2	- 18.0	18.0	-	-	-
08/04/2013	3	- 17.5	17.5	-	-	-
08/04/2013	4	- 17.9	17.9	-	-	-
08/04/2013	5	- 21.3	21.3	-	-	-
08/04/2013	6	- 37.6	-	-	-	37.6
08/04/2013	7	- 52.5	-	-	-	52.5
08/04/2013	8	- 55.6	-	-	-	55.6
08/04/2013	9	- 55.0	-	-	-	55.0
08/04/2013	10	- 53.4	-	-	-	53.4
08/04/2013	11	- 53.9	-	119.5	-	173.4
08/04/2013	12	- 60.5	-	58.9	-	-
08/04/2013	13	- 58.9	-	-	-	-
08/04/2013	14	- 51.3	-	88.9	-	140.2
08/04/2013	15	- 45.9	-	43.0	-	-
08/04/2013	16	- 43.0	-	-	-	-
08/04/2013	17	- 47.1	-	-	-	47.1
08/04/2013	18	- 58.6	-	-	-	58.6
08/04/2013	19	- 69.6	-	68.0	-	137.6
08/04/2013	20	- 68.0	-	-	-	-
08/04/2013	21	- 63.1	-	-	-	63.1
08/04/2013	22	- 54.9	-	-	-	54.9
08/04/2013	23	- 40.6	-	-	-	40.6

Figure 48: Consumer storage behaviour

The sharing behaviour shown in Figure 48 higher indicates that more electricity is exchanged than the current time-point requires. For example, object no. 31 receives 173.4 watt at the eleventh time-point, splitting electricity to cover a 53.9 watt demand and storing 119.5 watt for use at the next two time-points. As a consequence, consumers require their own storage functionality. Optimisation shows that consumers benefit from storage an average of 78 times. This comes as a result of the defined cost structure where exchange is more expensive than the internal flows of cells. Eventually, consumers discharge electricity during 55 time-points meaning that they are either fully or partially independent from external supply (missing flow). The same phenomenon is valid for all categories but will mainly affect lower ranked groups such as the prosumer with reduced consumption group (44 time-points) and the low temporary prosumer group (47 time-points).

Summer

The outcome of optimisation in the transition period which lasted from 12th to 18th August shows a very dynamic crowd with regards to storing and sharing activities. The dynamic is attributed to higher sun radiation during summer, leading to more surplus as well as a shift of cells, categorisation to high and low autarkic prosumers. Eventually, cells display more autarkic behaviour. In summary, potential independence is achieved through self-sustainability and persistent for all members of the crowd. The more self-sustainable a crowd is, the bigger effect it has on the total costs for optimisation showing a value of 107,679.02 CHF.

Consumption (14,696.0 kW) and production (14,293.2 kW) as stated in Table 27 is balanced in the crowd model. Therefore the crowd can sustain 97.26% of consumption with its own PV facilities. The shortage of 402.8 kW is just a fraction of its overall consumption and production, this also applies to previous periods. The balanced situation is expressed in a miniscule shortage of 0.03 kW on average reaching 6.7 kW at the time-point with the biggest shortage. Half of production is surplus with 7,148.5 kW in total produced on average by 70 cells during 78 TPs. Compared to a transition week, cells have surplus electricity of around 2,100 kW week.

Consumption	14,696.0				*(kW)*
Production	14,293.2				
	Total	Min	Max	Average	TP
Diff. Prod-Cons	- 402.8	- 6.7	3.3	- 0.03	-
Surplus	7,148.5	0.456	226.2	102	78
Flows	Total	Min	Max	Average	TP
Missing	617.2	0.001	2.7	0.5	10
Storage	2,927.5	0.0017	32.2	5.1	133
Sharing	4,221.0	0.0019	18.2	0.9	46

Table 27: Total number of crowd flows in summer current scenario

The flows are characterised by the higher availability of self-produced electricity. The missing flow delivers the amount of 617.2 kW and is utilised during 10 TPs on average. Model design means that 83 cells have missing flows in the first 6 TPs and eight cells require supply through the missing flow from 15 to 150 TPs. External suppliers deliver 0.5 kW on average with a maximum of 2.7 kW. The variation of production-consumption difference and missing flow figures exist due to the fact that electricity is left in storage (214.4 kW) after the week.

The available surplus is divided into 2,595.6 kW (40.95%) for charging storage and 4,221.0 kW (59.05%) for supplying other objects. It can be assumed that the additional 2,100 kW, compared to the transition week, is mainly used for sharing activities. Moreover, it can be said that cells are sufficiently strengthened through internal flows and it is cheaper to share electricity rather than to store it for self-interest. The model satisfies the behaviour of an optimal cell before crowd before external behaviour. The charging of storage occurs with 3.5 kW on average and has a maximum flow of 23.1 kW. Positive storage exists, on average, during 106 TPs (63.33% of total TPs) and is clearly above the 50% threshold. Therefore the crowd benefits from discharging electricity for much longer than it requires charging and a good charging-discharging ratio can be assumed. The increased sharing activities cover 28.72% of demand and occur during a quarter of all time-points (46 TPs, 27.38%). Despite more electricity for sharing, it seems that the additional amount is not necessarily delivered over many more TPs (the transition period shows an average of 43 TPs). This causes flows between cells to rise to a maximum of 18.2 kW.

Self-sustainability and supporting others affects the cell categorisation with increasing numbers of cells categorised as low or high autarkic prosumers (see Figure 49). The shift comes at the expense of low temporary prosumers and prosumers with reduced consumption. Furthermore, the categorisation shows the same number of high temporary prosumers with 22 objects of which 7 objects display self-sustainability and sharing behaviour. Half of the group are categorised as high temporary regardless of whether it’s a transition or summer period. Additionally, internal suppliers of electricity, in total 50 objects, outweigh receivers, with 44 objects. The self-sustainability of cells and the increased sharing activities allows saying that the community is autarkic. More detailed results of categorisation and key figures are provided in appendix 10.3.

	Categories						Key Figures						
	Consumer	Pros. red. C.	Pros. Temp. L.	Pros. Temp. H. (+)	Pros. Aut. L.	Pros. Aut. H.	Prod-Cons	Cons-Missing	Cons-External	Surplus to Storage	Surplus to External	% time surplus exists	% time storage positive
Total	17	4	1	22 (3)	16	31	97.26%	4.20%	28.72%	40.95%	59.05%	46.29%	79.15%

Figure 49: Crowd potential overview summer

All groups improve the figures by contributing in their scope of action to create independence. This means reduced consumption, higher production and lower missing flows, increased charging and discharging, and enhanced sharing activities in particular.

The group of prosumers with reduced consumption contains four members and production of 572.6 kW reduces demand of 1,821.4 kW to a negative difference of 1,248.7 kW (see Table 28). Production constitutes 33.14 % of consumption. The resulting difference is marginal and covered by missing flow (30.3 kW) over 6 TPs, this represents the first time-points in the simulation. The vast majority of 1,218.4 kW (97.57%) is provided by other members of the crowd. Supply of electricity through sharing happens 92 TPs on average indicating that more electricity is delivered than demanded at certain time-points. The additional electricity is temporarily stored allowing it to be discharged during 105 TPs (62.35%), on average.

The group of low temporary prosumers contains just one member consuming 390.6 kW and producing 189.8 kW in total. Production covers 48.58% of consumption leading to a shortage of 200.8 kW. A small surplus of 0.5 kW produced during 7 TPs indicates that production performance mainly helps to reduce consumption. The cell stores all surpluses resulting in electricity being discharged in 111 TPs. The charging-discharging ratio is impressive, however, must be regarded with care. In total the group receives 194.4 kW during 65 TPs on average and closer inspection shows that not all kW obtained are used immediately. The electricity which is temporarily stored increases available storage to 66.07% of total TPs. At 6 TPs, at the beginning of the simulation, consumption is covered by the missing flow (6.5 kW).

		Consumer	Pros. red. C.	Pros. Temp. L.	Pros. Temp. H.	Pros. Aut. L.	Pros. Aut. H.
Diff.	Total	- 1,631.4	- 1,248.7	- 200.9	- 1,659.9	678.0	3,660.2
	Members	17	4	1	22	16	30
Surplus	Total kW	-	-	0.5	687.7	1,804.3	4,656.0
	Aver. kW	-	-	0.5	31.3	112.8	150.2
	TP	-	-	7	60	84	89
Flows							
Missing	Total kW	208.5	30.3	6.5	281.3	47.2	43.4
	Aver. kW	12.3	7.6	6.5	12.8	3.0	1.4
	TP	15	6	6	16	6	6
Storage	Total kW	-	-	0.5	681.1	1,111.5	1,134.4
	TP	109	105	111	129	151	145
Sharing (R)	Total kW	1,423.0	1,218.4	194.4	1,385.2	-	-
	TP	53	92	64	31	-	-
Sharing (S)	Total kW	-	-	-	- 6.6	- 692.8	- 3,521.6
	TP	-	-	-	2	25	49

Table 28: Flows according to cell categories in summer period

The group of high temporary prosumers is consistently the same size and is made up of 22 objects, three of which are marked with a plus indicating that these members are involved in sharing activities. The group produces 3,746.7 kW and consumes 5,406.6 kW within a week, resulting in a negative difference of 1,659.9 kW. Production performance covers 69.99% of consumption and provides an additional surplus of 681.1 kW. Excess production, 31.3kW, occurs, on aver0age, during 60 TPs. A bulk of surplus is stored (98.96% or 681.1 kW in total) and is discharged during 129 TPs on average. Only a fraction of the surplus (6.6 kW) is supplied to other cells. The intense storage utilisation in this group means that a storage capacity of between 4.6 kW and 21.1 kW is needed, with around 12.6 kW on average. A characteristic of this group is the considerable proportion of members who are receiving electricity (1,385.2 kW). The proportion increases during the transition period by 418.5 kW hence it positively increases storage availability to 129 TPs on average. Once again, the group is bipartite showing a greater divergence in subgroup size. The subgroup of 17 cells requires the marginal addition of 73.3 kW from external electricity suppliers. Consequently, the missing flow covers 1.66% of consumption at the beginning of the simulation. Low dependence on missing flow is not attributed to an improved production-consumption ratio but rather to receiving a vast majority of shared kW – 1,249.1 kW in total. The other five members barely benefit from the sharing activities (136.1 kW in total) and this causes a higher capacity of missing flow (208.0 kW) to be required over 43 TPs on average. Surplus is generated by the larger and smaller subgroups in around 36% of time-points, however, another distinctive feature is large number of time-points of positive storage. The 17 cells show a much higher average time-points (80.95%, 136 TPs) than the 5 cells (62.5%, 105 TPs). Finally, it is the only group which receives and supplies electricity.

The low autarkic prosumer group contains 16 cells which consume a total of 2,839.1 kW and produce 3,517.1 kW. As indicated in the group's description, the production-consumption ratio is 126.7% on average resulting in a positive difference of 678.0 kW. Furthermore, the group has a slightly higher surplus in the transition period and generates a 1,804.3 kW surplus which is 112.8 kW on average during 84 TPs. The missing flow of 47.2 kW is caused by the model's design and hence the group is autarkic. The accrued surplus is unevenly distributed. The supply to other cells averages 37.31% (692.8 kW) but 62.69% (1,111.5 kW) on average is charged to storage. The storage provides electricity during 151 TPs (89.62% of all TPs) on average and it is charged in 84 time-points (50%) on average. These numbers suggest that low autarkic prosumer show endogenous autarkic behaviour by storing electricity. At the end of the week, 32.5 kW of electricity remains in storage. The required storage capacity for the group ranges from 8.1 kW to 26.9 kW, and it is around 16.6 kW on average.

The group of high autarkic prosumers experiences a considerable increase of members and comprises 31 cells. These cells consume 2,606.7 kW and produce 6,266.9 kW in total. A positive difference of 3,660.2 kW exists and shows the highest of all groups production-consumption ratio allowing them to cover 264.85% of demand, on average. There are three extraordinary production-consumption ratios within the set. Two objects have a ratio of over 400%, namely object no. 50 (consuming 56.5 kW, producing 261.2 kW) and object no. 53 (consuming 63.6 kW, producing 261.2 kW). The last object no. 10 has a ratio of 630% (consuming 20 kW, producing 130 kW). All of them have an assigned production potential. It can be argued that assigned production levels are too high for these objects, however, it can also be argued that these objects should be considered first when designing a crowd.

The ratio means that missing flow only exists at the beginning of the simulation (43.4 kW). Furthermore, the group has an increased surplus which is accounted for by more sun radiation rather than by the larger group size. A cell provides 150 kW on average during summer compared to 137 kW in a transition period. The even stronger independency permits a higher surplus of 4,656.0 kW, 150.2 kW on average to be generated during 89 TPs, this is roughly distributed in a ratio of one to four between charging storage and sharing. Around 24.36% or 1,134.4 kW is used for charging and it ensures that electricity can be extracted during 145 TPs on average or in 86.31% of total time-points. Some electricity remains in storage (181.9 kW) at the end of the week. It suggests that the missing flow shown would be further reduced if a new week started and the crowd could maintain the same production and consumption levels. Moreover, the average maximum storage size is 19.7 kW and sizes range from 11.5 kW to 32.2kW. By considering existing storage solutions, cells could still apply the simulated storage functionality, hence limited storage size for simulation is not necessary in this scenario. The increased sharing of 3,521.6 kW (75.64%) to other cells undoubtedly leads to the conclusion that the high autarkic group is the source for crowd independence. Electricity is supplied during 49 TPs on average. The sharing behaviour from high autarkic prosumers (and also other sharing suppliers) shows that quantities of exchange are higher than the electricity demanded at a specific time-point. This effect is more noticeable in the transition period. There is no external support from other cells hence it can be said that highly autarkic prosumers are self-maintaining. Eventually, the label of highly autarkic prosumer is established.

Consumers benefit from increased sharing activities receiving 1,423.0 kW in total during 53 TPs on average. During a summer week all consumers require storage capacity and maximum ranges are between 0.2 kW and 16.0 kW. On average, the group needs a storage capacity of 6.3 kW. Capacity means that dependence on the missing flow is reduced to 208.5 kW. Sixteen objects required support at the beginning of the simulation (6 TPs) indicating, on average, a positive storage of 68.30% of total TPs. One object required missing flow during 150 TPs on average and had few possibilities for discharging during 7.14% (12 TPs) of total TPs.

7.2.5 Comparing Season Results of the Current Scenario

Interesting results have been found for the aforementioned seasons and more findings can be discovered by comparing seasons. Table 29 shows that production and consumption have convergent development reducing the difference from 16,771 kW to 671.2 kW. A reason for this is that there is more sun radiation during summer (see appendix 10.2.1) as well as lower demand in summer, e.g. less light being used, no heating. Production grows, on average by 10,942.7 kW and is four times higher than in an average winter week. Conversely, consumption decreases by 5,425.6 kW or 27%. As a result the ratio of self-production to consumption eventually increases from 16.65% to 97.26%. The difference in developments between summer and winter are striking but considering the transition period a different picture emerges. Production and consumption figures take a leap when moving from winter to transition periods. This can be a result of the choice of month and related sun radiation. December accounts for 2.84% of annual sun radiation whereas an average April week accounts for 10.43% of annual sun radiation. Other months, namely January, February or March, show more sun radiation, however, an increase would still exist. Between transition and summer week examples the numbers are improving but less distinctive.

A surplus of 568.4 kW is generated in an average winter week. An additional surplus of 4,516.4 kW is available in the transition period and there is a further surplus of 2,063.7 kW in summer. This corresponds to around 12 times more electricity. Consequentially, more electricity provides possibilities to increase sharing and storing activities in a crowd. The number of occurrences of flow being used by cells, grows by 1,808 activities between winter (15,391) and summer (17,199). The distinctive leap of 1,500 activities between winter and the transition period exists followed by a marginal increase of 308 more activities in summer. Less dependence on external support, i.e. missing flow, and enhanced self-sustainability affect total costs. The total costs in a summer week (107,679.02 CHF) are around 15 times lower than those in a winter week (1,677,164.97 CHF) and around five times lower than those of a transition week (547,562.53 CHF). The total costs of a transition week are around a third of those of a winter week.

	Winter	*Transition*	*Summer*
Consumption	20,121.6	18,066.4	14,696.0
Production	3,350.5	12,735.9	14,293.2
Prod-Cons Ratio	16.65%	70.50%	97.26%
Surplus	568.4	5,084.8	7,148.5
Total Costs	1,677,164.97	547,562.53	107,679.02
No. of occurrences	15,391	16,891	17,199

Table 29: General key figures for winter, transition, and summer periods

Production and consumption levels alter flow constellation from extensive missing flow in winter to the high flow activities of sharing and storing in transition and summer (see Table

30). During a winter week, missing flows cover 83.35% of consumption and was used 13,340 times. In summer, missing flows occur 908 times with 4.20% consumption coverage. This is a reduction of 12,432 occurrences. Once more, there is a large decrease between winter and transition (11,440.5 kW, 9,134 occurrences) followed by a small adaption of occurrences between transition and summer (4,713.3 kW, 3,298 occurrences). On the other hand, sharing and storing flows increase between winter and summer. In a winter week, almost all surpluses are stored (99.46%) this decreases to 51.04% in a transition week and decreases further to 40.95% in a summer week. Despite a reduction in surplus for storing, the quantity of this flow increases by 2,030.3 kW (winter-transition) and by 331.9 kW (transition-summer). Additionally, the number of storing occurrences increases by 10,159 activities (winter-summer) and would imply that storing flows are highly utilised. This alteration of activities amounts to 83.95% of summer capacity. Storage activities are intensified but not necessarily the amount of electricity charged per occurrence. The amount charged to the storage per occurrence is 0.2912 kW in winter, 0.2870 kW in transition, and 0.2419 kW in summer.

	Winter	*Transition*	*Summer*
Missing	- 16,771.0 kW	- 5,330.5 kW	- 617.2 kW
Occurrence	13,340	4,206	908
Cons-Missing	83.35%	29.50%	4.20%
Storage	565.3 kW	2,595.6 kW	2,927.5 kW
Occurrence	1,941	9,043	12,100
Surplus to storage	99.46%	51.04%	40.95%
Sharing	3.1 kW	2,489.3 kW	4,221.0 kW
Occurrence receiver	7	1,748	2,024
Occurrence supply	7	1,654	1,927
Surplus for sharing	0.54%	48.96%	59.05%
Cons-Sharing	0.02%	13.78%	28.72%

Table 30: Key figures of flows current scenario

The share of surplus used for sharing grows from 0.54% in winter to 48.96% in transition and finally to 59.05% in summer. The sharing capacity grows between winter and transition by 2,486.2 kW and increases again between transition and summer by 1,731.7 kW. Sharing activities are capable of covering a maximum of 28.72% of consumption in the summer period. Along with more kW, the flow intensifies by 1,920 sharing occurrences (winter to summer). Internal suppliers provide around 0.44 kW electricity per occurrence in a winter week, 1.51 kW in a transition week, and 2.19 kW in a summer week. Both, sharing and storing increases in number of occurrence but in amount flowing per occurrence both have opposing behaviour. Furthermore, sharing activities indicates that there are more receivers than suppliers and hence there are more beneficiaries per occurrence. Production same Locations of overproduction exists within the crowd.

Another perspective on sharing behaviour can be seen by considering the distance that electricity sent travels through the network. Figure 50 shows sharing and storing amounts during a transition week. The dark blue bar indicates that the 2,595.6 kW of stored electricity, which is at node 0, means electricity stays at the object. Nodes are a synonym for object. The 2,489.3 kW of electricity for sharing is distributed according to the bars shown where number of nodes is counted for number of nodes between supplier and receiver. The negative nodes mean that electricity is sent to receiver nodes before the supplier node and positive nodes mean that electricity is sent to receiver nodes after the supplier node in the network. Around 1,165.72 kW is sent to a node before and 1,323.56 kW is sent after a supplier node. Before or after a node, the maximum distance is around 21 to 23 nodes. Furthermore, the distribution pattern shows that 51.8% of sharing happens within the first three nodes to either side of a building, to a close distance around production cells. 83.2% of sharing takes place within ten nodes. 31.4% of electricity is shared between the third and tenth node and 16.8% sharing takes place beyond the tenth node.

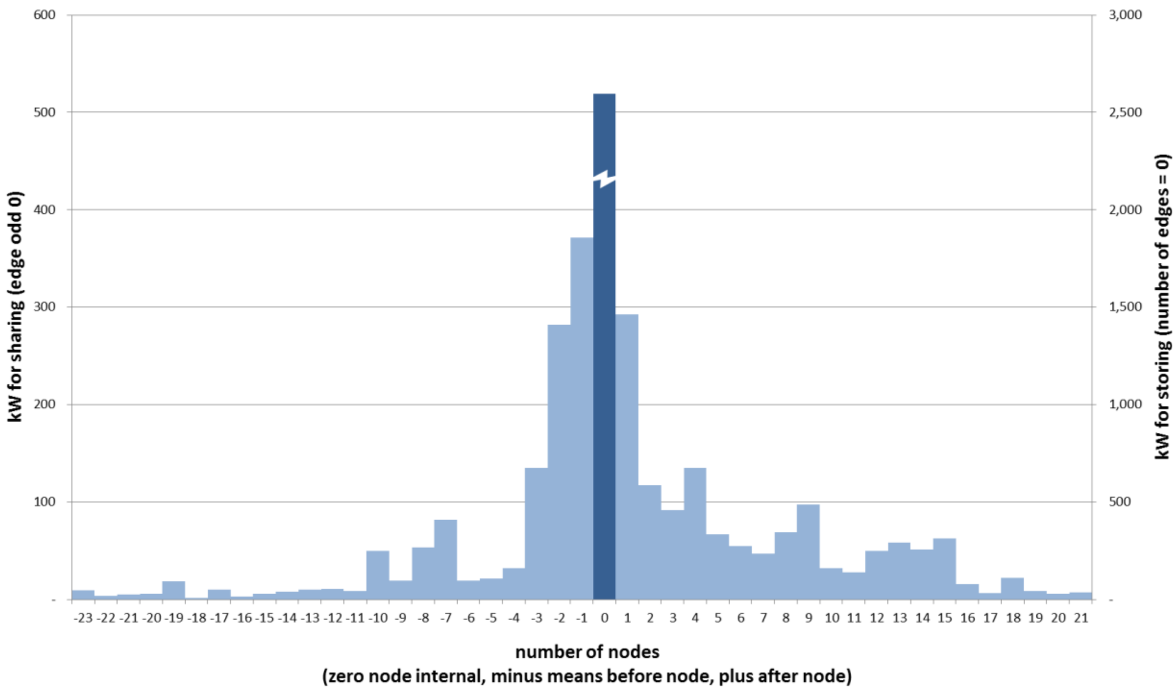

Figure 50: Distance of electricity distribution among cells during transition period

Sharing activities during summer week differ from the transition week mainly due to electricity being dispersed throughout the network and the preference to share electricity (see Figure 51). The total amount of electricity shared, 4,221.0 kW is almost equally distributed in both directions, with 2,177.95 kW being distributed before and 2,043.06 kW being distributed after the supply node. However, it seems that the network sends electricity farther after a supply node (maximum of 40 nodes) than before a supply node (maximum 22 nodes). The difference in maximum distance gives the graph its particular shape showing skewness before and after distribution. The dispersion of electricity among the first three nodes is 26.0% and increases to 58.0% within the first ten nodes. Almost three quarters (73.6%) of sharing happens within the first 15 nodes. The sharing of electricity does not follow a normal distribution shape and several peaks occurs (e.g. at node 4, 15 and -20).

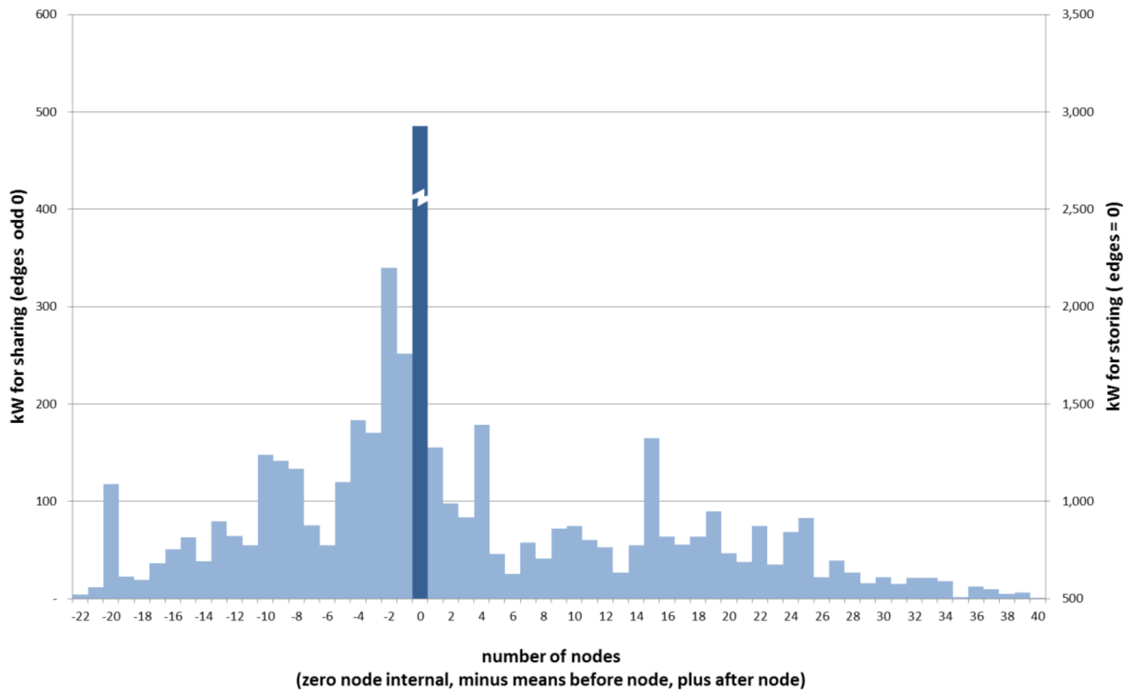

Figure 51: Distance of electricity distribution among cells during summer period

A comparison of prosumer categories in winter and summer shows upwards development from low to higher prosumer profiles (see Figure 52). Only four objects in the group of prosumers with reduced consumption are in the same category, besides consumers, regardless of whether it is a winter or a summer period. 69 objects are categorised otherwise and it seems that at least two category groups are in between. The majority of prosumers with reduced consumption develops into high temporary prosumers (22 out of 34 objects). Seven objects are even categorised as low autarkic prosumers. All prosumers categorised as low temporary either become low autarkic prosumers (9 objects) or high autarkic prosumers (22 objects) in a winter week. Every high temporary prosumer becomes a high autarkic prosumer.

The difference in prosumer categorisation between winter and transition requires closer investigation into the change in categories between the seasons. Figure 52 displays the changes showing augmented categorisation of prosumers between winter and transition. 18 objects, which are categorised, in winter, as prosumers with reduced consumption, become high temporary prosumers whereas 10 objects become low temporary prosumers. Six objects remain in the same category. All objects categorised as low temporary prosumers in a winter week develop to higher levels. In transition week four objects are grouped as high temporary prosumers, 15 objects are categorised as low autarkic prosumers and 12 objects are categorised as high autarkic prosumers. Members who are categorised as part of the high temporary and low autarkic groups in a winter week are later categorised in the high autarkic group.

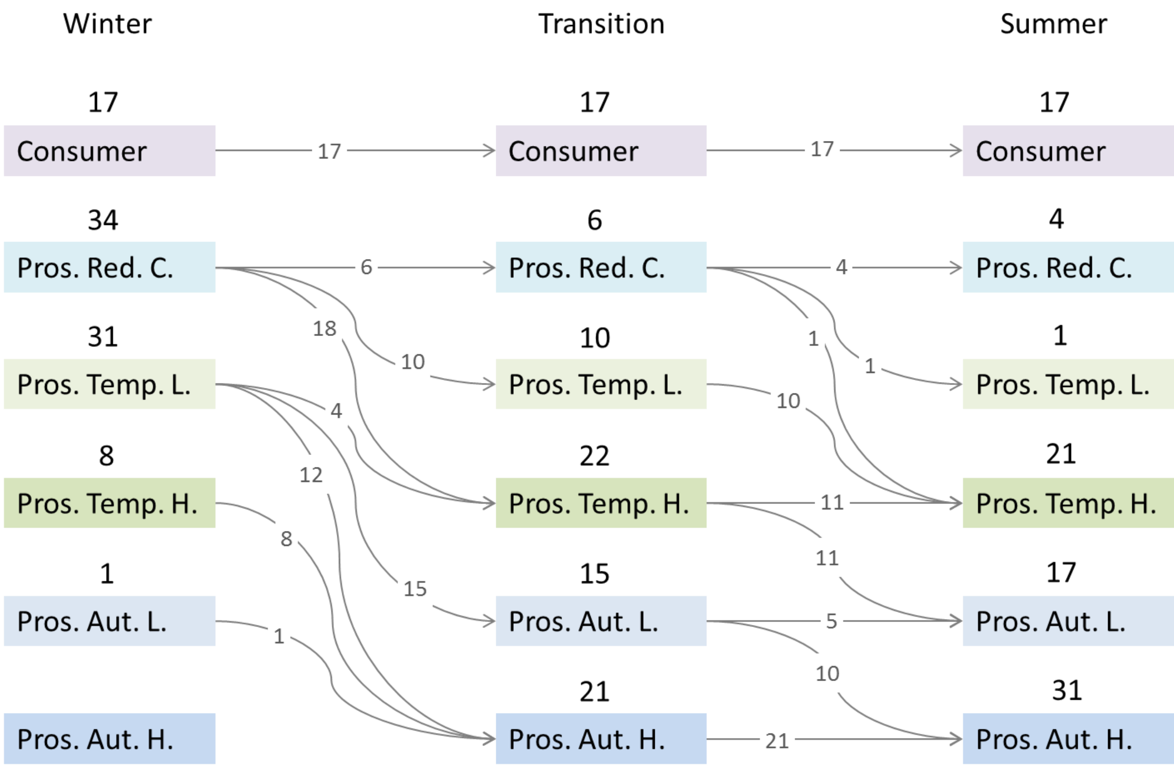

Figure 52: Alterations of categories in seasons

There are fewer changes to categories between transition and summer indicating that more objects are remaining in the same category and that upwards development is mostly to the next highest category. All 10 objects which are categorised as low temporary prosumers in transition become high temporary prosumers. Half of objects classified as high temporary remain in the group and the other half are low autarkic prosumers in summer. A third (five objects) remains in the low autarkic group whereas two thirds (10 objects) move up to the high autarkic prosumer group. All 21 high autarkic members remained in the group as they had already reached the highest category.

The above paragraphs presented the results of the current scenario considering different season. A summary of these results will be provided after showing the results of the future scenario. The reason is that current and future scenarios allow providing more in-depth insights in the crowd potential.

7.2.6 Potential in a Future Scenario

The model is applied to a future scenario using different inputs for production and consumption. A simulation of future potential should provide some insight into model behaviour under development perspectives. In particular, developments based on improved input variables which are envisioned by various policy makers. So, the future scenario calculates with an 11% reduction in consumption and an increased production performance of 43% due to technological development. The changes in consumption and production are based on forecasts from the report (BFE, 2013), however, the development in countries with more advanced decentralisation like Germany suggests that the future scenario might be realised in a shorter time period like five to ten years.

The overview presented in Table 31 shows the general key figures for the future scenario and compares the figures from current scenario. The reduction of consumption and increase in production has a positive effect on the independence of the crowd. The crowd is capable of reducing supply from electricity suppliers. Total autarky is not achieved due to the lack of production performance in the winter week. The table shows that a winter week in future scenario is similar to a winter week in current scenario except more surpluses are available for sharing and for storing.

	Winter		*Transition*		*Summer*	
	Future	Current	Future	Current	Future	Current
Consumption	18,008.8	*20,121.6*	16,169.5	*18,066.4*	13,152.9	*14,696.0*
Production	*4,791.2*	*3,350.5*	18,212.4	*12,735.9*	20,439.3	*14,293.2*
Prod-Cons Ratio	26.61%	*16.65%*	112.63%	*70.50%*	155.40%	*97.26%*
Surplus	1,568.1	*568.4*	10,508.9	*5,084.8*	13,514.8	*7,148.5*
Total Costs	1,322,009.53	*1,677,164.97*	59,639.84	*547,562.53*	39,464.88	*107,679.02*
No. of occurrences	15,441	*15,391*	16,612	*16,891*	16,344	*17,199*

Table 31: General key figures of seasons between current and future scenario

The distribution of flow capacity is similar with 96.26% of surplus being charged and 3.74% being used for sharing (see Table 32). Furthermore, the crowd produces surplus electricity during 17.97% of all TPs and storage is filled in 39.07% of all TPs. The additional electricity leads to an increase in the number of activities occurrences.

The improved availability of self-produced electricity reduces total costs by 355,155.44 CHF. Different results are gained in the transition and summer weeks demonstrating the independence of a crowd and the potential beyond crowd requirements.

	Winter		*Transition*		*Summer*	
	Future	Current	Future	Current	Future	Current
Missing kW	- 13,217.6	*- 16,771.0*	- 256.0	*- 5,330.5*	- 219.6	*- 617.2*
Occurrence	*11,471*	*13,340*	546	*4,206*	546	*908*
Cons-Missing	73.39%	*83.35%*	1.58%	*29.50%*	1.67%	*4.20%*
Storage kW	1,509.4	*565.3*	6,191.6	*2,595.6*	11,063.8	*2,927.5*
Occurrence	3,741	*1,941*	13,344	*9,043*	13,781	*12,100*
Surplus to storage	96.26%	*99.46%*	58.92%	*51.04%*	81.86%	*40.95%*
kW in storage	-	-	2,299.0	-	7,506.0	*214.4*
Sharing kW	58.7	*3.1*	4,317.3	*2,489.3*	2,451.1	*4,221.0*
Occurrence receiver	67	*7*	1,265	*1,748*	888	*2,024*
Occurrence supply	66	*7*	1,217	*1,654*	880	*1,927*
Surplus to sharing	3.74%	*0.54%*	41.08%	*48.96%*	18.14%	*59.05%*
Cons-Sharing	0.33%	*0.02%*	26.70%	*13.78%*	18.64%	*28.72%*

Table 32: Key figures of for flows and season in current and future scenario

Both weeks in a future scenario produce a positive difference of 2,042.9 kW (transition) and 7,286.4 kW (summer), sufficient for covering demand by own production by 112.63% in transition and by 155.40% in summer. The ratio beyond the 100% threshold indicates that the crowd exceeds its own requirements and this has several results. Surplus is doubled, leaving potential for sharing and storing activities. The number of sharing and storing occurrences in transition week is slightly lower but suggests that activities are at the same level as in current scenario. Reduced activity (difference of 855) shows that there is less activity in a summer week despite additional electricity. A more detailed investigation into flows and activities is provided in the next paragraph. Eventually, in both weeks total costs crucially decrease by 487,922.69 CHF and by 68,214.14 CHF which means expenses are roughly nine times and three times lower respectively.

The missing flow in transition and summer is used in the beginning of the simulation and hence shows 546 occurrences in total (91 objects multiplied by 6 TPs). The coverage of demand by missing flow is reduced to a minimum. In both cases, the generated surplus is mainly stored and less kW is shared. In total 6,191.6 kW or 58.92% of surplus during a transition week is charged to storage providing positive storage during 87.28% of total TPs on average. At the end of the week, 2,299.0 kW is still available in storage for further future use. The 41.08% or 4,317.3 kW of the surplus is used for sharing and covers 26.70% of the consumption. The focus on storing activities results in an increasing number of occurrences of storage activities (47.56%) and a reduction in sharing activities (26.42% of supplier occurrences).

The picture is even distinctive during a summer week. The majority of electricity, (81.86%, 11,063.8 kW) is stored whereas 18.14% (2,451.1 kW) is used for sharing. The future scenario indicates a considerable reduction in sharing (54.33% supplier occurrence) and an increase of storing activities (13.89%). The reduced number of sharing activities means that 18.64% of demand is covered by sharing. Increased storage capacity leads to positive storage during 90.14% of total TPs on average. Furthermore, the crowd has 7,506.0 kW of available electricity in storage at the end of the week. The reason for transition and summer surplus in storage is an unlimited capacity of storage. The average storage capacity is around 17.6 kW (transition) and 46.5 kW (summer) and some cell capacities go beyond current storage solutions, hence simulations for both periods were carried out with a limited capacity of 30 kW.

The consequence is that dominant storage is reduced and activities are shifting to sharing. In more detail it means that during transition the surplus is distributed between 49.80% for storing and 50.20% for sharing. Sharing covers 32.63% of demand. Storage holds, on average, 15.5 kW and provides electricity for 91.50% TPs in total. Additionally, an overflow of 3.4 kW is generated. The varied storage capacities raise total costs to 98,319.29 CHF. Storage limits have a stronger effect on the simulation results during a summer week. The share for storing decreases to 74.79% leaving 25.21% for sharing. The shift means that storage holds, on average, 12.7 kW and provides electricity for 78.21% of all TPs. The enhanced sharing activities cover 25.90% of total consumption.

Eventually, storage facilities reach maximum capacity and demand is saturated by exchange. Therefore the crowd produces a 333.9 kW surplus and according to model design, penalising overflow, increases the total costs to 535,039.59 CHF.

The categorisation reflects enhanced production performance (see Figure 53). Fifty objects are defined as having a lower prosumer profile, i.e. there are 19 objects with reduced consumption and 31 low temporary objects in a winter week. A considerable increase happens in the temporary high category with 21 objects compared to current scenario which had eight objects in this category. Growth occurs at the expense of less prosumers in the reduced consumption category.

Categories

	Consumer	Pros. red. C.	Pros. Temp. L.	Pros. Temp. H. (+)	Pros. Aut. L.	Pros. Aut. H.
Winter	17	19	31	21 (6)	2	1
Transition	17	2	2	21 (6)	10	39
Summer	17	-	2	8 (1)	16	48

Figure 53: Categorisation of cells seasons future scenario

The transition week distinctively shifts objects to the upper categories minimising prosumer with reduced consumption and low temporary categories. There is an immense increase in the high autarkic prosumer and a decent increase in the low autarkic group. High temporary prosumer groups have a stable number of members. The upwards trend of categorisation continues in the summer week leaving lower categories almost empty. The high temporary group shrinks to eight objects whereas low and high autarkic groups increase by six and seven members respectively. The final picture shows a shift to the two upper categories with 64 objects in total.

The sharing behaviour among the objects during a transition period in a future scenario shows specific distribution behaviour (see Figure 54). Electricity is shared slightly more often after a supply node (2,578.9 kW) than before a supply node (1,738.5 kW). This tendency is also reflected in the fact that sharing distance reaches a maximum 35 nodes after a supply node whereas 16 nodes is the maximum before a supply node. Furthermore, sharing is concentrated very close to a supply node 60.4% (2,607.1 kW) within the first four nodes and 75.8% (3,274.3) within the first 10 nodes.

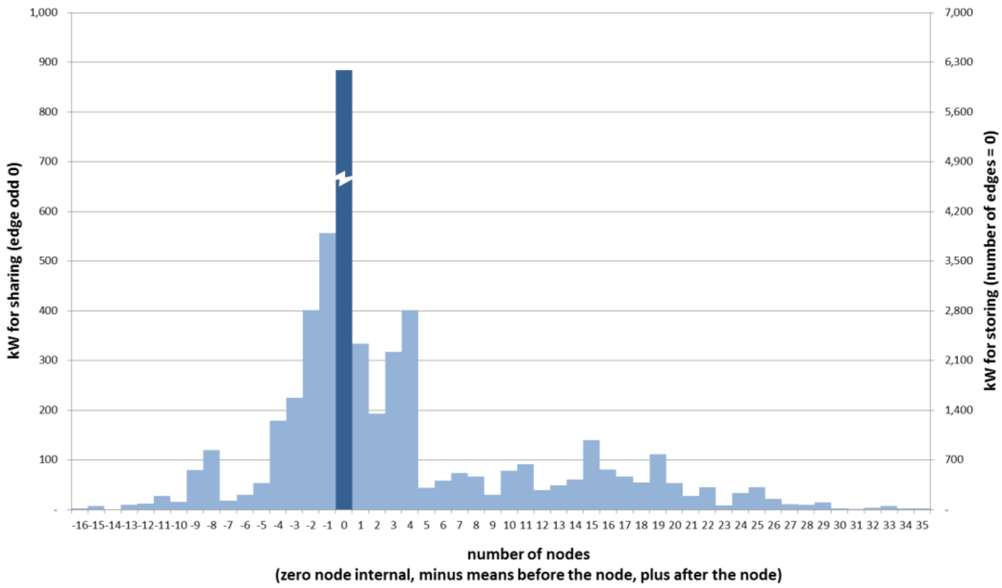

Figure 54: Distance of electricity distribution among cells (transition week, future scenario)

A slightly different situation in sharing behaviour exists when a limitation on storage is implemented generating a higher exchange in amount and longer exchange distance for electricity (see Figure 55). There is still a tendency to deliver electricity after a node (maximum 44) rather before a node (maximum 28). The shared amount within the first four nodes is 1,706.1 kW and corresponds to 32.3% of total sharing. Slightly more than half of all exchanges (55.1% or 2,910.3 kW) happen within the first ten nodes. More than three quarters (78.3% or 4,141.5 kW) of sharing activities take place within the first 20 nodes, showing a wider dispersion of exchange behaviour.

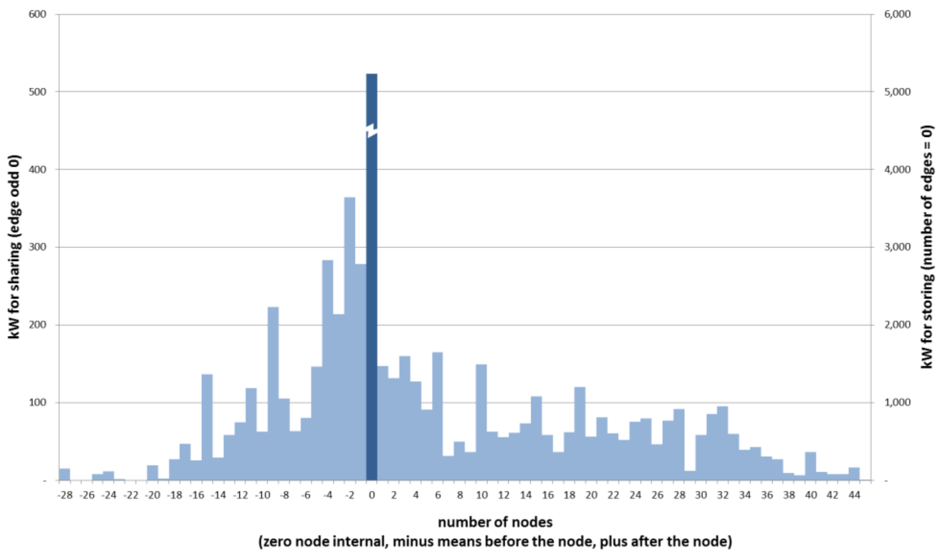

Figure 55: Distance of electricity distribution among cells (transition week, limited storage)

The unlimited storage scenario results in unique sharing behaviour during summer. The exchange of electricity is concentrated around four to six nodes around a supply node. Furthermore, 80.9% (1,983.8 kW) of electricity is delivered within the first two nodes. By considering the production-consumption ratio of cells and a strong independency of cells this means that electricity can be shared with nodes which are close by. This might also result from the constellation of production performance and demand locations. Nevertheless, the distance is significantly reduced. Using the simulation the same summer scenario with limited storage, sharing changes to more distributed behaviour. There is still a concentration around nodes four to six, however deliveries extend to nodes -25 and 40 with a skewness to after a supply node. The dispersion implies that 56.7% (1,846.6 kW) of electricity is exchanged within the first two nodes and at a distance of five nodes 87.0% (2,832.5 kW) of electricity has already been delivered. The residual electricity (575.6 kW) is exchanged beyond node five.

7.2.7 Findings Crowd Potential

The objective of the model was to determine the potential of a crowd by minimising the costs for electricity distribution. A specified cost structure, preferring local production-consumption over feeding into the external network, was established leading to certain storing and sharing behaviour within a crowd. Thus, the model design specifies the context in which findings can be discussed. The following paragraphs describe the findings of the crowd potential according to the model design and are summarised in Table 33.

The results of the current scenario were expected to show a heavy dependency on external supplies (missing flows) in a winter week, a mixed picture using external, sharing and storing flows in the transition period, and mainly storing and sharing flows in a summer week. A first conclusion is that the potential to create independency of a crowd from external electricity suppliers exists for specific points in time and seasons. The simulation also suggests that independency throughout the year could not be achieved by adapting production and consumption numbers according to a future scenario. The effect is that independency from external suppliers will only be sustained for longer, meaning that a crowd already shows independent behaviour during the transition period. Therefore, a crowd which would like to achieve independency throughout the year, cannot solely rely on PV facilities and must implement less volatile production forms.

By minimising transportation costs, the simulation shows that an object is earlier and longer independent than a crowd independency. The cell’s independency derives from enhanced storing activities. This implies that an enforced “ego-centric” behaviour has no negative impacts on a crowd’s independency. It minimises the demand of electricity from the crowd. Consequently, a cell indirectly supports the crowd’s independency; thereby the cell’s independency becomes a crucial factor for electricity management, besides the active sharing of electricity.

Potential
A. Independency of a crowd from external electricity supplier exists for specific points in time and seasons.
B. In a future scenario, independency throughout the year will not be able to be achieved either. However, independency will be sustained for longer.
C. In general, independency of single cells is achieved earlier and is maintained longer than crowd independency.
D. Sharing is a deliberate activity.
E. Sharing means that higher quantities are delivered immediately and are gradually consumed.
F. The production-consumption ratio influences the favouring of storing or sharing and can be defined as follows: a. A low ratio (>75% self-maintenance) favours storing activities b. A ratio closer to independency (100% self-maintenance) favours sharing activities c. A ratio above 100% favours storing activities.
G. The categorisation of prosumers is dynamic and depends upon the time of observation

Table 33: Findings of crowd potential

On the other hand, sharing behaviour in a crowd shows some specific characteristics. In general, sharing makes a smaller contribution to covering the consumption within a crowd. The simulations show that sharing should be applied when it is needed rather applied constantly. The need derives from the necessity to avoid shortages in the crowd and this is possible when electricity is available for sharing. Thus, sharing is a deliberate activity. Furthermore, the simulations indicate that a sharing activity at a specific point in time can involve the delivery of higher quantities. The shared quantity is stored and is gradually consumed. Such a sharing behaviour occurs multiple times within the simulated weeks and indicates that the determination of sharing quantities considers the current and future demand of other crowd members. Thus, delivery time and utilisation of shared electricity become crucial in the electricity management.

Another finding of the simulations is that the overall production-consumption ratio of a crowd favours either storing or sharing activity. Hence, certain ratios define storing and sharing dominance and can be summarised according to the following pattern. First, the simulation shows that a low ratio favours storing activities. The reason is that the small amount of available surplus is used to maintain electricity within a cell. The results suggest that a low ratio would roughly be defined below 75%. Secondly, a ratio closer to 100% self-maintenance of a crowd with self-produced electricity shows that sharing activities are favoured. The reason is that some cells are self-maintaining and are constantly producing surpluses. These cells develop to a source for sharing; the crowd establishes a surplus and shortage locations. A crowd, being close to self-maintenance, establishes maximum sharing activities in distance and quantities. Lastly, the simulation shows that a production-consumption ratio above 100% – a total maintenance with self-produced electricity exists – favours storing activities. The reason is that each cell is self-supporting and produces enough surpluses, even those who were not able to cover their own demands before, and hence less electricity must be exchanged. Exchanges only occur to those objects which have no production. The crowd shows an overflow of electricity and would be able to provide it to other crowds.

A last finding from the simulation concerns the prosumer categorisation which supports the understanding of a crowd potential from a member perspective. A finding in regard to categorisation is that a building can be assigned to various prosumer categories depending on the time of observation. Thus, categorisation of buildings should be dynamic. Another conclusion is that parameters of production-consumption ratio, surplus quantity, and quantity for supplying sharing activities are good indicators for categorisation.

8 Conclusions and Recommendations for Future Research

This chapter synthesises the findings presented in chapter 6.2 and 7.2 and constitutes the closing step according to the outline of the dissertation (see Figure 2, page 9). The chapter elaborates on the Crowd Energy concept (see chapter 3, page 46) from a value network perspective and the sustainable integration of all stakeholders, in particular crowds and their members. By pooling resources together, a crowd generates an internal coherency. Furthermore, a crowd's coherency, defined by strength (i.e. working together) and potential (i.e. producing enough electricity), shows dependency (or independency) of external stakeholders.

As a result, the closing chapter's objective is to answer the proposed research questions by characterising a CE value network (chapter 8.1.1), crowd strength (chapter 8.1.2) and potential (chapter 8.1.3). Finally, the chapter describes the limitations of this explorative research study (chapter 8.2) and provides recommendations for future research (chapter 8.3).

8.1 Conclusions of a Crowd Energy Value Network

This thesis contributes to the Crowd Energy research field by investigating a smart value energy network and the sustainable integration of all stakeholders, in particular crowds and their members. This research study showed that a crowd-based network contributes to a sustainable future value network by introducing a local production-consumption principle. Crowd Energy becomes the decisive concept for the energy turn around. The bottom-up approach depends upon the behaviour of prosumers to contribute to a community by converting tangible and intangible assets to deliverables. Thus, to build a CE value network, the electricity industry must recognise that the value network turns into a socio-technological system. Besides technological and economic factors, social and individual aspects are increasingly becoming the drivers for value creation. Eventually, a crowd-based value network is a more complex environment for value creation, defining interrelated creation processes and various value conversion strategies, and introducing new value types for exchange. The following paragraphs elaborate the stated conclusion in more detail.

8.1.1 A crowd-based Network Design

The de- and realignment of the existing value creation caused by the prosumer requires investigation into the new design including the stakeholders involved and the relationships and types of values they exchange. Therefore, this dissertation contributes to the Crowd Energy research field by proposing a CE value network. In order to do so, the study raised the following research question: *What does the design of the new value network in a Crowd Energy paradigm look like?* To answer the research question, a Crowd Energy value network was conceptualised according to a network value analysis approach (see chapter 5.1.4, p. 81). The gained insights from the various findings for crowd strength and potential allow to confirm some conceptual considerations.

A first affirmation is that a crowd will be created and hence a restructuring of the value network will be initiated. There are two factors which assume a crowd development: First, the emergence of the prosumer role. The stated willingness of individuals to invest in infrastructure indicates that consumers get to like the idea of being a prosumer (see Table 11, p. 108). They assign a high relevance to an iGSL system. Second, individuals stated a willingness to work together in a crowd (see Table 19, p. 123). It shows that a prosumer role concerns itself with individual and community related questions. The emergence of crowds in the value network means that a further stakeholder enters the market; thereby the crowd gains some leverage. Table 19 (p. 123) indicates that a crowd can have a dominant influence on the value network because of its size of a block/suburb or even village. Depending on the potential of a crowd, this could mean less dependency (e.g. electricity providers) or high importance due to a very lucrative business (e.g. service provider). External stakeholders are confronted with a partner who presents or even dictates challenges. This leads to an increase of service offerings and complexity. As a consequence, a restructuring of the value network is initiated and eventually alters roles and relationships.

The proposed crowd-based network in chapter 5.1.4 emphasises such a decentralisation of value creation and certain structure alterations can be affirmed. Even though responsibility is assigned to the electricity provider, the results of the crowd potential (see chapter 7.2, p. 130) suggests that, overall, the dependency of crowds on electricity providers will be reduced. Hence, in a crowd-based structure, electricity providers are required as a backbone. On the other hand, prosumers recognise the service provider as a role responsible for electricity management (see Table 11, p. 108). From the conceptual service provider role description, i.e. translation of expectations of a crowd into services and support of the crowd coherency, it can be expected that a close relationship will be established as electricity management is located inside a crowd. Provided services are highly customised. All managing tasks are canalised through the service provider and cause additional reduction of dependency on electricity suppliers. For the relationship between a crowd and supportive roles (i.e. manufacturers of decentralised solutions and appliances) no evidences could be established. However, it can be assumed that the linkages are based upon mutually beneficial business aspects. Manufacturers are required for the creation of innovative products and services, and the crowd is interested in obtaining excellent solutions to support independency of a crowd from external suppliers.

Besides the structure of the crowd-based value network, findings suggest essential requirements for cooperation in and with a crowd. A crowd establishes specific characteristics, which defines the requirements for the formation of a crowd. In consequence, these requirements are, likewise, the driver for defining interrelationships with other stakeholders. The findings regarding strength and potential lead to the conclusion that the following crowd characteristics are essential for relationships. First, a community shows a certain protective behaviour about their deliverables (i.e. electricity) by assigning a higher value to self-produced electricity (see Table 17, p. 118). Such an endowment indicates that electricity management prefer the handling of self-produced over external electricity. Negative impacts on the availability of self-produced electricity will be avoided. The second characteristic of a crowd is a transparent cooperation. Transparency emphasises a critical factor for participating and maintaining a relationship (see Table 19, p. 123) and refers to a transparent process for electricity and information exchange. A last characteristic of a crowd refers to an increased exchange based upon intangible values (e.g. emotions). The influx of intangibles derives from the following findings: a) relevance of personal willingness in a crowd (see Table 19, p. 123), b) requirements of transparency which supports trust and hence stimulates intangibles values, and c) decision making of prosumers to share or to store (see Table 17, p. 118). In conclusion, the value creation requires the addressing of these criteria. Furthermore, specification of these criteria, e.g. what is expected and what is non-permissible, by stakeholders is mandatory. An insufficient consideration by any stakeholder builds up a barrier, minimising cooperation and eventually negatively influencing the dynamic of the entire value network.

8.1.2 Conclusions of Crowd Strength

The insight of a crowd-based network development indicates the close examination of the ability of prosumers to convert values to deliverables. Deliverables, i.e. electricity and infrastructural resources (e.g. storage), constitute the backbone of a crowd and depend upon the prosumer's preference. Thus, this research study contributes to the CE research field by proposing and answering the research question: *How does a prosumer define the conversion of tangible and intangible assets into deliverables?* To answer the question, factors for the crowd strength were defined (see chapter 5.2.1, p. 84) according to the value conversion model, data were gathered through an online survey and findings were presented in chapters 6.2.2 (p. 102), 6.2.5 (p. 118) and 6.2.7 (p. 123). The following paragraphs elaborate on the findings of the prosumer's value conversion strategy in more detail.

As mentioned in chapter 8.1.1, prosumers are willing to invest in infrastructure and cooperate within a community, and these are both preconditions to convert tangible and intangible assets into deliverables. A further condition is transparency, emphasising a critical factor for maintaining conversion. Introduced intangible values are a further factor for stimulating conversion. An insufficient consideration of such values causes minimised efforts to convert assets into deliverables and eventually negatively influences the dynamic of the crowd.

Prosumers prefer to participate in a local production-consumption community, the size of a block or suburb. The preferred size for participation indicates a less clannish group. It was expected that familiarity with members of the crowd was necessary, which is more established in smaller groups. Instead, it seems that prosumers desire certain anonymity when contributing. However, anonymity is not favoured in all areas of a crowd. Transparency of electricity management, including the adequate sharing of information, is the common characteristic for dynamic and active participation. So, participation and hence the delivery of value is determined by anonymity and transparency.

Besides the crowd's size, the preference of prosumers for self-produced electricity influences the conversion strategy. The endowment of self-produced electricity places a greater value on self-produced electricity when a prosumer has established ownership. Thus, conversion of tangible and intangible assets occurs only for prosumer's benefit by consuming or storing. A prosumer might show protective behaviour; negative impacts are avoided at any circumstances. To secure sharing, a crowd must establish moral concepts to influence the prosumer's conversion strategy by associating the same value to self-produced as to crowd produced electricity. An endowment of all self-produced electricity within the crowd emerges and strengthens crowd cooperation. As a conclusion, a conversion strategy depends not only on the quality of the individual value perception but also on the quality of a crowd to establish moral concepts.

The decision making of a prosumer has a significant influence on the delivery of values to the value network. Thus, this research pays particular attention to decision making behaviour. Table 17 (p. 118) confirms that different decision making strategies exist and prosumers are distinguished into two groups: adaptive and non-adaptive. Prosumers with non-adaptive decision making behaviour will act in a risk averse manner, i.e. showing mainly autonomous behaviour, regardless of weather forecasts. The adaptive group alters decisions from a risk seeking to a risk averse behaviour depending on the dimensions of the weather forecast and the time period. In general, prosumers in the adaptive group are risk averse when bad weather and risk seeking when sunny weather is expected. These dimensions create a decision matrix shown in Figure 39 (p. 119). Nevertheless, the occurrence of risk averse and risk seeking behaviour suggests that prosumers will have different strategies to convert assets. Furthermore, both behaviours indicate different reasoning for prosumer's decision making.

The risk averse behaviour of non-adaptive prosumers expresses decision making accompanied by negative feelings (i.e. fear of disappointment or losses). Probably, the endowment of self-produced electricity is more distinctive. A conversion strategy is restrictive and self-centric. Any compensation for losses must outweigh personal interests; financial offers might show a low impact. Restraints, through regulations set by the crowd, could have an unfavourable effect on cooperation. The crowd must rather achieve influence by the previously mentioned moral concept, thus addressing fears through providing security of supply through a community. This is also applicable for adaptive prosumers when they show risk averse behaviour. Risk seeking behaviour expresses decision making accompanied by positive feelings (i.e. hope to gain or hope to avoid losses). The conversion strategy is also self-centric but unrestrictive. External options are considered in the decision making and can include buying electricity but also sharing and expecting a benefit later. Thus, options must fulfil the hope of large gain or avoid losses. To sum up, influencing the conversion strategy of prosumers means addressing fears and hopes.

A different conversion strategy of prosumers to deliver value is applied for storage capacities. Findings suggest the following characteristics: In general, a prosumer with higher storage capacities expresses a higher need to fill to capacity. This implies that a cell would store all electricity until storage capacity was reached. On the other hand, prosumers reduce consumption to extend the benefit of storage before buying electricity from external suppliers. This indicates that stored electricity seems to be valuable. The intention to buy capacities from prosumers requires financial compensation. Electricity as compensation object would be acceptable but less dominant than financial ones. The compensation for the prosumer is determined by the price they would obtain during discharging storage. Such an expected price perception from the prosumer can differ from the current market price; most likely on sunny summer days. This leads to the following implications: a) prosumers are restricted to sell electricity and b) there are minimised storage capacities available for general load balancing tasks. Thus, the finding proposes to consider the factor “storage level” in price determination models and in dynamic pricing algorithms.

8.1.3 Conclusions of Crowd Potential

The foundation of a crowd is the ability to produce enough electricity for exchange and balance load between surplus and shortage locations. The effect is a certain independency from external resources. The exchange can be regarded as the optimisation of flows among members or rather the minimisation of transportation costs. As on these terms, the research study contributes to the CE research field by proposing and answering the research question: *What is the potential of Crowd Energy?* To answer the question, factors for crowd potential were defined according to supply chain optimisation (see chapter 5.2.2, p. 87), data were gathered through simulation of a transformer station and findings were presented in chapter 7.2.7 (p. 162). The following paragraphs elaborate on the findings of crowd potential in more detail.

The simulation of the crowd potential shows that independence of a crowd can be achieved for specific points in time in transition periods (around lunch time) or throughout a summer week. The potential is achieved with a well-resourced but not fully fitted crowd. This means that not all objects have installed infrastructure for production or must necessarily have excellent production performances. Based on future consumption and production and the same infrastructure, independence of a crowd will already be achieved in transition periods. But, to create absolute independency, a crowd must install more production capacity, or less volatile production forms to compensate low production periods. Nevertheless, by following the local production-consumption principle, a crowd contributes to the energy turnaround and reduces the demand from external resources. The conclusion contradicts studies like (Bouffard & Kirschen, 2008; MIT, 2011; Pudjianto, Ramsay, & Strbac, 2007) indicating that a decentralised system is insufficient for the energy turnaround.

The potential of a crowd is achieved by well-managed storing and sharing activities. In general, a crowd should regard storing as a basic activity whereas sharing becomes essential in specific situations. The conclusion is based on the optimisation of transportation costs where shorter distances are preferred, indicating that flows within cells are favoured (i.e. storing), over flows between crowds (i.e. sharing). Consequentially, the crowd should show enhanced storing activities. An effect is that storing supports the fortification of cells and reduces the number of requests made to the crowd. Thus, an insight is that a cell's independency becomes a value delivered to the network. Nevertheless, the simulation proved that storing is indeed a basic activity. However, the dominance of storage diminishes, and even sharing becomes dominant, depending on the overall production-consumption ratio of a crowd. The simulation suggests that the highest number of sharing activities occurs when there is a close production-consumption ratio. In situations where crowd potential is insufficient, a crowd mainly lacks the availability of electricity rather than decision choices. In situations where production exceeds demand, sharing activities and the need for decision making is likewise reduced due to the increased independency of cells.

The gained insight in the storing-sharing activities pattern according to the production-consumption ratio is beneficial for the development of an electricity management strategy. The model assumed no restrictions for sharing from individuals, however, discussing potential implies the consideration of the decision making behaviours (see chapter 8.1.2). The insight that prosumers show less risk seeking behaviour suggest a reduced sharing behaviour depending on few adaptive prosumers and occurring when sunny weather is forecast. It does not necessarily mean that a crowd's independency would be negatively affected. But, a prosumer ideally chooses to share when sharing is required from an optimisation perspective. It is likely that both are not always aligned. Hence, a future crowd electricity management must consequentially accomplish several things for ensuring sharing activities. Firstly, a crowd must ensure that individuals build up sufficient infrastructure. This depends on the characteristics of buildings and the area. Support from a crowd for individuals is necessary. Secondly, a crowd ensures independency by addressing a prosumer's motivation for sharing. The goal is to generate affection and prosumers are self-motivated to share electricity. This is achieved by offering benefits, and defining common objectives and moral values. Lastly, a crowd must also introduce community-based regulations focusing on crowd welfare and overruling individual preferences at specific times. Such rules must be openly communicated and accepted by the prosumers.

In regard to infrastructure to ensure potential, two conclusions of the optimisation can be drawn to design a crowd. Consumers likewise require the installation of storage capacities. This is because of the delivery of higher quantities of electricity which are consumed only gradually over time. Therefore, storage management involves all members of a crowd. The approach of “higher quantities as needed” requires less interference in prosumer decision making and crowd request for sharing. The approach may reduce conflicts between a prosumer and the crowd. Eventually, all objects in a crowd are involved in generating independency, even if not necessarily all objects produce electricity. Another suggestion for crowd design is that the imperative storage capacity intention, as big as possible, is inconclusive from a prosumer perspective. Prosumers neglect the best option proposing a new perspective of defining required storage capacity. A crowd’s endeavour to increase storage capacities entails convincing prosumers of the common rather than the individual benefit.

A last finding drawn from the simulation concerns the prosumer’s contribution to the crowd. The prosumer categorisation suggests a broad variety of contributions. The considering factors of individual production-consumption ratio, the amount of surplus realised, and storing and sharing activities, show that the contribution of a prosumer varies over time and season. Hence, the categorisation of prosumers and their potential is dynamic. It also implies that the current notion of prosumer must be extended to providing different types of prosumer.

8.2 Limitations of the Thesis

The research conducted gained insights into the Crowd Energy value network and answered the questions raised. However, any research has to acknowledge its limitations and these will be addressed in the following paragraphs.

A limitation concerns the limited experiences and knowledge of prosumers converting tangible and intangible assets into deliverables. A reason is the absence of crowd-based value networks. Another is the passivity of the current demand side in the value creation. Furthermore, the complexity of the crowd-based value network induces a certain difficulty to understand crowd dynamics. The second limitation concerns the online survey. The small number of respondents does not allow to generalise the results for crowd strength. The last limitation refers to the model which allows drawing conclusions about potential. However, results cannot be generalised or more in-depth insights of crowd potential are non-admissible.

8.3 Recommendations for Future Research

This research study recommends elaborating on the prosumer behaviour in regard to value conversion of deliverables. It is necessary to develop more in-depth knowledge about relevant factors for converting assets. In particular, research should focus on decision making regarding sharing and storing. An investigation into relevant factors for altering decisions beyond the financial realm would be beneficial. Furthermore, it is recommended to investigate in negative effects, e.g. free-rider problematic, on the behaviour of crowd members. It is also of interest to conduct research regarding the influence of intangible values on regulating or controlling negative behaviour. In order to generalise results for value conversion strategy, it is necessary to create a greater sample. A strategy would be to work together with electricity providers, governmental institutions or other associations in the electricity industry. However, to deal with the complexity of crowd-based value networks, this research recommends utilising simulation experiments rather than surveys. Experiments permit to generate a crowd-based environment which allows individuals to understand and reflect on actions. Additionally, experiments ensure the investigation on more complex questions like the effects of free rider problematic on decision making.

Another recommendation for future research is to look at information and its role as a currency for exchange. In particular, the evaluation of information and hence the definition of value for exchange is an emerging field; thereby research should consider differences in evaluation between social, business and governmental roles. Additionally, the barriers and negative effects of information as a currency with regard to securing crowd functionalities should be explored. Investigations should consider a flexible information management approach where all stakeholders' perspectives on information are considered. A critical element of the information management approach is the establishment of an information culture and embedding it in the existing environment.

Finally, this research recommends exploring the modelling and simulation of crowds. The defined model in this research achieved to show the crowd potential by minimising transportation costs. But, the exploration of the potential requires more in-depth insights. A first improvement of the model is the integration of non-adaptive and adaptive decision making behaviour; thereby the model takes account of social and individual aspects.

Furthermore, a refinement of the cost structure would be beneficial to the investigation of scenarios of various price constellations and possible pricing strategies for sharing within crowds. Lastly, to show valuable insights for engineering, the model should consider network configuration and related factors like capacities of wiring or transformers. Furthermore, technical parameters like the charging of storages would allow to refine the gained insights. Consequently, conclusions about the specific efforts for exchange can be calculated.

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10 Appendix

10.1 Questionnaire

The objectives of the questionnaire are decision making pattern, acceptance of an iGSL structure, value of self-produced electricity, acceptance and willingness to work in a neighbourly network.

The online-survey is non-guided through an interviewer and hence respondents must understand the subject in hand. A storyboard was created to provide details about the procedure and information necessary for answering the questions. In particular, the understanding of a neighbourly system is not known yet. The structure of the questionnaire aims for successive sections starting from a single household to the neighbourly system. So, target questions focus on a specific area. Classification and administration questions are answered at the end of the questionnaire. In total a respondent answered 37 questions which all of them are obligatory.

Section: iGSL system – Production, storage, and consumption

Nr	Question	Answer	Condition/Group
1	How do you evaluate the possibility to produce autonomously electricity?	very irrelevant very relevant	G1
2	What is your opinion about the necessity of such intelligent electricity networks?	very irrelevant very relevant	G1
3	How do you assess the possibility to store self-produced electricity?	very irrelevant very relevant	G1
4	Which challenges have to be met for storing electricity?	☐ Increase of storage performance ☐ Sufficient technical integration ☐ Better cost-benefit ratio ☐ Available subvention ☐ Reduced administrative efforts ☐ Sufficient legal regulations	Max. 3 G2 Categories: • technical • administrative • economical

		☐ Others		
5	What minimum time period would you like to be covered with the storage capacity?	☐ For 6 hours ☐ For one night ☐ One day ☐ Two days ☐ Three days ☐ One week	Max. 1	G2
6	How relevant is it for you to have a 100% charged storage at the end of the day?	very irrelevant very relevant		G2
7	Which incentives for providing your storage to an electricity provider would you expect to obtain?	☐ Price reduction on purchased electricity ☐ Financial compensation ☐ Same amount of electricity (kWh) ☐ Other goods like vouchers, appliances etc. ☐ No compensation	Max. 2 Categories: • Financial • Immaterial	G2
8	How much of your storage capacity would you provide to an electricity supplier?	0% 100%		G2
9	Such an enhanced system of decentralised photovoltaic and storage units requires a higher degree of organisational efforts. Therefore, an augmented automatisation supports the coordination among the numerous units to secure the stability of the entire electricity grid. How do you assess an enhanced automated management?	very irrelevant very relevant		G3
10	Who should, in your view, undertake the duties of the electricity management?	☐ Autonomous ☐ Association, Club ☐ Service provider ☐ Electricity provider	Max. 1	G3
11	Which challenges should be met for an automated electricity management?	☐ Technical vulnerability ☐ Handling of conflicts ☐ Transparency of electricity management	Max. 3 Categories: • technical • personal	G3

	☐ Constraints of individual decision-making ☐ Administrative efforts ☐ Legal regulations ☐ Others ____	• administrative / legal

Section: Decision making, value of electricity – Day time

Nr	Question	Answer		Condition/Group
1	Which electricity has a higher value for you during the **surplus period**?	☐ self-generated ☐ from the electricity provider ☐ neither		G1
2	Which price would you assign to the electricity in the storage during **surplus period**?	☐ Electricity price during the discharging of the storage ☐ Electricity price during the current surplus period ☐ Other value		G1
3a	Storage allows creating an independency from the residual electricity network. We would like to know which basic decision approach would you prefer during the **surplus period**. What would be your decision on your self-generated electricity, if you know in advance that the tomorrow weather will be sunny?	I play it safe and store any surplus I would feed in any surplus to the grid		G2
3b	What would be your decision on your self-generated electricity, if you know in advance that the tomorrow weather will be very bad and you could not charge your storage completely?	I play it safe and store any surplus I would feed in any surplus to the grid		G2
4	If you know that you have some storage space left (any surplus is left), would you buy electricity from the electricity provider?	☐ Yes, at any rate ☐ Yes, if financial advantageous ☐ Yes, if I cannot cover my requirements over night ☐ No, in any case	Max. 1	G2

Section: Decision making, value of electricity – Night time

Nr	Question	Answer	Condition/Group
1	Which electricity has a higher value for you during the **discharging of the storage**?	☐ self-generated ☐ from the electricity provider ☐ neither	G1
2	Which price would you assign to the electricity in the storage during **discharging of the storage**?	☐ Electricity price during the discharging of the storage ☐ Electricity price during the next surplus period ☐ Other value	G1
3a	Storage allows creating an independency from the residual electricity network. We would like to know which basic decision approach would you prefer during the **discharging of the storage**. What would be your decision on your self-generated electricity, if you know in advance that the tomorrow weather will be sunny?	I extract any electricity from the storage I would buy electricity from the electricity provider	G2
3b	What would be your decision on your self-generated electricity, the tomorrow weather will be very bad?	I extract any electricity from the storage I would buy electricity from the electricity provider	G2
4	If the storage cannot meet your requirements during the night: At which depletion level of the storage would you consider to reduce your consumption?	0% 100%	G2
5	If the storage cannot meet your requirements during the night: At which depletion level of the storage would you consider to buy electricity from your electricity provider?	0% 100%	G2

Section: Neighbourly system, exchange of electricity – Crowd Energy idea

Nr	Question	Answer	Condition/Group
1	What is your opinion on such a neighbourly network which supports the local *"production-storage-consumption"* principle?	very irrelevant very relevant	G1
2	How relevant do you believe is the personal willingness to invest in such a neighbourly network?	very irrelevant very relevant	G1
3	Where would you define the boundaries of a neighbourly network?	☐ Direct neighbours ☐ Street ☐ Quarter ☐ Village / City ☐ Canton	G1
4	Where should the neighbourly electricity management be located?	☐ Inside the neighbourly network ☐ Outside the neighbourly network	Max. 1 G2
5	How would you asses the following characteristics of the neighbourly network?	very low very high Characteristics: • quality, • performance, • security, • profitability, • confidence, • transparency	G2
6	Under which conditions would you participate in a neighbourly network?	☐ Financial support ☐ Incentives to exchange electricity ☐ Automated system ☐ Technical security ☐ Transparency in the electricity management ☐ Legal regulations (e.g. contractual agreements) ☐ Personal engagement of participants ☐ Normative values/guidelines ☐ Others	Max. 3 • financial • social • organis-ational • technical G2

Section: Classification and administration

Nr	Questions	Answer	Condition/Group
1	Do you obtain electricity from an own or shared photovoltaic facility?	☐ Yes ☐ No	G1
2	Please state your consumption levels at home **during a typical workday**	very low very high Time slots: • 00:00 – 06:00, • 06:00 – 09:00, • 09:00 – 11:00, • 11:00 – 13:00, • 13:00 – 16:00, • 16:00 – 19:00, • 19:00 – 22:00, • 22:00 – 00:00	G1
3	Please state your consumption levels at home **during a typical weekend**	very low very high Time slots: • 00:00 – 06:00, • 06:00 – 09:00, • 09:00 – 11:00, • 11:00 – 13:00, • 13:00 – 16:00, • 16:00 – 19:00, • 19:00 – 22:00, • 22:00 – 00:00	G1
4	How many persons live in your household?	☐ 1 ☐ 2 ☐ 3 ☐ 4 ☐ 5 ☐ 6+	Max. 1 G2
5	I currently live as …	☐ Tentant ☐ Appartment owner ☐ House owner ☐ Others	Max. 1 G2
6	In which country do you live currently? Please state your post-code / zip code	Fribourg 1700	G2
7	What is your current job situation?	☐ Full-time employment	Max. 1 G2

		(incl. self-employment) ❑ Part-time employment (incl. self-employment) ❑ Training/Education ❑ House wife/man ❑ Retired ❑ Others		
8	Please state your gender	❑ Male ❑ Female		G2
9	Please state your age	35	Min 18 Max 99	G2

10.2 Modelling and Simulation Specifications

10.2.1 Sun Radiation Profile Spiez

Figure 56 shows the hourly sun radiation profile of Spiez according to DNI stated in percentage. The percentage refers to the annual total sun radiation.

Time	January	February	March	April	May	June	July	August	Septembe	October	November	December
01:00												
02:00												
03:00												
04:00												
05:00												
06:00				0.003557	0.004672	0.004778	0.005230	0.004301				
07:00			0.005416	0.006610	0.006557	0.006690	0.007619	0.007380	0.005973	0.00223		
08:00		0.005283	0.007646	0.008442	0.007778	0.008044	0.009265	0.009424	0.008628	0.005867		
09:00	0.005017	0.007354	0.00884	0.009583	0.008575	0.008946	0.010406	0.010752	0.010247	0.008044	0.005256312	0.004539542
10:00	0.006345	0.008442	0.009504	0.010274	0.009053	0.009557	0.011150	0.011575	0.011203	0.009291	0.006557116	0.005574876
11:00	0.006955	0.008999	0.009849	0.010645	0.009318	0.009875	0.011548	0.012026	0.011681	0.009929	0.007194245	0.006026175
12:00	0.007115	0.009132	0.009929	0.010725	0.009398	0.009955	0.011628	0.012132	0.011813	0.010088	0.007353527	0.006158911
13:00	0.006849	0.008893	0.009796	0.010566	0.009291	0.009822	0.011468	0.011946	0.011601	0.009822	0.007088056	0.005946534
14:00	0.006079	0.00823	0.009371	0.010141	0.008973	0.009424	0.010990	0.011415	0.01099	0.009026	0.006291646	
15:00		0.006929	0.008601	0.009345	0.008415	0.008761	0.010168	0.010460	0.009902	0.007592	0.004778465	
16:00		0.004513	0.007221	0.008044	0.007513	0.007752	0.008920	0.008999	0.008097	0.005124		
17:00			0.00454	0.005973	0.006159	0.006265	0.007088	0.006743	0.005044			
18:00					0.004062	0.004194	0.004486	0.003345				
19:00												
20:00												
21:00												
22:00												
23:00												
00:00												

Figure 56: Sun radiation profile Spiez - in percentage of annual sun radiation

10.2.2 Standard Load Profiles

Two standard consumption profiles were used one for business and one for private households (see Figure 57).

	Übergangsperiode (21.3. - 14.5. und 15.9 - 31.10.)			Sommermonate (15.5 - 14.9.)			Wintermonate (1.11. - 20.3.)		
Zeitraum	Werktage	Samstag	Sonntag	Werktage	Samstag	Sonntag	Werktage	Samstag	Sonntag
00:00 - 01:00	0.2747	0.3087	0.262	0.2703	0.307	0.2654	0.2447	0.2965	0.2401
01:00 - 02:00	0.24	0.3076	0.227	0.2312	0.3002	0.2276	0.2101	0.2933	0.2116
02:00 - 03:00	0.2212	0.2788	0.1954	0.2146	0.2743	0.2049	0.1935	0.2595	0.1847
03:00 - 04:00	0.2224	0.2719	0.1788	0.2165	0.2677	0.1923	0.1991	0.2555	0.1697
04:00 - 05:00	0.2643	0.2813	0.1746	0.26	0.278	0.1862	0.238	0.2642	0.1675
05:00 - 06:00	0.3002	0.2902	0.181	0.2852	0.2899	0.1847	0.2672	0.2827	0.1762
06:00 - 07:00	0.3249	0.2992	0.1819	0.3009	0.3071	0.188	0.3222	0.32	0.1982
07:00 - 08:00	0.4313	0.4548	0.1996	0.4085	0.4545	0.2125	0.4612	0.4727	0.2052
08:00 - 09:00	0.6973	0.6743	0.213	0.6544	0.6431	0.2152	0.7539	0.6784	0.1969
09:00 - 10:00	0.8453	0.7491	0.244	0.7935	0.704	0.2345	0.9165	0.7745	0.2217
10:00 - 11:00	0.8567	0.7641	0.2763	0.8117	0.7215	0.2656	0.9297	0.8153	0.264
11:00 - 12:00	0.8829	0.7802	0.3073	0.8347	0.7399	0.289	0.9568	0.8297	0.2912
12:00 - 13:00	0.8214	0.7683	0.3311	0.7858	0.7219	0.3093	0.8794	0.7889	0.3111
13:00 - 14:00	0.6996	0.675	0.3252	0.6858	0.6326	0.3164	0.7354	0.6898	0.3203
14:00 - 15:00	0.6608	0.5036	0.2969	0.6601	0.4714	0.2921	0.691	0.5168	0.2979
15:00 - 16:00	0.7153	0.3795	0.2674	0.7018	0.3557	0.2564	0.7623	0.3826	0.2646
16:00 - 17:00	0.7315	0.3159	0.2481	0.7039	0.3087	0.2405	0.8035	0.3345	0.2495
17:00 - 18:00	0.7179	0.3194	0.2898	0.6812	0.3014	0.2701	0.8162	0.3649	0.3159
18:00 - 19:00	0.5766	0.3366	0.3211	0.5585	0.3146	0.3016	0.6726	0.3878	0.3677
19:00 - 20:00	0.4062	0.3466	0.3365	0.3926	0.3188	0.3151	0.4673	0.3875	0.3761
20:00 - 21:00	0.3644	0.3646	0.3532	0.3557	0.3384	0.3324	0.3824	0.3745	0.3568
21:00 - 22:00	0.3446	0.3517	0.3322	0.3491	0.3414	0.327	0.3352	0.3414	0.3131
22:00 - 23:00	0.3267	0.3213	0.2914	0.3233	0.3137	0.2973	0.3043	0.3078	0.2805
23:00 - 00:00	0.3137	0.2915	0.2599	0.3051	0.2882	0.2631	0.2847	0.2744	0.2469

Figure 57: Standard load profile

The travel salesman problem (TSP) is a way to define an optimal path between a numbers of nodes which the salesman wants to visit. This classical algorithmic problem is based on minimising both travel costs and distances. To this end, TSP is used to minimise distances between nodes and hence the emerging network can be seen as a shortest path. During modelling and testing, TSP shows a good mixture between following infrastructure and the manner of object arrangement around a transformer. TSP is a typical class of "hard" optimization problems and solving requires experiences and for that reason R provides a TSP package. There are any in-depth investigations in quality of algorithm, only a visual verification of the path.

10.2.3 R Program Code for Data Preparation

The data preparation was done in R and the following figures present the code. For further investigation the attached files can be consultated. The source code contains three files ini.R, calucationCellStatus2.R, and distance.R providing specific functionalities to create the final consumption and production profiles.

The ini.R contains parameters, data frames, sql statements, and necessary R packages for the data preparation.

The second file is calucationCellStatus2.R which calculates all necessary production and consumption profiles of provided objects. To start the calculations, the function generateAbschlussobjektTable() has to be called and every further process is done automatically. The procedure has a specific sequence starting to load all objects from the database (MySQL) into the aoData dataframe. After some refinements, e.g. remove zero entries in the consumption, entries in the aoData are re-clustered meaning that the various electricity provider defined clusters (i.e. H1, H2,…) overwritten with either H0 or G0. Afterwards, production potential is assigned to objects without current production. Eventually, hourly production and consumption profiles are calculated and written to files. The entire code can be found in Figure 58.

calucationCellStatus2.R File

```r
#Author: Mario Gstrein, 05.05.2015, Fribourg (CH)
#Operation:
# 1) call generateAnschlussobjektTable() to provide basic dataset for distribution calculation.
#Outcome: files for consumption, production, tour, and existing production per Trafostation

#NOTE: This file is similar to the calculateCellStatus.R file, however, here the profiles for production and consumptions are different as well as managed differently

#the function reads the original data on Messpunkte level and generates a raw table in which each a house (=Anschlussobjekt).
#There are not unique IDs as a house can have different profiles (H0, G0).
#output: is a dataframe aoDataSet (columns: Anschlussobjekt, Clustering, GEM_Nr, C_MWh, P_MWh, Potential)
generateAnschlussobjektTable <- function () {

    #load all Messpunkte
    rs <- dbSendQuery(connectDB, sqlLoadTest)
    rawData <- fetch(rs, n = -1)

    #storing in global variable
    aoDataSet <<- rawData

    #remove entries (Anschlussobjekte) from the dataset
    aoDataSet <<- aoDataSet[!aoDataSet$Anschlussobjekt == deleteAO,]

    #rename columns to general terms
    names(aoDataSet)[names(aoDataSet) =="BKW_Clustering"] <<- "Clustering"
    names(aoDataSet)[names(aoDataSet) =="MWh_2013"] <<- "C_MWh_Original"

    #re-clustering of all different H0...H6 and G0...G6 to H0 respectively to G0 (currently it is a distinguishment of private = H0, business = G0, and agriculture = L0). Any detailled clustering adapt HERE
    reclusteringCell()

    #add columns "P_MWh" and "Potential" of PV to state if the ID produces currently electricity or not
    existProdOfCell()

    #Aggregating all "Messpunkte" of a house to an Anschlussobjekt (house) level - Still multiple entries possible if a house includes households and business as well as has a production
    aoDataSet <<- setNames(aggregate(aoDataSet[, c('C_MWh_Original')], by = list(aoDataSet$Anschlussobjekt, aoDataSet$Clustering, aoDataSet$GEM_Nr, aoDataSet$Potential, aoDataSet$Trafo_Nr, aoDataSet$P_MWh_Original), FUN = sum), c('Anschlussobjekt', 'Clustering', 'GEM_Nr', 'Potential', 'Trafo_Nr', 'P_MWh_Original','C_MWh_Original'))
    aoDataSet <<- aoDataSet[order(aoDataSet$Anschlussobjekt),]


    #remove all Anschlussobjekte without a consumption - no assignment of production or tour (network). Question is here if houses exist which have no consumption but current production. It is asumed that the object doesn't exist anymore (deconstruction). Even production units require some consumption
    aoDataSet <<- subset(aoDataSet, aoDataSet$C_MWh != 0)

    #assign MWh according the "Potential" column to Anschlussobjekte without a production
    assignProduction()

    #create tour - TSP; before cons and prod is calculated as the files may sort by the tour steps (is for LPL and the input data)
    createNeigbhours()

    #adaptations of production or consumption
    adaptMWh()


    #start calculating consumption and production patterns - LPL
    #sequence is consumption followed by production: reason is that some Anschlussobjekte have no consumption and those get removed (no production and no tour)
    calculatingDistrProd()
    calculatingDistrCons()

}

#NOTE: Adjustements on the form of the output as the current version is used for the LPL program. No merge with consumption data. It is written in an csv file

#calculation of hourly distribution for production by loading "profiles". In this case it is the daily (average) sun radiation from January to December
#input: is the aoDataSet (columns: Anschlussobjekt, Clustering, GEM_Nr, C_MWh, P_MWh, Potential)
#output: is a dataframe with the columns: 'Anschlussobjekt', 'Time', 'Month', 'P_MWh'. The results are stored in DB "XXX"
calculatingDistrProd <- function() {


    #load consumption or sun radiation profiles etc.
    rs <- dbSendQuery(connectDB, sqlLoadProdProfile2)
    profiles <- fetch(rs, n = -1)

    #two datasets required to merge them afterwards (only consumption or production can be calculated at once)
    distrDataSet_P <<- 0
    tmpdistrDataSet <- data.frame(profiles[ , 'Date'], profiles[ , 'Time'])
    prevCellID <- ''

    j <- 1


    for (cellID in aoDataSet$Anschlussobjekt) {

      if(prevCellID != cellID) {
            #load profiles (matching either Clustering for consumption or GEM_Nr for production)
            tmpProfile <- as.data.frame(profiles[, 3])

            #creates a production profile columns month per Anschlussobjekt and 24 h
            tmpdistrDataSet[ , cellID] <- data.frame(mapply('*',tmpProfile, aoDataSet[ j, 'P_MWh'] )) #tmpDataSet[j, 'Potential'] ))

      }
      prevCellID <- cellID
      j <- j + 1
    }

    colnames(tmpdistrDataSet)[1] <- 'Date'
    colnames(tmpdistrDataSet)[2] <- 'Time'

    #reorder columns according the tour steps
    tmpdistrDataSet <- tmpdistrDataSet[c('Date', 'Time', aoOrder)]

    distrDataSet_P <<- tmpdistrDataSet
    write.table(distrDataSet_P, paste(trafoNr, '_lpl_production_', sceanrioName ,'.txt', sep='', collapse = ''), sep = '\t', row.names = FALSE, eol = "\n")

    #write production files divided by dates --> building junks for specific calculations
    if(saveSubFiles == TRUE) saveFile('_lpl_production_', 'P')

}
```

```
#calculation of hourly distribution for consumption aaccording standard load profiles (SLP - VDEW. for week, saturday, sunday each of summer, winter, and transition period)
#Thus, the function mutliplies the yearly consumption of an Anschlussobjekt with the SLP and asigns for each month the specific SLP (e.g. for January the winter profile)
#input: is the aoDataSet (columns: Anschlussobjekt, Clustering, GEM_Nr, C_MWh, P_MWh, Potential)
#output: is a dataframe with the columns: 'Anschlussobjekt', 'Time', 'Month', 'C_MWh_Week', 'C_MWh_Saturday', 'C_MWh_Sunday')
calculatingDistrCons <- function() {


  #load consumption or sun radiation profiles etc.
  rs <- dbSendQuery(connectDB, sqlLoadConsProfile2)
  profiles <- fetch(rs, n = -1)

  #selecting only columns for the consumption or production calculation
  tmpDataSet <- aoDataSet[c('Anschlussobjekt', 'Clustering', 'C_MWh')]

  #split list in UNIQUE and DOUBLE elements list. Different calculation steps are required
  doubleAO <- unique(tmpDataSet[duplicated(tmpDataSet$Anschlussobjekt),])

  tmpDataSetDouble <- doubleAO[,'Anschlussobjekt']

  tmpDataSetUnique <- tmpDataSet$Anschlussobjekt[!(tmpDataSet$Anschlussobjekt %in% tmpDataSetDouble)]
  tmpDataSetDouble <- subset(tmpDataSet, tmpDataSet$Anschlussobjekt %in% tmpDataSetDouble)
  tmpDataSetUnique <- subset(tmpDataSet, tmpDataSet$Anschlussobjekt %in% tmpDataSetUnique)

  #two datasets required to merge them afterwards (only consumption or production can be calculated at once)
  distrDataSet_C <<- 0
  tmpdistrDataSet <- data.frame(profiles[ , 'Date'], profiles[ , 'Time'])


  #profiles for Anschlussobjekte which are UNIQUE in the list.
  j <- 1
  for (cellID in tmpDataSetUnique$Anschlussobjekt) {


      #load profiles (matching either Clustering for consumption)
      tmpProfile <- data.frame(profiles[, tmpDataSetUnique$Clustering])

      #calculate the consumption for summer, winter and transition phase according VDEW SLP. Divided by 1000 to create a factor as the SLP is normalised to 1000 kW/y
      tmpdistrDataSet[ , cellID] <- data.frame(mapply('*',tmpProfile, tmpDataSetUnique[j, 'C_MWh']/1000 ))

      j <-j+1
  }

  #profiles for Anschlussobjekte which are SEVERAL times in the list.
  h <- 1

  resTotal <- data.frame(c('Anschlussobjekt', 'Date', 'Time', 'Clustering', 'C_MWh'))
  resTotal <- 0

  for (cellID in tmpDataSetDouble$Anschlussobjekt) {


        #load profiles (matching either Clustering for consumption)
        tmpProfile <- data.frame(profiles[, colnames(profiles) == tmpDataSetDouble[h, 'Clustering']])

        #creates a production profile columns month per Anschlussobjekt and 24 h. Divided by 1000 to get kW
        res <- data.frame(mapply('*',tmpProfile, tmpDataSetDouble[h, 'C_MWh']/1000 ))

        #create a data frame for distribution per Anschlussobjekt (hourly) and add columns
        res[, 'Anschlussobjekt'] <- cellID
        res[, 'Date'] <- profiles[ , 'Date']
        res[, 'Time'] <- profiles[ , 'Time']

        #create a dataframe with all consumption/production distributions
        resTotal <- rbind(res, resTotal)

        h <- h + 1
  }

  #set colname
  colnames(resTotal)[1] <- 'C_MWh'

  #aggregate DOUBLE entries so only one exists
  resTotal <- setNames(aggregate(resTotal[, 'C_MWh'], by = list(resTotal$Anschlussobjekt, resTotal$Date, resTotal$Time), FUN = sum), c('Anschlussobjekt', 'Date', 'Time', 'C_MWh'))

   #sort double data frame to
  resTotal <- resTotal[order(resTotal$Anschlussobjekt, resTotal$Date, resTotal$Time), ]

  #merging UNIQUE and SEVERAL entries list.
  for (cellID in resTotal$Anschlussobjekt) {

        #tmpdistrDataSet[, cellID] <- resTotal[which(resTotal$Anschlussobjekt == cellID), ]
        tmpdistrDataSet[, cellID] <- subset(resTotal, resTotal$Anschlussobjekt == cellID, select='C_MWh')

  }

  #remove entries with all Zeros
  tmpdistrDataSet[, '0'] <- NULL
  colnames(tmpdistrDataSet)[1] <- 'Date'
  colnames(tmpdistrDataSet)[2] <- 'Time'

  #reorder columns according the tour steps
  tmpdistrDataSet <- tmpdistrDataSet[c('Date', 'Time', aoOrder)]

  distrDataSet_C <<- tmpdistrDataSet
  write.table(distrDataSet_C, paste(trafoNr, '_lpl_consumption_', sceanrioName, '.txt', sep='', collapse = ''), sep = '\t', row.names = FALSE, eol = "\n")

  #write production files divided by dates --> building junks for specific calculations
  if(saveSubFiles == TRUE) saveFile('_lpl_consumption_', 'C')

}
```

```r
#Re-clustering loop for the list of Anschlussobjekte - make H1, H2 etc. to H0. same with G and L
reclusteringCell <- function() {

    for (i in unique(aoDataSet$Clustering)) {
        aoDataSet[aoDataSet == i] <<- as.character(listClusteringCell[i])

    }

}


#creates an additional column "P_MWh" according a list of production tarifs. (Splitting MWH of consumption and production into different columns)
existProdOfCell <- function() {


    aoDataSet$C_MWh[aoDataSet$Tarif %in% as.list(listTarifsProd$Tarif)] <<- as.integer(0)
    aoDataSet <<- subset(aoDataSet, select=-Tarif)

    #assign N to all production. It is needed for aggregation (two entries for real production and consumption - aggregate to one line). Assignment of production type in function assignProduction()
    aoDataSet$Potential[is.na(aoDataSet$Potential)] <<- 'N'
    aoDataSet$P_MWh_Original[is.na(aoDataSet$P_MWh_Original)] <<- 0

}


#assign production status either current MWh with "Current" or the potential (currently "Good", "Medium", and "Bad" - see listProvisoryProd)
assignProduction <- function() {

      entriesNonInsert <- subset(aoDataSet, aoDataSet$Potential == 'N')

      #assign randomly potential PV production to all non-current production according the column "Potential"
      for (k in unique(entriesNonInsert)) {
            assignPot <- sample(rownames(listProvisoryProd), 1, replace = TRUE)

            aoDataSet$P_MWh_Original[aoDataSet$Anschlussobjekt == k] <<- listProvisoryProd[assignPot, 'MWh']
            aoDataSet$Potential[aoDataSet$Anschlussobjekt == k] <<- assignPot


      }

      #saving of non-assigned Anschlussobjekte with production
      listCellProdIDs <<- as.data.frame(unique(subset(aoDataSet$Anschlussobjekt, aoDataSet$Potential == 'Current')))
      colnames(listCellProdIDs)[1] <<- 'Anschlussobjekt'

      #write the existing production list
      write.table(listCellProdIDs, paste(trafoNr, '_lpl_existing_Prod_', sceanrioName ,'.txt', sep='', collapse = ''), sep = '\t', row.names = FALSE, eol = "\n")


      if (length(entriesNonInsert) > 0) {

            #building the INSERT statement out of the aoDataSet
            insertStatementBeg <- 'INSERT INTO `production_potential_per_cell` (`Anschlussobjekt`, `P_MWh_Original`, `Potential`) VALUES '

            valueInsertRows <- ''

            #assign "current" value to all active production units
            for (j in unique(entriesNonInsert$Anschlussobjekt)) {


                  #create insert statement for all production which are not in the DB
                  valueInsertRows <- paste(valueInsertRows, '(', j, ',', aoDataSet$P_MWh_Original[j == aoDataSet$Anschlussobjekt], ', ', paste0("'", aoDataSet$Potential[j == aoDataSet$Anschlussobjekt], "'"), '), ', sep = '', collapse = NULL)

            }

            #Finalize the insert statement and send query (insert only executed if there are values to be insert otherwise query is not executed)
            insertStatement <- paste(insertStatementBeg, valueInsertRows[1], sep = '', collapse = '')

            if (insertStatement != insertStatementBeg)  {

                  insertStatement <- substr(insertStatement,1,nchar(insertStatement)-2)
                  insertStatement <- paste(insertStatement, ';', sep = '', collapse = '')
                  dbSendQuery(connectDB, insertStatement)
            }

      }

}


#function to create files according dates - for calculation in LPL e.g. from 01.01. until the 14.05.
saveFile <- function (filename, distr) {

      h <- 1
      tmpPrevDate <- '2013-01-01'
      for(date in datesSubFile) {

            prevDate <- as.Date.factor(datesSubFile[h], origin = '1960-01-01')
            nextDate <- as.Date.factor(datesSubFile[h+1], origin = '1960-01-01')

            if(prevDate == '2013-12-31') next()

            if(prevDate != '2013-01-01') {
                  tmpPrevDate <- strptime(prevDate, "%Y-%m-%d", tz ="CEST")
                  tmpPrevDate <- tmpPrevDate + hrs(24)
                  prevDate <- as.Date.factor(tmpPrevDate, origin = '1960-01-01')
            }


            if(distr == 'P') {
                  subDataSet <- distrDataSet_P[which(as.Date.factor(distrDataSet_P$Date, origin='1960-01-01') >= prevDate & as.Date.factor(distrDataSet_P$Date, origin='1960-01-01') <=  nextDate), ]
            } else if(distr == 'C') {
                  subDataSet <- distrDataSet_C[which(as.Date.factor(distrDataSet_C$Date, origin='1960-01-01') >= prevDate & as.Date.factor(distrDataSet_C$Date, origin='1960-01-01') <=  nextDate), ]

            }

```

```
            write.table(subDataSet, paste(trafoNr, filename, sceanrioName, '_' ,tmpPrevDate, '.txt', sep='', collapse = ''), sep = '\t', row.names = FALSE,
            eol = "\n")

            h <- h + 1
        }

}

hrs <- function(u) {
    x <- u * 3600
    return(x)
}

#function to generate a table with AO, Date, Time, Consumption, Production columns out of the distribution variables
generateBigTable <- function () {
    #resCon <- data.frame(list('Anschlussobjekt' = 'character', 'Date' = 'integer', 'Time' = 'integer', 'C_MWh' = 'double'))
    resCon <- data.frame(matrix(0, ncol= 0, nrow = 8760))
    tmpdistrDataSet <- data.frame(list('Anschlussobjekt' = 'character', 'Date' = 'integer', 'Time' = 'integer', 'C_MWh' = 'double'))
    tmpdistrDataSet <- 0

    dateT <- as.data.frame(distrDataSet_C[, 'Date'])
    timeT <- as.data.frame(distrDataSet_C[, 'Time'])

    #add consumption values to the data frame
    for(i in unique(aoDataSet$Anschlussobjekt)) {
        resCon[,'Date'] <- dateT
        resCon[,'Time'] <- timeT[,1]
        resCon[, 'Anschlussobjekt'] <- i
        resCon[, 'C_MWh'] <- distrDataSet_C[, i]
        resCon[, 'P_MWh'] <- distrDataSet_P[, i]

        tmpdistrDataSet <- rbind(resCon, tmpdistrDataSet)


    }
    tmpdistrDataSet <- tmpdistrDataSet[complete.cases(tmpdistrDataSet),]
    write.table(tmpdistrDataSet, paste(trafoNr, '_total_cons_prod_', sceanrioName, '.txt', sep='', collapse = ''), sep = '\t', row.names = FALSE, eol =
    "\n")

}


#adaption of MWh for different scenario settings
adaptMWh <- function() {

    aoDataSet[ , 'C_MWh'] <<- data.frame(mapply('*', aoDataSet$C_MWh, newCWh))
    aoDataSet[ , 'P_MWh'] <<- data.frame(mapply('*', aoDataSet$P_MWh, newPWh))


}
```

Figure 58: Source code for generating production and consumption lists of all objects

In the Distance.R file there are more functions as presented here. During coding several other possibilities for network generation were elaborated, e.g. star construct with the transformer in the centre. Nevertheless, for the simulation a network according to TSP was used and the code can be found in Figure 59.

```
#Author: Mario Gstrein, 05.05.2015, Fribourg (CH)

#Creation of a network structure to define the next neigbhours of an Anschlussobjekt
#It works like the longest or shortest distance of  the Latitude/Longitude point of the Anschlussobjekt to the next Trafostation
#calculate the distance and save it to the list according to the Traveling Salesman Problem (TSP)
#order andidentify list members
createNeigbhours <- function() {

        #load consumption or sun radiation profiles etc.
        rs <- dbSendQuery(connectDB, sqlLoadLocationData)
        rawLocation <- fetch(rs, n = -1)
        #remove all Longitude and Latitudes with 0 value entries
        rawLocation <- subset(rawLocation, rawLocation$C_Latitude != 0 | rawLocation$C_Longitude != 0)
        row.names(rawLocation) <- rawLocation[, 'Anschlussobjekt']

        #using Traveling Salesman Problem to find the shortest way through a subnet
        for(h in unique(rawLocation$Trafo_Nr)) {
                #remove all Longitude and Latitudes with 0 value entries
                tmpRawLocation <- subset(rawLocation, rawLocation$Trafo_Nr == h, select = c('C_Latitude', 'C_Longitude'))
                tmpRowNames <- subset(rawLocation, rawLocation$Trafo_Nr == h, select = 'Anschlussobjekt')
                #have the Anschlussobjekt ID printed as label for the tour

                tsp <- TSP(dist(tmpRawLocation))
                #Cuts a tour at a specified city to form a path. To not loose a city a dummy variable is introduced
                tsp <- insert_dummy(tsp, label = "cut")
                tour <- solve_TSP(tsp, method="2-opt", control=list(rep=10))
                path.tsp <- unname(cut_tour(tour, "cut"))

                #create a dataframe with the required sequence - For LPL
                tourLabels <- as.data.frame(labels(tour))
                #remove cut entry
                tourLabels <- subset(tourLabels , !tourLabels[, 1] %in% 'cut')
                names(tourLabels)[1] <- 'Tour'

                # plot the results
                par(mfrow=c(1,2))
                plot(C_Latitude~C_Longitude,tmpRawLocation[path.tsp,],type="b",asp=1)

                tourSteps <<- as.data.frame(tourLabels)

                #list for reorder consumption and production files - required for input in LPL (according the tour)
                tmp <- as.data.frame(tourSteps[, 1])
                colnames(tmp) <- 'Anschlussobjekte'

                tmp2 <- data.frame(1:2)
                colnames(tmp2) <- 'Anschlussobjekte'
                tmp <- rbind(tmp2, tmp)
                tmp[1,1] <- 'Date'
                tmp[2,1] <- 'Time'
                rownames(tmp) <- tmp[,1]
                tmpTourSteps <<- t(tmp)

        }

}

```

Figure 59: Source code for generating network according to TSP

10.2.4 LPL Optimisation Code

The preparation for optimisation, e.g. calculating constraints, and presentation of the optimisation feedback received from Gurobi was done by LPL. The following source code shows the parameters, constraints, minimisation functionality, and output (see Figure 60).

```
model EnergieNetzwerk "Crowd Energy Network - NxN (LP)";
--GENERAL ---
SetSolver(gurobiLSol64,'timelimit 10000');

--- INPUT ---
--parameters to adjust for calculations
parameter trafoNr := [10783];
// Scenarios for 2013, 2035 und 2050
parameter scenario := [2013];
// Parameters for REAL CASE: use digit month, e.g. 4 for April. Multiple files for a month add 1,2, on the last postion etc.
// For example 01 for January -> 011, 012. Paramter für TEST: 1.2.3.4.
parameter version := [12];

-- sets --
set nodes,v,w;
--parameter maxTime := 768;
set time, t; --:= 1..maxTime;
set existProd{v};

-- data --
parameter demand, d{v,t};
//realised production capacity of a cell to a specific time point (if exists or potential)
parameter production, p{v,t};
string parameter hour{t};
string parameter dateT{t};

----- Test Scenario --------
--Read{v}('input/' & trafoNr & '_lpl_tour_corrected.txt,;1,\t',v);
--Read{v}('input/' & scenario & '/test/' & trafoNr & '_lpl_existing_Prod_' & scenario & '_scenario.txt,;1,\t', v, existProd[v]);
--Read{t}('input/' & scenario & '/test/' & trafoNr & '_lpl_consumption_' & scenario & '_scenario_' & version & '_test.txt,;1,\t', dateT[t], hour[t], {v} d[v,t]);
--Read{t}('input/' & scenario & '/test/' & trafoNr & '_lpl_production_' & scenario & '_scenario_' & version & '_test.txt,;1,\t', dateT[t], hour[t], {v} p[v,t]);

----- Entire Scenario -------
Read{v}('input/' & trafoNr & '_lpl_tour_corrected.txt,;1,\t',v);
Read{v}('input/' & scenario & '/' & trafoNr & '_lpl_existing_Prod_' & scenario & '.txt,;1,\t', v, existProd[v]);
Read{t}('input/' & scenario & '/' & trafoNr & '_lpl_consumption_' & scenario & '_' & version & '.txt,;1,\t', dateT[t], hour[t], {v} d[v,t]);
Read{t}('input/' & scenario & '/' & trafoNr & '_lpl_production_' & scenario & '_' & version & '.txt,;1,\t', dateT[t], hour[t], {v} p[v,t]);


-- constants --
parameter costNeigh{v,w} : Abs(v-w)+0.01;
parameter costMissingEn := 100;
parameter costOverflowEn := 100;
parameter costStorage := 0.01;
parameter costsInstallCapa{v} := 1000;
parameter initStorage, s{v} := 0; //initial storage of a cell
parameter storagecap, k{v} := 30; //capacity of storage in kWh (if realised)

--- VARIABLES ---
variable flow, x{v,w,t};
variable missingFlow, z{v,t};
variable overFlow, z2{v,t};

--- CONSTRAINTS ---
constraint flowBalance{v,t | t>1}: sum{w | w<>v} x[w,v,t] + x[v,v,t-1] + p[v,t] + z[v,t] = sum{w| w<>v} x[v,w,t] + x[v,v,t] + d[v,t] + z2[v,t];
constraint flowBalanceFirstPeriode{v}: sum{w| w<>v} x[w,v,1] + s[v] + p[v,1] + z[v,1] = sum{w| w<>v} x[v,w,1] + x[v,v,1] + d[v,1] + z2[v,1];
constraint capacityConstrSpeicherung{v,t}: x[v,v,t] <= k[v];
--- OBJECTIVE FUNCTION ---

minimize totCost: costMissingEn * (sum{v,t} z[v,t]) +
                  costOverflowEn * (sum{v,t} z2[v,t]) +
                  sum{v,w,t} x[v,w,t] * costNeigh[v,w] +
                  costStorage * (sum{v,t} x[v,v,t]);


--create output files
Write('output/' & scenario & '/' & trafoNr & '_flow_NxN_LP_' & version & '_' & scenario &'.txt','von\t zu\t Tag\t Zeit\t Watt\n');
Write{v,w,t | flow[v,w,t] >= 0.00001}('%s\t %s\t %s\t %s\t %f\n',v,w,dateT,hour,1000*flow);

Write('output/' & scenario & '/' & trafoNr & '_missingflow_NxN_LP_' & version & '_' & scenario & '.txt','AObjekt\t Tag\t Zeit\t Watt\n');
Write{v,t | missingFlow[v,t] >= 0.00001}('%s\t %s\t %s\t %f\n',v,dateT,hour,1000*missingFlow);

Write('output/' & scenario & '/' & trafoNr & '_overflow_NxN_LP_' & version & '_' & scenario & '.txt','AObjekt\t Tag\t Zeit\t Watt\n');
Write{v,t | overFlow[v,t] >= 0.00001}('%s\t %s\t %s\t %f\n',v,dateT,hour,1000*overFlow);

Write('output/' & scenario & '/' & trafoNr & '_storageSize_NxN_LP_' & version & '_' & scenario & '.txt','AObjekt\t Tag\t Zeit\t Watt\n');
Write{v,t | x[v,v,t] >= 0.00001}('%s\t %s\t %s\t %f\n',v,dateT,hour,1000*flow);

end
```

Figure 60: LPL optimisation code

10.2.5 Numeric Test of Optimisation Model

The previous chapter establishes a model with the cells, functionalities of production, consumption and storage as well as interaction between cells by defining various flows. The consequential optimisation should provide insights into flows and capacities but before doing so, it is necessary to establish credibility for the results by running a numeric test. Operational validation includes intense testing and evaluation as it determines the applicability of the model as well as providing valuable insights into the situation at hand. Through interpreting the results of the tests one should be able to see correct calculations and behaviour. Furthermore, it should be proved that the model is solvable through optimisation.

V \ time	1	2	3	4	5	6	7	8	9	10
1	89	1	-	40	2	24	85	55	83	46
2	57	20	19	95	38	34	84	28	5	69
3	58	95	47	54	72	55	97	92	72	18
4	53	9	60	31	94	8	72	76	20	61
5	69	13	72	36	61	46	73	74	66	34

Table 34: Randomised consumption of five cells

The numeric test contains five cells $v \in V$ with a randomised consumption pattern over ten time-points (see Table 34). The small set allows each step to be verified more easily. The outcome produced can be discussed in more detail according to the desired model behaviour. In this case, behaviour is mainly influenced by the aforementioned cost structure defining a "first cell than crowd than external gird" principle. Additionally, specified scenarios help to understand the outcome. The first scenario is an autarkic crowd which means that the crowd produces enough to sustain itself, storing is infinite, and no/minimised missing flow or overflow occurs throughout the time periods. This example is defined as follows:

The costs b_v for realised production installation at a cell are 1,000 units. The missing flow and overflow $x_{v,z}$ is assigned with costs c_2 of 10 units. The transport costs c_1 between cells $x_{v,w}$ are defined as $|v - w|$. Costs for internal flows c_0 have a value of zero units. Each cell has a storage capacity k_v of infinite kWh and starts with a storage level s_v of 40 kWh in the first time period. For each time period a constant cell production p_v of 150 units is assumed.

The constant production induces that two production cells exist within the crowd. The decision to have two production cells is defined by the amount of electricity to cover total consumption. Any further production units would be too expensive as a) installation costs must be paid and b) overflow would lead to additional costs. The optimisation of the model using a simple input generates an optimal solution with the total costs of 3,497.46. Table 35 presents the result of flows within and among cells and states the amount of electricity that is exchanged at a specific time point. Optimisation requires two production cells, namely v_2 and v_5. Besides covering own demand, both production cells supply specific cells, i.e. v_2 supplies v_1 and v_3 whereas v_5 supplies solely v_4. Exchange of electricity concerns solely time-dependent consumption meaning that a non-producing cell demands the amount of electricity which is required for a specific time-point. Eventually, there is no missing flow or overflow. The red rows in the table below show storage levels which are only realised by production units. The high figures indicate that production exceeds demand but any surplus is stored rather fed into the external grid. The results can be verified by investigating the flows of a cell.

From	*to*	*Time*									
v	**w**	**1**	**2**	**3**	**4**	**5**	**6**	**7**	**8**	**9**	**10**
2	**1**	49	1		40	2	24	85	55	83	46
2	**2**	**66**	**100**	**184**	**145**	**183**	**220**	**104**	**79**	**69**	**86**
2	**3**	18	95	47	54	72	55	97	92	72	18
5	**5**	**108**	**236**	**254**	**337**	**332**	**428**	**433**	**433**	**497**	**552**
5	**4**	13	9	60	31	94	8	72	76	20	61

Table 35: Results of the numeric test scenario

Table 36 shows the first time periods of v_2 and is interpreted that at time-point one 150 units are produced adding 40 units to those which are already in the storage. From that amount, own demand of 57 units and 67 units of supplies to v_1 and v_3 are subtracted leaving 26 units to charge the storage. The storage reaches a level of 66 units which is the initial storage level for time-point two. This way of calculating is one way of defining storage flow. It must be noted that any missing flow, overflow or flows from other cells must also be subtracted. A simpler way of determining storage flow is by subtracting storage levels, i.e. $s_{v,t-1}$ minus $s_{v,t}$. For example, time period three has a flow of 84 units which is a subtraction of $s_{2,3}$ (184 units) from $s_{2,2}$ (100 units).

The example shows that the model works according to the model design. Sufficient production and unlimited storage is less realistic and there will be missing flows. Therefore a more realistic scenario would be to adjust following parameters: p_v to 120 units, no initial storage s_v at the first time period, and limiting storage capacity k_v to 80 kWh. The optimisation with adjusted inputs generates an optimal solution with total costs of 23,646.91. The crowd has also two production cells but differs from the previous outcome (see Table 37). A relocation of production from v_5 to v_4 seems to be optimal. Both supply own demand and show a different support preferences where cell v_2 supports v_1 and v_3, whereas v_4 supplies electricity to v_3 and v_5. It seems that v_3 benefits from the position in the centre of the network.

Time	*Prod.*	*Initial Storage*	*Demand*	*Flow to 1,3*	*Flow Storage*	
1	150	+ 40	- 57	- 67 (49 + 18)	- 26	= 0
2	150	+ 66	- 20	- 96 (1 + 95)	- 34	= 0
3	150	+ 100	- 19	- 47 (0 + 47)	- 84	= 0
4	150	+ 184	…	…	…	…
…	…	…	…	…	…	…

Table 36: Flows of scenario for cell two

Reducing production leads to missing flows as the production cells are not able to supply enough electricity. The model works accordingly as the two production cells cannot build up enough storage to fully cover shortages in these periods. The consequence is that non-production cells must buy electricity from external sources. These results in higher total costs as missing flows and overflow are penalised. Yet production cells can partially supply at the first and seventh to ninth time-periods without charging the storage. It seems at these time-periods production exceeds consumption. Charging storage mostly occurs from the second to sixth time-points, these are lower consumption periods. Both production cells reach maximum capacity (in the second and sixth time-points) where an overflow of fourteen units is produced by cell two in the second period.

From	*to*	*Time*									
v	**w**	**1**	**2**	**3**	**4**	**5**	**6**	**7**	**8**	**9**	**10**
2	**1**	5	1		40	2	24	74	55	77	46
2	**2**		**8**	**62**	**47**	**55**	**80**				**5**
2	**3**	58	77	47		72	37	42	37	38	
4	**3**		18		54		18	55		34	18
4	**4**		**80**	**68**	**67**	**32**	**80**				**7**
4	**5**	67	13	72	36	61	46	73	44	66	34

Table 37: Results of the numeric test by reduced production and limited storage

It is not possible to explain the overflow from the figures as storage capacity in v_2 would be available. In particular, this behaviour occurs once (also with more time-points). An explanation could be that the solver considers an overflow at that time-point as the optimal solution over all flows rather storing it. The log file indicates that this is one optimal solution in which the solver states an optimum but upper (23,646.9) and lower (23,491.50) bounds converge rather correspond. This depends upon the multi-integer programming (MIP) where the optimal solution is not an extreme point rather within an area below the constraints.

As a consequence, the model is refined. Firstly, storage possibilities are expanded to all cells. Therefore, non-producing cells can store electricity, this allows more electricity to be demanded than current consumption would require. Consequentially, future demand is considered in the optimisation process. This functionality is necessary in light of a time-dependent cost structure. Secondly, the decision on where production location is situated will be replaced by randomly assigned production potential to a cell. This converts the model to a linear programming problem. Nevertheless, the numeric tests show that the design and functionalities of the model allow conclusions to be drawn concerning the crowd's potential.

10.3 Results Current Scenario

Object	Prod	Cons	Prod	Diff Prod- Cons					Pot. Surplus	Storage				
		Total	Total	Diff Prod-Cons	Min	Max	Average	No of occ.	Total	Status End of week	Min	Max	Average	No of occ.
1	Yes	306,583.7	30,615.1	- 275,968.6	- 3,528.5	- 638.6	- 1,642.7	-	-	0	-	-	-	-
2	Yes	262,181.6	30,615.1	- 231,566.5	- 3,017.5	- 546.1	- 1,378.4	-	-	- 0	-	-	-	-
3	Yes	90,368.7	30,615.1	- 59,753.6	- 1,040.1	355.7	- 355.7	32	7,306.3	- 0	1.3	1,358.5	576.4	43
4	No	215,664.1	-	- 215,664.1	- 2,482.1	- 449.2	- 1,283.7	-	-	0	-	-	-	-
5	Yes	593,158.9	50,610.6	- 542,548.3	- 6,826.7	- 1,235.6	- 3,229.5	-	-	- 0	-	-	-	-
6	Yes	279,105.1	30,615.1	- 248,490.0	- 3,212.2	- 581.4	- 1,479.1	-	-	0	-	-	-	-
7	Yes	203,720.7	61,230.2	- 142,490.5	- 2,344.6	564.6	- 848.2	28	9,807.9	- 0	34.5	1,950.1	848.2	34
8	Yes	380,756.1	44,487.6	- 336,268.5	- 4,382.1	- 793.1	- 2,001.6	-	-	- 0	-	-	-	-
9	Yes	483,773.3	31,323.1	- 452,450.2	- 5,567.8	- 1,007.7	- 2,693.2	-	-	0	-	-	-	-
10	Yes	28,470.2	30,615.1	2,144.9	- 327.7	752.7	12.8	35	23,225.4	0	28.6	3,203.5	1,309.1	152
11	Yes	264,980.1	30,615.1	- 234,365.0	- 3,049.7	- 552.0	- 1,395.0	-	-	0	-	-	-	-
12	Yes	88,341.4	11,697.5	- 76,643.9	- 1,016.7	- 184.0	- 456.2	-	-	0	-	-	-	-
13	Yes	109,297.4	61,230.2	- 48,067.2	- 1,257.9	1,167.8	- 286.1	35	32,861.1	- 0	236.7	5,100.5	2,511.1	73
14	Yes	250,899.3	44,487.6	- 206,411.7	- 2,887.6	- 247.2	- 1,228.6	-	-	0	-	-	-	-
15	Yes	256,231.9	30,615.1	- 225,616.8	- 2,949.0	- 533.8	- 1,343.0	-	-	- 0	-	-	-	-
16	Yes	155,594.6	44,487.6	- 111,107.0	- 1,790.7	361.8	- 661.4	21	5,798.7	0	0.4	1,177.6	582.7	27
17	Yes	123,334.2	44,487.6	- 78,846.6	- 1,419.5	567.9	- 469.3	33	12,507.4	- 0	16.8	2,240.4	905.7	50
18	Yes	141,469.6	61,230.2	- 80,239.4	- 1,628.2	962.3	- 477.6	35	24,510.5	0	307.5	4,027.1	1,867.8	58
19	Yes	165,268.3	61,230.2	- 104,038.1	- 1,902.1	810.2	- 619.3	35	18,333.3	0	122.8	3,233.0	1,353.5	51
20	Yes	357,354.1	61,230.2	- 296,123.9	- 4,112.8	- 417.0	- 1,762.6	-	-	0	-	-	-	-
21	Yes	175,867.5	44,487.6	- 131,379.9	- 2,024.1	232.2	- 782.0	20	3,040.1	- 0	137.5	636.1	407.1	20
22	Yes	1,016,113.5	44,487.6	- 971,625.9	- 11,694.5	- 2,116.6	- 5,783.5	-	-	- 0	-	-	-	-
23	Yes	540,978.2	27,815.1	- 513,163.1	- 6,226.1	- 1,126.9	- 3,054.5	-	-	0	-	-	-	-
24	Yes	207,356.6	61,230.2	- 146,126.4	- 2,386.5	541.3	- 869.8	28	9,104.2	- 0	10.0	1,828.8	764.8	34
25	Yes	537,254.1	44,487.6	- 492,766.5	- 6,183.3	- 1,119.1	- 2,933.1	-	-	0	-	-	-	-
26	Yes	170,600.9	61,230.2	- 109,370.7	- 1,963.5	776.2	- 651.0	33	17,012.8	- 0	5.1	3,055.1	1,247.3	49
27	Yes	89,905.9	44,487.6	- 45,418.4	- 1,034.7	781.5	- 270.3	35	21,151.7	0	158.8	3,355.7	1,605.5	66
28	Yes	137,260.8	30,615.1	- 106,645.7	- 1,579.7	56.1	- 634.8	6	256.1	0	1.8	57.9	34.5	12
29	No	1,013.6	-	- 1,013.6	- 11.7	- 2.1	- 6.0	-	-	- 0	-	-	-	-
30	Yes	337,015.1	30,615.1	- 306,400.0	- 3,878.7	- 702.0	- 1,823.8	-	-	0	-	-	-	-
31	No	8,594.0	-	- 8,594.0	- 98.9	- 17.9	- 51.2	-	-	0	-	-	-	-
32	Yes	94,643.6	44,487.6	- 50,156.1	- 1,089.3	751.2	- 298.5	35	19,922.0	- 0	9.0	3,197.6	1,526.9	62
33	Yes	104,008.8	44,487.6	- 59,521.3	- 1,197.0	691.4	- 354.3	35	17,491.1	- 0	214.0	2,885.1	1,317.0	58
34	Yes	166,656.5	30,615.1	- 136,041.4	- 1,918.1	- 131.7	- 809.8	-	-	- 0	-	-	-	-
35	Yes	444,042.8	61,230.2	- 382,812.6	- 5,110.5	- 925.0	- 2,278.6	-	-	0	-	-	-	-
36	No	74,723.3	-	- 74,723.3	- 860.0	- 155.7	- 444.8	-	-	- 0	-	-	-	-
37	Yes	170,446.7	44,487.6	- 125,959.1	- 1,961.7	266.9	- 749.8	20	3,768.4	0	171.9	780.9	496.2	20
38	Yes	89,972.1	44,487.6	- 45,484.5	- 1,035.5	781.0	- 270.7	35	21,134.5	0	154.2	3,353.5	1,603.0	66
39	Yes	192,835.0	44,487.6	- 148,347.4	- 2,219.3	123.8	- 883.0	15	851.0	0	29.7	192.9	128.1	20
40	Yes	75,384.4	30,615.1	- 44,769.3	- 867.6	451.4	- 266.5	35	11,048.4	0	10.1	1,858.4	858.0	53
41	No	58,615.2	-	- 58,615.2	- 674.6	- 122.1	- 348.9	-	-	- 0	-	-	-	-
42	Yes	106,168.3	61,230.2	- 44,938.1	- 1,221.9	1,187.8	- 267.5	35	33,673.3	- 0	480.4	5,204.9	2,638.7	73
43	Yes	251,648.5	63,960.1	- 187,688.4	- 2,896.2	341.5	- 1,117.2	20	4,531.6	0	205.3	946.5	605.0	20
44	Yes	85,785.3	30,615.1	- 55,170.1	- 987.3	385.0	- 328.4	33	8,391.5	0	1.0	1,511.4	636.5	47
45	Yes	88,473.6	30,615.1	- 57,858.5	- 1,018.2	367.8	- 344.4	33	7,754.1	0	16.1	1,421.7	624.0	43

Object	Prod	Missing					External To					External From				
		Total	Min	Max	Average	No of occ.	Total	Min	Max	Average	No of occ.	Total	Min	Max	Average	No of occ.
1	Yes	275,968.6	638.6	3,528.5	1,642.7	168	-	-	-	-	-	-	-	-	-	-
2	Yes	231,566.5	546.1	3,017.5	1,378.4	168	-	-	-	-	-	-	-	-	-	-
3	Yes	59,753.6	59.6	1,040.1	478.0	125	-	-	-	-	-	-	-	-	-	-
4	No	215,664.1	449.2	2,482.1	1,283.7	168	-	-	-	-	-	-	-	-	-	-
5	Yes	542,548.2	1,235.6	6,826.7	3,229.5	168	-	-	-	-	-	-	-	-	-	-
6	Yes	248,490.0	581.4	3,212.2	1,479.1	168	-	-	-	-	-	-	-	-	-	-
7	Yes	142,490.5	94.8	2,344.6	1,063.4	134	-	-	-	-	-	-	-	-	-	-
8	Yes	336,268.5	793.1	4,382.1	2,001.6	168	-	-	-	-	-	-	-	-	-	-
9	Yes	449,354.0	1,007.7	5,567.8	2,674.7	168	-	-	-	-	-	3,096.3	405.9	486.3	442.3	7
10	Yes	951.4	59.3	205.2	105.7	9	- 3,096.3	- 486.3	- 486.3	- 442.3	7	-	-	-	-	-
11	Yes	234,365.0	552.0	3,049.7	1,395.0	168	-	-	-	-	-	-	-	-	-	-
12	Yes	76,643.9	184.0	1,016.7	456.2	168	-	-	-	-	-	-	-	-	-	-
13	Yes	48,067.2	227.7	1,257.9	506.0	95	-	-	-	-	-	-	-	-	-	-
14	Yes	206,411.7	247.2	2,887.6	1,228.6	168	-	-	-	-	-	-	-	-	-	-
15	Yes	225,616.8	533.8	2,949.0	1,343.0	168	-	-	-	-	-	-	-	-	-	-
16	Yes	111,107.0	6.0	1,790.7	788.0	141	-	-	-	-	-	-	-	-	-	-
17	Yes	78,846.6	1.6	1,419.5	668.2	118	-	-	-	-	-	-	-	-	-	-
18	Yes	80,239.5	173.9	1,628.2	729.4	110	-	-	-	-	-	-	-	-	-	-
19	Yes	104,038.1	344.3	1,902.1	889.2	117	-	-	-	-	-	-	-	-	-	-
20	Yes	296,123.9	417.0	4,112.8	1,762.6	168	-	-	-	-	-	-	-	-	-	-
21	Yes	131,379.8	137.5	2,024.1	887.7	148	-	-	-	-	-	-	-	-	-	-
22	Yes	971,625.8	2,116.6	11,694.5	5,783.5	168	-	-	-	-	-	-	-	-	-	-
23	Yes	513,163.1	1,126.9	6,226.1	3,054.5	168	-	-	-	-	-	-	-	-	-	-
24	Yes	146,126.4	129.4	2,386.5	1,090.5	134	-	-	-	-	-	-	-	-	-	-
25	Yes	492,766.6	1,119.1	6,183.3	2,933.1	168	-	-	-	-	-	-	-	-	-	-
26	Yes	109,370.7	20.6	1,963.5	919.1	119	-	-	-	-	-	-	-	-	-	-
27	Yes	45,418.4	187.3	1,034.7	445.3	102	-	-	-	-	-	-	-	-	-	-
28	Yes	106,645.7	0.8	1,579.7	683.6	156	-	-	-	-	-	-	-	-	-	-
29	No	1,013.6	2.1	11.7	6.0	168	-	-	-	-	-	-	-	-	-	-
30	Yes	306,400.0	702.0	3,878.7	1,823.8	168	-	-	-	-	-	-	-	-	-	-
31	No	8,594.0	17.9	98.9	51.2	168	-	-	-	-	-	-	-	-	-	-
32	Yes	50,156.0	9.9	1,089.3	473.2	106	-	-	-	-	-	-	-	-	-	-
33	Yes	59,521.2	203.4	1,197.0	541.1	110	-	-	-	-	-	-	-	-	-	-
34	Yes	136,041.4	131.7	1,918.1	809.8	168	-	-	-	-	-	-	-	-	-	-
35	Yes	382,812.7	925.0	5,110.5	2,278.6	168	-	-	-	-	-	-	-	-	-	-
36	No	74,723.3	155.7	860.0	444.8	168	-	-	-	-	-	-	-	-	-	-
37	Yes	125,959.1	91.4	1,961.7	851.1	148	-	-	-	-	-	-	-	-	-	-
38	Yes	45,484.5	187.4	1,035.5	445.9	102	-	-	-	-	-	-	-	-	-	-
39	Yes	148,347.5	261.4	2,219.3	1,002.3	148	-	-	-	-	-	-	-	-	-	-
40	Yes	44,769.3	3.1	867.6	389.3	115	-	-	-	-	-	-	-	-	-	-
41	No	58,615.1	122.1	674.6	348.9	168	-	-	-	-	-	-	-	-	-	-
42	Yes	44,938.1	215.8	1,221.9	473.0	95	-	-	-	-	-	-	-	-	-	-
43	Yes	187,688.5	187.5	2,896.2	1,268.2	148	-	-	-	-	-	-	-	-	-	-
44	Yes	55,170.2	9.3	987.3	456.0	121	-	-	-	-	-	-	-	-	-	-
45	Yes	57,858.5	6.0	1,018.3	462.9	125	-	-	-	-	-	-	-	-	-	-

Figure 61: Results current scenario (in kW) - winter week (1)

Object	Prod	Cons Total	Prod Total	Diff Prod- Cons	Min	Max	Average	No of occ.	Pot. Surplus Total	Storage Status End of week	Min	Max	Average	No of occ.	Missing Total	Min	Max	Average	No of occ.	External To Total	Min	Max	Average	No of occ.	External From Total	Min	Max	Average	No of occ.
46	Yes	169,939.9	61,230.2	- 108,709.6	- 1,955.8	780.4	- 647.1	33	17,169.5	- 0	13.3	3,077.2	1,241.0	50	108,709.6	12.0	1,955.8	921.3	118	-	-	-	-	-	-	-	-	-	-
47	Yes	146,361.6	44,487.6	- 101,874.0	- 1,684.5	420.8	- 606.4	29	7,454.7	- 0	36.2	1,472.1	654.3	34	101,874.0	53.2	1,684.5	760.3	134	-	-	-	-	-	-	-	-	-	-
48	No	94,269.0	-	- 94,269.0	- 1,084.9	- 196.4	- 561.1	-	-	- 0	-	-	-	-	94,269.0	196.4	1,084.9	561.1	168	-	-	-	-	-	-	-	-	-	-
49	Yes	152,774.0	30,615.1	- 122,158.9	- 1,758.3	- 43.0	- 727.1	-	-	0	-	-	-	-	122,159.0	43.0	1,758.3	727.1	168	-	-	-	-	-	-	-	-	-	-
50	Yes	77,764.2	61,230.2	- 16,534.0	- 895.0	1,369.3	- 98.4	35	41,045.8	- 0	4.0	6,152.6	2,807.9	111	16,534.0	8.7	567.2	290.1	57	-	-	-	-	-	-	-	-	-	-
51	Yes	91,734.9	44,487.6	- 47,247.3	- 1,055.8	769.8	- 281.2	35	20,676.9	0	32.7	3,294.7	1,537.9	66	47,247.4	191.1	1,055.8	463.2	102	-	-	-	-	-	-	-	-	-	-
52	Yes	178,974.5	44,487.6	- 134,486.9	- 2,059.8	212.4	- 800.5	20	2,622.6	- 0	117.8	553.1	356.0	20	134,486.9	163.8	2,059.8	908.7	148	-	-	-	-	-	-	-	-	-	-
53	Yes	87,482.0	61,230.2	- 26,251.8	- 1,006.8	1,307.2	- 156.3	35	38,523.5	- 0	4.0	5,828.4	2,950.2	88	26,251.7	22.4	793.9	328.1	80	-	-	-	-	-	-	-	-	-	-
54	No	116,745.5	-	- 116,745.5	- 1,343.6	- 243.2	- 694.9	-	-	0	-	-	-	-	116,745.6	243.2	1,343.6	694.9	168	-	-	-	-	-	-	-	-	-	-
55	No	67,605.7	-	- 67,605.7	- 778.1	- 140.8	- 402.4	-	-	0	-	-	-	-	67,605.8	140.8	778.1	402.4	168	-	-	-	-	-	-	-	-	-	-
56	Yes	108,570.2	61,230.2	- 47,340.0	- 1,249.5	1,172.5	- 281.8	35	33,049.8	- 0	293.3	5,124.8	2,540.7	73	47,340.0	226.2	1,249.5	498.3	95	-	-	-	-	-	-	-	-	-	-
57	No	62,074.8	-	- 62,074.8	- 714.4	- 129.3	- 369.5	-	-	- 0	-	-	-	-	62,074.7	129.3	714.4	369.5	168	-	-	-	-	-	-	-	-	-	-
58	Yes	93,233.3	30,615.1	- 62,618.2	- 1,073.0	337.4	- 372.7	30	6,682.0	0	34.6	1,262.9	545.8	40	62,618.2	6.6	1,073.0	489.2	128	-	-	-	-	-	-	-	-	-	-
59	Yes	84,639.4	44,487.6	- 40,151.8	- 974.1	815.1	- 239.0	35	22,518.7	- 0	364.3	3,531.4	1,800.0	66	40,151.8	62.9	974.1	393.6	102	-	-	-	-	-	-	-	-	-	-
60	Yes	106,807.4	61,230.2	- 45,577.2	- 1,229.2	1,183.8	- 271.3	35	33,507.4	0	430.6	5,183.6	2,612.6	73	45,577.2	222.5	1,229.3	479.8	95	-	-	-	-	-	-	-	-	-	-
61	Yes	51,497.6	30,615.1	- 20,882.5	- 592.7	604.1	- 124.3	35	17,248.4	- 0	26.1	2,655.4	1,365.7	74	20,882.5	56.8	592.7	222.2	94	-	-	-	-	-	-	-	-	-	-
62	No	19,766.1	-	- 19,766.1	- 227.5	- 41.2	- 117.7	-	-	- 0	-	-	-	-	19,766.1	41.2	227.5	117.7	168	-	-	-	-	-	-	-	-	-	-
63	Yes	151,914.6	44,487.6	- 107,427.0	- 1,748.4	385.3	- 639.4	26	6,373.4	0	1.8	1,286.8	543.0	33	107,427.0	1.2	1,748.4	795.8	135	-	-	-	-	-	-	-	-	-	-
64	Yes	229,833.1	30,615.1	- 199,218.0	- 2,645.2	- 478.8	- 1,185.8	-	-	- 0	-	-	-	-	199,217.9	478.8	2,645.2	1,185.8	168	-	-	-	-	-	-	-	-	-	-
65	Yes	416,960.9	79,726.9	- 337,234.0	- 4,798.8	- 234.1	- 2,007.3	-	-	- 0	-	-	-	-	337,234.0	234.1	4,798.8	2,007.3	168	-	-	-	-	-	-	-	-	-	-
66	Yes	378,706.8	61,230.2	- 317,476.5	- 4,358.5	- 553.5	- 1,889.7	-	-	0	-	-	-	-	317,476.6	553.5	4,358.6	1,889.7	168	-	-	-	-	-	-	-	-	-	-
67	Yes	254,447.0	61,230.2	- 193,216.8	- 2,928.4	240.5	- 1,150.1	20	2,519.1	- 0	110.5	544.5	356.6	20	193,216.8	286.8	2,928.4	1,305.5	148	-	-	-	-	-	-	-	-	-	-
68	Yes	477,218.6	61,230.2	- 415,988.4	- 4,349.1	- 633.2	- 2,476.1	-	-	0	-	-	-	-	415,988.4	633.2	4,349.1	2,476.1	168	-	-	-	-	-	-	-	-	-	-
69	Yes	284,988.6	25,710.3	- 259,278.3	- 3,279.9	- 593.7	- 1,543.3	-	-	- 0	-	-	-	-	259,278.3	593.7	3,279.9	1,543.3	168	-	-	-	-	-	-	-	-	-	-
70	No	270,775.6	-	- 270,775.6	- 3,116.4	- 564.0	- 1,611.8	-	-	- 0	-	-	-	-	270,775.6	564.1	3,116.4	1,611.8	168	-	-	-	-	-	-	-	-	-	-
71	No	152,796.0	-	- 152,796.0	- 1,758.5	- 318.3	- 909.5	-	-	0	-	-	-	-	152,796.1	318.3	1,758.5	909.5	168	-	-	-	-	-	-	-	-	-	-
72	Yes	487,916.0	93,835.3	- 394,080.7	- 5,615.4	- 257.5	- 2,345.7	-	-	0	-	-	-	-	394,080.8	257.5	5,615.4	2,345.7	168	-	-	-	-	-	-	-	-	-	-
73	Yes	114,784.3	30,615.1	- 84,169.2	- 1,321.1	199.7	- 501.0	20	2,930.9	- 0	134.3	604.5	382.8	20	84,169.2	41.6	1,321.1	568.7	148	-	-	-	-	-	-	-	-	-	-
74	Yes	464,073.3	30,615.1	- 433,458.2	- 5,341.0	- 966.7	- 2,580.1	-	-	- 0	-	-	-	-	433,458.2	966.7	5,341.0	2,580.1	168	-	-	-	-	-	-	-	-	-	-
75	No	388,292.3	-	- 388,292.3	- 4,468.9	- 808.8	- 2,311.3	-	-	- 0	-	-	-	-	388,292.3	808.8	4,468.9	2,311.3	168	-	-	-	-	-	-	-	-	-	-
76	No	32,679.0	-	- 32,679.0	- 376.1	- 68.1	- 194.5	-	-	0	-	-	-	-	32,679.1	68.1	376.1	194.5	168	-	-	-	-	-	-	-	-	-	-
77	Yes	496,532.0	61,230.2	- 435,301.8	- 5,714.6	- 1,034.3	- 2,591.1	-	-	0	-	-	-	-	435,301.8	1,034.3	5,714.6	2,591.1	168	-	-	-	-	-	-	-	-	-	-
78	Yes	298,849.1	30,615.1	- 268,234.0	- 3,439.5	- 622.5	- 1,596.6	-	-	- 0	-	-	-	-	268,234.0	622.5	3,439.5	1,596.6	168	-	-	-	-	-	-	-	-	-	-
79	No	76,376.0	-	- 76,376.0	- 879.0	- 159.1	- 454.6	-	-	0	-	-	-	-	76,376.0	159.1	879.0	454.6	168	-	-	-	-	-	-	-	-	-	-
80	Yes	333,158.8	44,487.6	- 288,671.2	- 3,834.3	- 694.0	- 1,718.3	-	-	0	-	-	-	-	288,671.3	694.0	3,834.3	1,718.3	168	-	-	-	-	-	-	-	-	-	-
81	Yes	281,088.3	61,230.2	- 219,858.1	- 3,235.1	70.2	- 1,308.7	5	297.5	- 0	48.9	70.2	59.5	5	219,858.1	6.1	3,235.1	1,348.8	163	-	-	-	-	-	-	-	-	-	-
82	Yes	217,052.3	44,487.6	- 172,564.8	- 2,498.1	- 30.9	- 1,027.2	-	-	- 0	-	-	-	-	172,564.8	30.9	2,498.1	1,027.2	168	-	-	-	-	-	-	-	-	-	-
83	No	305,283.6	-	- 305,283.6	- 3,513.5	- 635.9	- 1,817.2	-	-	- 0	-	-	-	-	305,283.5	635.9	3,513.5	1,817.2	168	-	-	-	-	-	-	-	-	-	-
84	Yes	212,380.8	30,615.1	- 181,765.6	- 2,444.3	- 423.9	- 1,081.9	-	-	0	-	-	-	-	181,765.7	423.9	2,444.3	1,081.9	168	-	-	-	-	-	-	-	-	-	-
85	Yes	393,074.1	44,487.6	- 348,586.5	- 4,523.9	- 818.8	- 2,074.9	-	-	- 0	-	-	-	-	348,586.4	818.8	4,523.9	2,074.9	168	-	-	-	-	-	-	-	-	-	-
86	Yes	352,748.6	44,487.6	- 308,261.0	- 4,059.8	- 734.8	- 1,834.9	-	-	0	-	-	-	-	308,261.1	734.8	4,059.8	1,834.9	168	-	-	-	-	-	-	-	-	-	-
87	No	298,386.4	-	- 298,386.4	- 3,434.1	- 621.6	- 1,776.1	-	-	0	-	-	-	-	298,386.4	621.6	3,434.1	1,776.1	168	-	-	-	-	-	-	-	-	-	-
88	Yes	269,277.1	30,615.1	- 238,662.0	- 3,099.1	- 560.9	- 1,420.6	-	-	- 0	-	-	-	-	238,662.0	560.9	3,099.1	1,420.6	168	-	-	-	-	-	-	-	-	-	-
89	Yes	184,769.9	44,487.6	- 140,282.4	- 2,126.5	175.4	- 835.0	20	1,843.9	0	81.0	398.3	260.7	20	140,282.4	207.7	2,126.5	947.9	148	-	-	-	-	-	-	-	-	-	-
90	Yes	198,057.5	44,487.6	- 153,569.9	- 2,279.4	90.5	- 914.1	9	437.5	- 0	0.2	101.8	51.7	17	153,569.9	3.4	2,279.5	1,017.0	151	-	-	-	-	-	-	-	-	-	-
91	Yes	406,978.7	61,230.2	- 345,748.4	- 4,683.9	- 734.1	- 2,058.0	-	-	0	-	-	-	-	345,748.5	734.1	4,683.9	2,058.0	168	-	-	-	-	-	-	-	-	-	-

Figure 62: Results current scenario (in kW) - winter week (2)

Object	Prod	Cons	Prod	Diff Prod- Cons					Pot. Surplus	Storage					Missing					External To					External From				
		Total	Total	Diff Prod-Cons	Min	Max	Average	No of occ.	Total	Status End of week	Min	Max	Average	No of occ.	Total	Min	Max	Average	No of occ.	Total	Min	Max	Average	No of occ.	Total	Min	Max	Average	No of occ.
1	Yes	274,950.0	116,373.7	- 158,576.3	- 2,804.5	131.7	- 943.9	1	131.7	- 0	131.7	131.7	131.7	1	158,576.2	77.3	2,804.5	949.6	167	-	-	-	-	-	-	-	-	-	-
2	Yes	235,129.3	116,373.7	- 118,755.6	- 2,398.3	265.8	- 706.9	24	1,679.1	0	13.5	290.3	106.4	31	116,267.3	21.6	2,398.3	945.3	123	-	-	-	-	-	2,488.3	1.2	288.0	131.0	19
3	Yes	81,044.3	116,373.7	35,329.4	- 826.7	1,144.8	210.3	84	70,259.5	0	26.5	5,383.0	2,172.2	113	1,278.0	183.8	283.7	213.0	6	- 36,607.3	-	- 1,144.8	- 747.1	49	-	-	-	-	-
4	No	193,411.6	-	- 193,411.6	- 2,062.0	- 429.5	- 1,151.3	-	-	- 0	133.3	133.3	133.3	1	159,292.5	76.2	1,972.8	953.8	167	-	-	-	-	-	34,119.0	183.0	1,144.8	775.4	44
5	Yes	531,955.9	192,380.3	- 339,575.7	- 5,426.0	- 43.1	- 2,021.3	-	-	0	-	-	-	-	339,575.7	43.1	5,426.0	2,021.3	168	-	-	-	-	-	-	-	-	-	-
6	Yes	250,306.6	116,373.7	- 133,932.9	- 2,553.1	214.7	- 797.2	6	293.2	- 0	18.6	1,658.8	706.4	46	112,920.9	374.3	2,553.1	1,129.2	100	-	-	-	-	-	21,012.0	19.4	2,359.3	567.9	37
7	Yes	182,700.5	232,747.4	50,046.9	- 1,863.5	2,147.5	297.9	84	128,791.0	0	194.4	13,772.1	5,327.4	144	2,881.0	414.3	639.5	480.2	6	- 52,927.9	- 3,398.5	- 3,398.5	- 1,176.2	45	-	-	-	-	-
8	Yes	341,469.2	169,105.5	- 172,363.6	- 3,483.0	386.9	- 1,026.0	24	2,470.2	- 0	24.2	2,596.9	570.2	49	140,447.8	81.9	3,483.0	1,560.5	90	-	-	-	-	-	31,915.8	104.3	3,104.0	997.4	32
9	Yes	433,856.9	119,064.8	- 314,792.1	- 4,425.3	- 379.0	- 1,873.8	-	-	0	11.4	396.3	230.7	8	223,601.1	68.2	4,425.4	1,760.6	127	-	-	-	-	-	91,191.1	51.1	1,982.7	1,169.1	78
10	Yes	25,532.6	116,373.7	90,841.1	- 260.4	1,527.3	540.7	84	101,845.7	- 0	56.8	1,695.9	580.2	117	402.6	57.9	89.4	67.1	6	- 91,243.7	- 1,982.7	- 1,982.7	- 1,169.8	78	-	-	-	-	-
11	Yes	237,639.1	116,373.7	- 121,265.4	- 2,423.9	257.3	- 721.8	22	1,314.2	0	10.4	7,731.9	4,265.9	83	70,809.6	158.4	2,423.9	885.1	80	-	-	-	-	-	50,455.9	148.9	4,406.1	1,868.7	27
12	Yes	79,226.2	44,464.5	- 34,761.8	- 808.1	137.3	- 206.9	47	3,174.7	- 0	20.3	4,962.5	1,023.7	134	1,249.3	179.7	277.3	208.2	6	-	-	-	-	-	33,512.4	21.9	4,499.2	1,196.9	28
13	Yes	98,020.0	232,747.4	134,727.4	- 999.8	2,731.0	801.9	84	176,974.1	- 0	473.0	18,643.0	5,762.5	133	1,545.7	222.3	343.1	257.6	6	- 136,273.1	- 6,178.8	- 6,178.8	- 2,163.1	63	-	-	-	-	-
14	Yes	225,011.2	169,105.5	- 55,905.6	- 2,295.1	924.4	- 332.8	78	42,847.9	0	4.2	11,308.6	4,631.6	136	3,548.2	510.3	787.6	591.4	6	-	-	-	-	-	52,357.5	254.7	6,178.8	1,689.0	31
15	Yes	229,793.6	116,373.7	- 113,419.9	- 2,343.9	283.8	- 675.1	31	2,590.6	- 0	62.5	14,438.7	5,186.0	135	3,623.6	521.1	804.4	603.9	6	-	-	-	-	-	109,796.3	88.4	5,538.5	1,960.6	56
16	Yes	139,540.1	169,105.5	29,565.4	- 1,423.3	1,513.4	176.0	84	89,707.3	- 0	310.6	11,638.2	4,446.6	141	2,200.4	316.4	488.5	366.7	6	- 31,765.8	- 2,839.2	- 2,839.2	- 1,323.6	24	-	-	-	-	-
17	Yes	110,608.4	169,105.5	58,497.1	- 1,128.2	1,712.8	348.2	84	106,169.4	0	246.2	14,361.2	4,294.4	139	1,744.2	250.8	387.2	290.7	6	- 60,241.3	- 5,538.5	- 5,538.5	- 1,771.8	34	-	-	-	-	-
18	Yes	126,872.6	232,747.4	105,874.8	- 1,294.1	2,532.2	630.2	84	160,557.0	0	20.7	20,996.7	6,185.3	131	2,000.6	287.7	444.1	333.4	6	- 107,875.4	- 6,533.2	- 6,533.2	- 1,926.3	56	-	-	-	-	-
19	Yes	148,215.7	232,747.4	84,531.7	- 1,511.8	2,385.1	503.2	84	148,412.8	- 0	329.9	14,950.3	5,408.7	125	2,337.2	336.1	518.8	389.5	6	- 86,868.9	- 5,032.7	- 5,032.7	- 1,809.8	48	-	-	-	-	-
20	Yes	320,481.8	232,747.4	- 87,734.4	- 3,268.9	1,198.0	- 522.2	68	53,599.0	- 0	14.7	19,587.0	6,069.6	128	5,053.7	726.8	1,121.8	842.3	6	- 1,501.7	- 373.5	- 373.5	- 300.3	5	84,182.5	34.9	7,451.7	1,830.1	46
21	Yes	157,721.2	169,105.5	11,384.3	- 1,608.8	1,388.2	67.8	84	79,362.3	- 0	351.0	10,476.0	4,442.6	140	2,487.1	357.7	552.1	414.5	6	- 13,871.4	- 3,920.5	- 3,920.5	- 533.5	26	-	-	-	-	-
22	Yes	911,269.5	169,105.5	- 742,164.0	- 9,295.0	- 1,315.6	- 4,417.6	-	-	0	4,638.7	10,903.4	8,381.2	3	621,859.3	315.9	9,295.0	4,230.3	147	-	-	-	-	-	120,304.7	372.1	12,841.7	3,341.8	36
23	Yes	485,159.3	105,730.4	- 379,429.0	- 4,948.6	- 623.6	- 2,258.5	-	-	- 0	13.9	7,738.7	3,284.4	11	294,114.7	149.4	4,948.6	2,028.4	145	-	-	-	-	-	85,314.3	19.6	8,010.7	1,854.7	46
24	Yes	185,961.3	232,747.4	46,786.1	- 1,896.8	2,125.0	278.5	84	126,935.6	- 0	127.7	12,351.7	4,971.3	131	2,932.4	421.7	651.0	488.7	6	- 49,718.6	- 3,829.8	- 3,829.8	- 1,343.7	37	-	-	-	-	-
25	Yes	481,819.5	169,105.5	- 312,714.0	- 4,914.6	- 85.8	- 1,861.4	-	-	0	376.5	20,903.0	7,115.0	91	89,281.8	142.6	4,914.6	1,539.3	58	-	-	-	-	-	223,432.2	75.0	15,212.9	3,191.9	70
26	Yes	152,998.1	232,747.4	79,749.3	- 1,560.6	2,352.2	474.7	84	145,691.6	- 0	340.5	16,789.6	4,756.0	133	2,412.6	347.0	535.6	402.1	6	- 82,161.9	- 8,519.4	- 8,519.4	- 2,220.6	37	-	-	-	-	-
27	Yes	80,629.3	169,105.5	88,476.2	- 822.4	1,919.4	526.6	84	123,227.5	0	179.5	12,651.6	3,571.5	128	1,271.4	182.9	282.2	211.9	6	- 89,747.6	- 6,496.4	- 6,496.4	- 2,301.2	39	-	-	-	-	-
28	Yes	123,098.1	116,373.7	- 6,724.4	- 1,255.6	855.0	- 40.0	78	46,521.8	- 0	22.7	7,233.3	2,959.0	148	1,941.1	279.2	430.9	323.5	6	- 1,186.0	- 1,186.0	- 1,186.0	- 1,186.0	1	5,969.3	24.9	1,459.0	459.2	13
29	No	909.1	-	- 909.1	- 9.7	- 2.0	- 5.4	-	-	0	2.0	61.0	15.3	92	14.3	2.1	3.2	2.4	6	-	-	-	-	-	894.7	2.0	63.5	12.8	70
30	Yes	302,241.4	116,373.7	- 185,867.7	- 3,082.9	39.8	- 1,106.4	1	39.8	0	171.1	12,166.0	4,458.9	109	4,766.0	685.4	1,058.0	794.3	6	-	-	-	-	-	181,101.7	108.3	11,091.8	2,235.8	81
31	No	7,707.2	-	- 7,707.2	- 82.2	- 17.1	- 45.9	-	-	0	17.1	1,118.1	286.0	83	121.5	17.5	27.0	20.3	6	-	-	-	-	-	7,585.7	17.2	1,144.7	96.0	79
32	Yes	84,878.2	169,105.5	84,227.4	- 865.8	1,890.1	501.4	84	120,809.9	- 0	190.9	17,399.5	5,916.0	143	1,338.4	192.5	297.1	223.1	6	- 85,565.8	- 11,091.8	- 11,091.8	- 983.5	87	-	-	-	-	-
33	Yes	93,277.1	169,105.5	75,828.5	- 951.4	1,832.3	451.4	84	116,031.0	- 0	207.6	15,060.5	5,026.8	142	1,470.9	211.5	326.5	245.1	6	- 77,299.4	- 7,162.8	- 7,162.8	- 1,932.5	40	-	-	-	-	-
34	Yes	149,460.7	116,373.7	- 33,087.0	- 1,524.5	673.3	- 196.9	78	32,376.5	0	39.6	9,158.1	2,920.6	140	2,356.8	338.9	523.2	392.8	6	-	-	-	-	-	30,730.2	149.4	4,212.0	1,181.9	26
35	Yes	398,225.9	232,747.4	- 165,478.5	- 4,061.9	774.2	- 985.0	48	21,713.0	- 0	264.5	16,190.6	6,058.8	118	6,279.6	903.1	1,394.0	1,046.6	6	-	-	-	-	-	159,198.8	129.8	9,559.4	2,341.2	68
36	No	67,013.2	-	- 67,013.2	- 714.4	- 148.8	- 398.9	-	-	0	48.6	7,328.6	1,762.3	93	1,056.7	152.0	234.6	176.1	6	-	-	-	-	-	65,956.5	107.4	5,317.4	879.4	75
37	Yes	152,859.8	169,105.5	16,245.8	- 1,559.2	1,421.7	96.7	84	82,128.5	0	56.1	12,146.9	5,120.3	150	2,410.4	346.7	535.1	401.7	6	- 18,656.2	- 4,518.8	- 4,518.8	- 848.0	22	-	-	-	-	-
38	Yes	80,688.6	169,105.5	88,416.9	- 823.0	1,919.0	526.3	84	123,193.8	- 0	188.1	15,480.7	5,458.9	148	1,272.4	183.0	282.5	212.1	6	- 89,689.3	- 8,712.1	- 8,712.1	- 1,758.6	51	-	-	-	-	-
39	Yes	172,938.0	169,105.5	- 3,832.5	- 1,764.0	1,283.3	- 22.8	78	70,788.6	0	4.4	11,132.8	4,782.7	151	2,727.1	392.2	605.4	454.5	6	- 2,468.3	- 1,839.9	- 1,839.9	- 617.1	4	3,573.8	7.6	2,352.0	324.9	11
40	Yes	67,606.1	116,373.7	48,767.6	- 689.6	1,237.4	290.3	84	77,905.9	0	150.5	10,763.7	3,797.6	145	1,066.1	153.3	236.7	177.7	6	- 49,833.7	- 4,194.0	- 4,194.0	- 1,158.9	43	-	-	-	-	-
41	No	52,567.2	-	- 52,567.2	- 560.4	- 116.7	- 312.9	-	-	0	116.7	4,549.3	1,079.9	104	828.9	119.2	184.0	138.2	6	-	-	-	-	-	51,738.2	73.9	4,959.1	821.2	63
42	Yes	95,213.7	232,747.4	137,533.7	- 971.2	2,750.4	818.7	84	178,570.9	- 0	221.9	20,027.7	7,421.1	144	1,501.4	215.9	333.3	250.2	6	- 139,035.1	- 9,559.4	- 9,559.4	- 1,829.4	76	-	-	-	-	-
43	Yes	225,683.1	243,124.1	17,441.0	- 2,302.0	2,003.2	103.8	84	114,710.6	- 0	104.0	16,531.8	7,157.6	151	3,558.8	511.8	790.0	593.1	6	- 20,999.8	- 3,178.0	- 3,178.0	- 724.1	29	-	-	-	-	-
44	Yes	76,933.8	116,373.7	39,439.9	- 784.7	1,173.1	234.8	84	72,598.4	0	179.3	10,579.7	3,699.7	144	1,213.2	174.5	269.3	202.2	6	- 40,653.0	- 4,319.0	- 4,319.0	- 1,098.7	37	-	-	-	-	-
45	Yes	79,344.8	116,373.7	37,028.9	- 809.3	1,156.5	220.4	84	71,226.6	- 0	38.3	10,135.5	3,857.4	146	1,251.2	179.9	277.7	208.5	6	- 38,280.1	- 4,357.3	- 4,357.3	- 1,093.7	35	-	-	-	-	-

Figure 63: Results current scenario (in kW) - transition week (1)

Object	Prod	Total	Total	Diff Prod-Cons	Min	Max	Average	No of occ.	Total	Status End of week	Min	Max	Average	No of occ.	Total	Min	Max	Average	No of occ.	Total	Min	Max	Average	No of occ.	Total	Min	Max	Average	No of occ.
46	Yes	152,405.2	232,747.4	80,342.2	- 1,554.5	2,356.3	478.2	84	146,028.9	0	405.6	16,039.5	6,137.3	136	2,403.3	345.6	533.5	400.5	6	- 82,745.4	- 5,461.8	- 5,461.8	- 1,532.3	54	-	-	-	-	-
47	Yes	131,259.8	169,105.5	37,845.7	- 1,338.9	1,570.5	225.3	84	94,418.8	0	292.1	13,441.4	4,321.1	142	2,069.8	297.7	459.5	345.0	6	- 39,915.5	- 3,738.1	- 3,738.1	- 1,287.6	31	-	-	-	-	-
48	No	84,542.2	-	- 84,542.2	- 901.3	- 187.7	- 503.2	-	-	- 0	83.5	5,942.9	1,816.4	132	1,333.1	191.7	295.9	222.2	6	-	-	-	-	-	83,209.1	188.2	5,095.1	1,698.1	49
49	Yes	137,010.6	116,373.7	- 20,636.9	- 1,397.5	759.1	- 122.8	78	39,056.8	0	124.4	9,100.4	2,856.8	147	2,160.5	310.7	479.6	360.1	6	-	-	-	-	-	18,476.4	89.6	4,768.3	1,231.8	15
50	Yes	69,740.4	232,747.4	163,007.0	- 711.4	2,925.9	970.3	84	193,065.2	0	162.5	15,661.8	5,758.1	135	1,099.7	158.2	244.1	183.3	6	- 164,106.7	- 4,841.3	- 4,841.3	- 1,691.8	97	-	-	-	-	-
51	Yes	82,269.6	169,105.5	86,836.0	- 839.2	1,908.1	516.9	84	122,294.2	- 0	183.1	14,861.6	5,024.5	134	1,297.3	186.6	288.0	216.2	6	- 88,133.3	- 5,365.1	- 5,365.1	- 1,398.9	63	-	-	-	-	-
52	Yes	160,507.7	169,105.5	8,597.8	- 1,637.2	1,369.0	51.2	84	77,776.8	0	439.2	12,516.2	5,136.3	149	2,531.0	364.0	561.9	421.8	6	- 11,128.9	- 1,960.6	- 1,960.6	- 618.3	18	-	-	-	-	-
53	Yes	78,455.5	232,747.4	154,291.9	- 800.2	2,865.9	918.4	84	188,106.3	0	174.6	17,884.5	5,829.2	136	1,237.2	177.9	274.6	206.2	6	- 155,529.1	- 8,351.9	- 8,351.9	- 1,787.7	87	-	-	-	-	-
54	No	104,699.6	-	- 104,699.6	- 1,116.2	- 232.5	- 623.2	-	-	0	238.4	5,631.2	1,574.4	105	1,651.0	237.4	366.5	275.2	6	-	-	-	-	-	103,048.6	10.4	5,603.8	1,515.4	68
55	No	60,630.1	-	- 60,630.1	- 646.4	- 134.6	- 360.9	-	-	- 0	62.1	4,956.8	1,637.6	114	956.1	137.5	212.2	159.3	6	-	-	-	-	-	59,674.0	134.6	5,027.3	1,028.9	58
56	Yes	97,367.8	232,747.4	135,379.6	- 993.2	2,735.5	805.8	84	177,345.2	- 0	161.9	16,878.9	6,993.7	138	1,535.4	220.8	340.8	255.9	6	- 136,915.0	- 5,746.2	- 5,746.2	- 1,875.5	73	-	-	-	-	-
57	No	55,669.8	-	- 55,669.8	- 593.5	- 123.6	- 331.4	-	-	- 0	124.8	4,063.1	1,330.3	93	877.9	126.2	194.9	146.3	6	-	-	-	-	-	54,791.9	123.6	4,444.8	740.4	74
58	Yes	83,613.4	116,373.7	32,760.3	- 852.9	1,127.1	195.0	84	68,797.7	0	186.1	9,391.0	3,597.6	145	1,318.5	189.6	292.7	219.7	6	- 34,078.8	- 3,968.8	- 3,968.8	- 1,099.3	31	-	-	-	-	-
59	Yes	75,906.2	169,105.5	93,199.3	- 774.2	1,952.0	554.8	84	125,915.0	- 0	90.7	15,619.3	5,016.4	141	1,197.0	172.1	265.7	199.5	6	- 94,396.3	- 10,453.2	- 10,453.2	- 1,815.3	52	-	-	-	-	-
60	Yes	95,786.8	232,747.4	136,960.6	- 977.0	2,746.4	815.2	84	178,244.8	- 0	213.2	19,035.2	7,438.7	135	1,510.5	217.2	335.3	251.7	6	- 138,471.0	- 8,985.3	- 8,985.3	- 2,472.7	56	-	-	-	-	-
61	Yes	46,184.0	116,373.7	70,189.7	- 471.1	1,385.0	417.8	84	90,095.0	- 0	102.8	10,878.6	2,983.7	140	728.3	104.7	161.7	121.4	6	- 70,918.0	- 6,693.6	- 6,693.6	- 1,729.7	41	-	-	-	-	-
62	No	17,726.6	-	- 17,726.6	- 189.0	- 39.4	- 105.5	-	-	0	39.5	945.2	249.8	92	279.5	40.2	62.1	46.6	6	-	-	-	-	-	17,447.1	39.6	1,070.8	245.7	71
63	Yes	136,239.8	169,105.5	32,865.7	- 1,389.6	1,536.2	195.6	84	91,585.2	0	371.4	13,204.0	5,080.6	145	2,148.4	309.0	476.9	358.1	6	- 35,014.0	- 4,715.7	- 4,715.7	- 1,458.9	24	-	-	-	-	-
64	Yes	206,118.6	116,373.7	- 89,744.9	- 2,102.4	363.5	- 534.2	47	8,687.6	0	67.6	11,241.3	3,688.8	123	3,250.3	467.4	721.5	541.7	6	-	-	-	-	-	86,494.6	51.2	9,224.4	1,572.6	55
65	Yes	373,938.3	303,056.5	- 70,881.8	- 3,814.2	1,858.7	- 421.9	78	92,513.8	0	226.3	23,086.9	9,053.4	145	5,896.6	848.0	1,309.0	982.8	6	-	-	-	-	-	64,985.2	315.6	6,177.9	1,856.7	35
66	Yes	339,631.3	232,747.4	- 106,883.9	- 3,464.2	1,066.0	- 636.2	65	44,946.0	0	2.3	17,856.2	6,947.3	132	5,355.6	770.2	1,188.9	892.6	6	-	-	-	-	-	101,528.3	163.4	7,306.9	2,115.2	48
67	Yes	228,192.9	232,747.4	4,554.5	- 2,327.6	1,834.0	27.1	84	102,905.9	- 0	507.9	16,352.9	6,879.3	150	3,598.4	517.5	798.8	599.7	6	- 8,152.9	- 2,681.5	- 2,681.5	- 679.4	12	-	-	-	-	-
68	Yes	449,020.8	232,747.4	- 216,273.4	- 3,351.2	1,104.9	- 1,287.3	14	10,009.9	0	73.3	13,335.4	4,153.3	104	8,252.9	1,200.0	1,581.5	1,375.5	6	-	-	-	-	-	208,020.5	182.6	13,169.8	2,506.3	83
69	Yes	255,583.1	97,729.7	- 157,853.4	- 2,607.0	27.5	- 939.6	1	27.5	0	153.8	9,203.4	2,739.3	98	26,475.6	567.5	2,607.0	1,103.1	24	-	-	-	-	-	131,377.9	294.3	8,985.3	2,153.7	61
70	No	242,836.6	-	- 242,836.6	- 2,588.9	- 539.2	- 1,445.5	-	-	0	249.3	3,722.0	1,856.7	9	197,846.2	133.7	2,476.9	1,364.5	145	-	-	-	-	-	44,990.4	282.2	5,727.2	1,666.3	27
71	No	137,030.3	-	- 137,030.3	- 1,460.9	- 304.3	- 815.7	-	-	- 0	253.3	7,298.8	2,937.2	13	119,844.2	304.3	1,397.7	799.0	150	-	-	-	-	-	17,186.1	322.2	8,150.0	2,455.2	7
72	Yes	437,572.2	356,685.4	- 80,886.8	- 4,463.2	2,205.1	- 481.5	78	110,246.9	0	261.0	18,386.5	8,363.1	106	76,609.9	285.0	3,320.9	1,255.9	61	-	-	-	-	-	4,277.0	66.7	2,674.2	611.0	7
73	Yes	102,940.7	116,373.7	13,433.0	- 1,050.0	993.9	80.0	84	57,800.5	0	229.1	6,837.4	2,867.1	134	1,623.3	233.4	360.3	270.5	6	- 15,056.2	- 1,598.4	- 1,598.4	- 501.9	30	-	-	-	-	-
74	Yes	416,189.6	116,373.7	- 299,815.9	- 4,245.1	- 344.0	- 1,784.6	-	-	- 0	1,431.7	2,308.3	1,870.0	2	263,121.2	430.3	4,245.1	1,708.6	154	-	-	-	-	-	36,694.7	227.7	4,181.8	1,048.4	35
75	No	348,227.8	-	- 348,227.8	- 3,712.4	- 773.3	- 2,072.8	-	-	- 0	-	-	-	-	348,227.7	773.3	3,712.4	2,072.8	168	-	-	-	-	-	-	-	-	-	-
76	No	29,307.2	-	- 29,307.2	- 312.4	- 65.1	- 174.4	-	-	- 0	-	-	-	-	29,307.2	65.1	312.4	174.4	168	-	-	-	-	-	-	-	-	-	-
77	Yes	445,299.2	232,747.4	- 212,551.8	- 4,542.1	615.6	- 1,265.2	34	7,932.1	0	91.3	1,431.3	645.0	47	212,551.8	25.0	4,542.1	1,756.6	121	-	-	-	-	-	-	-	-	-	-
78	Yes	268,013.5	116,373.7	- 151,639.8	- 2,733.7	155.0	- 902.6	1	155.0	- 0	155.0	155.0	155.0	1	151,639.7	24.5	2,733.7	908.0	167	-	-	-	-	-	-	-	-	-	-
79	No	68,495.4	-	- 68,495.4	- 730.2	- 152.1	- 407.7	-	-	- 0	-	-	-	-	68,495.4	152.1	730.2	407.7	168	-	-	-	-	-	-	-	-	-	-
80	Yes	298,783.0	169,105.5	- 129,677.5	- 3,047.6	530.7	- 771.9	47	12,849.0	- 0	67.5	2,328.5	1,092.2	59	128,044.0	18.9	3,047.6	1,174.7	109	-	-	-	-	-	1,633.5	1,633.5	1,633.5	1,633.5	1
81	Yes	252,085.2	232,747.4	- 19,337.8	- 2,571.3	1,669.3	- 115.1	78	89,883.7	0	99.0	13,515.6	6,024.1	128	20,971.3	73.6	1,513.2	537.7	39	- 1,633.5	- 1,633.5	- 1,633.5	- 1,633.5	1	-	-	-	-	-
82	Yes	194,656.6	169,105.5	- 25,551.1	- 1,985.5	1,133.6	- 152.1	78	59,135.1	0	57.9	8,971.5	4,258.3	114	25,551.1	30.7	1,389.7	473.2	54	-	-	-	-	-	-	-	-	-	-
83	No	273,784.0	-	- 273,784.0	- 2,918.8	- 607.9	- 1,629.7	-	-	0	-	-	-	-	273,784.1	608.0	2,918.8	1,629.7	168	-	-	-	-	-	-	-	-	-	-
84	Yes	190,467.0	116,373.7	- 74,093.3	- 1,942.8	416.2	- 441.0	54	13,802.3	0	42.5	2,419.3	1,042.1	71	74,093.3	3.4	1,942.8	763.8	97	-	-	-	-	-	-	-	-	-	-
85	Yes	352,516.2	169,105.5	- 183,410.6	- 3,595.7	349.7	- 1,091.7	16	1,075.1	- 0	8.6	349.7	81.8	21	183,410.6	1.8	3,595.7	1,247.7	147	-	-	-	-	-	-	-	-	-	-
86	Yes	316,351.5	169,105.5	- 147,246.0	- 3,226.8	471.5	- 876.5	43	7,530.3	- 0	4.0	1,381.0	633.2	50	147,246.0	4.5	3,226.8	1,247.8	118	-	-	-	-	-	-	-	-	-	-
87	No	267,598.5	-	- 267,598.5	- 2,852.9	- 594.2	- 1,592.8	-	-	0	-	-	-	-	267,598.5	594.2	2,852.9	1,592.8	168	-	-	-	-	-	-	-	-	-	-
88	Yes	241,492.7	116,373.7	- 125,119.0	- 2,463.2	244.4	- 744.8	17	851.8	- 0	1.4	858.5	148.5	29	118,472.8	5.4	2,463.2	877.6	135	-	-	-	-	-	6,646.2	64.5	1,697.3	511.2	13
89	Yes	165,705.1	169,105.5	3,400.4	- 1,690.2	1,333.1	20.2	84	74,819.5	0	12.8	11,137.6	4,523.2	147	3,336.9	355.2	580.0	417.1	8	- 6,737.3	- 1,697.3	- 1,697.3	- 396.3	17	-	-	-	-	-
90	Yes	177,621.7	169,105.5	- 8,516.1	- 1,811.7	1,251.0	- 50.7	78	68,275.5	- 0	49.4	10,228.2	4,345.2	138	10,305.9	2.8	768.7	355.4	29	- 1,880.9	- 1,880.9	- 1,880.9	- 1,880.9	1	91.1	18.2	27.4	22.8	4
91	Yes	364,986.0	232,747.4	- 132,238.6	- 3,722.9	891.3	- 787.1	63	34,009.0	0	35.5	5,805.3	2,723.1	80	130,357.8	333.5	3,722.9	1,481.3	88	-	-	-	-	-	1,880.9	1,880.9	1,880.9	1,880.9	1

Figure 64: Results current scenario (in kW) - transition week (2)

Object	Prod	Cons	Prod	Diff Prod- Cons					Pot. Surplus	Storage					Missing					External To					External From				
		Total	Total	Diff Prod- Cons	Min	Max	Average	No of occ.	Total	Status End of week	Min	Max	Average	No of occ.	Total	Min	Max	Average	No of occ.	Total	Min	Max	Average	No of occ.	Total	Min	Max	Average	No of occ.
1	Yes	222,925.9	130,603.2	- 92,322.8	- 2,020.6	361.6	- 549.5	49	9,083.5	0	6.6	8,019.6	1,395.2	80	59,469.9	15.4	2,020.6	837.6	71	-	-	-	-	-	32,852.9	44.1	5,338.4	1,173.3	28
2	Yes	190,639.9	130,603.2	- 60,036.7	- 1,727.9	515.1	- 357.4	65	21,583.3	- 0	54.6	8,650.4	2,285.8	126	4,192.6	70.8	700.2	465.8	9	-	-	-	-	-	55,844.1	90.2	5,748.7	1,551.2	36
3	Yes	65,709.7	130,603.2	64,893.5	- 595.6	1,397.1	386.3	90	89,946.4	0	71.9	13,276.2	5,176.1	150	1,093.2	153.9	241.4	182.2	6	- 65,986.7	-	- 5,748.7	- 1,736.5	38	-	-	-	-	-
4	No	156,815.6	-	- 156,815.6	- 1,653.3	- 367.3	- 933.4	-	-	0	178.0	9,596.4	2,144.3	97	2,608.9	367.3	576.0	434.8	6	-	-	-	-	-	154,206.8	82.1	10,980.9	2,002.7	77
5	Yes	431,303.1	215,903.4	- 215,399.7	- 3,909.3	377.7	- 1,282.1	16	1,432.5	0	5.5	16,825.1	5,892.0	125	7,175.6	1,010.3	1,584.2	1,195.9	6	-	-	-	-	-	208,224.2	16.2	9,766.9	3,017.7	69
6	Yes	202,945.4	130,603.2	- 72,342.3	- 1,839.5	434.3	- 430.6	63	16,275.2	- 0	19.6	9,860.4	3,201.9	134	3,376.4	475.4	745.4	562.7	6	-	-	-	-	-	68,965.9	169.8	6,805.5	2,224.7	31
7	Yes	148,131.3	261,206.3	113,075.1	- 1,342.6	2,675.9	673.1	85	169,771.1	0	364.7	20,270.2	7,656.7	149	2,464.5	347.0	544.1	410.7	6	- 115,539.5	- 10,980.9	- 10,980.9	- 2,888.5	40	-	-	-	-	-
8	Yes	276,858.8	189,782.7	- 87,076.1	- 2,509.4	749.6	- 518.3	65	31,437.0	- 0	159.8	13,529.2	5,257.2	136	4,606.1	648.5	1,016.9	767.7	6	-	-	-	-	-	82,470.0	130.0	13,311.8	2,749.0	30
9	Yes	351,765.7	133,623.4	- 218,142.3	- 3,188.4	- 63.5	- 1,298.5	-	-	0	20.1	13,117.1	3,952.6	109	5,852.3	824.0	1,292.0	975.4	6	-	-	-	-	-	212,290.0	34.0	10,631.3	2,687.2	79
10	Yes	20,701.5	130,603.2	109,901.6	- 187.6	1,715.7	654.2	91	117,784.4	0	51.0	15,938.1	6,636.4	148	344.4	48.5	76.0	57.4	6	- 110,246.1	- 13,311.8	- 13,311.8	- 2,826.8	39	-	-	-	-	-
11	Yes	192,674.8	130,603.2	- 62,071.6	- 1,746.4	501.8	- 369.5	63	20,699.6	0	90.1	10,369.5	3,647.5	140	3,205.5	451.3	707.7	534.3	6	-	-	-	-	-	58,866.1	58.2	7,075.9	2,102.4	28
12	Yes	64,235.6	49,901.3	- 14,334.3	- 582.2	256.9	- 85.3	78	12,354.0	0	19.9	4,577.2	1,385.6	141	1,068.7	150.5	235.9	178.1	6	-	-	-	-	-	13,265.6	59.2	2,710.9	603.0	22
13	Yes	79,473.3	261,206.3	181,733.0	- 720.3	3,161.8	1,081.7	91	211,995.0	- 0	236.3	23,256.9	8,281.8	143	1,322.2	186.2	291.9	220.4	6	- 183,055.2	- 9,614.6	- 9,614.6	- 2,816.2	65	-	-	-	-	-
14	Yes	182,436.2	189,782.7	7,346.5	- 1,653.6	1,414.9	43.7	84	80,722.3	0	74.1	14,594.1	5,988.3	157	3,035.2	427.3	670.1	505.9	6	- 10,381.7	- 2,900.6	- 2,900.6	- 1,297.7	8	-	-	-	-	-
15	Yes	186,313.7	130,603.2	- 55,710.5	- 1,688.7	543.7	- 331.6	66	23,535.0	- 0	68.5	11,153.9	3,630.8	140	3,099.7	436.4	684.3	516.6	6	-	-	-	-	-	52,610.9	62.2	5,784.8	1,594.3	33
16	Yes	113,137.3	189,782.7	76,645.4	- 1,025.5	1,905.2	456.2	85	120,179.0	- 0	150.3	16,096.8	6,650.0	147	1,882.3	265.0	415.6	313.7	6	- 78,527.6	- 6,805.5	- 6,805.5	- 2,122.4	37	-	-	-	-	-
17	Yes	89,679.9	189,782.7	100,102.8	- 812.9	2,071.2	595.9	91	134,251.3	- 0	220.8	17,698.7	6,399.7	143	1,492.0	210.1	329.4	248.7	6	- 101,594.8	- 7,075.9	- 7,075.9	- 2,477.9	41	-	-	-	-	-
18	Yes	102,866.7	261,206.3	158,339.6	- 932.4	2,996.2	942.5	91	197,509.4	- 0	253.2	24,358.1	8,505.1	139	1,711.4	241.0	377.8	285.2	6	- 160,051.1	- 8,317.9	- 8,317.9	- 2,500.8	64	-	-	-	-	-
19	Yes	120,171.4	261,206.3	141,035.0	- 1,089.2	2,873.8	839.5	91	186,794.1	- 0	108.1	24,608.8	8,223.1	142	1,999.3	281.5	441.4	333.2	6	- 143,034.2	- 11,448.1	- 11,448.1	- 2,804.6	51	-	-	-	-	-
20	Yes	259,842.6	261,206.3	1,363.8	- 2,355.2	1,885.5	8.1	84	106,125.0	0	63.1	18,567.6	7,982.1	159	4,323.0	608.7	954.4	720.5	6	- 5,686.8	- 2,648.4	- 2,648.4	- 1,895.6	3	-	-	-	-	-
21	Yes	127,878.4	189,782.7	61,904.4	- 1,159.1	1,800.9	368.5	84	111,761.5	- 0	332.7	14,672.8	5,509.3	150	2,127.5	299.5	469.7	354.6	6	- 64,031.9	- 6,631.1	- 6,631.1	- 2,134.4	30	-	-	-	-	-
22	Yes	738,845.7	189,782.7	- 549,063.0	- 6,696.8	- 928.5	- 3,268.2	-	-	0	62.1	19,548.4	7,060.9	102	12,292.1	1,730.6	2,713.8	2,048.7	6	-	-	-	-	-	536,770.9	194.0	18,188.2	4,587.8	117
23	Yes	393,361.0	118,658.4	- 274,702.6	- 3,565.4	- 340.2	- 1,635.1	-	-	- 0	5.0	14,579.6	4,321.0	117	6,544.3	921.4	1,444.8	1,090.7	6	-	-	-	-	-	268,158.2	141.5	12,519.1	3,230.8	83
24	Yes	150,775.0	261,206.3	110,431.3	- 1,366.6	2,657.2	657.3	85	168,250.2	0	78.4	23,693.9	8,195.3	149	2,508.4	353.2	553.8	418.1	6	- 112,939.7	- 13,981.5	- 13,981.5	- 4,343.8	26	-	-	-	-	-
25	Yes	390,653.1	189,782.7	- 200,870.4	- 3,540.8	291.6	- 1,195.7	7	456.2	0	24.8	16,621.8	5,016.3	111	6,499.3	915.1	1,434.9	1,083.2	6	-	-	-	-	-	194,371.2	14.7	15,781.7	3,037.0	64
26	Yes	124,048.9	261,206.3	137,157.4	- 1,124.4	2,846.4	816.4	90	184,395.1	0	322.7	25,054.8	9,378.4	146	2,063.8	290.6	455.6	344.0	6	- 139,221.2	- 15,170.0	- 15,170.0	- 3,314.8	42	-	-	-	-	-
27	Yes	65,373.2	189,782.7	124,409.5	- 592.5	2,243.2	740.5	91	149,302.5	- 0	160.9	23,921.4	7,720.3	148	1,087.6	153.1	240.1	181.3	6	- 125,497.1	- 12,519.1	- 12,519.1	- 3,302.6	38	-	-	-	-	-
28	Yes	99,806.3	130,603.2	30,796.8	- 904.6	1,155.8	183.3	84	70,195.6	583	176.2	12,432.4	4,454.9	150	1,660.5	233.8	366.6	276.7	6	- 31,874.4	- 6,735.8	- 6,735.8	- 1,448.8	22	-	-	-	-	-
29	No	737.1	-	- 737.1	- 7.8	- 1.7	- 4.4	-	-	0	1.8	271.4	97.3	152	12.3	1.7	2.7	2.0	6	-	-	-	-	-	724.8	1.9	275.8	72.5	10
30	Yes	245,053.5	130,603.2	- 114,450.3	- 2,221.1	284.0	- 681.3	25	3,148.6	- 0	31.2	16,297.4	5,303.1	124	4,076.9	574.0	900.1	679.5	6	-	-	-	-	-	110,373.3	95.2	18,071.0	2,399.4	46
31	No	6,248.9	-	- 6,248.9	- 65.9	- 14.6	- 37.2	-	-	0	15.3	820.2	210.9	132	104.0	14.6	23.0	17.3	6	-	-	-	-	-	6,145.0	30.5	843.1	204.8	30
32	Yes	68,818.1	189,782.7	120,964.6	- 623.8	2,218.8	720.0	91	147,169.3	9,331	138.0	26,487.2	9,153.1	150	1,144.9	161.2	252.8	190.8	6	- 112,778.4	- 21,741.9	- 21,741.9	- 2,967.9	38	-	-	-	-	-
33	Yes	75,627.9	189,782.7	114,154.9	- 685.5	2,170.7	679.5	91	142,952.6	17,614	186.2	20,318.6	8,067.3	145	1,258.2	177.2	277.8	209.7	6	- 97,799.2	- 9,885.8	- 9,885.8	- 2,876.4	34	-	-	-	-	-
34	Yes	121,180.8	130,603.2	9,422.3	- 1,098.4	1,004.6	56.1	84	58,035.2	205	70.3	8,071.2	3,481.8	154	2,016.1	283.9	445.1	336.0	6	- 11,233.8	- 1,757.8	- 1,757.8	- 1,021.3	11	-	-	-	-	-
35	Yes	322,876.5	261,206.3	- 61,670.1	- 2,926.5	1,439.5	- 367.1	78	71,841.4	0	69.9	17,738.0	6,704.8	144	5,371.7	756.3	1,185.9	895.3	6	-	-	-	-	-	56,298.5	244.7	6,977.6	2,251.9	25
36	No	54,333.5	-	- 54,333.5	- 572.8	- 127.3	- 323.4	-	-	0	133.8	6,053.3	1,921.5	126	903.9	127.3	199.6	150.7	6	-	-	-	-	-	53,429.6	135.3	5,950.8	1,370.0	39
37	Yes	123,936.8	189,782.7	65,846.0	- 1,123.4	1,828.8	391.9	84	114,004.0	4,723	305.1	16,359.1	6,199.3	147	2,061.9	290.3	455.2	343.7	6	- 63,184.7	- 9,524.2	- 9,524.2	- 2,256.6	28	-	-	-	-	-
38	Yes	65,421.3	189,782.7	124,361.4	- 593.0	2,242.9	740.2	91	149,272.7	18,896	161.1	21,235.4	6,678.5	147	1,088.4	153.2	240.3	181.4	6	- 106,554.1	- 9,533.6	- 9,533.6	- 2,732.2	39	-	-	-	-	-
39	Yes	140,216.0	189,782.7	49,566.8	- 1,270.9	1,713.6	295.0	84	104,742.4	9,502	278.5	15,171.6	6,569.5	151	2,332.8	328.4	515.0	388.8	6	- 42,397.1	- 5,180.5	- 5,180.5	- 1,766.5	24	-	-	-	-	-
40	Yes	54,814.2	130,603.2	75,789.0	- 496.8	1,474.2	451.1	91	96,661.3	11,542	134.9	13,901.6	4,849.3	142	911.9	128.4	201.3	152.0	6	- 65,159.4	- 9,946.1	- 9,946.1	- 1,810.0	36	-	-	-	-	-
41	No	42,620.8	-	- 42,620.8	- 449.4	- 99.8	- 253.7	-	-	- 0	34.0	4,831.5	1,702.5	135	709.1	99.8	156.5	118.2	6	-	-	-	-	-	41,911.7	110.4	4,677.5	1,352.0	31
42	Yes	77,198.1	261,206.3	184,008.2	- 699.7	3,177.9	1,095.3	91	213,403.9	22,499	190.0	25,260.4	8,727.0	149	1,284.3	180.8	283.5	214.1	6	- 162,793.2	- 15,646.3	- 15,646.3	- 2,806.8	58	-	-	-	-	-
43	Yes	182,981.0	272,851.8	89,870.8	- 1,658.5	2,595.4	534.9	84	161,175.5	15,999	414.2	22,627.9	9,223.9	151	3,044.3	428.6	672.1	507.4	6	- 76,916.4	- 6,977.6	- 6,977.6	- 2,330.8	33	-	-	-	-	-
44	Yes	62,377.0	130,603.2	68,226.2	- 565.4	1,420.7	406.1	90	91,982.2	10,824	162.3	13,054.7	5,434.7	147	1,037.8	146.1	229.1	173.0	6	- 58,440.2	- 6,338.7	- 6,338.7	- 1,669.7	35	-	-	-	-	-
45	Yes	64,331.7	130,603.2	66,271.4	- 583.1	1,406.8	394.5	90	90,788.2	10,578	110.0	12,879.1	4,554.3	145	1,070.3	150.7	236.3	178.4	6	- 56,763.4	- 4,598.3	- 4,598.3	- 1,320.1	43	-	-	-	-	-

Figure 65: Results current scenario (in kW) - summer week (1)

Object	Prod	Cons	Prod	Diff Prod- Cons					Pot. Surplus	Storage					Missing					External To					External From				
		Total	Total	Diff Prod-Cons	Min	Max	Average	No of occ.	Total	Status End of week	Min	Max	Average	No of occ.	Total	Min	Max	Average	No of occ.	Total	Min	Max	Average	No of occ.	Total	Min	Max	Average	No of occ.
46	Yes	123,568.2	261,206.3	137,638.1	- 1,120.0	2,849.8	819.3	91	184,690.7	21,796	268.0	26,215.8	8,023.2	139	2,055.8	289.4	453.9	342.6	6	- 117,897.4	- 8,393.3	- 8,393.3	- 1,813.8	65	-	-	-	-	-
47	Yes	106,423.8	189,782.7	83,359.0	- 964.6	1,952.8	496.2	85	124,041.3	5,138	9.8	26,455.7	6,906.4	153	1,770.6	249.3	390.9	295.1	6	- 79,991.8	- 10,816.5	- 10,816.5	- 1,999.8	40	-	-	-	-	-
48	No	68,545.8	-	- 68,545.8	- 722.7	- 160.6	- 408.0	-	-	0	168.2	8,394.4	2,037.1	123	1,140.4	160.6	251.8	190.1	6	-	-	-	-	-	67,405.4	162.1	6,690.6	1,434.2	47
49	Yes	111,086.4	130,603.2	19,516.7	- 1,006.9	1,076.0	116.2	84	63,778.1	4,706	120.0	9,314.6	4,290.3	153	1,848.1	260.2	408.0	308.0	6	- 16,658.4	- 2,872.5	- 2,872.5	- 876.8	19	-	-	-	-	-
50	Yes	56,544.6	261,206.3	204,661.7	- 512.5	3,324.0	1,218.2	91	226,192.9	30,214	139.2	32,236.1	9,079.7	142	940.7	132.5	207.7	156.8	6	- 175,388.6	- 8,059.4	- 8,059.4	- 2,138.9	82	-	-	-	-	-
51	Yes	66,703.1	189,782.7	123,079.6	- 604.6	2,233.8	732.6	91	148,479.0	18,735	173.5	21,120.3	6,962.5	146	1,109.7	156.2	245.0	185.0	6	- 105,454.6	- 7,204.6	- 7,204.6	- 1,787.4	59	-	-	-	-	-
52	Yes	130,137.6	189,782.7	59,645.1	- 1,179.6	1,785.0	355.0	84	110,476.2	1,526	320.4	15,646.6	6,020.9	147	2,165.1	304.8	478.0	360.8	6	- 60,283.8	- 7,679.3	- 7,679.3	- 1,435.3	42	-	-	-	-	-
53	Yes	63,610.7	261,206.3	197,595.6	- 576.6	3,274.0	1,176.2	91	221,817.4	- 0	73.9	17,523.0	7,080.9	136	1,058.3	149.0	233.6	176.4	6	- 198,653.9	- 10,397.4	- 10,397.4	- 2,257.4	88	-	-	-	-	-
54	No	84,889.1	-	- 84,889.1	- 895.0	- 198.8	- 505.3	-	-	0	56.2	6,722.4	1,638.8	113	1,412.3	198.8	311.8	235.4	6	-	-	-	-	-	83,476.8	75.7	6,107.1	1,391.3	60
55	No	49,158.1	-	- 49,158.1	- 518.3	- 115.1	- 292.6	-	-	0	120.2	4,538.9	1,122.3	110	817.8	115.2	180.6	136.3	6	-	-	-	-	-	48,340.3	115.9	4,654.6	878.9	55
56	Yes	78,944.6	261,206.3	182,261.7	- 715.5	3,165.5	1,084.9	91	212,322.4	- 0	173.4	19,269.0	7,594.8	139	1,313.4	184.9	290.0	218.9	6	- 183,575.2	- 6,193.3	- 6,193.3	- 1,892.5	97	-	-	-	-	-
57	No	45,136.4	-	- 45,136.4	- 475.9	- 105.7	- 268.7	-	-	- 0	106.1	4,468.4	1,613.5	122	750.9	105.7	165.8	125.2	6	-	-	-	-	-	44,385.4	113.7	4,242.6	986.3	45
58	Yes	67,792.7	130,603.2	62,810.5	- 614.5	1,382.4	373.9	90	88,674.0	0	176.4	12,441.7	4,182.5	149	1,127.9	158.8	249.0	188.0	6	- 63,938.3	- 7,244.6	- 7,244.6	- 1,826.8	35	-	-	-	-	-
59	Yes	61,543.8	189,782.7	128,239.0	- 557.8	2,270.3	763.3	91	151,673.7	0	6.9	15,874.4	4,788.5	140	1,023.9	144.2	226.1	170.7	6	- 129,262.8	- 7,201.4	- 7,201.4	- 2,308.3	56	-	-	-	-	-
60	Yes	77,662.8	261,206.3	183,543.6	- 703.9	3,174.6	1,092.5	91	213,116.2	- 0	191.2	20,477.7	7,049.9	131	1,292.1	181.9	285.3	215.3	6	- 184,835.7	- 9,951.4	- 9,951.4	- 2,100.4	88	-	-	-	-	-
61	Yes	37,445.4	130,603.2	93,157.8	- 339.4	1,597.1	554.5	91	107,416.3	- 0	92.2	12,587.7	4,438.6	141	623.0	87.7	137.5	103.8	6	- 93,780.8	- 11,692.1	- 11,692.1	- 2,084.0	45	-	-	-	-	-
62	No	14,372.5	-	- 14,372.5	- 151.5	- 33.7	- 85.6	-	-	0	33.8	1,336.3	357.1	114	239.1	33.7	52.8	39.9	6	-	-	-	-	-	14,133.4	35.2	1,389.4	288.4	49
63	Yes	110,461.5	189,782.7	79,321.2	- 1,001.2	1,924.2	472.1	85	121,718.4	- 0	56.7	16,730.2	6,295.7	143	1,837.7	258.7	405.7	306.3	6	- 81,159.0	- 10,220.2	- 10,220.2	- 1,726.8	47	-	-	-	-	-
64	Yes	167,118.3	130,603.2	- 36,515.2	- 1,514.7	679.5	- 217.4	78	32,870.8	- 0	56.7	8,760.6	3,362.4	136	2,780.3	391.5	613.8	463.4	6	-	-	-	-	-	33,734.8	150.1	3,741.3	1,204.8	28
65	Yes	303,184.4	340,112.4	36,928.0	- 2,748.0	2,703.8	219.8	84	158,182.5	- 0	244.1	23,163.6	9,630.5	152	5,044.1	710.2	1,113.6	840.7	6	- 41,972.1	- 5,657.8	- 5,657.8	- 1,998.7	21	-	-	-	-	-
66	Yes	275,368.7	261,206.3	- 14,162.4	- 2,495.9	1,775.6	- 84.3	79	97,377.1	0	311.2	17,185.0	7,798.5	152	4,581.3	645.0	1,011.4	763.6	6	- 2,732.2	- 2,113.6	- 2,113.6	- 1,366.1	2	12,313.3	14.8	3,718.9	1,026.1	12
67	Yes	185,015.9	261,206.3	76,190.5	- 1,677.0	2,415.0	453.5	84	148,695.6	0	427.0	23,905.2	8,100.8	149	3,078.1	433.4	679.6	513.0	6	- 79,268.6	- 12,256.8	- 12,256.8	- 2,331.4	34	-	-	-	-	-
68	Yes	412,012.5	261,206.3	- 150,806.2	- 2,488.9	1,564.5	- 897.7	27	18,711.9	0	96.5	15,334.4	5,219.3	119	7,762.7	1,126.3	1,489.4	1,293.8	6	- 3,732.7	- 2,133.4	- 2,133.4	- 933.2	4	146,776.2	69.2	10,628.2	2,367.4	62
69	Yes	207,223.5	109,679.5	- 97,544.1	- 1,878.3	233.5	- 580.6	25	2,420.5	0	22.5	12,209.8	3,398.5	129	3,447.6	485.4	761.1	574.6	6	-	-	-	-	-	94,096.6	19.0	8,578.4	2,188.3	43
70	No	196,888.8	-	- 196,888.8	- 2,075.8	- 461.2	- 1,172.0	-	-	0	38.7	10,843.1	2,996.0	104	3,275.6	461.2	723.2	545.9	6	-	-	-	-	-	193,613.2	81.7	11,692.1	2,390.3	81
71	No	111,102.4	-	- 111,102.4	- 1,171.4	- 260.2	- 661.3	-	-	- 0	143.0	7,233.1	1,995.0	112	1,848.4	260.2	408.1	308.1	6	-	-	-	-	-	109,254.0	169.9	8,249.9	1,707.1	64
72	Yes	354,778.0	400,298.7	45,520.7	- 3,215.7	3,196.8	271.0	84	187,345.3	- 0	154.4	26,944.8	11,459.0	151	5,902.4	831.0	1,303.1	983.7	6	- 51,423.2	- 8,461.0	- 8,461.0	- 1,512.4	34	-	-	-	-	-
73	Yes	83,463.0	130,603.2	47,140.1	- 756.5	1,271.5	280.6	84	79,493.7	- 0	197.1	11,468.8	4,499.6	146	1,388.6	195.5	306.6	231.4	6	- 48,528.7	- 5,523.2	- 5,523.2	- 1,673.4	29	-	-	-	-	-
74	Yes	337,441.2	130,603.2	- 206,838.1	- 3,058.5	- 39.7	- 1,231.2	-	-	- 0	319.1	13,060.5	3,521.9	91	5,614.0	790.4	1,239.4	935.7	6	-	-	-	-	-	201,224.1	39.7	8,240.9	2,235.8	90
75	No	282,338.7	-	- 282,338.7	- 2,976.7	- 661.3	- 1,680.6	-	-	0	54.6	16,010.5	4,217.8	102	4,697.3	661.3	1,037.0	782.9	6	-	-	-	-	-	277,641.4	616.3	15,323.3	3,345.1	83
76	No	23,761.9	-	- 23,761.9	- 250.5	- 55.7	- 141.4	-	-	0	59.4	2,836.2	684.3	111	395.3	55.7	87.3	65.9	6	-	-	-	-	-	23,366.6	55.9	2,731.3	440.9	53
77	Yes	361,042.9	261,206.3	- 99,836.6	- 3,272.5	1,169.4	- 594.3	66	52,317.4	0	53.1	21,067.4	7,384.3	140	6,006.6	845.7	1,326.1	1,001.1	6	-	-	-	-	-	93,829.9	49.5	10,220.2	2,606.4	36
78	Yes	217,301.9	130,603.2	- 86,698.7	- 1,969.6	381.3	- 516.1	49	10,911.9	0	30.9	10,023.0	3,127.1	123	3,615.3	509.0	798.1	602.5	6	-	-	-	-	-	83,083.5	74.9	8,309.8	1,730.9	48
79	No	55,535.2	-	- 55,535.2	- 585.5	- 130.1	- 330.6	-	-	- 0	130.7	3,526.6	1,154.1	99	923.9	130.1	204.0	154.0	6	-	-	-	-	-	54,611.3	138.3	3,914.9	827.4	66
80	Yes	242,249.5	189,782.7	- 52,466.8	- 2,195.7	991.7	- 312.3	78	48,084.5	- 0	86.3	14,263.8	4,771.5	144	4,030.3	567.4	889.8	671.7	6	-	-	-	-	-	48,436.5	215.2	8,461.0	2,018.2	24
81	Yes	204,387.5	261,206.3	56,818.8	- 1,852.5	2,277.9	338.2	84	137,674.7	- 0	167.8	15,513.4	5,870.8	147	3,400.4	478.8	750.7	566.7	6	- 60,219.2	- 4,837.3	- 4,837.3	- 1,771.2	34	-	-	-	-	-
82	Yes	157,825.1	189,782.7	31,957.6	- 1,430.5	1,589.0	190.2	84	94,724.2	0	195.8	15,293.2	5,446.3	147	2,625.7	369.7	579.7	437.6	6	- 34,583.3	- 5,265.1	- 5,265.1	- 1,441.0	24	-	-	-	-	-
83	No	221,980.6	-	- 221,980.6	- 2,340.3	- 520.0	- 1,321.3	-	-	- 0	179.9	13,239.5	3,888.4	84	4,799.4	520.0	815.3	599.9	8	-	-	-	-	-	217,181.2	82.4	10,816.5	2,262.3	96
84	Yes	154,428.2	130,603.2	- 23,825.1	- 1,399.7	769.3	- 141.8	78	39,684.7	- 0	90.5	8,890.7	3,128.1	126	12,416.8	31.6	1,153.4	459.9	27	-	-	-	-	-	11,408.3	88.1	2,925.7	760.6	15
85	Yes	285,815.6	189,782.7	- 96,032.9	- 2,590.6	690.8	- 571.6	63	27,565.5	- 0	51.2	14,445.5	3,433.2	98	65,962.8	193.7	2,590.6	1,099.4	60	-	-	-	-	-	30,070.1	187.9	7,668.5	2,004.7	15
86	Yes	256,493.8	189,782.7	- 66,711.1	- 2,324.8	890.9	- 397.1	69	40,727.9	0	1.7	10,056.7	3,733.5	97	61,610.4	0.9	1,983.0	880.1	70	-	-	-	-	-	5,100.7	1,010.4	2,840.0	1,700.2	3
87	No	216,965.4	-	- 216,965.4	- 2,287.5	- 508.2	- 1,291.5	-	-	- 0	119.3	6,961.8	2,494.3	12	183,841.5	6.0	1,985.6	1,225.6	150	-	-	-	-	-	33,123.9	150.5	5,355.6	1,577.3	21
88	Yes	195,799.2	130,603.2	- 65,196.1	- 1,774.7	481.2	- 388.1	63	19,353.7	- 0	13.8	7,818.7	1,875.0	124	8,519.0	35.4	1,160.7	567.9	15	-	-	-	-	-	56,677.0	115.9	5,038.4	1,453.3	39
89	Yes	134,351.6	189,782.7	55,431.1	- 1,217.8	1,755.1	329.9	84	108,078.8	0	11.0	15,215.2	6,249.6	144	2,235.2	314.7	493.5	372.5	6	- 57,666.3	- 5,038.4	- 5,038.4	- 1,696.1	34	-	-	-	-	-
90	Yes	144,013.4	189,782.7	45,769.3	- 1,305.3	1,686.8	272.4	84	102,582.0	0	259.9	14,342.0	5,604.2	147	2,395.9	337.3	529.0	399.3	6	- 48,165.2	- 6,003.9	- 6,003.9	- 2,006.9	24	-	-	-	-	-
91	Yes	295,926.0	261,206.3	- 34,719.7	- 2,682.2	1,630.2	- 206.7	78	86,312.3	- 0	141.0	19,162.9	7,406.2	154	4,923.3	693.2	1,086.9	820.6	6	- 150.5	- 150.5	- 150.5	- 150.5	1	29,946.9	113.1	6,003.9	2,722.4	11

Figure 66: Results current scenario (in kW) - summer week (2)

10.4 Results Future Scenario

Object	Prod	Cons: Total	Prod: Total	Diff Prod- Cons: Diff Prod-Cons	Diff Prod- Cons: Min	Diff Prod- Cons: Max	Diff Prod- Cons: Average	Diff Prod- Cons: No of occ.	Pot. Surplus: Total	Storage: Status End of week	Storage: Min	Storage: Max	Storage: Average	Storage: No of occ.	Missing: Total	Missing: Min	Missing: Max	Missing: Average	Missing: No of occ.	External To: Total	External To: Min	External To: Max	External To: Average	External To: No of occ.	External From: Total	External From: Min	External From: Max	External From: Average	External From: No of occ.
1	Yes	274,392.4	43,779.6	- 230,612.8	- 3,158.0	- 418.8	- 1,372.7	-	-	- 0	-	-	-	-	230,612.7	418.8	3,158.0	1,372.7	168	-	-	-	-	-	-	-	-	-	-
2	Yes	234,652.5	43,779.6	- 190,872.9	- 2,700.6	- 164.9	- 1,136.1	-	-	- 0	-	-	-	-	190,872.9	164.9	2,700.6	1,136.1	168	-	-	-	-	-	-	-	-	-	-
3	Yes	80,880.0	43,779.6	- 37,100.4	- 930.9	817.6	- 220.8	35	22,786.5	0	11.7	3,555.7	1,775.9	69	37,100.4	6.9	930.9	378.6	98	-	-	-	-	-	-	-	-	-	-
4	No	193,019.4	-	- 193,019.4	- 2,221.5	- 402.1	- 1,148.9	-	-	0	-	-	-	-	193,019.4	402.1	2,221.5	1,148.9	168	-	-	-	-	-	-	-	-	-	-
5	Yes	530,877.2	72,373.2	- 458,504.0	- 6,109.9	- 1,105.9	- 2,729.2	-	-	- 0	-	-	-	-	458,504.0	1,105.9	6,109.9	2,729.2	168	-	-	-	-	-	-	-	-	-	-
6	Yes	249,799.0	43,779.6	- 206,019.4	- 2,874.9	- 261.7	- 1,226.3	-	-	0	-	-	-	-	206,019.5	261.7	2,874.9	1,226.3	168	-	-	-	-	-	-	-	-	-	-
7	Yes	182,330.0	87,559.2	- 94,770.8	- 2,098.4	1,503.7	- 564.1	35	40,233.8	- 0	174.1	6,425.1	3,007.6	65	94,770.8	58.3	2,098.4	920.1	103	-	-	-	-	-	-	-	-	-	-
8	Yes	340,776.7	63,617.2	- 277,159.5	- 3,922.0	- 238.4	- 1,649.8	-	-	0	-	-	-	-	277,159.5	238.4	3,922.0	1,649.8	168	-	-	-	-	-	-	-	-	-	-
9	Yes	432,977.1	44,792.0	- 388,185.1	- 4,983.1	- 901.9	- 2,310.6	-	-	- 836	-	-	-	-	369,034.8	379.9	4,983.2	2,196.6	168	-	-	-	-	-	18,314.6	310.9	1,074.5	872.1	21
10	Yes	25,480.8	43,779.6	18,298.8	- 293.3	1,183.9	108.9	35	37,165.8	836	118.5	2,867.2	1,184.0	137	851.5	53.1	183.7	94.6	9	- 18,661.7	- 1,171.5	- 1,171.5	- 888.7	21	347.0	347.0	347.0	347.0	1
11	Yes	237,157.2	43,779.6	- 193,377.6	- 2,729.4	- 180.9	- 1,151.1	-	-	0	-	-	-	-	193,377.6	180.9	2,729.5	1,151.1	168	-	-	-	-	-	-	-	-	-	-
12	Yes	79,065.6	16,727.5	- 62,338.1	- 910.0	4.7	- 371.1	4	9.5	- 394	0.1	176.5	37.2	5	61,944.0	1.4	910.0	380.0	163	-	-	-	-	-	-	-	-	-	-
13	Yes	97,821.2	87,559.2	- 10,262.0	- 1,125.8	2,043.6	- 61.1	35	62,168.8	642	280.9	9,244.7	4,031.7	137	10,904.2	75.3	713.5	376.0	29	- 1,359.6	- 1,359.6	- 1,359.6	- 1,359.6	1	1,359.6	1,359.6	1,359.6	1,359.6	1
14	Yes	224,554.9	63,617.2	- 160,937.6	- 2,584.4	504.2	- 958.0	21	7,998.6	- 248	32.2	1,629.1	843.2	25	160,689.6	25.2	2,584.4	1,139.6	141	- 384.4	- 384.4	- 384.4	- 384.4	1	384.4	384.4	384.4	384.4	1
15	Yes	229,327.6	43,779.6	- 185,548.0	- 2,639.3	- 130.9	- 1,104.5	-	-	- 0	-	-	-	-	185,548.0	130.9	2,639.3	1,104.5	168	-	-	-	-	-	-	-	-	-	-
16	Yes	139,257.1	63,617.2	- 75,639.9	- 1,602.7	1,049.2	- 450.2	35	27,471.8	0	306.7	4,441.9	2,162.2	59	75,640.0	211.2	1,602.7	693.9	109	-	-	-	-	-	-	-	-	-	-
17	Yes	110,384.1	63,617.2	- 46,766.9	- 1,270.4	1,233.7	- 278.4	35	34,966.0	- 0	493.1	5,405.2	2,738.4	73	46,766.8	229.9	1,270.4	492.3	95	-	-	-	-	-	-	-	-	-	-
18	Yes	126,615.3	87,559.2	- 39,056.1	- 1,457.2	1,859.7	- 232.5	35	54,695.0	0	510.9	8,284.0	4,243.2	86	39,056.2	108.0	1,192.6	476.3	82	-	-	-	-	-	-	-	-	-	-
19	Yes	147,915.1	87,559.2	- 60,355.9	- 1,702.4	1,723.6	- 359.3	35	49,166.5	- 0	21.1	7,573.3	3,879.8	74	60,355.9	216.8	1,702.4	642.1	94	-	-	-	-	-	-	-	-	-	-
20	Yes	319,831.9	87,559.2	- 232,272.7	- 3,681.0	625.2	- 1,382.6	20	9,517.9	0	437.7	1,954.6	1,233.8	20	232,272.7	37.5	3,681.0	1,569.4	148	-	-	-	-	-	-	-	-	-	-
21	Yes	157,401.4	63,617.2	- 93,784.2	- 1,811.5	933.3	- 558.2	35	22,762.3	0	171.0	3,836.5	1,794.2	52	93,784.2	22.7	1,811.5	808.5	116	-	-	-	-	-	-	-	-	-	-
22	Yes	909,421.6	63,617.2	- 845,804.3	- 10,466.6	- 1,894.4	- 5,034.5	-	-	0	-	-	-	-	845,804.4	1,894.4	10,466.6	5,034.5	168	-	-	-	-	-	-	-	-	-	-
23	Yes	484,175.5	39,775.6	- 444,399.9	- 5,572.4	- 1,008.6	- 2,645.2	-	-	0	-	-	-	-	444,399.9	1,008.6	5,572.4	2,645.2	168	-	-	-	-	-	-	-	-	-	-
24	Yes	185,584.2	87,559.2	- 98,024.9	- 2,135.9	1,482.9	- 583.5	35	39,389.2	0	26.9	6,316.5	2,981.6	63	98,025.0	9.8	2,135.9	933.6	105	-	-	-	-	-	-	-	-	-	-
25	Yes	480,842.4	63,617.2	- 417,225.2	- 5,534.0	- 1,001.6	- 2,483.5	-	-	0	-	-	-	-	417,225.2	1,001.6	5,534.0	2,483.5	168	-	-	-	-	-	-	-	-	-	-
26	Yes	152,687.8	87,559.2	- 65,128.6	- 1,757.3	1,693.1	- 387.7	35	47,927.7	- 0	619.4	7,414.1	3,738.0	73	65,128.6	318.1	1,757.3	685.6	95	-	-	-	-	-	-	-	-	-	-
27	Yes	80,465.8	63,617.2	- 16,848.6	- 926.1	1,424.8	- 100.3	35	42,731.6	- 0	1.2	6,403.5	2,885.9	113	16,848.6	25.5	586.9	306.3	55	-	-	-	-	-	-	-	-	-	-
28	Yes	122,848.4	43,779.6	- 79,068.8	- 1,413.9	549.4	- 470.6	33	11,958.2	- 0	51.4	2,155.4	945.8	45	79,068.8	3.3	1,413.9	642.8	123	-	-	-	-	-	-	-	-	-	-
29	No	907.2	-	- 907.2	- 10.4	- 1.9	- 5.4	-	-	0	-	-	-	-	907.3	1.9	10.4	5.4	168	-	-	-	-	-	-	-	-	-	-
30	Yes	301,628.5	43,779.6	- 257,848.9	- 3,471.5	- 592.9	- 1,534.8	-	-	- 0	-	-	-	-	257,848.9	592.9	3,471.5	1,534.8	168	-	-	-	-	-	-	-	-	-	-
31	No	7,691.6	-	- 7,691.6	- 88.5	- 16.0	- 45.8	-	-	0	-	-	-	-	7,691.6	16.0	88.5	45.8	168	-	-	-	-	-	-	-	-	-	-
32	Yes	84,706.1	63,617.2	- 21,088.8	- 974.9	1,397.7	- 125.5	35	41,631.0	0	121.8	6,262.0	3,062.4	98	21,088.9	40.6	622.4	301.3	70	-	-	-	-	-	-	-	-	-	-
33	Yes	93,087.9	63,617.2	- 29,470.7	- 1,071.4	1,344.2	- 175.4	35	39,455.4	- 0	267.6	5,982.3	3,030.2	86	29,470.7	187.5	876.8	359.4	82	-	-	-	-	-	-	-	-	-	-
34	Yes	149,157.6	43,779.6	- 105,378.0	- 1,716.7	381.3	- 627.2	28	6,335.8	- 0	1.1	1,277.6	526.2	34	105,378.0	101.0	1,716.7	786.4	134	-	-	-	-	-	-	-	-	-	-
35	Yes	397,418.3	87,559.2	- 309,859.1	- 4,573.9	129.4	- 1,844.4	5	571.3	0	4.5	129.4	76.1	9	309,859.1	11.2	4,573.9	1,948.8	159	-	-	-	-	-	-	-	-	-	-
36	No	66,877.4	-	- 66,877.4	- 769.7	- 139.3	- 398.1	-	-	- 0	-	-	-	-	66,877.4	139.3	769.7	398.1	168	-	-	-	-	-	-	-	-	-	-
37	Yes	152,549.8	63,617.2	- 88,932.5	- 1,755.7	964.3	- 529.4	35	24,021.6	- 0	110.9	3,998.4	1,758.1	58	88,932.5	317.8	1,755.7	808.5	110	-	-	-	-	-	-	-	-	-	-
38	Yes	80,525.0	63,617.2	- 16,907.7	- 926.8	1,424.4	- 100.6	35	42,716.2	0	21.5	6,401.5	2,908.0	112	16,907.8	5.5	587.3	301.9	56	-	-	-	-	-	-	-	-	-	-
39	Yes	172,587.4	63,617.2	- 108,970.1	- 1,986.3	836.2	- 648.6	35	18,820.6	- 0	120.8	3,329.9	1,380.6	51	108,970.1	359.5	1,986.3	931.4	117	-	-	-	-	-	-	-	-	-	-
40	Yes	67,469.0	43,779.6	- 23,689.4	- 776.5	903.2	- 141.0	35	26,267.4	- 0	307.9	4,003.1	2,072.5	80	23,689.4	63.7	635.5	269.2	88	-	-	-	-	-	-	-	-	-	-
41	No	52,460.6	-	- 52,460.6	- 603.8	- 109.3	- 312.3	-	-	- 982	80.8	582.7	331.8	2	51,478.6	109.3	603.8	310.1	166	-	-	-	-	-	-	-	-	-	-
42	Yes	95,020.7	87,559.2	- 7,461.5	- 1,093.6	2,061.5	- 44.4	35	62,895.7	982	32.9	9,338.1	4,089.2	141	8,443.4	4.2	693.0	337.7	25	- 1,378.2	- 1,378.2	- 1,378.2	- 1,378.2	1	1,378.2	1,378.2	1,378.2	1,378.2	1
43	Yes	225,225.4	91,462.9	- 133,762.5	- 2,592.1	1,348.6	- 796.2	35	33,003.6	0	29.4	5,551.5	2,562.8	53	133,762.6	10.0	2,592.1	1,163.2	115	-	-	-	-	-	-	-	-	-	-
44	Yes	76,777.8	43,779.6	- 32,998.2	- 883.6	843.8	- 196.4	35	23,851.2	0	275.9	3,692.6	1,851.3	73	32,998.2	159.9	883.6	347.3	95	-	-	-	-	-	-	-	-	-	-
45	Yes	79,183.9	43,779.6	- 35,404.3	- 911.3	828.4	- 210.7	35	23,226.7	0	88.6	3,612.3	1,753.2	73	35,404.3	165.0	911.3	372.7	95	-	-	-	-	-	-	-	-	-	-

Figure 67: Results future scenario (in kW) - winter week (1)

Object		Cons	Prod	Diff Prod- Cons					Pot. Surplus	Storage					Missing					External To					External From				
	Prod	Total	Total	Diff Prod- Cons	Min	Max	Average	No of occ.	Total	Status End of week	Min	Max	Average	No of occ.	Total	Min	Max	Average	No of occ.	Total	Min	Max	Average	No of occ.	Total	Min	Max	Average	No of occ.
46	Yes	152,096.2	87,559.2	- 64,537.0	- 1,750.5	1,696.9	- 384.1	35	48,081.3	0	665.5	7,433.8	3,762.1	73	64,537.0	316.8	1,750.5	679.3	95	-	-	-	-	-	-	-	-	-	-
47	Yes	130,993.6	63,617.2	- 67,376.4	- 1,507.6	1,102.0	- 401.0	35	29,616.7	0	59.7	4,717.6	2,206.1	66	67,376.4	272.9	1,507.6	660.6	102	-	-	-	-	-	-	-	-	-	-
48	No	84,370.8	-	- 84,370.8	- 971.0	- 175.8	- 502.2	-	-	- 0	-	-	-	-	84,370.8	175.8	971.0	502.2	168	-	-	-	-	-	-	-	-	-	-
49	Yes	136,732.7	43,779.6	- 92,953.1	- 1,573.7	460.7	- 553.3	30	8,832.2	- 1,547	8.0	4,736.6	2,644.0	61	72,667.0	48.5	1,573.7	679.1	107	-	-	-	-	-	18,738.8	244.6	1,802.9	1,338.5	14
50	Yes	69,599.0	87,559.2	17,960.2	- 801.0	2,236.3	106.9	35	69,494.2	1,547	323.8	7,831.4	3,289.4	144	2,325.9	145.0	501.7	258.4	9	- 20,770.8	- 2,032.0	- 2,032.0	- 1,384.7	15	2,032.0	2,032.0	2,032.0	2,032.0	1
51	Yes	82,102.7	63,617.2	- 18,485.5	- 944.9	1,414.4	- 110.0	35	42,306.7	0	20.6	6,348.8	2,946.2	107	18,485.5	6.4	598.8	303.0	61	-	-	-	-	-	-	-	-	-	-
52	Yes	160,182.2	63,617.2	- 96,565.0	- 1,843.5	915.5	- 574.8	35	22,040.5	- 0	13.5	3,743.7	1,711.2	52	96,564.9	183.7	1,843.5	832.5	116	-	-	-	-	-	-	-	-	-	-
53	Yes	78,296.4	87,559.2	9,262.8	- 901.1	2,174.9	55.1	35	67,236.7	695	364.2	8,810.1	3,598.9	152	2,616.5	163.1	564.4	290.7	9	- 11,184.2	- 1,163.8	- 1,163.8	- 588.6	19	-	-	-	-	-
54	No	104,487.2	-	- 104,487.2	- 1,202.5	- 217.7	- 621.9	-	-	- 695	-	-	-	-	92,607.9	119.6	1,202.6	597.5	155	-	-	-	-	-	11,184.2	52.1	1,163.8	588.6	19
55	No	60,507.1	-	- 60,507.1	- 696.4	- 126.0	- 360.2	-	-	- 0	-	-	-	-	60,046.7	126.0	696.4	359.6	167	-	-	-	-	-	460.4	460.4	460.4	460.4	1
56	Yes	97,170.4	87,559.2	- 9,611.2	- 1,118.3	2,047.8	- 57.2	35	62,337.8	261	8.4	9,266.4	4,038.9	138	10,332.3	8.8	708.7	369.0	28	- 1,824.3	- 1,363.9	- 1,363.9	- 912.2	2	1,363.9	1,363.9	1,363.9	1,363.9	1
57	No	55,556.9	-	- 55,556.9	- 639.4	- 115.7	- 330.7	-	-	- 261	-	-	-	-	55,296.2	115.7	639.4	329.1	168	-	-	-	-	-	-	-	-	-	-
58	Yes	83,443.8	43,779.6	- 39,664.2	- 960.4	801.2	- 236.1	35	22,121.0	- 133	60.0	3,470.2	1,776.0	66	39,530.9	143.0	960.4	391.4	101	- 450.1	- 450.1	- 450.1	- 450.1	1	450.1	450.1	450.1	450.1	1
59	Yes	75,752.3	63,617.2	- 12,135.0	- 871.8	1,454.9	- 72.2	35	43,955.1	0	18.8	6,560.7	2,801.4	130	12,034.0	7.9	552.5	325.2	37	-	-	-	-	-	101.0	101.0	101.0	101.0	1
60	Yes	95,592.6	87,559.2	- 8,033.4	- 1,100.2	2,057.9	- 47.8	35	62,747.3	812	194.4	9,319.0	4,121.6	139	8,945.9	4.5	697.2	331.3	27	- 1,475.4	- 1,374.4	- 1,374.4	- 737.7	2	1,374.4	1,374.4	1,374.4	1,374.4	1
61	Yes	46,090.3	43,779.6	- 2,310.7	- 530.5	1,039.8	- 13.8	35	31,816.4	324	22.8	4,716.4	2,093.4	145	2,974.0	1.0	332.2	141.6	21	- 1,037.8	- 698.5	- 698.5	- 518.9	2	698.5	698.5	698.5	698.5	1
62	No	17,690.6	-	- 17,690.6	- 203.6	- 36.9	- 105.3	-	-	- 1,002	122.2	698.3	330.1	6	16,349.1	36.9	203.6	102.8	159	- 189.3	- 189.3	- 189.3	- 189.3	1	528.6	189.3	339.3	264.3	2
63	Yes	135,963.6	63,617.2	- 72,346.3	- 1,564.8	1,070.2	- 430.6	35	28,326.7	- 0	8.8	4,551.8	2,234.2	60	72,346.3	1.5	1,564.8	669.9	108	-	-	-	-	-	-	-	-	-	-
64	Yes	205,700.6	43,779.6	- 161,921.0	- 2,367.4	20.1	- 963.8	5	61.0	0	4.4	20.1	12.2	5	161,921.0	56.6	2,367.4	993.4	163	-	-	-	-	-	-	-	-	-	-
65	Yes	373,180.0	114,009.4	- 259,170.6	- 4,294.9	1,090.5	- 1,542.7	29	19,490.1	0	105.6	3,836.0	1,720.4	34	259,170.6	118.1	4,294.9	1,934.1	134	-	-	-	-	-	-	-	-	-	-
66	Yes	338,942.5	87,559.2	- 251,383.3	- 3,900.9	503.1	- 1,496.3	20	6,950.1	0	316.3	1,444.2	919.5	20	251,383.4	209.5	3,900.9	1,698.5	148	-	-	-	-	-	-	-	-	-	-
67	Yes	227,730.1	87,559.2	- 140,170.9	- 2,621.0	1,213.6	- 834.4	35	28,449.8	0	242.4	4,910.3	2,187.9	51	140,170.9	393.0	2,621.0	1,198.0	117	-	-	-	-	-	-	-	-	-	-
68	Yes	427,110.6	87,559.2	- 339,551.4	- 3,892.4	226.6	- 2,021.1	5	798.6	0	185.4	798.6	505.3	5	339,551.5	889.1	3,892.4	2,083.1	163	-	-	-	-	-	-	-	-	-	-
69	Yes	255,064.8	36,765.7	- 218,299.1	- 2,935.5	- 509.1	- 1,299.4	-	-	0	-	-	-	-	218,299.1	509.1	2,935.6	1,299.4	168	-	-	-	-	-	-	-	-	-	-
70	No	242,344.1	-	- 242,344.1	- 2,789.1	- 504.8	- 1,442.5	-	-	- 0	-	-	-	-	242,344.0	504.8	2,789.2	1,442.5	168	-	-	-	-	-	-	-	-	-	-
71	No	136,752.5	-	- 136,752.5	- 1,573.9	- 284.9	- 814.0	-	-	- 0	-	-	-	-	136,752.5	284.9	1,573.9	814.0	168	-	-	-	-	-	-	-	-	-	-
72	Yes	436,684.9	134,184.5	- 302,500.4	- 5,025.8	1,299.6	- 1,800.6	29	23,452.3	- 0	141.3	4,599.3	2,083.0	34	302,500.3	115.0	5,025.8	2,257.5	134	-	-	-	-	-	-	-	-	-	-
73	Yes	102,732.0	43,779.6	- 58,952.4	- 1,182.3	677.9	- 350.9	35	17,114.6	- 0	207.6	2,826.6	1,283.6	58	58,952.3	214.0	1,182.4	535.9	110	-	-	-	-	-	-	-	-	-	-
74	Yes	415,345.6	43,779.6	- 371,566.0	- 4,780.2	- 865.2	- 2,211.7	-	-	- 0	-	-	-	-	371,566.0	865.2	4,780.2	2,211.7	168	-	-	-	-	-	-	-	-	-	-
75	No	347,521.6	-	- 347,521.6	- 3,999.6	- 723.9	- 2,068.6	-	-	- 0	-	-	-	-	347,521.6	723.9	3,999.6	2,068.6	168	-	-	-	-	-	-	-	-	-	-
76	No	29,247.7	-	- 29,247.7	- 336.6	- 60.9	- 174.1	-	-	- 0	-	-	-	-	29,247.7	60.9	336.6	174.1	168	-	-	-	-	-	-	-	-	-	-
77	Yes	444,396.2	87,559.2	- 356,836.9	- 5,114.6	- 170.7	- 2,124.0	-	-	0	-	-	-	-	356,837.0	170.7	5,114.6	2,124.0	168	-	-	-	-	-	-	-	-	-	-
78	Yes	267,470.0	43,779.6	- 223,690.4	- 3,078.3	- 374.6	- 1,331.5	-	-	0	-	-	-	-	223,690.4	374.6	3,078.3	1,331.5	168	-	-	-	-	-	-	-	-	-	-
79	No	68,356.5	-	- 68,356.5	- 786.7	- 142.4	- 406.9	-	-	- 0	-	-	-	-	68,356.4	142.4	786.7	406.9	168	-	-	-	-	-	-	-	-	-	-
80	Yes	298,177.1	63,617.2	- 234,559.9	- 3,431.7	33.8	- 1,396.2	5	112.1	0	11.2	33.8	22.4	5	234,560.0	77.6	3,431.7	1,439.0	163	-	-	-	-	-	-	-	-	-	-
81	Yes	251,574.0	87,559.2	- 164,014.8	- 2,895.4	1,061.3	- 976.3	33	22,523.1	0	24.3	4,114.8	1,780.6	44	164,014.8	104.5	2,895.4	1,322.7	124	-	-	-	-	-	-	-	-	-	-
82	Yes	194,261.8	63,617.2	- 130,644.6	- 2,235.8	697.7	- 777.6	30	13,773.5	0	66.9	2,606.7	1,120.9	40	130,644.6	17.6	2,235.8	1,020.7	128	-	-	-	-	-	-	-	-	-	-
83	No	273,228.8	-	- 273,228.8	- 3,144.6	- 569.2	- 1,626.4	-	-	- 0	-	-	-	-	273,228.8	569.2	3,144.6	1,626.4	168	-	-	-	-	-	-	-	-	-	-
84	Yes	190,080.8	43,779.6	- 146,301.2	- 2,187.6	119.8	- 870.8	15	806.2	- 0	27.3	183.7	120.9	20	146,301.2	259.3	2,187.7	988.5	148	-	-	-	-	-	-	-	-	-	-
85	Yes	351,801.3	63,617.2	- 288,184.1	- 4,048.9	- 308.8	- 1,715.4	-	-	- 0	-	-	-	-	288,184.0	308.8	4,048.9	1,715.4	168	-	-	-	-	-	-	-	-	-	-
86	Yes	315,710.0	63,617.2	- 252,092.8	- 3,633.5	- 78.2	- 1,500.6	-	-	0	-	-	-	-	252,092.8	78.2	3,633.5	1,500.6	168	-	-	-	-	-	-	-	-	-	-
87	No	267,055.8	-	- 267,055.8	- 3,073.6	- 556.3	- 1,589.6	-	-	- 0	-	-	-	-	267,055.8	556.3	3,073.6	1,589.6	168	-	-	-	-	-	-	-	-	-	-
88	Yes	241,003.0	43,779.6	- 197,223.4	- 2,773.7	- 205.5	- 1,173.9	-	-	- 0	-	-	-	-	197,223.4	205.5	2,773.7	1,173.9	168	-	-	-	-	-	-	-	-	-	-
89	Yes	165,369.1	63,617.2	- 101,751.9	- 1,903.2	882.3	- 605.7	35	20,694.2	- 0	176.8	3,570.7	1,592.3	51	101,751.9	280.4	1,903.2	869.7	117	-	-	-	-	-	-	-	-	-	-
90	Yes	177,261.5	63,617.2	- 113,644.2	- 2,040.1	806.4	- 676.5	33	17,673.7	0	4.8	3,173.9	1,295.6	49	113,644.2	21.9	2,040.1	955.0	119	-	-	-	-	-	-	-	-	-	-
91	Yes	364,245.9	87,559.2	- 276,686.7	- 4,192.1	341.4	- 1,646.9	20	3,550.3	0	155.6	768.2	503.5	20	276,686.7	412.7	4,192.1	1,869.5	148	-	-	-	-	-	-	-	-	-	-

Figure 68: Results future scenario (in kW) - winter week (2)

Object	Prod	Cons Total	Prod Total	Diff Prod- Cons: Diff Prod-Cons	Diff Prod- Cons: Min	Diff Prod- Cons: Max	Diff Prod- Cons: Average	Diff Prod- Cons: No of occ.	Pot. Surplus: Total	Storage: Status End of week	Storage: Min	Storage: Max	Storage: Average	Storage: No of occ.
1	Yes	246,080.2	166,414.4	- 79,665.8	- 2,510.0	739.9	- 474.2	64	30,708.2	0	138.6	8,603.0	2,913.0	138
2	Yes	210,440.8	166,414.4	- 44,026.4	- 2,146.5	985.5	- 262.1	78	48,062.6	0	84.4	12,964.0	5,178.2	148
3	Yes	72,534.7	166,414.4	93,879.7	- 739.9	1,935.8	558.8	84	125,142.2	- 0	161.4	21,052.2	7,338.3	152
4	No	173,103.4	-	- 173,103.4	- 1,845.4	- 384.4	- 1,030.4	-	-	0	111.7	20,348.2	4,827.4	134
5	Yes	476,100.6	275,103.8	- 200,996.8	- 4,856.2	896.8	- 1,196.4	48	23,971.1	0	191.8	17,139.1	5,672.7	136
6	Yes	224,024.4	166,414.4	- 57,610.0	- 2,285.1	891.9	- 342.9	74	40,799.4	- 0	137.0	14,853.8	5,312.9	144
7	Yes	163,517.0	332,828.8	169,311.8	- 1,667.9	3,744.5	1,007.8	84	239,787.8	- 0	125.3	26,894.9	10,579.2	148
8	Yes	305,614.9	241,820.9	- 63,794.0	- 3,117.3	1,433.3	- 379.7	78	69,938.6	0	116.0	20,822.2	7,530.1	150
9	Yes	388,301.9	170,262.7	- 218,039.2	- 3,960.7	239.7	- 1,297.9	1	239.7	0	154.4	14,267.3	4,169.3	124
10	Yes	22,851.7	166,414.4	143,562.7	- 233.1	2,278.2	854.5	84	153,411.8	- 0	50.9	19,696.0	7,770.4	144
11	Yes	212,687.0	166,414.4	- 46,272.6	- 2,169.4	970.0	- 275.4	78	46,857.4	0	69.1	14,506.3	4,620.7	152
12	Yes	70,907.5	63,584.2	- 7,323.3	- 723.3	442.0	- 43.6	78	23,460.5	0	29.9	4,454.4	1,850.0	151
13	Yes	87,727.9	332,828.8	245,100.9	- 894.8	4,266.8	1,458.9	84	282,911.7	12,141	239.1	37,885.9	12,462.4	145
14	Yes	201,385.0	241,820.9	40,435.9	- 2,054.1	2,151.5	240.7	84	127,233.0	7,268	207.1	17,750.5	8,018.5	151
15	Yes	205,665.3	166,414.4	- 39,250.9	- 2,097.8	1,018.4	- 233.6	78	50,625.0	- 0	111.5	13,982.2	5,124.3	150
16	Yes	124,888.4	241,820.9	116,932.5	- 1,273.9	2,678.7	696.0	84	170,759.5	18,883	278.0	32,781.9	12,824.1	153
17	Yes	98,994.5	241,820.9	142,826.4	- 1,009.7	2,857.1	850.2	84	185,493.1	35,475	270.9	39,634.5	16,143.7	155
18	Yes	113,551.0	332,828.8	219,277.8	- 1,158.2	4,088.8	1,305.2	84	268,218.4	24,886	252.7	29,657.7	7,746.7	145
19	Yes	132,653.0	332,828.8	200,175.8	- 1,353.1	3,957.2	1,191.5	84	257,349.3	0	295.2	35,188.6	9,266.4	150
20	Yes	286,831.2	332,828.8	45,997.6	- 2,925.7	2,894.7	273.8	84	169,622.1	- 0	233.0	23,439.4	8,743.7	150
21	Yes	141,160.5	241,820.9	100,660.4	- 1,439.8	2,566.5	599.2	84	161,500.7	- 0	314.2	27,558.8	7,435.9	145
22	Yes	815,586.2	241,820.9	- 573,765.3	- 8,319.0	- 548.9	- 3,415.3	-	-	0	115.9	53,301.0	18,035.9	146
23	Yes	434,217.6	151,194.4	- 283,023.2	- 4,429.0	- 88.2	- 1,684.7	-	-	- 0	307.5	31,662.8	8,539.0	138
24	Yes	166,435.3	332,828.8	166,393.5	- 1,697.6	3,724.4	990.4	84	238,127.2	0	370.4	22,273.8	6,687.7	141
25	Yes	431,228.5	241,820.9	- 189,407.6	- 4,398.5	745.5	- 1,127.4	47	17,157.0	- 0	142.9	35,049.2	12,765.2	145
26	Yes	136,933.3	332,828.8	195,895.5	- 1,396.7	3,927.7	1,166.0	84	254,913.8	4,648	304.8	29,238.8	9,401.4	146
27	Yes	72,163.2	241,820.9	169,657.7	- 736.1	3,042.0	1,009.9	84	200,760.1	65,389	2,285.9	68,421.2	31,066.5	159
28	Yes	110,172.8	166,414.4	56,241.6	- 1,123.8	1,676.4	334.8	84	103,726.2	30,274	762.0	38,789.6	19,069.0	161
29	No	813.6	-	- 813.6	- 8.7	- 1.8	- 4.8	-	-	0	3.9	735.9	356.4	160
30	Yes	270,506.1	166,414.4	- 104,091.7	- 2,759.2	601.4	- 619.6	56	20,422.4	0	1.0	29,175.7	9,320.1	145
31	No	6,898.0	-	- 6,898.0	- 73.5	- 15.3	- 41.1	-	-	0	45.2	6,320.5	3,133.8	156
32	Yes	75,966.0	241,820.9	165,854.9	- 774.9	3,015.8	987.2	84	198,596.3	87,342	2,159.4	90,774.9	41,593.2	159
33	Yes	83,483.0	241,820.9	158,337.9	- 851.5	2,964.0	942.5	84	194,319.2	159,654	775.2	163,162.3	84,895.2	162
34	Yes	133,767.3	166,414.4	32,647.1	- 1,364.4	1,513.8	194.3	84	90,300.9	13,947	601.2	20,358.0	10,662.8	161
35	Yes	356,412.2	332,828.8	- 23,583.4	- 3,635.4	2,415.2	- 140.4	78	130,717.4	2,557	49.0	23,865.9	9,612.9	152
36	No	59,976.9	-	- 59,976.9	- 639.4	- 133.2	- 357.0	-	-	- 0	165.4	20,270.0	6,045.1	151
37	Yes	136,809.5	241,820.9	105,011.4	- 1,395.5	2,596.5	625.1	84	163,976.4	48,427	222.1	54,175.7	24,071.7	160
38	Yes	72,216.3	241,820.9	169,604.6	- 736.6	3,041.7	1,009.6	84	200,729.9	170,743	830.2	173,777.9	90,412.8	162
39	Yes	154,779.6	241,820.9	87,041.4	- 1,578.8	2,472.7	518.1	84	153,751.5	89,482	427.2	95,985.8	49,979.2	162
40	Yes	60,507.5	166,414.4	105,906.9	- 617.2	2,018.7	630.4	84	131,985.7	106,861	518.6	109,403.6	56,925.5	162
41	No	47,047.6	-	- 47,047.6	- 501.6	- 104.5	- 280.0	-	-	- 0	227.0	37,405.7	16,581.4	156
42	Yes	85,216.3	332,828.8	247,612.5	- 869.2	4,284.1	1,473.9	84	284,340.8	202,651	982.2	206,231.3	92,374.8	162
43	Yes	201,986.3	347,667.4	145,681.1	- 2,060.3	3,696.6	867.1	84	232,737.3	148,866	714.4	157,353.5	81,915.0	162
44	Yes	68,855.8	166,414.4	97,558.6	- 702.3	1,961.2	580.7	84	127,235.5	98,644	477.8	101,537.7	52,837.1	162
45	Yes	71,013.6	166,414.4	95,400.8	- 724.3	1,946.3	567.9	84	126,007.7	96,521	467.3	99,504.6	51,780.3	162

Object	Missing: Total	Missing: Min	Missing: Max	Missing: Average	Missing: No of occ.	External To: Total	External To: Min	External To: Max	External To: Average	External To: No of occ.	External From: Total	External From: Min	External From: Max	External From: Average	External From: No of occ.
1	3,880.4	558.1	861.4	646.7	6	-	-	-	-	-	75,785.4	151.2	9,000.1	2,806.9	27
2	3,318.4	477.2	736.6	553.1	6	-	-	-	-	-	40,708.0	14.5	7,062.6	2,035.4	20
3	1,143.8	164.5	253.9	190.6	6	- 95,023.5	-	- 10,049.6	- 3,393.7	28	-	-	-	-	-
4	2,729.7	392.6	605.9	454.9	6	-	-	-	-	-	170,373.7	385.3	21,657.0	3,872.1	44
5	7,507.6	1,079.7	1,666.6	1,251.3	6	-	-	-	-	-	193,489.2	190.3	11,814.1	4,116.8	47
6	3,532.6	508.0	784.2	588.8	6	-	-	-	-	-	54,077.4	7.8	10,707.5	2,846.2	19
7	2,578.5	370.8	572.4	429.7	6	- 171,890.4	- 12,540.8	- 12,540.8	- 3,736.7	46	-	-	-	-	-
8	4,819.2	693.1	1,069.8	803.2	6	-	-	-	-	-	58,974.8	303.5	11,575.9	4,212.5	14
9	6,123.1	880.6	1,359.2	1,020.5	6	-	-	-	-	-	211,916.1	80.3	12,635.4	3,418.0	62
10	360.3	51.8	80.0	60.1	6	- 143,923.1	- 12,635.4	- 12,635.4	- 3,062.2	47	-	-	-	-	-
11	3,353.9	482.3	744.5	559.0	6	-	-	-	-	-	42,918.8	220.4	9,931.6	3,901.7	11
12	1,118.1	160.8	248.2	186.4	6	- 190.3	- 190.3	- 190.3	- 190.3	1	6,395.5	16.1	1,672.9	639.6	10
13	1,383.4	198.9	307.1	230.6	6	- 234,343.6	- 21,657.0	- 21,657.0	- 4,421.6	53	-	-	-	-	-
14	3,175.6	456.7	704.9	529.3	6	- 36,343.9	- 4,737.2	- 4,737.2	- 1,652.0	22	-	-	-	-	-
15	3,243.1	466.4	719.9	540.5	6	-	-	-	-	-	36,007.7	182.4	8,818.8	2,769.8	13
16	1,969.3	283.2	437.2	328.2	6	- 100,019.3	- 18,750.4	- 18,750.4	- 3,846.9	26	-	-	-	-	-
17	1,561.0	224.5	346.5	260.2	6	- 108,912.6	- 13,536.3	- 13,536.3	- 4,356.5	25	-	-	-	-	-
18	1,790.6	257.5	397.5	298.4	6	- 196,182.0	- 21,273.1	- 21,273.1	- 9,342.0	21	-	-	-	-	-
19	2,091.8	300.8	464.3	348.6	6	- 202,267.5	- 29,001.5	- 29,001.5	- 14,447.7	14	-	-	-	-	-
20	4,523.0	650.5	1,004.0	753.8	6	- 50,520.6	- 10,082.0	- 10,082.0	- 2,971.8	17	-	-	-	-	-
21	2,226.0	320.1	494.1	371.0	6	- 102,886.4	- 18,915.7	- 18,915.7	- 5,415.1	19	-	-	-	-	-
22	12,860.9	1,849.5	2,854.9	2,143.5	6	-	-	-	-	-	560,904.4	19.9	32,660.6	10,198.3	55
23	6,847.1	984.7	1,520.0	1,141.2	6	-	-	-	-	-	276,176.0	1,236.5	16,945.2	6,276.7	44
24	2,624.5	377.4	582.6	437.4	6	- 169,018.0	- 16,945.2	- 16,945.2	- 6,500.7	26	-	-	-	-	-
25	6,800.0	977.9	1,509.5	1,133.3	6	-	-	-	-	-	182,607.5	270.8	38,526.6	6,521.7	28
26	2,159.3	310.5	479.3	359.9	6	- 193,406.8	- 14,935.1	- 14,935.1	- 4,604.9	42	-	-	-	-	-
27	1,137.9	163.7	252.6	189.7	6	- 105,406.7	- 32,437.4	- 32,437.4	- 8,108.2	13	-	-	-	-	-
28	1,737.3	249.8	385.7	289.5	6	- 27,704.9	- 26,688.0	- 26,688.0	- 9,235.0	3	-	-	-	-	-
29	12.8	1.9	2.9	2.1	6	-	-	-	-	-	800.8	59.9	740.8	400.4	2
30	4,265.6	613.4	946.9	710.9	6	-	-	-	-	-	99,826.1	6.3	29,247.3	4,991.3	20
31	108.8	15.6	24.2	18.1	6	-	-	-	-	-	6,789.2	33.3	6,368.3	1,131.5	6
32	1,197.9	172.3	265.9	199.7	6	- 79,711.1	- 29,247.3	- 29,247.3	- 3,465.7	23	-	-	-	-	-
33	1,316.4	189.3	292.2	219.4	6	-	-	-	-	-	-	-	-	-	-
34	2,109.4	303.4	468.2	351.6	6	- 20,809.4	- 8,103.9	- 8,103.9	- 1,891.8	11	-	-	-	-	-
35	5,620.2	808.3	1,247.6	936.7	6	- 289.4	- 289.4	- 289.4	- 289.4	1	20,809.4	85.7	8,103.9	1,891.8	11
36	945.8	136.0	210.0	157.6	6	-	-	-	-	-	59,031.1	289.4	20,630.9	4,540.9	13
37	2,157.3	310.3	478.9	359.6	6	- 58,741.7	- 20,630.9	- 20,630.9	- 4,895.1	12	-	-	-	-	-
38	1,138.8	163.8	252.8	189.8	6	-	-	-	-	-	-	-	-	-	-
39	2,440.7	351.0	541.8	406.8	6	-	-	-	-	-	-	-	-	-	-
40	954.1	137.2	211.8	159.0	6	-	-	-	-	-	-	-	-	-	-
41	741.9	106.7	164.7	123.6	6	-	-	-	-	-	46,305.7	229.7	37,773.8	7,717.6	6
42	1,343.8	193.3	298.3	224.0	6	- 46,305.7	- 37,773.8	- 37,773.8	- 7,717.6	6	-	-	-	-	-
43	3,185.1	458.1	707.0	530.9	6	-	-	-	-	-	-	-	-	-	-
44	1,085.8	156.2	241.0	181.0	6	-	-	-	-	-	-	-	-	-	-
45	1,119.8	161.0	248.6	186.6	6	-	-	-	-	-	-	-	-	-	-

Figure 69: Results future scenario (in kW) - transition week (1)

Object	Prod	Cons	Prod	Diff Prod- Cons					Pot. Surplus	Storage					Missing					External To					External From				
		Total	Total	Diff Prod-Cons	Min	Max	Average	No of occ.	Total	Status End of week	Min	Max	Average	No of occ.	Total	Min	Max	Average	No of occ.	Total	Min	Max	Average	No of occ.	Total	Min	Max	Average	No of occ.
46	Yes	136,402.7	332,828.8	196,426.1	- 1,391.3	3,931.3	1,169.2	84	255,215.8	198,577	962.0	204,308.6	106,315.1	162	2,150.9	309.3	477.5	358.5	6	-	-	-	-	-	-	-	-	-	-
47	Yes	117,477.5	241,820.9	124,343.4	- 1,198.3	2,729.8	740.1	84	174,976.3	51,939	320.2	56,875.4	22,401.1	161	1,852.5	266.4	411.2	308.7	6	- 74,256.8	- 30,860.4	- 30,860.4	- 3,094.0	24	-	-	-	-	-
48	No	75,665.3	-	- 75,665.3	- 806.7	- 168.0	- 450.4	-	-	- 0	365.1	30,599.5	10,657.2	139	1,193.2	171.6	264.9	198.9	6	-	-	-	-	-	74,472.1	369.3	30,860.4	3,103.0	24
49	Yes	122,624.5	166,414.4	43,789.9	- 1,250.8	1,590.6	260.7	84	96,641.2	45,508	677.1	50,660.9	26,453.0	161	1,933.7	278.1	429.2	322.3	6	- 215.3	- 215.3	- 215.3	- 215.3	1	-	-	-	-	-
50	Yes	62,417.7	332,828.8	270,411.1	- 636.7	4,441.2	1,609.6	84	297,313.2	271,395	1,323.1	274,018.1	142,547.7	162	984.3	141.6	218.5	164.0	6	-	-	-	-	-	-	-	-	-	-
51	Yes	73,631.3	241,820.9	168,189.6	- 751.0	3,031.9	1,001.1	84	199,924.8	155,489	1,696.2	158,583.2	81,628.5	161	1,161.1	167.0	257.7	193.5	6	- 13,861.5	- 4,385.9	- 4,385.9	- 1,980.2	7	-	-	-	-	-
52	Yes	143,654.4	241,820.9	98,166.5	- 1,465.3	2,549.4	584.3	84	160,081.7	16,529	334.8	22,685.2	9,616.1	147	2,265.3	325.8	502.9	377.5	6	- 83,902.9	- 11,298.5	- 11,298.5	- 2,893.2	29	-	-	-	-	-
53	Yes	70,217.7	332,828.8	262,611.1	- 716.2	4,387.4	1,563.2	84	292,875.0	26,988	115.4	32,082.9	11,550.6	138	1,107.3	159.2	245.8	184.5	6	- 236,730.5	- 17,398.4	- 17,398.4	- 3,114.9	76	-	-	-	-	-
54	No	93,706.1	-	- 93,706.1	- 999.0	- 208.1	- 557.8	-	-	0	208.1	13,267.9	3,788.7	131	1,477.6	212.5	328.0	246.3	6	-	-	-	-	-	92,228.5	208.6	12,172.7	2,427.1	38
55	No	54,263.9	-	- 54,263.9	- 578.5	- 120.5	- 323.0	-	-	0	120.8	11,661.5	3,044.9	146	855.7	123.1	190.0	142.6	6	-	-	-	-	-	53,408.3	241.3	6,810.5	1,978.1	27
56	Yes	87,144.2	332,828.8	245,684.6	- 888.9	4,270.8	1,462.4	84	283,243.8	23,680	194.0	27,844.0	8,381.2	135	1,374.2	197.6	305.0	229.0	6	- 223,378.8	- 11,572.6	- 11,572.6	- 2,757.8	81	-	-	-	-	-
57	No	49,824.5	-	- 49,824.5	- 531.2	- 110.6	- 296.6	-	-	0	110.9	6,835.3	2,073.9	128	785.7	113.0	174.4	130.9	6	-	-	-	-	-	49,038.8	117.2	5,327.5	1,325.4	37
58	Yes	74,834.0	166,414.4	91,580.4	- 763.3	1,920.0	545.1	84	123,833.9	14,271	174.4	17,415.2	5,283.5	146	1,180.0	169.7	262.0	196.7	6	- 78,489.7	- 8,962.6	- 8,962.6	- 2,378.5	33	-	-	-	-	-
59	Yes	67,936.0	241,820.9	173,884.9	- 692.9	3,071.2	1,035.0	84	203,165.4	26,025	158.3	28,880.0	8,119.8	145	1,071.3	154.1	237.8	178.5	6	- 148,930.7	- 14,066.3	- 14,066.3	- 3,309.6	45	-	-	-	-	-
60	Yes	85,729.2	332,828.8	247,099.6	- 874.4	4,280.5	1,470.8	84	284,048.9	36,795	125.4	40,397.2	9,680.0	136	1,351.9	194.4	300.1	225.3	6	- 211,656.5	- 10,044.1	- 10,044.1	- 3,256.3	65	-	-	-	-	-
61	Yes	41,334.7	166,414.4	125,079.7	- 421.6	2,150.8	744.5	84	142,895.0	7,105	23.1	19,037.6	6,500.6	149	651.8	93.7	144.7	108.6	6	- 118,626.4	- 13,005.7	- 13,005.7	- 3,041.7	39	-	-	-	-	-
62	No	15,865.3	-	- 15,865.3	- 169.1	- 35.2	- 94.4	-	-	- 0	35.3	2,500.7	769.5	140	250.2	36.0	55.5	41.7	6	-	-	-	-	-	15,615.1	77.4	2,620.7	709.8	22
63	Yes	121,934.7	241,820.9	119,886.2	- 1,243.7	2,699.0	713.6	84	172,440.2	- 0	271.4	22,988.7	6,928.7	143	1,922.8	276.5	426.8	320.5	6	- 121,809.1	- 14,273.4	- 14,273.4	- 3,123.3	39	-	-	-	-	-
64	Yes	184,476.1	166,414.4	- 18,061.8	- 1,881.7	1,164.4	- 107.5	78	61,994.4	- 0	73.0	13,414.5	5,493.3	154	2,909.0	418.3	645.8	484.8	6	- 636.8	- 380.2	- 380.2	- 318.4	2	15,789.5	83.2	5,031.0	1,973.7	8
65	Yes	334,674.7	433,370.8	98,696.1	- 3,413.7	4,036.5	587.5	84	242,941.2	- 0	109.3	31,209.0	12,052.3	145	5,277.5	759.0	1,171.5	879.6	6	- 103,973.5	- 11,904.5	- 11,904.5	- 2,888.2	36	-	-	-	-	-
66	Yes	303,970.0	332,828.8	28,858.8	- 3,100.5	2,776.6	171.8	84	159,870.1	0	155.2	28,425.8	11,640.0	157	4,793.3	689.3	1,064.0	798.9	6	- 33,652.1	- 13,057.3	- 13,057.3	- 2,804.3	12	-	-	-	-	-
67	Yes	204,232.6	332,828.8	128,596.2	- 2,083.2	3,463.9	765.5	84	216,620.6	0	282.1	30,962.8	10,108.9	149	3,220.5	463.2	714.9	536.8	6	- 131,816.7	- 13,479.6	- 13,479.6	- 3,215.0	41	-	-	-	-	-
68	Yes	401,873.6	332,828.8	- 69,044.8	- 2,999.4	2,725.0	- 411.0	74	80,825.1	- 0	11.1	18,657.9	6,260.8	143	7,386.3	1,074.0	1,415.4	1,231.1	6	- 14,094.6	- 4,999.4	- 4,999.4	- 2,349.1	6	75,753.1	124.0	9,917.9	3,607.3	21
69	Yes	228,746.9	139,753.4	- 88,993.5	- 2,333.2	499.8	- 529.7	54	16,569.9	- 0	170.7	12,674.9	3,600.4	136	3,607.1	518.7	800.7	601.2	6	-	-	-	-	-	85,386.4	4.2	7,361.7	2,439.6	35
70	No	217,338.7	-	- 217,338.7	- 2,317.0	- 482.6	- 1,293.7	-	-	0	364.6	26,568.7	9,017.2	120	3,427.2	492.9	760.8	571.2	6	-	-	-	-	-	213,911.5	94.0	17,398.4	3,506.7	61
71	No	122,642.1	-	- 122,642.1	- 1,307.5	- 272.3	- 730.0	-	-	0	273.0	12,612.3	3,396.8	128	1,933.9	278.1	429.3	322.3	6	-	-	-	-	-	120,708.3	267.7	11,457.7	2,874.0	42
72	Yes	391,627.1	510,060.1	118,433.0	- 3,994.6	4,766.5	705.0	84	287,224.6	- 0	590.2	32,375.2	12,695.0	139	6,175.6	888.1	1,370.9	1,029.3	6	- 124,608.6	- 9,743.1	- 9,743.1	- 2,651.2	47	-	-	-	-	-
73	Yes	92,132.0	166,414.4	74,282.4	- 939.7	1,800.8	442.2	84	113,991.4	- 0	205.1	13,081.6	5,207.8	144	1,452.8	208.9	322.5	242.1	6	- 75,735.3	- 6,903.1	- 6,903.1	- 2,046.9	37	-	-	-	-	-
74	Yes	372,489.7	166,414.4	- 206,075.3	- 3,799.4	258.0	- 1,226.6	1	258.0	- 0	131.2	24,776.2	6,786.0	124	5,873.8	844.7	1,303.9	979.0	6	-	-	-	-	-	200,201.5	222.3	13,479.6	3,393.2	59
75	No	311,663.9	-	- 311,663.9	- 3,322.6	- 692.1	- 1,855.1	-	-	0	3.4	27,807.3	9,635.2	141	4,914.6	706.8	1,091.0	819.1	6	-	-	-	-	-	306,749.3	65.0	14,210.9	5,199.1	59
76	No	26,229.9	-	- 26,229.9	- 279.6	- 58.2	- 156.1	-	-	0	58.4	2,747.4	755.6	124	413.6	59.5	91.8	68.9	6	-	-	-	-	-	25,816.3	59.3	2,921.4	645.4	40
77	Yes	398,542.8	332,828.8	- 65,714.0	- 4,065.1	2,124.9	- 391.2	78	108,111.5	- 0	20.3	23,241.4	9,796.5	142	6,284.6	903.8	1,395.1	1,047.4	6	-	-	-	-	-	59,429.4	288.3	6,749.3	2,201.1	27
78	Yes	239,872.0	166,414.4	- 73,457.7	- 2,446.7	782.7	- 437.2	65	33,457.1	- 0	89.1	11,075.0	4,504.6	135	3,782.5	544.0	839.7	630.4	6	-	-	-	-	-	69,675.1	96.9	8,483.8	2,111.4	33
79	No	61,303.4	-	- 61,303.4	- 653.6	- 136.1	- 364.9	-	-	0	136.4	9,988.1	2,535.0	130	966.7	139.0	214.6	161.1	6	-	-	-	-	-	60,336.7	144.1	10,044.1	1,547.1	39
80	Yes	267,410.8	241,820.9	- 25,589.9	- 2,727.6	1,696.5	- 152.3	78	90,437.6	0	376.2	16,385.4	7,168.8	149	4,216.8	606.4	936.1	702.8	6	- 1,007.6	- 1,007.6	- 1,007.6	- 1,007.6	1	22,380.7	103.0	8,146.8	1,721.6	13
81	Yes	225,616.3	332,828.8	107,212.5	- 2,301.3	3,316.5	638.2	84	204,453.3	0	377.9	18,945.5	6,810.5	141	3,557.7	511.6	789.8	593.0	6	- 110,770.2	- 10,475.9	- 10,475.9	- 3,164.9	35	-	-	-	-	-
82	Yes	174,217.6	241,820.9	67,603.3	- 1,777.0	2,338.7	402.4	84	142,691.2	0	338.7	16,774.3	6,155.9	146	2,747.2	395.1	609.8	457.9	6	- 70,350.5	- 6,881.3	- 6,881.3	- 2,705.8	26	-	-	-	-	-
83	No	245,036.7	-	- 245,036.7	- 2,612.3	- 544.1	- 1,458.6	-	-	0	295.0	15,049.4	4,951.4	128	3,864.0	555.7	857.7	644.0	6	-	-	-	-	-	241,172.7	164.3	10,475.9	3,445.3	70
84	Yes	170,468.0	166,414.4	- 4,053.6	- 1,738.8	1,260.9	- 24.1	78	69,510.7	- 0	11.9	10,796.2	4,425.0	155	2,688.1	386.6	596.7	448.0	6	- 2,393.6	- 2,229.4	- 2,229.4	- 1,196.8	2	3,759.1	18.2	1,697.6	626.5	6
85	Yes	315,502.0	241,820.9	- 73,681.0	- 3,218.1	1,365.1	- 438.6	78	64,633.5	0	48.6	19,479.0	6,650.2	141	4,975.1	715.5	1,104.4	829.2	6	-	-	-	-	-	68,705.9	232.0	6,890.3	2,544.7	27
86	Yes	283,134.6	241,820.9	- 41,313.7	- 2,888.0	1,588.2	- 245.9	78	82,000.8	- 0	269.1	18,017.2	7,965.7	147	4,464.7	642.1	991.1	744.1	6	-	-	-	-	-	36,849.0	183.7	5,462.3	2,047.2	18
87	No	239,500.6	-	- 239,500.6	- 2,553.3	- 531.8	- 1,425.6	-	-	- 0	66.4	13,182.8	3,313.5	92	3,776.7	543.1	838.4	629.4	6	-	-	-	-	-	235,723.9	179.4	14,154.7	2,709.5	87
88	Yes	216,136.0	166,414.4	- 49,721.6	- 2,204.6	946.2	- 296.0	78	45,006.8	0	40.2	16,323.1	5,338.4	146	3,408.2	490.1	756.6	568.0	6	-	-	-	-	-	46,313.4	229.2	9,345.5	2,315.7	20
89	Yes	148,306.1	241,820.9	93,514.8	- 1,512.7	2,517.3	556.6	84	157,434.9	- 0	182.4	19,467.9	6,927.6	152	2,338.6	336.3	519.1	389.8	6	- 95,853.5	- 11,728.7	- 11,728.7	- 2,904.7	33	-	-	-	-	-
90	Yes	158,971.4	241,820.9	82,849.5	- 1,621.5	2,443.8	493.2	84	151,366.3	- 0	21.3	19,120.4	7,779.4	151	2,506.8	360.5	556.5	417.8	6	- 85,356.3	- 9,345.5	- 9,345.5	- 2,371.0	36	-	-	-	-	-
91	Yes	326,662.5	332,828.8	6,166.3	- 3,332.0	2,620.2	36.7	84	146,958.1	- 0	33.3	25,388.1	10,127.0	158	5,151.1	740.8	1,143.5	858.5	6	- 11,317.4	- 3,530.4	- 3,530.4	- 1,414.7	8	-	-	-	-	-

Figure 70: Results future scenario (in kW) - transition week (2)

Object	Prod	Cons	Prod	Diff Prod- Cons					Pot. Surplus	Storage					Missing					External To					External From				
		Total	Total	Diff Prod- Cons	Min	Max	Average	No of occ.	Total	Status End of week	Min	Max	Average	No of occ.	Total	Min	Max	Average	No of occ.	Total	Min	Max	Average	No of occ.	Total	Min	Max	Average	No of occ.
1	Yes	199,518.7	186,762.5	- 12,756.2	- 1,808.4	1,251.0	- 75.9	78	68,193.4	1,623	343.7	15,998.9	7,217.0	158	3,319.4	467.4	732.8	553.2	6	-	-	-	-	-	11,060.0	22.0	2,714.4	1,228.9	9
2	Yes	170,622.7	186,762.5	16,139.8	- 1,546.5	1,455.4	96.1	84	84,506.9	5,252	97.2	13,485.7	5,563.6	155	2,838.7	399.7	626.7	473.1	6	- 13,726.3	-	- 2,714.4	- 1,055.9	13	-	-	-	-	-
3	Yes	58,810.2	186,762.5	127,952.3	- 533.1	2,246.6	761.6	91	150,346.2	1,616	59.1	9,794.8	2,929.7	117	978.4	137.8	216.0	163.1	6	- 127,314.9	-	- 10,953.4	- 1,929.0	66	-	-	-	-	-
4	No	140,350.0	-	- 140,350.0	- 1,479.7	- 328.8	- 835.4	-	-	- 0	255.2	15,733.5	6,256.1	136	2,335.0	328.8	515.5	389.2	6	-	-	-	-	-	138,014.9	119.6	10,953.4	1,916.9	72
5	Yes	386,016.3	308,741.8	- 77,274.5	- 3,498.8	1,670.4	- 460.0	78	82,562.9	0	451.5	58,024.6	28,356.1	160	6,422.1	904.2	1,417.8	1,070.4	6	-	-	-	-	-	70,852.3	310.7	34,727.1	4,428.3	16
6	Yes	181,636.2	186,762.5	5,126.4	- 1,646.3	1,377.5	30.5	84	78,241.1	- 0	61.1	12,490.4	5,264.8	154	3,021.9	425.5	667.1	503.6	6	- 8,148.2	- 2,389.6	- 2,389.6	- 1,018.5	8	-	-	-	-	-
7	Yes	132,577.5	373,525.1	240,947.6	- 1,201.7	4,387.4	1,434.2	91	291,430.7	172,415	392.8	177,156.9	72,314.1	154	2,205.7	310.5	487.0	367.6	6	- 70,737.9	- 34,727.1	- 34,727.1	- 6,430.7	11	-	-	-	-	-
8	Yes	247,788.7	271,389.3	23,600.6	- 2,245.9	2,116.0	140.5	84	122,883.0	8,529	165.9	21,984.2	8,568.2	158	4,122.5	580.4	910.1	687.1	6	- 19,194.0	- 8,309.6	- 8,309.6	- 3,838.8	5	-	-	-	-	-
9	Yes	314,830.3	191,081.4	- 123,748.9	- 2,853.6	568.7	- 736.6	52	17,024.3	0	87.7	61,031.4	25,540.2	148	5,237.8	737.5	1,156.4	873.0	6	-	-	-	-	-	118,511.1	153.1	18,651.9	4,558.1	26
10	Yes	18,527.9	186,762.5	168,234.7	- 167.9	2,540.5	1,001.4	91	175,289.7	69,226	55.1	72,909.1	22,548.4	153	308.2	43.4	68.1	51.4	6	- 99,317.1	- 18,651.9	- 18,651.9	- 4,514.4	22	-	-	-	-	-
11	Yes	172,443.9	186,762.5	14,318.6	- 1,563.0	1,442.5	85.2	84	83,470.8	17,188	110.2	23,714.1	12,667.5	162	2,868.9	403.9	633.4	478.2	6	-	-	-	-	-	-	-	-	-	-
12	Yes	57,490.9	71,358.8	13,868.0	- 521.1	610.6	82.5	84	36,670.1	14,824	83.1	16,964.3	8,944.3	162	956.5	134.7	211.2	159.4	6	-	-	-	-	-	-	-	-	-	-
13	Yes	71,128.6	373,525.1	302,396.4	- 644.7	4,822.2	1,800.0	91	329,480.9	303,580	1,557.2	306,123.6	159,141.4	162	1,183.4	166.6	261.3	197.2	6	-	-	-	-	-	-	-	-	-	-
14	Yes	163,280.4	271,389.3	108,108.9	- 1,480.0	2,713.9	643.5	85	170,996.5	110,825	586.5	116,665.0	61,078.5	162	2,716.5	382.5	599.7	452.7	6	-	-	-	-	-	-	-	-	-	-
15	Yes	166,750.8	186,762.5	20,011.8	- 1,511.4	1,482.8	119.1	84	86,709.8	22,786	138.0	29,072.7	15,450.1	162	2,774.2	390.6	612.5	462.4	6	-	-	-	-	-	-	-	-	-	-
16	Yes	101,257.9	271,389.3	170,131.4	- 917.8	3,152.8	1,012.7	91	208,688.6	171,816	889.3	175,437.4	91,393.5	162	1,684.6	237.2	371.9	280.8	6	-	-	-	-	-	-	-	-	-	-
17	Yes	80,263.5	271,389.3	191,125.8	- 727.5	3,301.4	1,137.7	91	221,688.7	192,461	991.8	195,331.7	101,655.0	162	1,335.4	188.0	294.8	222.6	6	-	-	-	-	-	-	-	-	-	-
18	Yes	92,065.7	373,525.1	281,459.4	- 834.5	4,674.0	1,675.4	91	316,516.3	282,991	1,455.0	286,283.7	148,907.9	162	1,531.7	215.7	338.2	255.3	6	-	-	-	-	-	-	-	-	-	-
19	Yes	107,553.4	373,525.1	265,971.7	- 974.9	4,564.4	1,583.2	91	306,926.1	236,157	1,128.0	240,003.2	114,069.8	160	1,789.4	251.9	395.0	298.2	6	- 31,604.3	- 12,704.5	- 12,704.5	- 3,160.4	10	-	-	-	-	-
20	Yes	232,559.1	373,525.1	140,966.0	- 2,107.9	3,679.9	839.1	84	230,848.0	4,273	572.5	47,418.3	18,585.9	157	3,869.1	544.7	854.2	644.8	6	- 140,561.9	- 26,015.3	- 26,015.3	- 4,534.3	31	-	-	-	-	-
21	Yes	114,451.1	271,389.3	156,938.2	- 1,037.4	3,059.4	934.2	91	200,519.1	0	281.8	55,907.1	16,109.2	154	1,904.1	268.1	420.4	317.4	6	- 158,842.3	- 33,592.1	- 33,592.1	- 4,963.8	32	-	-	-	-	-
22	Yes	661,266.9	271,389.3	- 389,877.6	- 5,993.7	57.4	- 2,320.7	1	57.4	- 0	102.4	31,772.8	9,166.8	92	11,001.5	1,548.9	2,428.8	1,833.6	6	-	-	-	-	-	378,876.1	478.7	33,592.1	4,857.4	78
23	Yes	352,058.1	169,681.5	- 182,376.5	- 3,191.0	251.0	- 1,085.6	6	313.7	- 0	123.1	21,855.5	5,591.0	103	5,857.2	824.7	1,293.1	976.2	6	-	-	-	-	-	176,519.4	23.7	21,842.8	2,674.5	66
24	Yes	134,943.6	373,525.1	238,581.4	- 1,223.1	4,370.6	1,420.1	91	289,965.5	16,439	400.5	41,773.5	14,385.1	151	2,245.1	316.1	495.6	374.2	6	- 224,387.0	- 21,842.8	- 21,842.8	- 2,952.5	76	-	-	-	-	-
25	Yes	349,634.5	271,389.3	- 78,245.2	- 3,169.1	1,395.3	- 465.7	78	67,033.1	- 0	113.3	66,468.5	33,446.5	160	5,816.8	819.0	1,284.2	969.5	6	-	-	-	-	-	72,428.4	323.5	17,834.3	7,242.8	10
26	Yes	111,023.8	373,525.1	262,501.3	- 1,006.3	4,539.9	1,562.5	91	304,777.2	191,920	1,038.9	195,890.6	80,580.7	154	1,847.1	260.1	407.8	307.9	6	- 72,428.4	- 17,834.3	- 17,834.3	- 7,242.8	10	-	-	-	-	-
27	Yes	58,509.0	271,389.3	212,880.3	- 530.3	3,455.3	1,267.1	91	235,159.5	213,854	1,098.0	215,946.2	112,288.0	162	973.4	137.1	214.9	162.2	6	-	-	-	-	-	-	-	-	-	-
28	Yes	89,326.7	186,762.5	97,435.9	- 809.6	2,030.7	580.0	90	131,456.7	69,362	264.7	72,556.5	30,211.3	153	1,486.1	209.2	328.1	247.7	6	- 29,560.2	- 9,361.5	- 9,361.5	- 1,847.5	16	-	-	-	-	-
29	No	659.7	-	- 659.7	- 7.0	- 1.5	- 3.9	-	-	0	2.0	451.2	183.8	153	11.0	1.6	2.4	1.8	6	-	-	-	-	-	648.7	3.2	455.9	72.1	9
30	Yes	219,322.9	186,762.5	- 32,560.3	- 1,987.9	1,110.8	- 193.8	78	57,559.6	- 0	385.3	29,137.6	14,105.5	161	3,648.9	513.7	805.6	608.1	6	-	-	-	-	-	28,911.5	314.8	9,361.5	2,891.1	10
31	No	5,592.8	-	- 5,592.8	- 59.0	- 13.1	- 33.3	-	-	0	16.6	3,266.3	1,247.5	148	93.1	13.1	20.5	15.5	6	-	-	-	-	-	5,499.7	34.3	3,306.8	392.8	14
32	Yes	61,592.2	271,389.3	209,797.1	- 558.3	3,433.5	1,248.8	91	233,250.3	205,322	980.0	207,524.8	106,907.7	162	1,024.7	144.3	226.2	170.8	6	- 5,499.7	- 3,306.8	- 3,306.8	- 392.8	14	-	-	-	-	-
33	Yes	67,686.9	271,389.3	203,702.4	- 613.5	3,390.3	1,212.5	91	229,476.3	204,828	1,053.2	207,249.2	107,802.1	162	1,126.1	158.6	248.6	187.7	6	-	-	-	-	-	-	-	-	-	-
34	Yes	108,456.8	186,762.5	78,305.7	- 983.0	1,895.3	466.1	85	119,923.4	80,110	422.7	83,988.9	43,942.7	162	1,804.4	254.1	398.4	300.7	6	-	-	-	-	-	-	-	-	-	-
35	Yes	288,974.4	373,525.1	84,550.6	- 2,619.2	3,280.7	503.3	84	198,752.0	88,750	493.5	100,055.1	52,658.1	162	4,807.7	676.9	1,061.4	801.3	6	- 608.1	- 343.3	- 343.3	- 304.0	2	-	-	-	-	-
36	No	48,628.5	-	- 48,628.5	- 512.7	- 113.9	- 289.5	-	-	0	144.6	13,796.7	4,493.5	144	809.0	113.9	178.6	134.8	6	-	-	-	-	-	47,819.4	237.4	14,070.2	2,656.6	18
37	Yes	110,923.4	271,389.3	160,465.9	- 1,005.4	3,084.4	955.2	91	202,703.6	115,100	604.7	119,067.0	58,912.5	162	1,845.4	259.8	407.4	307.6	6	- 47,211.4	- 14,070.2	- 14,070.2	- 2,950.7	16	-	-	-	-	-
38	Yes	58,552.1	271,389.3	212,837.2	- 530.7	3,455.0	1,266.9	91	235,132.8	213,811	1,097.8	215,905.4	112,267.0	162	974.1	137.2	215.1	162.4	6	-	-	-	-	-	-	-	-	-	-
39	Yes	125,493.3	271,389.3	145,896.0	- 1,137.5	2,981.3	868.4	91	193,681.6	147,984	771.0	152,472.0	79,547.8	162	2,087.8	294.0	460.9	348.0	6	-	-	-	-	-	-	-	-	-	-
40	Yes	49,058.7	186,762.5	137,703.8	- 444.7	2,315.6	819.7	91	156,384.5	101,009	526.4	102,763.6	42,826.6	162	816.2	114.9	180.2	136.0	6	- 37,511.0	- 28,221.8	- 28,221.8	- 5,358.7	7	-	-	-	-	-
41	No	38,145.6	-	- 38,145.6	- 402.2	- 89.4	- 227.1	-	-	- 0	207.7	27,921.9	12,023.3	155	634.6	89.4	140.1	105.8	6	-	-	-	-	-	37,511.0	186.3	28,221.8	5,358.7	7
42	Yes	69,092.3	373,525.1	304,432.8	- 626.2	4,836.6	1,812.1	91	330,741.9	305,582	1,567.1	308,053.3	160,136.7	162	1,149.5	161.8	253.8	191.6	6	-	-	-	-	-	-	-	-	-	-
43	Yes	163,768.0	390,178.0	226,410.1	- 1,484.4	4,404.1	1,347.7	91	288,770.0	229,135	1,189.8	234,991.7	122,506.7	162	2,724.6	383.6	601.5	454.1	6	-	-	-	-	-	-	-	-	-	-
44	Yes	55,827.4	186,762.5	130,935.2	- 506.0	2,267.7	779.4	91	152,193.2	131,864	679.7	133,860.6	69,666.6	162	928.8	130.8	205.1	154.8	6	-	-	-	-	-	-	-	-	-	-
45	Yes	57,576.9	186,762.5	129,185.6	- 521.9	2,255.3	769.0	91	151,109.9	130,144	671.1	132,202.7	68,811.5	162	957.9	134.9	211.5	159.7	6	-	-	-	-	-	-	-	-	-	-

Figure 71: Results future scenario (in kW) - summer week (1)

Object	Prod	Cons	Prod	Diff Prod- Cons					Pot. Surplus	Storage					Missing					External To					External From				
		Total	Total	Diff Prod-Cons	Min	Max	Average	No of occ.	Total	Status End of week	Min	Max	Average	No of occ.	Total	Min	Max	Average	No of occ.	Total	Min	Max	Average	No of occ.	Total	Min	Max	Average	No of occ.
46	Yes	110,593.6	373,525.1	262,931.5	- 1,002.4	4,542.9	1,565.1	91	305,043.5	264,771	1,364.5	268,726.7	139,851.9	162	1,839.9	259.1	406.2	306.7	6	-	-	-	-	-	-	-	-	-	-
47	Yes	95,249.3	271,389.3	176,140.0	- 863.3	3,195.3	1,048.5	91	212,409.2	130,125	918.6	133,531.5	60,149.5	162	1,584.7	223.1	349.9	264.1	6	- 47,599.7	- 42,795.6	- 42,795.6	- 23,799.8	2	-	-	-	-	-
48	No	61,348.5	-	- 61,348.5	- 646.8	- 143.7	- 365.2	-	-	- 0	167.2	42,397.6	16,928.5	158	1,020.7	143.7	225.3	170.1	6	-	-	-	-	-	60,327.8	466.8	42,795.6	7,541.0	8
49	Yes	99,422.4	186,762.5	87,340.2	- 901.2	1,959.2	519.9	90	125,289.7	76,266	294.6	79,821.9	36,955.8	158	1,654.1	232.9	365.2	275.7	6	- 12,728.1	- 6,345.3	- 6,345.3	- 2,121.4	6	-	-	-	-	-
50	Yes	50,607.5	373,525.1	322,917.6	- 458.7	4,974.5	1,922.1	91	342,188.0	323,760	1,657.4	325,569.5	169,171.6	162	842.0	118.5	185.9	140.3	6	-	-	-	-	-	-	-	-	-	-
51	Yes	59,699.3	271,389.3	211,690.0	- 541.1	3,446.9	1,260.1	91	234,422.4	212,683	1,092.2	214,818.3	111,706.2	162	993.2	139.8	219.3	165.5	6	-	-	-	-	-	-	-	-	-	-
52	Yes	116,473.1	271,389.3	154,916.2	- 1,055.7	3,045.1	922.1	91	199,267.0	156,854	815.0	161,019.5	83,956.6	162	1,937.8	272.8	427.8	323.0	6	-	-	-	-	-	-	-	-	-	-
53	Yes	56,931.6	373,525.1	316,593.5	- 516.0	4,924.7	1,884.5	91	338,272.0	242,829	168.7	244,865.0	106,259.5	152	947.2	133.4	209.1	157.9	6	- 74,711.7	- 15,436.4	- 15,436.4	- 5,747.1	13	-	-	-	-	-
54	No	75,975.7	-	- 75,975.7	- 801.0	- 178.0	- 452.2	-	-	- 0	413.6	53,995.4	29,797.1	159	1,264.0	178.0	279.1	210.7	6	-	-	-	-	-	74,711.7	651.0	15,436.4	5,747.1	13
55	No	43,996.5	-	- 43,996.5	- 463.9	- 103.1	- 261.9	-	-	0	239.5	31,478.9	13,408.6	156	732.0	103.1	161.6	122.0	6	-	-	-	-	-	43,264.6	214.8	31,641.0	6,180.7	7
56	Yes	70,655.4	373,525.1	302,869.7	- 640.4	4,825.5	1,802.8	91	329,774.0	221,056	209.4	223,582.6	92,527.7	156	1,175.5	165.5	259.5	195.9	6	- 82,989.5	- 31,641.0	- 31,641.0	- 8,299.0	10	-	-	-	-	-
57	No	40,397.1	-	- 40,397.1	- 425.9	- 94.6	- 240.5	-	-	- 0	30.4	28,236.3	16,210.6	161	672.1	94.6	148.4	112.0	6	-	-	-	-	-	39,725.0	1,344.7	18,672.5	6,620.8	6
58	Yes	60,674.5	186,762.5	126,088.1	- 549.9	2,233.4	750.5	91	149,191.8	127,098	656.0	129,267.5	67,297.5	162	1,009.4	142.1	222.9	168.2	6	-	-	-	-	-	-	-	-	-	-
59	Yes	55,081.7	271,389.3	216,307.6	- 499.3	3,479.5	1,287.5	91	237,281.7	217,224	1,114.8	219,194.0	113,963.2	162	916.4	129.0	202.3	152.7	6	-	-	-	-	-	-	-	-	-	-
60	Yes	69,508.2	373,525.1	304,016.9	- 630.0	4,833.7	1,809.6	91	330,484.4	305,173	1,565.1	307,659.2	159,933.4	162	1,156.4	162.8	255.3	192.7	6	-	-	-	-	-	-	-	-	-	-
61	Yes	33,513.6	186,762.5	153,248.9	- 303.8	2,425.6	912.2	91	166,010.3	141,162	1,417.4	142,360.2	71,537.6	161	557.6	78.5	123.1	92.9	6	- 12,644.9	- 8,973.3	- 8,973.3	- 1,053.7	12	-	-	-	-	-
62	No	12,863.4	-	- 12,863.4	- 135.6	- 30.1	- 76.6	-	-	- 0	38.1	8,889.8	3,449.7	150	214.0	30.1	47.3	35.7	6	-	-	-	-	-	12,649.4	4.5	8,973.3	973.0	13
63	Yes	98,863.1	271,389.3	172,526.2	- 896.1	3,169.7	1,026.9	91	210,171.5	174,167	901.0	177,702.3	92,559.5	162	1,644.8	231.6	363.1	274.1	6	- 4.5	- 4.5	- 4.5	- 4.5	1	-	-	-	-	-
64	Yes	149,570.9	186,762.5	37,191.6	- 1,355.7	1,604.4	221.4	84	96,483.8	39,680	221.9	45,242.7	23,847.2	162	2,488.4	350.4	549.4	414.7	6	-	-	-	-	-	-	-	-	-	-
65	Yes	271,350.0	486,360.7	215,010.7	- 2,459.5	5,014.2	1,279.8	87	318,688.6	219,525	1,154.9	229,229.8	119,854.5	162	4,514.4	635.6	996.7	752.4	6	-	-	-	-	-	-	-	-	-	-
66	Yes	246,455.0	373,525.1	127,070.1	- 2,233.8	3,581.6	756.4	84	222,942.3	121,909	1,674.3	130,813.5	66,853.5	161	4,100.3	577.3	905.2	683.4	6	- 9,261.8	- 6,374.8	- 6,374.8	- 2,315.5	4	-	-	-	-	-
67	Yes	165,589.2	373,525.1	207,935.9	- 1,500.9	4,153.8	1,237.7	91	270,989.3	32,565	121.6	38,486.9	10,856.8	140	2,754.9	387.9	608.2	459.1	6	- 178,126.0	- 11,030.8	- 11,030.8	- 2,698.9	66	-	-	-	-	-
68	Yes	368,751.2	373,525.1	4,773.8	- 2,227.6	3,291.5	28.4	79	129,007.9	14,661	340.7	31,116.9	10,591.8	157	6,947.6	1,008.1	1,333.0	1,157.9	6	- 12,635.8	- 4,953.3	- 4,953.3	- 1,263.6	10	15,575.8	531.8	7,590.0	2,225.1	7
69	Yes	185,465.1	156,841.6	- 28,623.4	- 1,681.0	923.8	- 170.4	78	47,651.1	0	123.5	11,057.3	3,941.8	149	3,085.6	434.4	681.2	514.3	6	-	-	-	-	-	25,537.9	108.7	4,723.5	1,502.2	17
70	No	176,215.5	-	- 176,215.5	- 1,857.8	- 412.8	- 1,048.9	-	-	- 0	432.5	15,045.1	4,505.7	108	2,931.7	412.8	647.2	488.6	6	-	-	-	-	-	173,283.8	56.2	11,030.8	2,548.3	68
71	No	99,436.7	-	- 99,436.7	- 1,048.4	- 232.9	- 591.9	-	-	0	244.8	10,031.1	3,141.1	134	1,654.3	232.9	365.2	275.7	6	-	-	-	-	-	97,782.4	486.3	10,735.8	3,154.3	31
72	Yes	317,526.3	572,427.1	254,900.9	- 2,878.0	5,914.5	1,517.3	90	376,196.0	- 0	67.8	35,924.6	12,431.1	137	5,282.7	743.8	1,166.3	880.4	6	- 260,183.5	- 16,549.3	- 16,549.3	- 3,335.7	78	-	-	-	-	-
73	Yes	74,699.4	186,762.5	112,063.1	- 677.1	2,134.2	667.0	91	140,507.3	0	13.1	14,839.9	3,885.5	130	1,242.8	175.0	274.4	207.1	6	- 113,305.9	- 8,343.2	- 8,343.2	- 2,060.1	55	-	-	-	-	-
74	Yes	302,009.9	186,762.5	- 115,247.4	- 2,737.4	575.8	- 686.0	53	18,649.4	- 0	21.4	18,385.6	7,544.4	132	5,024.5	707.4	1,109.3	837.4	6	-	-	-	-	-	110,222.9	16.1	14,174.6	2,449.4	45
75	No	252,693.1	-	- 252,693.1	- 2,664.1	- 591.9	- 1,504.1	-	-	- 0	25.7	10,255.0	2,779.4	73	4,204.0	591.9	928.1	700.7	6	-	-	-	-	-	248,489.0	24.7	10,093.3	2,279.7	109
76	No	21,266.9	-	- 21,266.9	- 224.2	- 49.8	- 126.6	-	-	0	53.0	3,139.5	688.2	105	353.8	49.8	78.1	59.0	6	-	-	-	-	-	20,913.1	52.4	3,189.6	360.6	58
77	Yes	323,133.4	373,525.1	50,391.7	- 2,928.9	3,039.0	300.0	84	179,318.2	- 0	76.6	24,228.3	10,500.2	150	5,376.0	756.9	1,186.9	896.0	6	- 55,767.6	- 7,557.1	- 7,557.1	- 961.5	58	-	-	-	-	-
78	Yes	194,485.2	186,762.5	- 7,722.7	- 1,762.8	1,286.6	- 46.0	81	70,936.9	0	2.6	11,401.4	4,914.6	155	3,235.6	455.6	714.3	539.3	6	- 2,255.4	- 775.6	- 775.6	- 375.9	6	6,742.4	1.9	2,090.7	842.8	8
79	No	49,704.0	-	- 49,704.0	- 524.0	- 116.4	- 295.9	-	-	0	122.4	15,069.4	5,740.3	138	826.9	116.4	182.6	137.8	6	-	-	-	-	-	48,877.1	40.0	12,651.2	1,286.2	38
80	Yes	216,813.3	271,389.3	54,576.0	- 1,965.2	2,335.1	324.9	84	140,505.6	7,014	519.3	20,009.0	7,835.1	145	3,607.1	507.9	796.3	601.2	6	- 51,169.5	- 5,615.6	- 5,615.6	- 1,088.7	47	-	-	-	-	-
81	Yes	182,926.8	373,525.1	190,598.3	- 1,658.0	4,031.1	1,134.5	90	260,302.9	112,620	137.0	119,162.4	57,949.4	156	3,043.3	428.5	671.9	507.2	6	- 81,021.5	- 12,651.2	- 12,651.2	- 2,383.0	34	-	-	-	-	-
82	Yes	141,253.4	271,389.3	130,135.9	- 1,280.3	2,869.8	774.6	90	184,028.3	0	367.5	17,198.9	5,697.8	127	2,350.0	330.9	518.8	391.7	6	- 132,485.9	- 16,962.5	- 16,962.5	- 2,880.1	46	-	-	-	-	-
83	No	198,672.6	-	- 198,672.6	- 2,094.6	- 465.4	- 1,182.6	-	-	- 0	22.4	25,361.6	8,008.4	132	3,305.3	465.4	729.7	550.9	6	-	-	-	-	-	195,367.3	192.8	16,962.5	3,005.7	65
84	Yes	138,213.3	186,762.5	48,549.3	- 1,252.8	1,684.8	289.0	84	102,945.4	5,402	274.1	22,084.0	8,528.0	158	2,299.4	323.8	507.7	383.2	6	- 45,446.9	- 10,988.2	- 10,988.2	- 2,524.8	18	-	-	-	-	-
85	Yes	255,805.0	271,389.3	15,584.3	- 2,318.6	2,059.2	92.8	84	118,322.4	0	126.5	17,349.7	7,658.9	153	4,255.8	599.2	939.6	709.3	6	- 19,840.1	- 3,894.6	- 3,894.6	- 1,167.1	17	-	-	-	-	-
86	Yes	229,561.9	271,389.3	41,827.4	- 2,080.7	2,244.9	249.0	84	133,252.6	0	565.1	39,198.8	15,179.4	155	3,819.2	537.7	843.2	636.5	6	- 45,646.6	- 25,981.2	- 25,981.2	- 3,511.3	13	-	-	-	-	-
87	No	194,184.1	-	- 194,184.1	- 2,047.3	- 454.8	- 1,155.9	-	-	- 0	161.6	26,971.3	6,665.0	126	3,230.6	454.9	713.2	538.4	6	-	-	-	-	-	190,953.4	16.2	28,063.5	3,182.6	60
88	Yes	175,240.3	186,762.5	11,522.2	- 1,588.4	1,422.7	68.6	84	81,879.9	0	92.5	13,625.5	5,426.7	155	2,915.5	410.5	643.7	485.9	6	- 14,437.7	- 2,088.3	- 2,088.3	- 1,031.3	14	-	-	-	-	-
89	Yes	120,244.7	271,389.3	151,144.6	- 1,089.9	3,018.5	899.7	91	196,931.6	40,984	356.3	45,906.8	11,594.0	148	2,000.5	281.7	441.7	333.4	6	- 112,160.8	- 14,663.4	- 14,663.4	- 3,618.1	31	-	-	-	-	-
90	Yes	128,892.0	271,389.3	142,497.3	- 1,168.3	2,957.3	848.2	90	191,579.3	144,642	754.4	149,251.4	77,886.6	162	2,144.4	301.9	473.4	357.4	6	-	-	-	-	-	-	-	-	-	-
91	Yes	264,853.8	373,525.1	108,671.3	- 2,400.6	3,451.4	646.9	84	212,474.8	113,078	611.3	122,758.0	64,453.5	162	4,406.4	620.4	972.8	734.4	6	-	-	-	-	-	-	-	-	-	-

Figure 72: Results future scenario (in kW) - summer week (2)

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