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Sirkka Heinonen, Samuli Honkapuro, Joni Karjalainen, Tiina Koljonen,
Juho Ruotsalainen and Lassi Similä

FINAL NEO-CARBON ENERGY COUNTDOWN
– Ready for Renewables

FINLAND FUTURES RESEARCH CENTRE
FFRC eBOOK 11/2017

Turun yliopisto
University of Turku

FINLAND FUTURES
RESEARCH CENTRE

NEO
CARBON
ENERGY

The Neo-Carbon Energy project (2014–2017) is one of the Tekes – the Finnish Funding Agency for Innovation – strategic research openings, which is carried out in cooperation jointly with VTT Technical Research Centre of Finland Ltd (co-ordinator), Lappeenranta University of Technology (LUT), and University of Turku, Finland Futures Research Centre (FFRC).

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Finland Futures Research Centre
Turku School of Economics
FI-20014 University of Turku

Rehtorinpellonkatu 3, 20500 Turku
Korkeavuorenkatu 25 A 2, FI-00130 Helsinki
Åkerlundinkatu 2, FI-33100 Tampere

utu.fi/ffrc
tutu-info@utu.fi, firstname.lastname@utu.fi

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"The secret of change is to focus all of your energy, not on fighting the old, but on building the new."

Socrates

PREFACE

Energy demand of humankind grew by a factor of about 25 from the times of pre-industrial revolution to the current level, and this is expected to further triple during this century. The intensive utilization of energy resources for all kinds of products and services created a historically unique rise in standards of living. It also provided a rapidly increasing percentage of humankind access to this energetic wealth. However, the dark side of this development is an unprecedented distortion of planetary ecosystems, foremost by massive greenhouse gas emissions, which threaten humankind with the destruction of civilization. A consequent and fast rebalance of human activities within the limits of planet Earth is desperately required to avoid an all-time record collapse of civilization.

This compact summary of findings of the team of Professor Sirkka Heinonen at Finland Futures Research Centre, University of Turku, achieved in the Neo-Carbon Energy project highlights societal requirements and options for an effective rebalance.

Renewable energy will be the key, based on abundant resources, effective technologies, very high levels of sustainability, compatibility to distributed and highly interconnected systems and low barriers for individual accessibility. Visions for a Neo-Carbon Society by the mid-21st century are discussed in detail following different possible energy futures, in particular in the dimensions of ecological awareness and degree of peer-to-peer engagement. These energy futures imply specific roles for the various actors and lead to different energy market structures in such Neo-Carbon futures ahead.

The following overview on key insights of the Neo-Carbon Energy project on energy futures helps to frame the academic and societal discourse in the years to come. The window of opportunities for effectively managing the massive ecological and hence societal issues is closing soon. Very fast decision-making is required, for which an understanding of energy futures options is indispensable.

Helsinki 6th March 2018

Christian Breyer
Professor of Solar Economy
Lappeenranta University of Technology LUT

SUMMARY

Renewables-based Neo-Carbon Vision of the world in 2050 portrays an electrified, resilient and secure society with empowered, prosumeristic citizens who upload their surplus energy into smart grids as well as download energy when needed. Four scenarios assume a social perspective to open up very different avenues as transformative manifestations of this vision. The vision shows the preferred goal – a renewables-based society – while the scenarios outline alternative expressions and pathways towards the desired vision. Finally, the actors that can make this change happen have to be identified and supported, especially in policy-making, and the role of energy markets re-thought.

Transformative leadership and the drive of pioneering actors can expedite concrete changes to take place. Policies need to construct the emerging regime and disrupt the old – to be transformative and to empower actors. Peer-to-peer collaboration and prosumerism, as inherently democratic ideals, are principles increasingly in use. New ways of organising create novel economic opportunities, as shown by the sharing economy and platform economy. Futures changes, urgently desired, aim to overcome entrenched policies, vested interests, concentration of wealth, to ensure ownership of the solutions by the many.

In the past, energy transitions were long-term processes because energy infrastructure changes slowly. The whole-of-society scenarios, actor analysis, energy market analysis, and novel collaborative efforts, aligned with peer-to-peer principles and radical values, show various ways of the changes and actions that may emerge in the future.

It is hoped that these thoughts can serve as inspiration and a possible guardrail for future energy system planning that more holistically considers the precursors and effects of large-scale change.

1. INTRODUCTION – WHAT WILL THE RENEWABLES-POWERED FUTURE HOLD FOR US?

A look at the emerging renewable energy systems is a direct glimpse into the future. One of the main goals of the Neo-Carbon Energy research project was to anticipate possible social and cultural changes in a new, renewable energy world.[1] Under emerging energy technologies, our whole way of life is ripe for change. Each major change in human history has been catalysed by new energy technologies, such as the transition from agricultural to industrial societies, which has taken place from the 17th century onwards.[2] The story of human progress and civilization is the story of increasing energy supply (see e.g. Smil 2017).

With the exponentially emerging renewable energy technologies, we are at the brink of a new historical transformation. The amount of energy that the humankind uses each year is only about 1/6000 of the Sun's energy facing the Earth. The cost of a solar panel today is less than 1/100 than it was in the 1970s. If humanity is able to harness more of that energy with renewable energy technologies in a sustainable way, many new activities become possible – from supplying electricity to dispersed, rural areas in Africa to the mass-scale use of artificial intelligences (AI).

Although it is impossible to predict and foresee exactly how societies will develop under the new energy regime, we can anticipate their possible futures by looking at the values and practices that are "built-in" as potentials to renewable energy technologies – in the same way as decentralised communication and freedom of self-expression are "built-in" to the internet.

The core values of renewables are, arguably, the following:

- Abundance. Renewables hold a promise for an ecologically sustainable abundance of energy.
- Ecological sustainability. It is self-evident that renewable energy is ecologically sustainable when compared to non-renewables. It remains to be seen if a wide adoption of renewable energy turns citizens' values more ecological – perhaps even a transformation towards deep ecology?

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[1] For the whole project, see http://www.neocarbonenergy.fi/, and for the foresight part of the project, see https://www.utu.fi/en/units/ffrc/research/projects/energy/Pages/neo-fore.aspx

[2] Key issues of emerging techno-economic and socio-cultural changes were addressed through a process of five futures cliniques. The first of them was focused on the industrial change (Heinonen et al. 2015).

- Decentralisation and networkedness. Renewable energy resources are evenly distributed, whereas non-renewables are concentrated and expensive to extract and utilize. Renewable energy technologies are decentralised and relatively inexpensive. They thus belong to the same set of decentralised, "grassroots" technologies as the internet, social media, and mobile devices. Together they form the basis for the future information and network society.
- Democracy and the grassroots. In the renewable energy system, citizens can become energy producers – so called "prosumers". This increases their independence and autonomy. In the future, the prosumer citizens can, for instance, establish their own micro-factories powered by renewables.

From these values we can extrapolate possible outcomes for future societies. To shed light on such futures, this paper presents a societal vision of a renewables-powered world. In another report (Heinonen et al. 2017e, www.utu.fi/fi/yksikot/ffrc/julkaisut/e-tutu/Documents/eBook_10-2017.pdf), we present four different scenarios reflected upon this vision[3]. Exploration of bold, transformational futures opens up the potential of renewable based society and supports decision-making towards the preferred futures. Innovations and new technologies spread and become established only, if they become part of collective culture, arising to the regime level[4]. When people find similar meanings to the innovation they have encountered, the innovation starts to spread more and more easily (Lang 2018). This is, actually, the very reason why we need stories and narratives that give cultural and social meaning to renewable energy technologies. Such narratives – as part of respective scenarios – reflect the aspirations of a shared vision, and make it comprehensible for the broader audience.

[3] The scenario report depicts one scenario, which is very different from the other three, called Green DIY Engineers. It is by type a collapse scenario and rather dystopic – therefore not a direct variation of this preferred vision as presented in chapter 2 in this document. However, even the collapse scenario shares many core elements with the vision. The world is just very different due to the intervening ecological catastrophe that took place.

[4] As perceived through the multi-level perspective (MLP) lens (Geels & Schot 2007).

2. POWER BY THE PEOPLE – VISION OF NEO-CARBON SOCIETY 2050

By 2050 energy will be emission free, almost entirely renewable, and used much more efficiently than today. We will thereby have a wealth of inexpensive, clean energy in use. An internet of energy will empower an electrified, resilient and secure society, and inspire its networked and autonomous citizens.

Ubiquitous Electricity

Humanity harnesses extensively the potential of sustainable renewable energy sources, especially solar and wind energy. The use of fossil energy resources has more or less halted. Energy harvesting is ubiquitous. Clothing, devices, gadgets, vehicles, building envelopes and other infrastructure gather energy in its many forms from the environment. Solar-accessible roofs and many non-used land areas such as highway shoulders are covered with solar cells, wind turbines and other means of energy production, such as cyborg plants and trees with artificial photosynthesis.

Most of the sectors in society are powered by electricity, enabled by intelligent systems, e.g. smart grids and energy storage, and flexible energy use. Mobility is arranged as a service with robotic electric cars. Those sectors, such as aviation and freight transport, which have not been able to be electrified, use synthetic fuels. The raw materials for synthetic fuels are produced by electrolysing hydrogen from water and capturing carbon dioxide from air or process gases. Hydrogen and carbon dioxide are then synthesised as fuels using renewable electricity. An array of other products, such as chemicals, plastics, fertilizers, and even food can also be produced from these synthetic hydrocarbons. Almost no waste is produced as all materials are recycled. Rare earths and other critical metals are fully recycled or replaced with other materials in circular economy. If needed, in extreme cases they can also be mined from asteroids nearby the Earth to avoid resource wars. This, however, would of course break the planetary boundaries.

Owing to this energy system, the amount of available energy has increased significantly. Not only is energy renewable and available for all, but also low-cost. Analogous to previous energy transitions, such as the shift from steam engines to electricity, the increase in surplus energy has led to broad

social, cultural and economic changes. This time, however, societies keep within planetary boundaries thanks to emission-free energy, recycled materials, and new consciousness.[5]

Renewed Society

Thanks to available surplus energy, almost all industrial production is robotised and automated. Owing to ubiquitous artificial intelligence and big data, also immaterial and creative production is highly efficient. The increases in productivity have led to unprecedented prosperity, but also decreased the need for human labour.[6] The new wealth is distributed through universal basic income. Because the costs of living have plummeted, due to almost free energy and the highly efficient production, decent standards of living are more or less guaranteed for all. The global world lives in a condition of abundance. The world has become more equitable, resilient, eco-smart and secure.

Citizens are *energy prosumers* (producers & consumers), who feed or "upload" surplus energy into the smart grid as well as "download" energy when needed. In this way, they can get some of their energy for free, and reinforce their self-sufficiency and independent lifestyles.

The new energy system with consequent decrease in the costs of living and production has increased the autonomy of citizens. This has enabled citizens to self-organise. People prefer living and working in communities of like-minded individuals. Producing their own energy is not only a practical question, but also a way for communities to build group solidarity and a sense of a shared identity. Owing to this kind of "indo-collectivity" (see Dator 2012), the concept of ownership has loosened, and sharing economy prevails, further enhancing the use of resources. Typically communities are networked with each other as peer-to-peer networks, but some favour living in their own "bubble" communities – often outside centres of population.

Usually people work only half-time as paid labour. The rest of the time they use for their own and community projects, often producing use-value for the rest of society as well. Characteristically the products and services are open source, released for others to be used and refined freely, as *non-proprietary commons*. The more useful products communities provide for others, the more the prestige of these communities increases – monetary wealth is partly replaced by "reputation wealth". Low-cost

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[5] Here, however, it has to be borne in mind that for 100% circular economy, first huge amounts of raw material are needed for building the new renewables-based electricity infrastructure. Furthermore, not all the nine criteria of planetary boundaries can be kept solely through recycling and renewable energy (http://www.stockholmresilience.org/research/planetary-boundaries/planetary-boundaries/about-the-research/the-nine-planetary-boundaries.html)

[6] In the second Futures Clinique conducted within the Neo-Carbon Energy project the focus was on future of work, employment and automation (Ruotsalainen et al 2016; see also 2016b)

energy, cheap and renewable raw materials, artificial intelligences, platforms matching supply and demand (of products, services and workforce) and digital manufacturing devices such as sophisticated 3D printing have emancipated ordinary citizens to become serious and responsible producers. Many have established their own "cottage industry" or cooperative communal production, or work as freelancers.

Nevertheless, companies still exist. Most of them are either small startups or huge mega-corporations, sometimes referred to as "techemoths". Companies are unlike traditional companies of the industrial era. They are also communities for those who share common interests and to some degree also common values. Companies prosper by solving wicked environmental and social challenges, and the pursuit of profits is only one of their aims.

The reason why companies still exist is that they are concentrations of social and cultural capital. They represent certain traditions, and perhaps most importantly they bring together different people from different backgrounds. These features are hard to replace by constantly changing ad hoc communities with relatively homogenous members.

Energy Companies of Tomorrow

Energy companies have not disappeared, but their role has changed. Their main function is to maintain the smart grid infrastructure and provide a platform for peer-to-peer trading and sharing of distributed energy resources. These resources provide flexibility for the system. For instance, heating, cooling, and consumer devices such as refrigerators can be switched off by the companies for short periods in times of high energy demand, without loss of consumer comfort. Electric vehicle batteries, especially during night time, are also used for demand response.

Energy is not seen as a consumed energy unit or technical commodity, but more as a service enabling different things. Energy companies sell services for ecological lifestyles and living comfort, such as optimal indoor temperature. They offer charging stations for electric cars. Practically all objects are connected to the Internet of Everything, and to the "Internet of Energy". This enables the maximum optimisation of energy production with energy use and storage, and also helps in balancing the grid. However, this also makes the internet of energy a very complex system, requiring maintaining from numerous companies.[7]

Partly due to the prosumeristic nature of the energy system, energy products and services have become an integral part of the consumer market. All energy devices, such as solar photovoltaics and

[7] Clean disruption, abundance and the Internet of Energy were key topics in the third Futures Clinique (Heinonen et al. 2017b).

batteries, are designed as aesthetically pleasing – as desirable brand products. Energy technologies and related services are an attractive part of citizens' everyday ambiance. This reflects the consciousness of citizens of energy as the fundamental enabler of their lifestyles – their housing, work, leisure, mobility, communication, communities, personal interests and values, et cetera. Energy is not seen as a separate "techno-economic energy sector", but has cultural and social meaning, and an almost spiritual and existential dimension as the source of all living.

The "cool factor" of energy is enhanced with sharing energy consumption and production information with others. Frugal energy consumption is a mark of a "good citizen": although clean energy is available aplenty, people are conscious that if the increase in energy and material consumption broke loose, humanity would once again risk of going astray, on the unsustainable path. The underlying ecological ethos is pervasive despite material and energy abundance. For instance, urban construction *nourishes* biodiversity as a rule, and artificial intelligences monitor global energy and material consumption continuously to keep it within set planetary boundaries and sustainable growth trajectories. Keeping ecosystems healthy matters. Artificial intelligences also help in allocating resources, making for instance the sharing economy function without friction.

Practically all objects have become "ecologically smart", embedded with artificial intelligence, and connected through the internet of things. Because of a massive increase in the number and sophistication of devices, the electricity consumption of devices and other objects has increased in total, despite increases in energy efficiency. Numerous consumer product companies have thus become also energy producers. Energy is usually included in the price of the product – in a similar way as in the 2010s unlimited data was often included in the internet connection services, or as Tesla offered free charge stations for its electric cars. For the end customer, energy is typically bundled in other services. Customers get "free" energy, by giving service provider data on energy use and right to control power demand.

Condition of Complexity

Despite the high living standards and material abundance, the world is not a utopia. The increase in energy supply has caused an increase in general complexity in society. Similar to energy, social power is relatively evenly distributed. This means that compared to previous times, many more actors are equipped to have a say in how society should be organised and what should be valued and pursued. This has made decision-making rather messy. The world has been divided into multitudes of different niche communities, each with their own value systems and conceptions. Some underground groups disturb and terrorise others with cyber-attacks, often aimed at energy systems and the internet of things. Although tensions between nations have eased due to global prosperity, the world has been

divided into liberal, globally oriented cultures and authoritarian, nationalistic cultures[8]. Geopolitical conflicts are rare, but they still occasionally occur with resulting momentary upheavals. Many feel that the world has become more chaotic and unforeseeable due to constant change and the weakness of a commonly shared public sphere.[9] Although many of yesterday's problems have been settled, these complexity-based fragility issues still remain to be solved.

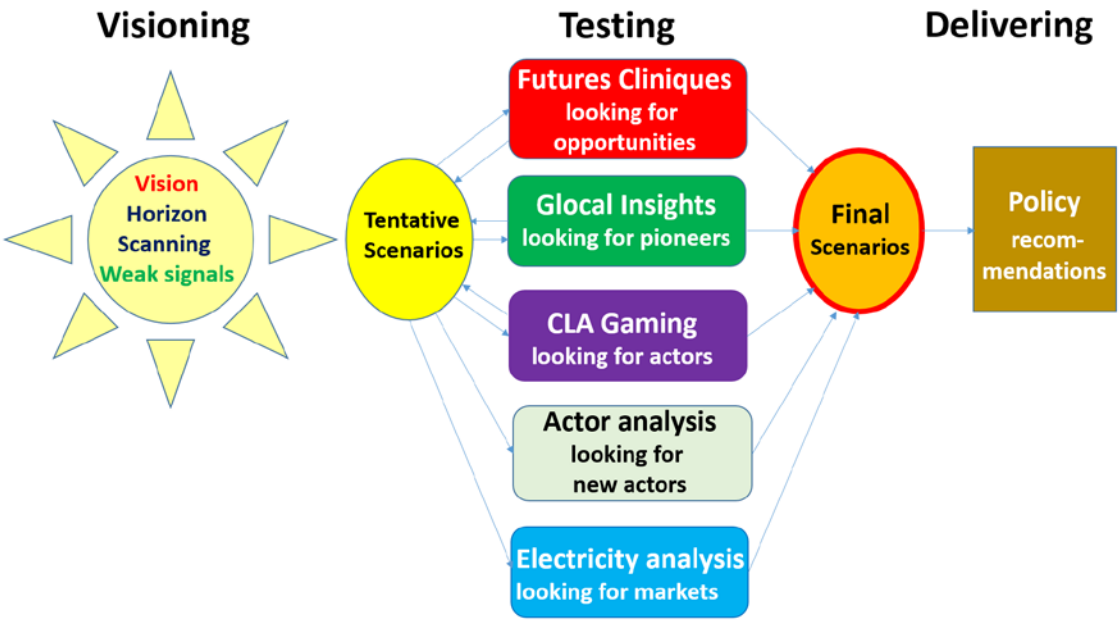

Figure 1. *Flow chart of the foresight part (WP1) of the Neo-Carbon Energy project and its research process.*

The research process of the foresight part advanced in stages. Based on a vision of the preferred futures and the horizon scanning of weak signals, scenarios have been constructed and tested. The research process has consisted of identification of opportunities, particularly in Futures Cliniques, searching for new actors with multiple research strategies, and exploring what new energy markets in the future could look like. This research process, consisting of independent yet interlinked parts, has paved the way to conclusions, and subsequently, policy recommendations (see Figure 1). These elements are presented next.

[8] Provocatively, this could be framed to be a divide between "Western" and "Eastern".

[9] The fifth Futures Clinique in the Neo-Carbon Energy project concentrated on discontinuities and the VUCA world, full of volatility, uncertainty, complexity and ambiguity (Heinonen et al 2017d).

3. NEO-CARBON SOCIETAL SCENARIOS

Four different scenarios, which are summarised below, describe potential outcomes, manifestations or reflections of the vision. The scenarios emphasise the fact that when looking into the future, we should construct and bear in mind alternative images and scenarios of the future. A core rationale for foresight and futures studies is scenario thinking – as synonymous to thinking in alternatives. There is never only one future, but different possible future*s*. The full scenarios are published in a report (Heinonen et al. 2017e).[10] The scenario report includes three scenarios – *Radical Startups*, *Value-driven Techemoths* and *New Consciousness* – which can be viewed as different worlds that efficiently fulfill the vision as presented in chapter 2. A fourth, rather different scenario – *Green DIY Engineers* – is also provided. In this Green DIY Engineers scenario, engineer-minded citizens have organised in local peer-to-peer, renewables-powered communities to survive an ecological collapse. This scenario shares many features with the other three scenarios and the vision. However, it is not a manifestation of the vision as such, but rather a world which dramatically suffered from a catastrophe. After this "valley of the death", these communities reorganised to pursue the values embedded in the vision as well as they can, within the constraints of the turmoil.

1. Radical Startups

Inexpensive renewable energy has levelled the playing field for startups and small and medium-sized enterprises. These companies act as peer-to-peer communities and they also harness peer-to-peer principles in their efforts. Startups are known for their culture and values of bold aspirations. Startups have a "social consciousness", and many of them operate in the energy, environment, and related sectors.

2. Value-Driven Techemoths

Inexpensive energy has empowered giant, global technology corporations. Peer-to-peer models are practiced in these "techemoths". They represent the Silicon Valley vision of emancipation, freedom, creativity, and open source, but at the same time seek to dominate economy and culture. Technology companies assume a powerful role – they provide infrastructure, education, urban planning, and so forth.

[10] Also see Breyer et al. 2017 for an article specifically on the New Consciousness scenario.

3. Green DIY Engineers

The world has faced an ecological collapse. In order to survive, engineer-oriented citizens have organized themselves as local communities. Environmental problems are solved and energy produced extremely locally, so smart scarcity prevails. Nation-states and national cultures have more or less withered away.

4. New Consciousness

Information and communication technologies, ecological values and decentralised renewable energy have transformed citizens' mindsets. People do not conceive themselves as separate, self-profit seeking individuals, but deeply intertwined with other humans and nature. Societies collaborate openly and globally to share energy, resources and information.

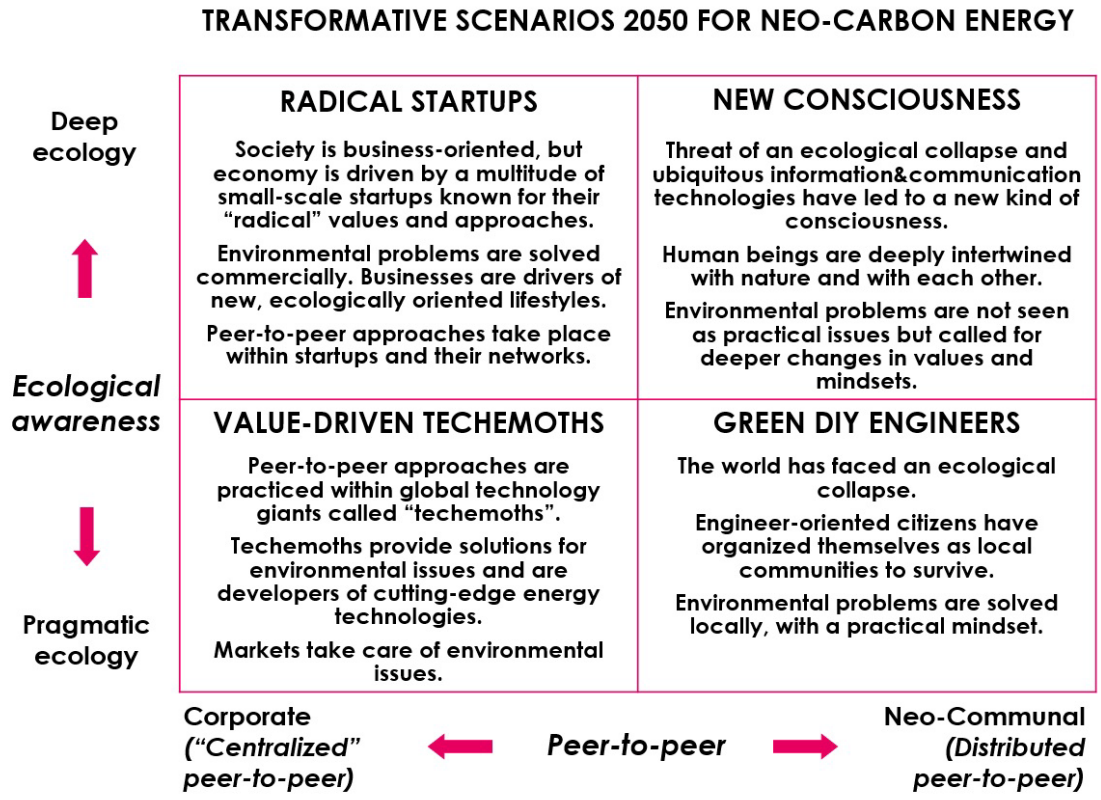

Figure 2. *The framework of two axes – peer-to-peer and ecological awareness – for the four different scenarios*

Chapter 4 describes different actors in the scenarios in more detail. The scenarios outline macro-level societal changes. In practice, a plethora of different actors from the grassroots to established players will work to realise a renewables-powered future (Similä et al. 2016; Lang 2018; Lang et al. 2016; Karjalainen & Heinonen 2018; Heinonen & Karjalainen 2018). Hence we need to pay close attention to individual actors: their motivations, values, visions – and concrete actions.

4. ACTORS ENABLING THE NEO-CARBON FUTURES

Actor analysis: focus on "who?"

In addition to developing societal scenarios described above, a 100 % renewable energy world was thoroughly studied in the other parts of the Neo-Carbon Energy project. An extensive amount of quantitative modelling and scenario results as well as other techno-economic information was produced to outline its feasibility and describe the parameters of transformation towards it.

Broadly speaking, the focus of quantitative scenario models can be characterized as answering to question of *what*: what kind of technical changes are expected in the energy system that relies very highly on renewables, as the so-called *neo-carbon energy system*? What will its power plant fleet look like in technological respect? What is the economic performance of the studied technological solutions?

Should the techno-economic data about societies that use high levels of renewable energy[11] be available, it is not always clear how to best make use of this data. Especially, there are development needs to transfer the results into action plans with needed stakeholders and other actors. Most importantly, the inclusion of actors is often superficial, if anything, in quantitative energy system models.

Actor analysis was explored as a means of developing scenario analyses and other results more instrumental as a part of the foresight research. The key actors of today's energy systems are companies producing and using energy, power grid companies, ministries and regulators, energy technology businesses and developers, together with environmental organisations (NGOs) and different advocacy (or lobbying) organisations, which is a point of departure in the identification of relevant actors. However, in assuming a broad, whole-of-society perspective and thinking about transformative futures, it may be concluded that tomorrow's relevant actors are not necessarily the incumbents of today.

The efforts in actor analysis can be divided in two phases. In the first phase, systematic methodologies for actor analysis and their application were considered (Similä et al. 2016). In the second part, the application of actor analysis was conducted in view of a high-RES context in Finland (Similä et al. 2017). In thinking of a highly renewables-based neo-carbon energy system, the target of the efforts can be summarized in focusing on the question of *who* instead of *what*. The actor analysis was motivated by a need to "identify and add actors" to the Neo-Carbon scenarios, and, subsequently, to develop justified action and policy plans. In the following, we briefly review the most important results.

[11] RES = renewables

Actor identification in very high-RES worlds

The actor analysis (Similä et al. 2016) based highly on the analysis of scenario narratives built by Finland Futures Research Centre (FFRC). The analysis revealed different "actor worlds" and provided suggestions about the role and significanc of the actors. Furthermore, attributes, according to which differences arise between the actors in the scenarios, were characterized. Importantly, these results can be seen to bring added value to very high-RES scenarios. Consideration of actors enhances their potential for utilization. Especially, the suggested key actors, presented in the following, are highlighted out of dozens of actors in each of the societal scenarios.

In the Radical Startups scenario, startups, companies, investors, workers, cities, and entrepreneurs are suggested as key actors. These actors potentially have a role in the field of small-scale and innovative energy solutions. Media, freelancers and consumers are suggested as other actors identified.

The Value-driven Techemoths scenario considers large technology companies, so-called "techemoths", as the main actors in driving the future. Google, Facebook, Apple and Samsung are mentioned as examples in today's world. Conclusively, the strategies and actions of these giant companies strongly outline the development towards a neo-carbonized world in the scenario.

In the Green DIY Engineers scenario, actors are relatively few. However, a potentially high number of individuals are identified, in comparison to other scenarios. The scenario is driven by self-made and communal actions, so local communities, people, and "do-it-yourself engineers" are the key influencers.

In the New Consciousness scenario, global systems face a radical transformation. The actors identified are the most diverse, and singling out particular actors, in charge of the transformation, is more difficult. However, the role of international collaboration and global systems seems evident. International organizations and networks are enablers of these developments.

Characterization of "actor worlds"

In addition to the key question of who discussed above, differences are identified between the societal scenarios in other respects. That is, both the structures of the network, according to which actors are connected, as well as their internal motives are seen varying. This information can be seen useful in considering policy and action plans, e.g. in choosing measures for RES policies. Consequently, the following qualities were identified to classify societal scenarios:

"How" reflects on the axis on values in the societal scenarios. Deep ecological values prevail in the "New Consciousness" and "Radical Startups" scenarios, whereas pragmatic ecology, markets and a practical mindset are present in the "Value-driven Techemoths" and "Green DIY Engineers" scenarios. According to Hermans & Thiessen (2009) values describe the internal motivations of actors.

The number of actor types refers to identified groups. New Consciousness was assessed as the most diversified scenario in respect of different actor types. That is, the actions taken were seen to spread globally all over societies, and involving a large number of types of actors.

The number of actors (as decision-making entities) refers to the number of variations among the agents belonging to a group. "Consumers", for example, as one actor type, may involve even millions of actors to be included in the models, each potentially having a different profile on behaviour.

Network characterization demonstrates the links between the actors. The most intertwined and wide networks are suggested for the New Consciousness scenario. This is reasoned by both high number of actor types and decision-making entities. In the Green DIY Engineers scenario, on the contrary, the operations build highly on local actions, suggesting a dispersed and localised network topology. Activity between companies can be seen especially emphasized in the "Radical Startups" and "Value-driven Techemoths" scenarios.

The most important actors – a Finnish perspective

The identified actors, actor types and networks in the transformative societal scenarios represent alternative developments on how a very high-RES world may appear in actor respect. However, the identification of actors does not present guidance on what kind of actions could be justified for Finland. Thus, to take the actor analysis to a more concrete level, the results on the most important next steps in Finland and who are the most important actors for the realisation of "Neo-Carbon Finland" were approached through a futures workshop designed for this purpose (Similä et al. 2017).

The aim of the workshop was declared as '*to define building blocks for roadmap and action plan for "Neo-Carbon Finland 2050*''. As a guideline, the participants were instructed to think of Finland as a front-runner in climate change mitigation, implementation of the Paris Climate Agreement and the "new economy" of robotization, environmental businesses etc. Noteworthy, the starting point embraced possible positive outcomes of the energy transition. This way, the target was to identify opportunities for Finnish actors. Additionally, the vision developed within the project (ch. 2 in this report, see also Ruotsalainen et al. 2017) was considered a good starting point for defining an action plan and was used as an introductory material for the workshop participants.

Accordingly, a major share of the suggested key and pioneer actors fall under the category of citizen movements appearing as new communities, or in the business sector with a novel structure in regards to the energy sector. In the business sector, the role of new type of business actors was particularly highlighted: non-energy companies were suggested to enter the energy business. Start-up companies are seen a strong mover as drivers of change. The role of funding (and related) organisations was highlighted repeatedly, signalling their importance as key actors. Both international and national funds, as well as crowdfunding were mentioned. The pinpointed public actors consisted of cities

or city-owned companies. Also, different governmental groups (parties, inter-party groups) and individuals were, to a lesser extent, named as pioneers, particularly as the executors of the considered actions.

As a conclusion, several new actors outside the traditional energy supply chain are suggested to take a pioneering role, when considering Finland's evolution towards a neo-carbon energy system. However, of course, this does not mean that the present energy sector actors would inevitably disappear. Actors who are part of these groups were also considered in the workshop, but their role was somewhat taken for granted. The focus was on highly transformative scenarios, and these two factors potentially contributed to the emphasis being on new actors.

Interestingly, the actor elements suggested in the workshop consisting of Finnish experts appeared also in the global scenarios, which were constructed in a separate process.[12]

1. Citizens and citizen movements are strongly reflected in the "Green DIY Engineers" and "New Consciousness" scenarios
2. Start-up companies are – self-evidently – presented in the "Radical Startups" scenario. Also, the role of cities was suggested in it.
3. Global technology firms are often referred to as important for test sites and RES technology investments in Finland, as is the significance of firms coming outside traditional energy sector. These features are present in the "Value-driven Techemoths" scenario.

The use of results in designing a roadmap and an action plan

To consider actions plans and roadmaps for Finland in the short-term future, the identified pioneer actors appear to be the most logical frame for actions over the period of the next few years. That is, a major share of suggested pioneer actors named fall under the categories of *business with renewed structures and emerging startups*, as well as *citizen movements and new type of community actors*. Hence, should there be any policy processes targeting at very high share of renewables, the results suggests these actors being a promising target groups for actions.

In addition to relevant actors, relevant *actions* were explored. A large list of suggestions was obtained, organized according to their nature into six categories: Political, Economic, Social, Technological, Environmental/Energy and Cultural/Customer/Citizen aspects (using the so called PESTEC

[12] Another way still to identify actors and stakeholders is gaming. Such an approach was adopted for an experiment to use CLA (causal layered analysis) game as identifying and creating roles for making renewable energy transformation happen. (Heinonen et al. 2017).

method). Especially, the next electoral terms and Governmental Programmes were suggested as concrete steps for actions in Finland. A list of actions includes *bans on fossil fuels, new intended nationally determined contributions (INDCs), subsidies or the termination of unnecessary or harmful ones, tax reforms, campaigns, re-focusing national strategies, research and development (R&D) support, establishing a position of a renewable energy (RE) minister, free public transport, and boosting ecological lifestyles*. The full list of ideas is presented in Similä et al. (2017).

Citizens are suggested to be empowered, when they act as part of citizen movements. Citizens appear particularly strongly as pioneer actors in online communities. Involvement, concretization, learning, and influencing attitudes are mentioned as examples from actions of this group.

As a reminder, the results do not provide guidance on the effect of the actions, but must be rather considered as a "set of suggestions" for potential actions. Despite this weakness, the results provide an additional and insightful element adjacent to quantitative model-based energy scenarios. The latter are typically very useful for analysing techno-economic dimensions, but have limitations in answering other types of questions, as each model has their chosen aim and structure.

5. ENERGY MARKET IN NEO-CARBON FUTURE

The Neo-Carbon Energy future provides a vision about a renewable energy system and sustainable society. However, transformation towards a renewable energy system will require networks and markets to accommodate a significant amount of distributed, intermittent generation. Fundamental changes in the design of the electricity markets are needed, as present market design may not be feasible anymore.

Generally, electricity market design should provide sufficient incentives for meeting demand and supply in real time, as well incentives for long-term capacity adequacy. Marginal cost based pricing has worked quite well for the traditional generation mix, where fixed costs represent quite a low share of total costs, and variable costs are in a key role in determining the total cost. In such a case, marginal generation cost based pricing system ensures cost recovery for power plants. However, RES generation based on solar and wind is inflexible and typically has near zero marginal cost. The key cost element is capital cost, which is mostly dictated by the cost of technology and the interest rate, of which the latter depends highly on the risks faced by investors.

These changes in the cost structure and composition of the generation facilities raises a question of whether the marginal cost based pricing and energy only market is an adequate market design for the renewable driven energy system. However, there is no clear answer for what the most feasible pricing mechanism for renewable energy markets is. Nevertheless, a uniform market price is seen important, as it is needed to ensure that power plants and demand response and storage resources are given an incentive to be available when their value to the system is highest.

Moreover, consumers and prosumers are focal players in a world powered by the people. Therefore, the present electricity market, which was designed for transactions between larger entities, may not be feasible to capture energy and flexibility provided by scattered small resources. Finally yet importantly, as renewable generation is typically the least cost solution in life-cycle costs, but has higher initial costs than some fossil based solutions, innovative financing tools are needed. This is crucial to promote the building of the renewables-based system also to those countries and areas, which do not have the capital for necessary, initial investments. Hence, reforms in electricity market designs, financing solutions, and innovative partnerships are essential for renewing the energy system.

In a renewables based system, energy is a non-limited resource, while security of supply remains a limited resource. Hence, the energy market has to be capable of valuing flexibility from both small distributed and larger centralized resources. All stakeholders have to face cost-based prices for demand and supply of power and the use of network capacity. Hence, ensuring adequate temporal and geographical resolution in prices, which are based on the value or cost of the service, is essential in ensuring the development towards a cost-efficient, sustainable, and secure energy system. Based on

the cost structure of the renewables-based generation and the need for valuation of the flexibility, it is likely that there will be different markets for different resources – that is, for instance, near real-time markets for flexibility and long-term auctions for renewable generation capacity. In addition, for end customer, energy will be typically bundled in other services. Hence, the direct price of energy for customer in such a case could be zero, but customer would "pay" for this "free" energy by giving service provider data on energy use and the right to control his/her electricity demand within the given comfort limits. This would be a bit similar to how people nowadays use "free" services that are provided by Google and other internet companies.

Finally, although we are facing revolutionary changes in the energy system as well as in the everyday living and services of entire communities, as illustrated above, the development of the energy market design and regulation have to be foreseeable for stakeholders. This is important in order to minimize regulatory and political risks, and to ensure a steady development towards a renewable system powered by the people.

6. CO-CREATION IN GLOBAL INNOVATION COLLABORATION

Current approaches to promote renewable energy technologies around the world differ in many ways. Different initiatives and modes of operating aim to advance the local uptake of renewable energy. Certain projects come and go, others are more long-lasting, and a few are visionary and truly inclusive. Innovators possess the will to develop the sector forward, but often times, there has been a lack of attention to the nature and timing of learning and development processes around renewable energy in a systemic way. Therefore, countries will need to increase their efforts to build carbon-neutral energy systems. This is why all involved actors should be aware of their role as agents of future creation. Individuals, companies, non-governmental organisations (NGOs) – and even governments may – pioneer, and collaborate. Tesla, for instance, gave away some of its patents for free, in part to expedite the emergence of the future system.

It is possible to think of alternative futures and innovate with those affected. This seems to be specifically important, if the innovation partners are starting from a different base. It could be useful to connect futures thinking, intrinsically connected and beneficial for innovation, with innovation ecosystems thinking – to ensure that innovative capabilities and knowledge are accumulated. Looking forward, in turn, may help think more boldly. The aim is to build capabilities, so that novel initiatives – from sustainable business models to improved management know-how – can thrive and are able to scale up. More investment in knowledge inputs may lead to higher value creation and retention, and then, growing ownership of the emerging technology. Further, in the process, the innovations themselves might become more innovative, locally fit, and transformational. (Karjalainen & Heinonen 2017; Lang et al 2016; Karjalainen & Heinonen 2018; Heinonen & Karjalainen 2018).

In a globalised world, actors – both local and international – can strive to build collaborative frameworks with knowledge and network components for systemic innovation. Countries that have renewable energy potential can harness diverse collaboration modes. This is why, to achieve effective innovation, policymakers should not only know technologies, but recognise power structures and institutional dynamics. Only this way, they can support entrepreneurship with enabling policies, measures, systems and institutions – to empower innovators. Co-creation is particularly useful, if technology, key staff, business model design, and/or financing are foreign or unfamiliar, to allow local actors also to be strategic in developing their efforts. Emerging and developing countries who typically wish to diversify their economies, should in particular think of hybrid approaches to collaboration, diffusion, knowledge

production, social networks and development instead of passive adoption strategies. (Heinonen, Vähäkari & Karjalainen 2017c).[13]

Actions can be creative, evidence-based, futures-oriented, and inclusive of the grassroots. A recognition of power dynamics, when driving desired future outcomes could, ideally, mean broader benefit-sharing from innovation efforts. Future can even seek to recognize the past, if emerging technologies reflect local cultural practices, or are even coupled with indigenous knowledge production. Different geographies, sectoral dynamics, socio-economic factors, and levels of openness to knowledge sharing may shape how the old is dismantled and the future energy system built. Given these conditions, increasingly diverse innovation pathways and co-creative collaboration patterns could emerge in the future.

[13] This report documents the results from the fourth Futures Clinique conducted within the Neo-Carbon Energy project in Santiago de Chile. This Futures Clinique focused on the prospects for a renewable future in Chile.

7. CONCLUSIONS

The future is shaped by today's decisions. The envisioned transformations, as described in the vision and the scenarios as its manifestations, can be targeted with consciously emancipatory approaches. Treating renewable energy holistically in society could make renewables an increasingly inviting and value-creating opportunity through empowerment for *citizens and communities*, business for a *value-driven private sector* and novel ways for *governments* to serve their constituents. These opportunities can be acknowledged in *visions, strategies, plans and decision-making* in several levels, as outlined in Figure 3.

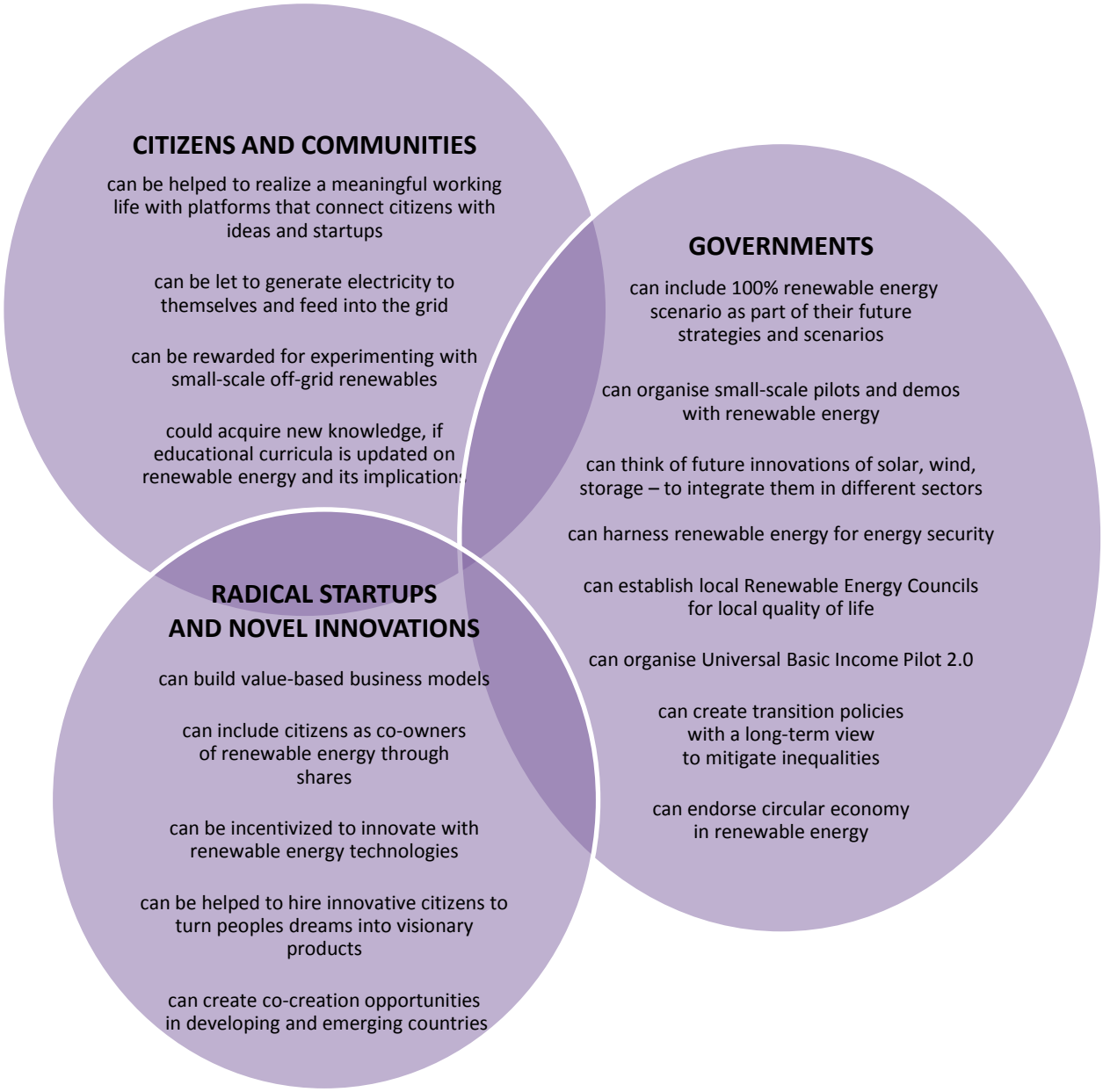

Figure 3. *Summary of envisioned roles and actions for actors in a collaborative strategy.*

Emancipating citizens and communities

A bottom-up perspective engages citizens' enthusiasm to "own" emerging technologies. Citizens envision arising benefits, which is why they want to be involved and experiment themselves. Like societies, which are hoped to be democratic, the same concerns energy production. Enabling self-organising in the energy sector would allow the prosumer citizens to act concretely. New knowledge and new models can increase the freedom of individuals to be creative and productive – nurturing their agency in the transition. Autonomous citizens can lead the way, especially when provided with the necessary space and tools.

Radical values and novel models to be nurtured

Peer-to-peer principles provide more power to the grassroots than before. They can also be harnessed in the form of novel services, organisational and business models. The peer-to-peer stance cherishes inclusive and networked innovation. Innovations, radical and incremental, could diffuse and change the world faster than before. A conducive environment for the uptake of the renewable energy system should recognize these patterns. With a reasonable amount of predictability, the environment should be *transformative*, developing the innovation ecosystem, and inviting a range of actors to act.

Governments to take the Initiative

In light of the urgency to limit global warming within Paris COP21 commitments, policies at different levels can aim to be increasingly transformative, supporting novelty and the pioneering actors. Policy mixes, for example, could be more effective than individual policy tools[14]. How different actors are incentivised, guided and enabled shapes future transition pathways. In the past, energy policy supported "centralised" actors. Decision-makers can play an active role by partnering with the pioneers and the civic sphere to support the peer-to-peer ethos, and drive a new direction boldly.

The potential and technical feasibility for renewable-based future has been confirmed – all we need is political will, visionary leadership and empowered actors collaborating to grab this readiness and make the vision a plausible and prosperous reality.

[14] Policy-makers can mobilize "hard" financial (such as taxes, subsidies, grants, and loans) or regulatory measures (laws, standards and targets) and "soft", indirect processes (small-scale pilots, demonstration projects, create networks, debates, consultations, foresight exercises, and roadmaps) to advance the transition debate.

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APPENDIX

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