The Effect of Institutions on Sustainable Innovation.

The Transition towards Smart Electric Mobility.

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Abstract

This paper analyses the effect of institutions on sustainable innovation. Therefore, the energy transition towards the sustainable new socio-technical system of smart charging is elaborated. Smart charging is an essential part of the energy transition, it connects the energy supply and electric driving. The electricity systems have to change and adapt to maximize the use of renewable energy and implement new technologies such as electric vehicles. A survey reveals the impact of a positive attitude towards a new system and Dutch norms and values on smart charging innovation. The regulatory framework of the DSO is limiting innovation, as it is focused on affordability and reliability, leaving sustainability only mentioned as an important objective. Other necessities for the institutionalization of smart charging are exposed through interviews and open questions to experts in the field. The social aspect and the customer acceptance and needs must be central. Policy recommendations are given to put the knowledge into practice.

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Introduction

The disaster of Fukushima in Japan (2011) made the importance to abandon nuclear power widely recognized (Schneider et al., 2011). Nuclear power carries catastrophic risks and the unresolved waste problem, also nuclear power does not have the capacity to become crucial in the future energy supply (Morris & Pehnt, 2016). Therefore, the energy transition to a low-carbon society is required for life security (Cleef, 2017). We have to fight climate change and move away from our fossil fuel-based energy mix. This may require an increase in energy conservation and efficiency and switching from fossil fuels to diverse sources of renewable energy, therewith we can make our energy supply sustainable (Smil, 2010).

The Intergovernmental Panel on Climate Change (IPCC), which reports on the general international consensus in research, has frequently warned for the disaster caused by climate change. According to climate experts we should stop global warming, i.e. adding carbon dioxide (CO_2) to the atmosphere, at two degrees Celsius to prevent the most disastrous changes. Many academics are even convinced that taking away CO_2 from the atmosphere is desired in the long-term (IPCC, 2011).

Smart charging is an essential part of the energy transition. So not only charging the car, but rather the connection between two worlds, on the one hand the energy supply and on the other hand the electric driving. Something will have to be done to facilitate the transition and the growing number of electric cars and to prevent problems in the grid (Jaap van Tiggelen, personal communication, 8 December 2017). The electricity systems have to change and adapt to maximize the use of renewable energy and implement new technologies such as electric vehicles. Therewith, the latter is a valuable component in the electric system, as it assists in the transformation to a sustainable economy in two ways. First, the car can be charged with renewables instead of harmful fuels. Second, the batteries can be used as a storage place for renewables when demand for electricity is low and supply of renewables high, and therefrom give back the electricity to the grid when demand for electricity is high and supply of renewables is relatively low.

In 2015 the Netherlands agreed to make our world sustainable with signing the Climate Accord in Paris. The literature on socio-technical systems helps to understand the gradually energy transition towards a new and more sustainable system. Therewith, sustainable transitions originate from sustainable innovation and a change of the conditions belonging to the old socio-technical system towards a new one. Sustainable innovation in this research entails the (distributed) renewable energy sources that rapidly drop in price and generate energy more efficiently. In addition, electric mobility is strongly on the rise, the batteries to store energy are getting better and cheaper rapidly. The electrification of cars together with the decentralization of renewable energy generation change the old electricity and transport system, and they even become more and more interdependent. To use the renewables efficiently and be able to charge cars without rapid increase of costs for the electricity grid, many conditions belonging to the old socio-technical system of electricity and transport have to change. For example, markets and user practices related to electricity and re-“fuelling” your car, regulations and policies, and the industry structure. These conditions or “rules of society” that shape and structure our behavior are institutions. Institutions that are embedded in society, of belong to an old socio-technical system. Some institutions, such as norms and values can be helpful for the energy transition, like that 78% of the Dutch think that climate change is a very serious problem. And that 82% of the Dutch agrees that “Fighting climate change and using energy more efficiently can boost the economy and jobs in the EU” (Eurostat, 2017) though institutions such as customs can also create difficulties for a transition. For example, the Dutch have always had a reliable electricity network and do not realize that there are restrictions, especially with the large impact electric vehicles have on the grid. This social aspect has been largely underestimated and should get more attention to enabling the energy transition. Besides, the government has to put effort in adapting the institutional environment of formal rules that belong to the locked-in old electricity system. The regulatory framework of the network operators has to be changed to be able to facilitate the energy transitions. Even though sustainability is one of the three objectives of the legislation the law is out-of-date. The sustainability goals have to be translated in the regulation of the energy markets by the policy makers. Thus, the government will have to play a central role in the energy transition. Good policy and legislation should lead to more investments and innovations. It is important that the government communicates clearly and timely and establishes a stable path (Cleef, 2017).

Institutions belonging to the old socio-technical system may hinder development of the new socio-technical system. That is why these institutions will have to adapt to the new socio-technical system and new legislation will be put in place to promote sustainable innovation. Innovation is necessary in the major transition we are facing in the electricity system. That is why this paper elaborates on the effect of institutions on sustainable innovation. More specifically the sustainable innovation being researched is the development of smart charging. Hence, the main question of this research is
"What is the effect of institutions on sustainable innovation and therewith the transition towards smart electric mobility?"
To find an answer the following research questions are addressed:

1. What is the influence of a positive attitude on sustainable innovation?
2. What is the influence of country related norms and values on sustainable innovation?
3. What is the influence of the institutional form on smart charging innovation?
4. What is the influence of the institutional environment of the DSO on smart charging development?
5. In what way should the institutionalization of smart charging be encouraged?

This paper contributes to the literature of transitions and institutions with the empirical determination of how the development of a sustainable new socio-technical system can be encouraged with use of institutions. As well as how the institutions relating to the old system should be changed and adapted. Since, the barriers and difficulties a new socio-technical system faces do often relate to the old system. Besides, this paper connects the subject of the energy transition to institutional literature what ensures a different perspective than the usual transition approach. Hence, elaborate on the role and possibilities of institutions. Also, in addition to Schiavo et al. 2013, contributes this research with an elaboration on the necessities to go from step three on regulatory reforms on technical innovation to step four. That is from the demonstration phase of real-life projects and test-cases towards output based regulation into the deployment of the innovative solution. It details the limitations, possibilities and required changes on this subject.

The next section presents the context concerning climate change, smart charging and regulation. The second section is shows the definition of institutions as used in this research. It details the theoretical background of various levels of institutions, sustainable transitions and elaborates on sustainable innovation. In addition, it describes previous work with lessons on regulatory reforms concerning technical innovation. The third section is dedicated to research method and the way in which data is collected. The fourth section is focused on the results of the first three sub questions. However, the main empirical research is shared in section five. It discusses that the laws and regulations for grid operators do not control for sustainability. Section six elaborates on the requirements for the institutionalization of smart charging among which social acceptance of the customer must become more central in further development of smart charging. After concluding bring the discussion and policy recommendations the paper to the end. The policy recommendations describe the extent to which it is considered desirable for the legislator to formulate a specific task for the work of ACM in the field of sustainability aspects of the energy supply, and how this should be structured. Moreover, how social acceptance can be created and what is needed for that.

1. Context

Smart Charging is a comprehensive term in the world of electro mobility and renewable energy. According to ElaadNL, (2016) smart charging is "when charging an electric vehicle can be externally controlled (i.e. "altered by external events"), allowing for adaptive charging habits, providing the electric vehicle with the ability to integrate into the whole power system in a grid- and user-friendly way. Smart charging must facilitate the security (reliability) of supply and while meeting the mobility constraints and requirements of the user" (Living Lab Smart Charging, 2017).

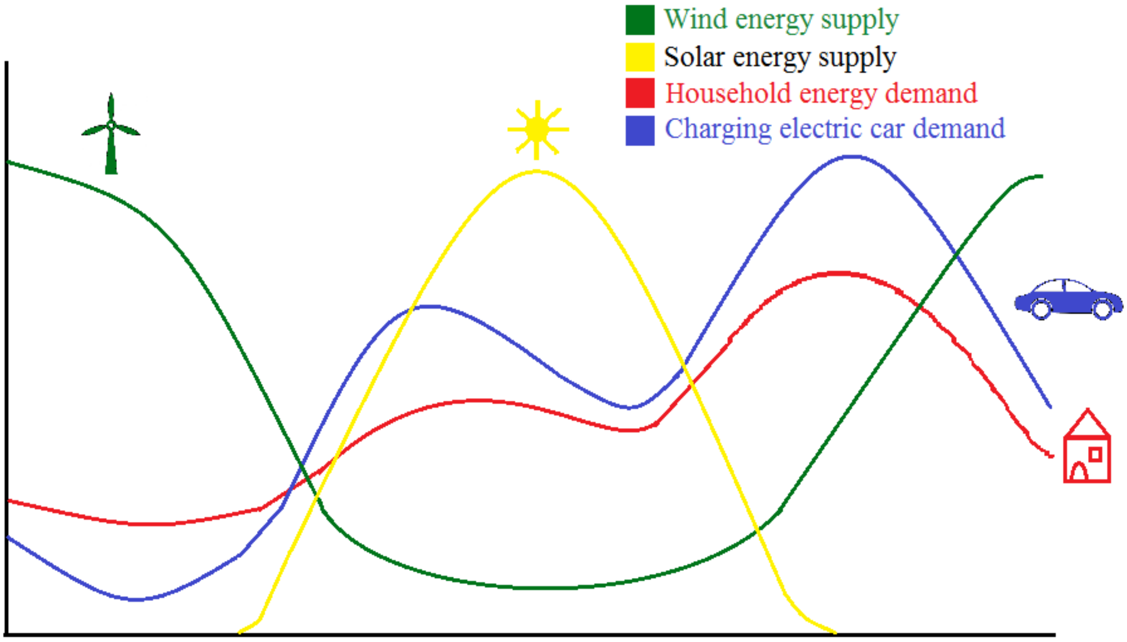

Figure 1. Approach of the future demand and supply of energy during the day. Demand of energy shows a morning peak and an evening peak. While wind energy generally is available when demand is low, by night, and sun energy is available during the day (B. Remmerswaal, 2017).

Figure 1 shows that future demand and supply of energy during the day do not match. As one can see in demand there is a peak in the morning and evening, while in supply there is a peak in the middle of the day and night. Within the energy grid demand and supply need to be equal at all times. Thus, when demand exceeds supply than nuclear power plants will produce the energy deficit. And when there is a surplus of wind or solar energy that cannot be stored in a battery until it is needed, we have to throw away a part of the sustainable generated energy.

Naturally, at this time the demand of charging electric cars is not yet as high as shown in the figure. However, the amount of electric vehicles is growing steadily and in about ten years there will come a moment from when driving an electric car will be cheaper than driving a fuel car. By that time, the transition from fuel to electric cars will not go slowly and fluently, instead it shall be a turning point in history wherefore the Netherlands have to be prepared (Seba, 2014). And from that turning point on, figure 1 gives a good outline of the situation (H.J. Idema, personal communication, 2017).

The charging infrastructure has to be prepared for a large number of electric vehicles. This means that the energy distribution grid must be able for transporting a huge amount of energy at peak hours. Increasing the capacity of the network and transformers is expensive though the full capacity is only used at peak times. Naturally, electricity prices will rise due to demand overreaching supply, and the risen network costs as well.

The Netherlands is lagging far behind the climate targets as agreed on in the Climate Accord in Paris, especially when it comes to renewable energy. The Netherlands should get fourteen percent of her energy from renewable sources in 2020 (ECN, 2017). Whether this will be achieved remains to be seen. In the *Nationale Energieverkenning* (2017), is reported that the share of renewable energy in 2016 was 6.0 (ECN, 2017).

The number of fully electric vehicles (BEVs) on 31 March 2018 is 25,134 and the number of partly electric vehicles (PHEVs) 98,098 (RVO, 2017). The growing amount of electric vehicles results in an increasing availability of storage capacity in the network, which can be used for smart charging. The current storage capacity is negligible, but will increase in future (Bespaar Energie, 2016). By adjusting the way, the speed, and timing of (un-)loading, to the customer, market and network conditions, we can solve congestion and imbalance situations in the grid. In the future these situations will occur more and more due to the growth of renewable electricity (PWC, 2017). “The smart charging market is still in its infancy but will develop rapidly in the coming years. It is important to create the necessary conditions now in order to enable this development (Living Lab Smart Charging, p. 32, 2017).”

Smart charging will become an important factor as more electric vehicles arrive on the market. Then it is important to be able to avoid peak loads with smart charging and to be able to charge in a controlled manner. With the growth of renewable energy in the energy mix, smart charging will become more important. It is therefore relevant to gradually introduce smart charging methods, to test them in pilots and to create the necessary preconditions (e.g. concerning legality). It is especially interesting when a critical mass of electric vehicles is on the market and can be integrated into smart charging (Katja Gicklhorn, personal communication, 14 February 2018).

Grid operators have a unique position in the energy supply and are able to speed up sustainability. This requires a regulation that provides space for the necessary investments in the networks to make this sustainability possible (Netbeheer Nederland, 2018). However, with regard to the monitoring authority ACM there is no specific policy with regard to sustainability aspects. The policy as laid down in the Electricity Act 1998 and the regulations based on this is primarily aimed at promoting market forces in the energy sector and controlling the monopolistic position of network operators (ACM, p. 4, 2013).

Besides the energy transition being a technical challenge, the electricity consumers have to change their behavior. This cultural change of society entails the whole society that has to adapt for the sustainable system. Some policies are required to help people adopt ideas about sustainable energy consumption. Therefore, awareness of the climate problem, limitations of the electricity grid, charging electric vehicles, and smart charging have to be created. Fortunately, the Dutch attitude towards fighting climate change is favorable. Over nine in ten (95%) of the Dutch think it is important that the “national government provides support for improving energy efficiency by 2030, e.g. by encouraging people to buy electric cars” (p. 4). In addition, even 97% think it is important that the “national government sets targets to increase the amount of renewable energy used by 2030” (p. 4). Also, the economic potential is widely (91% agrees) recognized by the Dutch. They think that “promoting EU expertise in new clean technologies to countries outside the EU can benefit the EU economically” (p. 3). And 86% of the Dutch agrees with the statement that “more public financial support should be given to the transition to clean energies even if it means subsidies to fossil fuels should be reduced” (p. 4) (European Commission, 2017).

2. Theory and Concepts

The theory serves as a tool to understand the process, system, and its functioning. Accordingly, this chapter introduces the concepts and theories that are the foundation for this investigation on institutions, with a focus on sustainable innovation. The main investigation of this research is the influence of (economic) institutions on sustainable innovation. In the first paragraph, the subject of sustainable innovation is introduced, whereby the meaning for smart charging (§1.1). As the transition is useful to understand, in the next paragraph (§1.2) the current sustainable transition is elaborated. Then, the topic of institutions is elaborated (§1.3), which is linked to and illustrated with examples from the area of smart charging and electric driving. Institutions enable and disable the functioning of the emerging sustainable innovation system. Therefore, I focus on institutions, as those help to understand why processes happen as they do, why people and actors behave in a certain manner, wherefore a system is organized as it is and how it may be changed. Subsequently, §1.4 starts with the elaboration of the subject of the transition itself with lessons learned regulatory reforms on sustainable innovations.

The structure of and interrelations within the theoretical framework are illustrated and explained in figure 2 below.

Figure 2. Structure and interrelations within the theoretical framework

2.1. Sustainable Innovation

Sustainable innovation is a comprehensive concept; therefore, it is elaborated in the essentials below. Flores et al. (p. 557, 2008) describes sustainable innovation as “a process where sustainability considerations (environmental, social, and financial) are integrated into company systems from idea generation through to research and development and commercialization”. The object of change may be a service, product, process, technology, as well as an organizational or business model. Moreover, the innovation is linked to sustainability goals through the long-term and holistic process of sustainable development (e.g. Truffer, 2003; Charter et al., 2008; Charter & Clark, 2007). Besides, it improves sustainability performance – that comprises social, economic and ecological criteria, which are in turn are embedded in culture, space and time (Carillo-Hermosilla et al., 2010).

For sustainable innovation, a change of larger portions of consumption and production systems is needed (Boons, 2009; Truffer, 2003). Furthermore, in the literature about product innovation, a transformation even may happen in product architectures – that is the manner a set of product elements is interrelated – consequently it entails a changed link between the same elements (Davies & Brady, 2000; Hall & Vredenburg, 2004). In addition, innovation requires some extent of radicalness which is featured by disruptive markets for producers as well as customers which are “new to the world” (Markides & Geroski, 2005). Both the formation of new markets and the actors involved (new entrants or incumbent firms) are affected by radicalness (Boons, 2009). For example, if the openness of incumbents for radical changes is not enough to get along with disruptive innovation (Christensen, 2003).

As shown in the conceptual framework, there are different sorts of innovation. Social innovation is for example about the enlargement of social acceptance of smart charging solutions. Technological innovation has to do with R&D, smart systems, smart grids and infrastructure. Environmental innovation is about limit CO2 emissions and charging with renewables. And last but not least, economic innovation implies higher efficiency (through link with local energy) and a less dependent and vulnerable economy (efficient use own energy).

2.3. Socio-technical systems and Sustainability Transitions

2.3.1. Sustainability transitions

The socio-technical system concepts are an analysis based on a transition approach, what entails the (sustainable) change of systems (Boons et al., 2013, Geels, 2004). The internal dynamics of a system are in the transition research considered of major importance, likewise the innovation research concept just discussed. The linkages among the diverse components are critical in realizing societal functions (Geels, 2004; Markard et al., 2012).

The process of gradual and continuous change from one socio-technical system to another is called a transition. The transformation of the structure of (a complex sub-system) of society generally takes fifty years, and includes many actors (Farla et al., 2010; Geels, 2005, Markard et al., 2012). A transition is sustainable if it is a change of a societal domain towards more sustainable consumption and production models in the long run (Geels, 2005; Grin et al., 2010, Markard et al., 2012). Transitions are assumed to start in a niche market and can become mainstream under preferable conditions (e.g. Van den Bergh et al., 2011). Hence, transition research is focused on radical innovation in consumer niches, market niches and business model niches – as an example for the latter car sharing (Boons et al., 2013).

2.3.2. Socio-technical systems

A useful way of showing interrelated factors in the socio-technical system of transportation – which incorporates automobile – is a graphic overview, such as figure 3. The graphic representation of the socio-technical system for land-based road transportation contributes to this research with an overview of the components of the internal dynamics. The service of travelling to different places is possible for society through the interplay of a variance of technical and social elements. Together, those interlinked – and embedded in one another – elements fulfill the transport function to society (Markard et al., 2012). Interaction between distinct agency categories must result in adaptation of user behavior and new rules created by policy makers with the introduction of new technologies (Geels, 2004).

For radical technologies it is difficult to break through an established system, therefore it is worthy to map the regime of the sector a new innovation system is operating in. The mature technology is featured by its stable system of synchronized elements, what generally has a mismatch with the emerging technology (Geels, 2004; Geels & Kemp, 2007). Dominant technologies of the existing regime derive advantages from lock-in and path dependency. This creates barriers and difficulties for the emerging and more sustainable technologies, which require for example other user behavior, infrastructure and regulations (Geels, 2005).

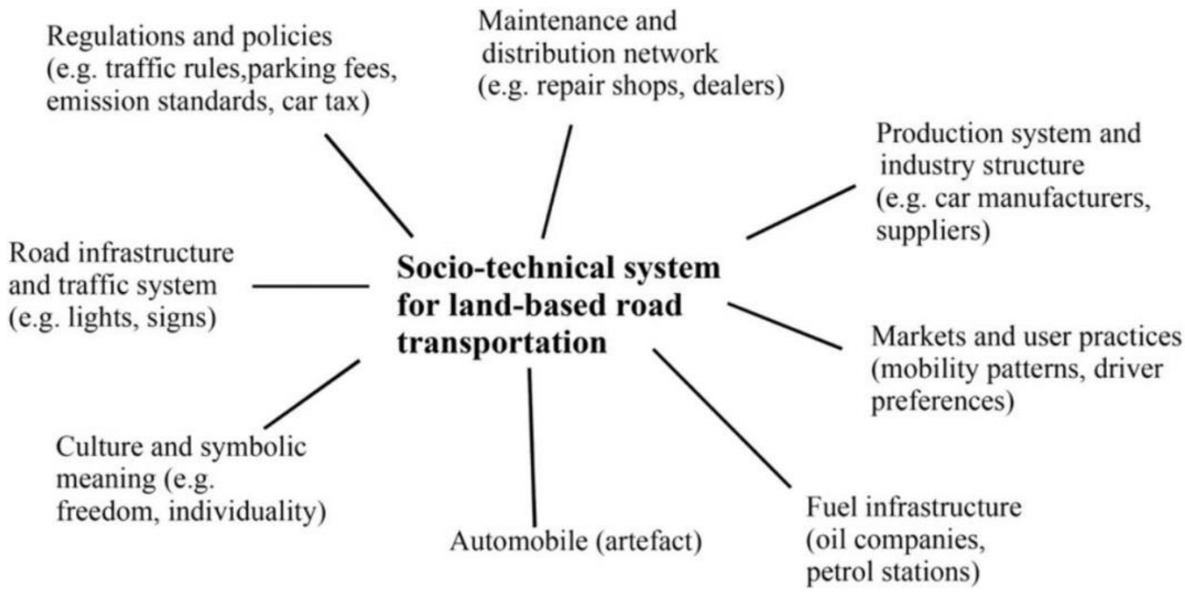

Figure 3. Socio-technical system of land-based road transportation (van Bree, Verbong & Kramer, p. 531, 2010).

2.3. Economic Institutions

2.3.1. Introduction to Institutions

Institutions are a broad concept, they are the formal and informal rules that structure and shape interactions between actors and people in society (North, 1991). Moreover, they constrain the information flow between people, strategies and actions of people, as well as the result of and reasoning about situations (Acemoglu et al., 2002; 2005). In this research the influence of economic institutions on sustainable innovation is further examined, as shown in figure 4.

Figure 4. The effect of institutions on sustainable innovation.

2.3.2. Economic institutions

As argued by a variety of academics among which Adam Smith (1776), North and Thomas (1973), Coase (1998), and Acemoglu, Johnson and Robinson (2005) differences in institutions are a fundamental explanation of economic development and innovation (North and Thomas, 1973, p. 2). Some institutions can provide opportunities and incentives to innovate and to take risks to solve problems. Hence, societies can successfully encourage people with their institutions to take part in sustainable innovation (e.g. North and Thomas, 1973; North and Weingast, 1989; Olson, 2000; Acemoglu et al, 2002). Whereas innovation systems theories explicitly acknowledge that a stable institutional system of existing systems can deter the development of new technologies – also known as blocking mechanisms - (Geels, 2002; 2005; Geels & Kemp, 2007), institutional theories focus on the incentives that institutions create (Acemoglu et al., 2005). In this research context of electric vehicle transport, incentives to innovate might come from existing or new rules and goals that encourage distribution system operators (DSO) to find ways to facilitate the sustainability transition and to keep the costs of the electricity network for society also low in future (Rutger de Croon, personal communication, 26 July 2017).

North (1991, p. 3) describes institutions as: "The rules of the game in a society or, more formally, the humanly devised constraints that shape human interaction. […] In consequence they structure incentives in human exchange, whether political, social, or economic". As one might expect economic institutions are the humanly devised constraints that shape economic outcomes, they structure incentives of and constraints on economic actors in society (Acemoglu et al., 2005). Key economic institutions are property rights, perfect markets and rules that help allocate resources. Property rights are essential for innovation, investment incentives and successful economic performance. Markets make for, among other things, efficient distribution of resources and factor accumulation (e.g. North and Thomas, 1973; North and Weingast, 1989; Olson, 2000; Acemoglu et al., 2005). To exemplify the working of institutions, box 2.1 elaborates on the matter of property rights. Economic institutions are "good" when those allocate economic resources approximately equal on society and provide secure property rights (Acemoglu et al., 2005).

Box 2.1 Importance of Property Rights for Innovation (Acemoglu & Akcigit, 2012)

One of the fundamentals to develop a knowledge based economy is property rights. This are the rights to exclude others from the commercial exploitation of your knowledge. Hence, protection of the inventor creates the incentive to invest in more efficient technologies and human or physical capital. If the institutional environment would not protect the innovator there would be no incentive to invest as people could steal the idea when there is no right to commercially exploit the invention.

2.3.3. The Economics of Institutions

Williamson (2000) has illustrated the economics of institutions in social analysis levels, based on the approximate amount of years institutional change takes (see figure 5) . In the overview institutions are nested in the higher level above. The interconnection is represented by the arrows going down representing constraints on the first level below, and feedback mechanisms going back to the higher level, which may also be interpreted as blocking mechanisms and incentives to change the first level above.

The highest level is *social embeddedness*, this is where norms, traditions, customs, religion etc. are positioned. The top level can be treated as given informal constraints, of mostly spontaneous and evolutionary origin, since these institutions are assumed to change very slowly (Williamson, 2000). Customs, norms and traditions, such as buying petrol at the petrol station, need time to adjust to a new pattern of electricity charging at home and work.

Douglass North is the big name on the second level, the *institutional environment.* These structures of "formal rules", namely property rights, laws and constitutions are besides being chosen for their functioning partly susceptible to evolutionary processes (North, 1991, p. 97). Therefore, the purpose of this level is to get the formal rules of the game right, also called "first-order economizing". Constrained by path dependency the design opportunities include, inter alia, legislative, executive, and judicial functions of government. Hence, major changes occur on a medium to long term – on the order of decades or centuries – although it is hard to forecast on the way of change (Williamson, 2000, p. 598). It is necessary to realize that this level represents the constraints on the level below, which is naturally also the case in smart charging. Therefore, blocking mechanisms might come from the institutional environment.

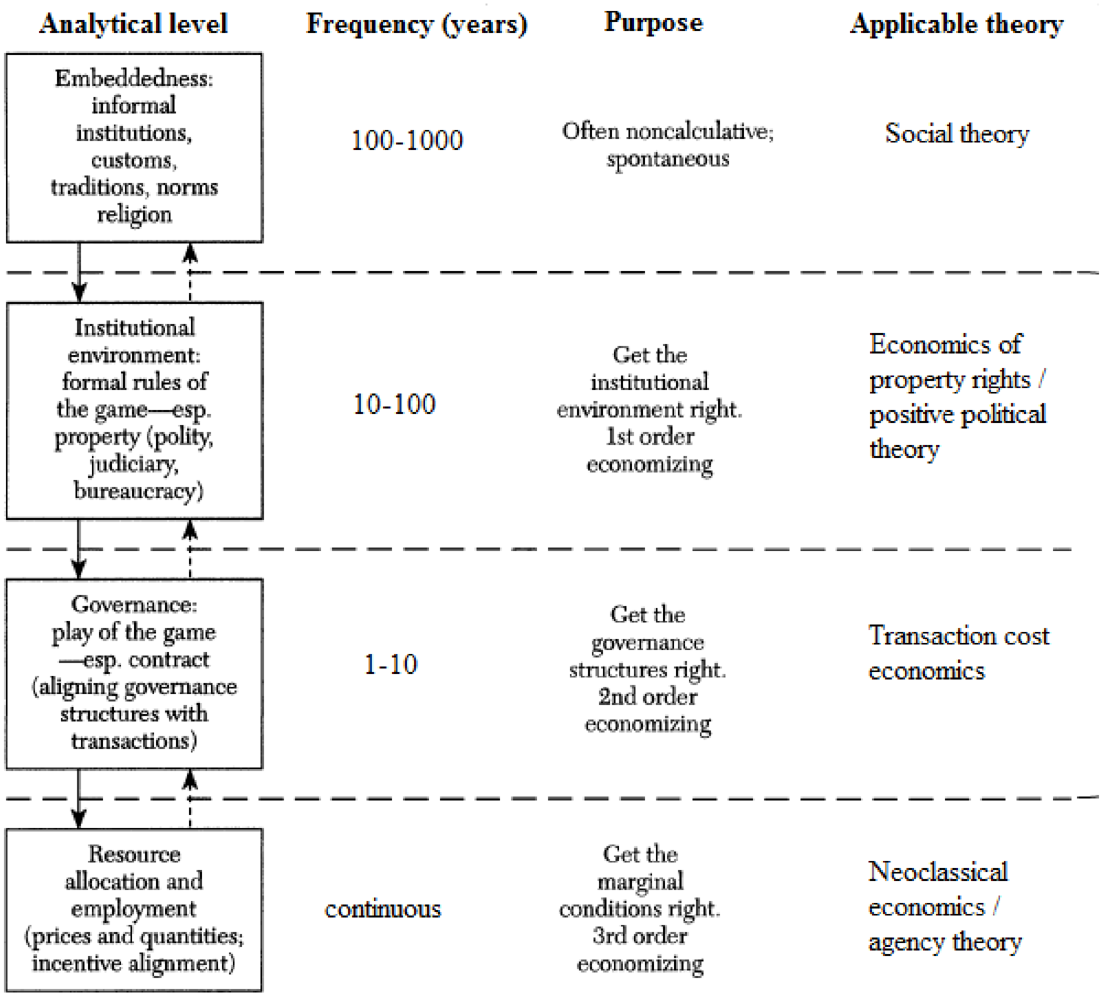

Figure 5. A representation of Economics of Institutions. Source: Williamson, 2000, p. 597.

Positive political theory (PPT) engages the elaboration of the political and economic consequences of the characteristics of the institutional environment (Williamson, 2000). PPT elaborates on aggregating individual preferences directly as well as indirectly into collective choice or preference. Two examples of representative systems are elections and legislative decision-making processes, clearly connecting individual preferences to collective outcomes (Austen-Smith & Banks, 1999).

The third level refers to *the institutions of governance*, can be examined with transaction cost economics. This theory believes that the basic unit of analysis is the transaction, in addition governance attempts to “craft *order*, thereby to mitigate *conflict* and realize *mutual gains*” (Williamson, 2000, p. 599). Rearranging transactions among governance structures occurs on a timeframe of a year to a decade, regularly at renewal intervals of contracts and equipment (Williamson, 2000).

The fourth level locates the neoclassical analysis, with typical characteristics as a production function describing the firm, and somewhat continuously adjustment of prices and output. This has to do with the marginal conditions. Whereas agency theory has to do with conflicts between agents and principals due to different risk levels or unaligned goals (Williamson, 2000). This is something that will happen in the future smart charging market, to create the incentive for user behavior to charge and discharge to match the supply and demand.

2.4. Regulatory Reforms on Sustainable Innovations

Various researchers found evidence that current regulation of the distribution service operators does not provide adequate incentives for both network users and operators to participate in the evolution of global warming (Schiavo, Delfanti, Fumagalli, & Olivieri, 2013). Schiavo et al. (2013) analyzed the way in which regulation of energy can transform to promote and encourage innovation in electricity markets and electric power systems. Two main building blocks are important in the transition to a sustainable energy system. Firstly, to unite and incorporate disrupting energy production in the energy system (both on the generation and distribution side). Secondly, energy distribution grids need to change into active networks being competent to fit in the dispersed generation units – thus make these individual components part of the larger and more complex whole, i.e. sustainable energy system.

Innovation is substantial when regulators are dedicated to give the right incentives to invest in test cases – especially for DSO's, considering that gaining experience and familiarization are absolutely necessary in order to switch towards more advanced regulatory instruments. Furthermore, regulation is more and more involved with both traditional and new (e.g. EVs) electricity network users and should therefore be aimed at fostering more active behavior. Whereby, the active grids of the future should to be built on incentives related to output (Schiavo et al., 2013).

The regulatory framework of the DSO and sustainable innovation

Looking at the regulatory process, there are several lessons learned about the regulatory reforms on technical innovation that may be helpful for other national governments. These lessons can be summarized in steps that are linked to phases of regulatory development (figure 6). Each phase provides a base for the following phase (Schiavo et al., 2013). The steps are further elaborated below.

Figure 6. Overview of regulatory reforms on technical innovation.

"Knowledge building" phase
Step 1. Research projects, laboratory tests and prototypes, i.e. innovative investments
Step 2. Identify functional key-indicators

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"Demonstration" phase
Step 3. Real-life demonstration projects; test cases and pilots

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"Initial" phase → deployment of innovative solutions
Step 4. Moving to output-based regulation
Step 5. Ensure to extract value from the innovative investments for the customers
Step 6. Identify the new border between regulated companies and the competitive market

↓

"Development" phase
Step 7. Integration of the various innovations

To be able to base their future propositions on up-to-date and solid technological knowledge, regulators need to make investments to create a foundation, especially since the power system shall be extremely affected by technological innovation. A reliable regulatory framework to introduce and integrate new functionalities such as renewable energy sources into the grid, starts with a good understanding of the long-established stable electric system, as well as its possibilities to deal with decentralized energy production. Therefore, collaboration in research with specialists from the industry, academia or other technical environments is necessary (Schiavo et al., 2013).

Technical knowledge is useful for building an accurate method to measure the results of future developments and situations, for example the integration of renewables. For that use, functional key indicators can be identified in research projects. These indicators can serve as parameter in test cases to monitor the influence of modifications that take place in the electric network. The indicators are decisive in choosing and assessing demonstration projects (Schiavo et al., 2013).

Real networks, which include both active and passive users of the energy grids (producers and consumers), enable the regulator to improve the solutions derived from research and experiments. Besides, test cases offer important information that can be used in the initial phase. Real-life demonstration projects can be expensive, for that reason one should carefully choose and only induce those expected to be most suitable and advantageous (Schiavo et al., 2013).

The gained experience from the knowledge building and demonstration phase can be used in the initial phase. Ideally, to deploy innovative solutions one should move to output-based regulation, which puts the results of a specified action, service or activity at center. That means that incentives are applied to the output, thus the real project value for customers or for the entire system. Opposite, with input-based regulation does the regulator try to influence the internal process, that means incentives on input, such as incurred project costs for the regulated companies. There are two ways to regulate outputs, giving rewards and punishments connected to determined performance standards and purposes, and directly regulating with for example a maximum or minimum for a certain parameter.

In theory, a regulation concentrated on output is the more efficient option as it has low expenses on administration and decreased risk to select inefficient investments. However, the development of an output-based regulatory framework for smart grids brings some difficulties. To measure performance, the objectives have to be well defined; one needs indicators that are equitable, easy to perceive and understand, and in addition strict and precisely connected to the purposes. Besides external effects out of control of the DSO should be filtered out of the measurements. Hence, the dominant approach in regulatory frameworks in existence is input-based (Schiavo et al., 2013).

The value added for the customers taken from the innovative investments has to be made certain by the regulator. Regulation should incentivize and embrace innovation, and moreover ensure that value is extracted for the consumers. This can be done with for instance compulsory time of use pricing, or compulsory new customer services. It is important to pay attention to what is useful and valuable for both the whole system and the customers. For example, open communication protocols can be ensured by regulatory provisions, or suggestions and indicators for new functionalities can be supplied (Schiavo et al., 2013).

New functionalities such as electro mobility, renewable energy sources and demand response bring the regulated companies closer to a competitive market. Therefore, a new border between the competitive- and regulated sector have to be identified by regulators. For electro mobility it is of central importance to define the role of - the actions and activities assigned to - regulated companies and the other actors that surround them, likewise the role of energy regulation among the organizations that make the policy. Naturally it is also fundamental to find an effective manner to communicate (Schiavo et al., 2013).

Lastly, the integration of the diverse integrations such as electro mobility, renewable energy sources, storage possibilities and bidirectional charging. Different innovations at various levels that all should be connected. Whereby, incorporating smart grids at the medium voltage level in distribution networks and smart meters at low voltage levels, expectedly will give the most benefits (Schiavo et al., 2013).

2.5. Conceptual Framework

This paper investigates the effect of institutions on sustainable innovation. For this aim, smart charging is the sustainable innovation that has been researched. In relation to smart charging, a variation of relevant institutions is chosen and divided into sub questions. Therefore, each sub question contains another institution. The incentive of the institutions for smart charging innovation that has been elaborated in each question is represented with the arrows. Institutions usually create a certain incentive, which is also known as a positive effect. This is shown with a plus sign in the conceptual framework, which can be found in the appendix. The minus sign is does not mean that the institution is purposed to limit or constrain, instead it indicates that the institution is limiting for the smart charging innovation. As explained, there are different kinds of innovation, and these can be found in the column on the right. Belonging to sub question 1 up to 2 there is also a research model per question included.

3. Research Method

To explore the subject and the context of smart charging, I first conducted various interviews and conversations. Subsequently, I made an online survey in three languages, namely Dutch, English and German to elaborate on the acceptation of smart charging and its components in the future smart charging market. The respondents have been personally emailed with the question to fill in the survey. This were people from different companies, organizations universities and governments. As well as different type of companies, i.e. with another role along the electric mobility value chain. I have also given the option to arrange a phone call that I filled in the survey for them, what a number of people preferred. Contacts were mainly obtained via network. After an initial e-mail round, I have sent a reminder mail after approximately three weeks to people whom had not yet responded. To keep an overview of who I thanked, processed, etc., I created a to do list in Excel which can be found in the Appendix.

Also, German contacts that I had first emailed in English e-mailed again, though this time in German. I have chosen to include the Germans in this research as this country it roots some important components of the sustainable transition, such as the (electric) car industry, charge plugs. In addition, the Germans might see other important factors than the Dutch. Germany is also interesting as the Netherlands trade a lot with this neighbor country.

The survey can be found in the Appendix. At the end of the survey, there was a question whether I could approach the respondent for additional questions, many people were open to this. Hence, I have asked a variance people a number of open questions such as: “How do you think smart charging should develop in future?” That is how I have obtained interesting insights for sub-question five. The first three sub questions test the results of the survey. The sample is not large enough to be representative of the research group. Question four, was mainly based on literature research supplemented with interesting notices from interviews. This research is qualitative. Even though the survey leads to certain statistics, these are only to indicate a possible correlation, as well as to find out how the actors involved in the development of smart charging actually behave.

4. Results derived from survey

4.1. Sub question 1: Positive attitude towards smart charging

Sub question 1 is "*What is the influence of attitude on sustainable innovation?*" The associated proposition: Development of smart charging is more likely when organizations have a positive attitude towards smart charging, i.e. embracement of the new socio-technical system is beneficial for sustainable innovation. This implies that organizations are more likely to encourage sustainable innovation when they have a positive attitude towards the new socio-technical system. Translated into my research focused on smart charging the following two hypothesis are defined and tested.

Hypothesis 1A. Organizations are more likely to undertake action to enlarge the social acceptance of smart charging when they have a positive attitude towards smart charging, i.e. view smart charging as desirable, suitable and the social acceptance of smart charging within the organization is high.

Hypothesis 1B. Organizations are more likely to actively do research and development of smart charging when they have a positive attitude towards smart charging, i.e. view smart charging as desirable, suitable or the social acceptance of smart charging within the organization is high.

In this sub question, an organization that meets three requirements - it views smart charging as desirable, suitable and has a lot of social acceptance of smart charging within the organization - is defined as having positive attitude towards smart charging. For more detailed information of each individual aspect of this positive attitude on research and development or action to enlarge the social acceptance of smart charging, see the appendix (page).

A chi-square test of independence with an alpha level of .05 was performed to examine the relation between positive attitude and innovation. With hypothesis 1A, the relation between these variables was moderate but positive and statistically significant, χ^2 (1, N = 51) = 4.42, p = .035, Cramér's V = .29, Kendall's tau-b τ_b = 0.0114. Organizations with a positive attitude towards smart charging were more likely to undertake action to enlarge the social acceptance of smart charging than organizations without a positive attitude were. Also, with hypothesis 1B, a chi-square test of independence showed a moderately positive correlation (Cramér's V = .29, Kendall's τ_b = 0.0114) between positive attitude towards smart charging and the performance measurement of innovation, statistically significant at an alpha level of .05, χ^2 (1, N = 51) = 4.42, p = .035. Organizations with a positive attitude towards smart charging were more likely to actively do research on development of smart charging than organizations without a positive attitude were. Still, a positive attitude towards smart charging is composed to viewing smart charging as desirable, suitable and high social acceptance.

Coming back on proposition 1, the predicted relation is assumed to be correct based on the results. Organizations with a positive attitude towards the new socio-technical system are more likely to encourage sustainable innovation, i.e. actively do research and development and undertake action to enlarge the social acceptance of it.

4.2. Sub question 2: Country related norms and values

Sub question 2 is about informal institutions that are embedded in a certain area. "*What is the influence of country related norms and values or operating in multiple countries on sustainable innovation?*" The associated proposition 2 is: Development of smart charging is more likely when organizations have Dutch roots or are operating in multiple countries, i.e. having norms and values with a trade mentality to export a good or service and exploit knowledge about the new socio-technical system is beneficial for sustainable innovation. This implies that organizations are more likely to encourage sustainable innovation when they have a trade mentality in their norms and values.

Also, with this question a number of hypothesis are stated and tested. To see the exact figures, you can have a look at the appendix.

Hypothesis 2A. Organizations are more likely to actively do research and development of smart charging when they have Dutch roots, i.e. when they have a trade mentality to export a good or service and exploit knowledge rooted in their norms and values.

To examine the relation between nationality of the founding fathers of the organization and attitude towards smart charging research and development, a chi-square test of independence with an alpha level of .05 was performed. The observed frequencies were significantly different with the expected frequencies, hence the relation between these variables is significant, χ^2 (1, N = 48) = 4.96, p = .03, this is a positive moderately strong link (Cramér's V = .37, Kendall's τ_b = .37). Organizations with Dutch roots were more likely to actively do research and development of smart charging than organizations with German roots were.

Hypothesis 2B. Organizations are more likely to have infrastructure totally ready for smart charging in their area when they have Dutch roots, i.e. when they have a trade mentality to export a good or service and exploit knowledge rooted in their norms and values.

With use of a chi-square test of independence the relationship between these two variables is shown to be moderately strong, positive and statistically significant at an alpha level of .05, χ^2 (1, N = 48) = 4.79, p = .03, Cramér's V = .36, Kendall's τ_b = .36. Organizations with Dutch roots were more likely to have a totally smart charging ready infrastructure in their area than organizations with German roots were.

Hypothesis 2C. Organizations are more likely to actively do research and development of smart charging when they are operating in multiple countries, i.e. when they have a trade mentality to export a good or service and exploit knowledge rooted in their norms and values.

A chi-square test of independence examined the relation between the amount of countries the organization is operating in and the attitude towards smart charging research and development (α = .05). The results showed a strong positive significant trending as displayed by figure 16, χ^2 (2, N = 51) = 12.43, p = .002, Cramér's V = .53, Kendall's τ_c = .43. The value and p-value are coming from the two-sided Fisher's exact test as 2 cells (33.3%) have an expected count less than 5, of which the minimum expected count is 3.06. Organizations operating in multiple countries were more likely to actively do research and development of smart charging than organizations only operating in the Netherlands and Germany were. Following this, organizations only operating in the Netherlands were more likely to actively do research and development of smart charging than organizations only operating in Germany were.

Hypothesis 2D. Organizations are more likely to have infrastructure totally ready for smart charging in their area when they are operating in multiple countries, i.e. when they have a trade mentality to export a good or service and exploit knowledge rooted in their norms and values.

A chi-square test of independence with an alpha of .05 was carried out to study the relation between the countries an organization is operating in, and the smart charging readiness of charging infrastructure. The strong positive relation between these variables appeared to be significant, χ^2 (2, N = 51) = 11.24, *p* = .004, Cramér's *V* = .47, Kendall's τ_c = .46. Organizations operating only in the Netherlands were most likely to have a totally smart charging ready infrastructure in their area, followed by organizations operating in multiple countries which were more likely to have a totally smart charging ready infrastructure in their area than were the organizations only operating in Germany.

The results on hypothesis 2A up to 2D confirmed the expectations as stated by proposition 2, hence this is assumed to be correct. Organizations with a trade mentality in their norms and values are more likely to encourage sustainable innovation, i.e. actively do research and development and prepare the infrastructure for implementation of the new socio-technical system. Note that the trade mentality an assumption is about the norms and values, naturally these norms and values or even customs and informal institutions are embedded in the culture of the society.

4.3. Sub question 3: Institutional form

Sub question 3 is "*What is the influence of the institutional form on smart charging innovation?"* The associated proposition 3 states that: Smart charging innovation is more likely when the institution has a greater interest in innovation, i.e. innovation has a big influence on the succes of the institution. What implies that organizations are more likely to encourage sustainable innovation when they have great interest in innovation.

Hypothesis 3A. Organizations are more likely to actively do research and development of smart charging when they are a company or university, i.e. when they have great interest in innovation.

A chi-square test of independence with an alpha level of .05 was performed to examine the relation between institutional form and smart charging research and development. The strong positive relation between these variables was significant with the two-sided Fisher's exact, χ^2 (2, N = 51) = 7.75, *p* = .02, Cramér's *V* = .41, Kendall's τ_c = .33. Two cells (33.3%) have an expected count less than 5, and the minimum expected count is 1.78. Companies and universities were more likely to actively do research and development than governments were.

Hypothesis 3B. Companies are more likely to have a lot of social acceptance of smart charging when the management level is responsible for smart charging than when the operational/technical department is responsible for smart charging, i.e. when the strategic decision makers pave the path for smart charging.

A chi-square test of independence with α = .05 was executed to look at the link between the department responsible for smart charging and the social acceptance of smart charging within the company. The strong positive relation is significant, χ^2 (1, N = 29) = 4.83, *p* = .03. Cramér's *V* = .51, Kendall's τ_b = .51. However, the second assumption is not met, two cells (50.0%) have expected count which is less than 5. The minimum expected count is 1.45. The value and p-value of the continuity correction are taken as those are more critical than the Fishers Exact Test. Companies are more likely to have a lot of social acceptance of smart charging when the management level is responsible for smart charging than when the technology and operations department is responsible for smart charging.

To sum up, the results on the hypotheses are still good reasons to assume that proposition 3 does apply. Smart charging innovation is more likely when the institution has a greater interest in innovation, i.e. innovation has a big influence on the succes of the institution. Organizations are more likely to encourage sustainable innovation when they have great interest in innovation. Companies and universities clearly have a greater interest in innovation than governments do.

5. Regulatory Framework of the DSO (Results sub question 4)

Sub question 4 is "*What is the influence of the institutional environment of the DSO on smart charging development?"* The associated proposition 4 states that: The regulatory framework of the DSO is impeding the development of smart charging, i.e. the institutional environment of an old socio-technological system can impede sustainable innovation and therewith the transition towards the new socio-technical system. This implies that smart charging innovation is less likely when institutional environment has to adapt and transform from the old socio-technological system towards a new one.

5.1. The Regulation of Electricity Networks

An affordable, reliable and clean energy supply is of great social importance. However, the energy markets cannot secure these interests without the help of the government, due to the existence of various (inherent) market failures. Hence, the government has to ensure that social interests are safeguarded (Baarsma, et al, 2009). The government has translated these public interests into three energy policy objectives: 'reliability, affordability and clean' (Ministry of Economic Affairs, 2008). As described by the NMa (p. 13, 2010), the regulation therefore serves to safeguard the social interests, i.e. a reliable and affordable energy supply. The NMa is in compliance with the regulation and does check if the DSOs comply with the regulation (WRR, p.151, 2007). Through a combination of tariff regulation and quality regulation, grid managers are encouraged to work efficiently (NMa, p.18, 2010).

How much each grid operator may charge to its customers for services is determined by the ACM. The tariff regulation keeps the tariffs at an affordable level, this encourages network operators to work efficiently and ensures that grid operators have enough income to deliver reliable, high-quality services and to make the energy supply more sustainable (ACM, 2017). For the tariffs, the costs and revenues are compared in a specific regulatory period. As a result, the costs of a large investment can only be eligible if the yields are already sufficiently noticeable during that period (WRR, p.152, 2007). The quality regulation should stimulate network operators to work efficiently and ensure the reliability of the electricity supply and networks, this is based on the Electricity Act 1998 (NMa, 2010; ACM, 2017). In addition, the current regulatory system is based on ex post evaluation and output, i.e. not ex ante and input. This means that the regulator monitors or the statutory tasks are carried out adequately, regardless of which techniques the network operators use for this (NMa, 2010).

The NMa thinks that both grid operators and customers have an interest in a stable regulatory framework (NMa, 2010; ACM, 2017), and therefore maintains the general principles of regulation. Although the NMa does realize that more flexibility may be necessary to take better account of the specific circumstances of individual network operators (NMa, 2010), the need is extremely underestimated. The current institutional arrangements set short-term efficiency objectives above long-term public values. This causes "considerable risks regarding the achievement of public values other than static efficiencies, especially [when] system innovation is required as a result of climate change and the depletion of fossil fuel resources in the coming decades" (WRR, p. 138, 2007). This is well explained in the box below.

Box 5.1. Static efficiencies in the regulatory regime (WRR, p. 151 & 170, 2007)
"Compared to access and tariff modelling regulation, the regulatory framework for the governance of network investments is much less developed […] (Shuttleworth 2008) (p. 150). As a consequence, substantial network investments are being dealt with on an ad hoc basis, often driven by 'crises' and/or court cases, under a considerable degree of uncertainty and regulatory reservation (p. 170). […] The problem of applying short-term economic efficiency principles – the basis of the current regulatory approach is jeopardizing the long term development of adequate infrastructural systems for a sustainable and reliable energy supply (p. 150)."

NMa's vision on regulation, concerning Innovation and experiments

In order to keep the energy supply affordable, reliable and sustainable, innovation is indispensable. The general objective of the NMa (ACM) is that the regulation makes all efficient innovations and experiments possible but hinders inefficiencies: "The regulation of the energy networks must be such that these developments are promoted as well as possible" (NMa, p. 60, 2010). The starting point is that network operators may decide on the efficiency of innovations. Where "efficient" means that the expected social benefits of these innovations and experiments are greater than the expected social costs. The regulation must ensure that network operators can incur costs for innovations that are expected to be beneficial to society as a whole and in the long term, while avoiding energy consumers having to pay for innovations that are likely to yield too little (NMa, p. 60, 2010). However, the regulation is not as good as it seems, the large investments for the long term entail high costs, and these will only be recovered much later. While, supervision is based on ex post costs and benefits evaluation. As a result, important long-term investments are assessed as not efficient, and the costs may not be incurred by the network operators. Various parties, such as the WRR (2007) and the AER (2009), therefore argue that current regulations hamper innovation and that it therefore needs to be adapted. Additional legislation is necessary to remake the energy infrastructure and replace mislaid incentives. Right now, companies are punished for investing in the grid, while they should be rewarded. Utilities, customers and industries should be given reasons to turn on, engage, and transform. Consumers have to be empowered as well (Wired, 2009).

5.2. Regime changes in infrastructures

The above can be further explained with use of so-called "Type I" and "Type II" market failures. Type I market failures are about lack of or improper market functioning, i.e. easily defined, visible and measurable cost-saving matters – which are (short-term) efficiency issues. Type II market failures denote inability to tackle major social problems (Van Dijk, 2008), which causes the failure to accomplish goals on public values, that are fundamental for the long term. These values are difficult to define, notice and measure and therefore are generally in need of dynamic institutional arrangements. Accordingly, when long-term values are fulfilled unsuccessful or inadequately this appoints 'Type II' market failures. Changes in regime appear to support 'Type I' market failures, whereas no attention has been given to the possibilities for 'Type II' market failures (WRR, p. 53-54, 2007) "there is a bias towards short-term interests at the expense of long-term investment requirements" (WRR, p. 36, 2007).

Energy policy is governed by four different levels of ministries, supra-national, European, local and national. Besides, the process of combining the insights and interests of all the stakeholders in the energy sector features strategic behavior and inherent uncertainties. This results in essential, yet contradictory input for the continuous discussions on restructuring and regulation which makes agreement difficult (WRR, p. 168-169, 2007).

A transition of this magnitude has never occurred before in the electricity grids. Therefore, a lot will have to change, which is difficult due to the ex post regulation. In addition, the forecasts used currently generally hold to traditional values and attitudes and are cautious about change or innovation, which results in strongly underestimating growth and change. As noticed by many experts (among others Breyer et al., 2017; Metayer et al., 2015; Teske et al., 2012; Osmundsen, 2014; Whitmore, 2013; 2015) the growth of wind and solar power is consistently underestimated by leading energy agencies. For example, the influential International Energy Agency (IEA) which is the most used predictor by policy makers in the energy world, the Energy Information Administration (EIA) and many other organizations make predictions that are far from observed reality, even the forecasts of International Renewable Energy Agency (IRENA) and Greenpeace were too conservative. As stated, the predictions on photovoltaic growth of the IEA are far from actual developments. While the solar industry is rapidly increasing, the IEA keeps predicting that it will hardly grow or shrink. In short, the projections have been way of the mark. This is shown in the graph below, where the flat colored lines represent the expectations of the IEA (Hoekstra, 2017).

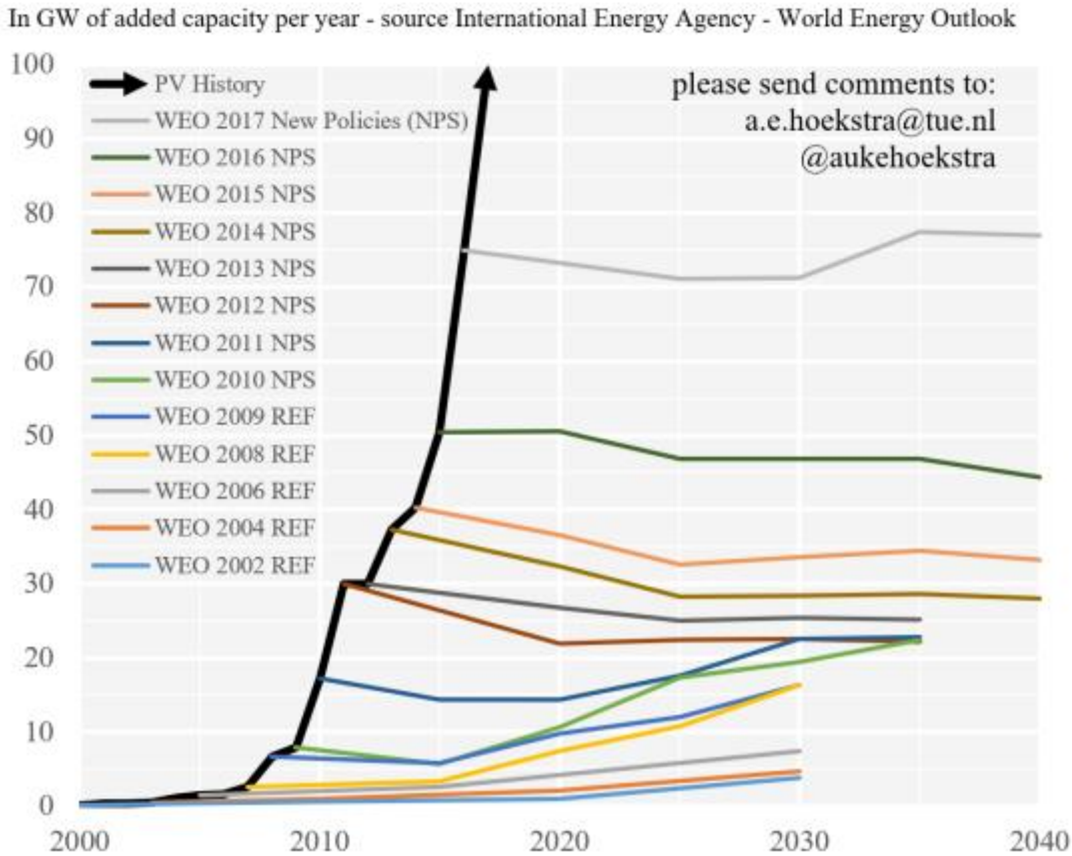

Figure 7. Annual PV additions: historic data versus IEA WEO predictions.
Source: Hoekstra, A. (2017). *Photovoltaic growth: reality versus projections of the International Energy Agency – the 2017 update.*

5.3. The importance of smart charging for the DSO

It is the task of the network operator to keep the grid *affordable* and *reliable*, therewith the ACM monitors the incurred costs via the tariff regulation. With major changes in the electricity system ahead - such as the emergence of electric mobility and sustainability -, the grid operators have to find a different approach for the care for the electricity grid, otherwise the costs will rise rapidly and be recounted on society in the long term, which is not desirable. It is still unclear which manner of smart charging will ultimately lead to an improved and more reliable network. Therefore, it is useful for the grid operators to delve into smart charging so that a knowledge base can be built, and the best and most reliable solution can be examined (Rutger de Croon, personal communication, 22 June 2017). They obtain "an overview of the measures to be taken to ensure that the network remains reliable and affordable, whilst enabling the development of E-mobility", take a look at the innovative solutions that may lead to great benefits for society, and explore how the existing grid can be optimally used with smart charging (ElaadNL, 2018). This is illustrated with an example in the box below.

Network operators are investigating whether they can make the grid smarter, instead of increasing the network capacity. If the network operator wants to increase the capacity, he has to justify to the ACM, and only with a solid substantiation, the rates may go up the following year. However, the network operator wants an alternative to prevent costs from increasing, and therefore wants to innovate. Nonetheless he is formally not allowed to spend the budget on innovation to keep these costs low. It is a decision of the network operator himself to not want to increase the costs, while he does not have to take that decision from the legal framework (Jaap Burger, personal communication, 20 June 2017). Why does the network operator not simply increase the costs?

Box 5.2. Social costs and the rise of electric transport

Last year, the grid operator Stedin has doubled the one-time connection costs for a connection. This implies all sorts of connections, as a charging station connection is the same as a house connection in the legislation. This results in a doubled price for every consumer requesting a connection in that particular category (in technical terms 3x25 or 3x35). This is caused by the rise of electric transport, because a charging station connection is more than twice as expensive. Since new connections often arise in new residential areas, households are generally systematically connected, that is a series of for example 20 connections at all at once. This is very efficient, which is not the case with EV connections. Connections must be placed at the most inconvenient spots, in inner cities, under the road surface, and one by one since the charge point follows electric vehicle. If you want to go into the ground in the street you have to break up the stones or the asphalt what lies on the road. This is ad hoc, and there are many emergency requests, so the costs increase enormously. Because there is no distinction between an EV connection and a house connection, the extra costs incurred are distributed over all connections. The costs are being socialized, so despite one connection being more expensive than the other, everyone pays the same rate. In other words, if there is no other solution devised, then everyone will pay for the rise of electric transport and the costs for the energy transition will also be charged at people who might not be able to pay. This leads to the necessary social discussion who has to pay for the rise of electric transport, i.e. the more expensive connections that are realized. Since the social costs must remain low, the lobby world and grid operators argue for a distinction between the two connections (Rutger de Croon, personal communication, 22 June 2017).

There is a lot of discussion about the rates that the consumer has to pay for a connection. Every euro that the grid operator wants it to go up, the ACM wants it to go down three euros. So when the network operator has to realize extremely expensive connections, the discussion with the monitoring authority will only become more difficult. Therefore, the grid operator has a great interest to prevent these costs from rising - considering the tariff regulation. In addition, it is important that the DSO ensures a reliable network, otherwise the network operator will be fined by the ACM according to the quality regulation, for example because they do not comply with the law. A network is reliable if you can handle the capacity, otherwise you get black outs due to the rise of electric transport. Hence, if ten Tesla's arrive in the street and the electricity grid is suddenly out of order for three days, this is not accepted. A certain percentage of the total network has to be uptime. It is checked whether the grid operator achieves the percentages for service levels on an annual basis by the ACM. “The most important goal of course is that the grid operator keeps the *social costs low* and realizes a *reliable network*” (Rutger de Croon, personal communication, 22 June 2017).

Where is sustainability in the explanation above? The regulation is clearly focused on affordability and reliability. It is striking that when you talk with experts in the field about complying with law that network operators are primarily focused on keeping the costs low and reliable network. The third component ‘sustainable’ is not checked as specifically as the other two are. For example, when Rutger and I were having a conversation about the legislation, regulations and sustainable innovation for the grid manager, he just mentions this third objective quite some time after we have extensively discussed the other two objectives on which the current regulation is mainly focused - reliable and affordable; “sustainable, that is the third part”. And, “the third element is the energy transition, which also can be seen in the mission statements of the network operators - that includes sustainability” (Rutger de Croon, personal communication, 22 June 2017). However, the network operators have to facilitate the energy transition and are already working on the sustainable future, whereby smart charging can support well. Nevertheless, to make this sustainable future possible, flexibility is required throughout the whole system. Obviously, no specific place or space has been made in legislation and regulations, for a proper integration of sustainability and the energy transition.

5.4. The limitations of the regulation

Flexibility of the Capacity and Rigidity of the Legislation

There is not enough flexibility to facilitate the energy transition on a large scale. With regard to electric transport, the grid operator wants to have sufficient adjustable capacity that can be controlled by means of charging electric cars flexibly. This can be aggregated, or without intervention directly from a DSO to a car. Even so, it is more realistic that an aggregator will gather the flexibility of all EVs in the Netherlands and fulfill the role of coordinating the capacity to be adjusted. Or that several aggregators manage and conduct different car fleets, so that controllable capacity is available and grid congestion can be prevented. The controllable capacity involves the speed as well as the quantity of both charging and discharging. This is further elaborated in the textbox below. Unfortunately, the use of flexibility is not yet permitted in this way, though it can assist network operators in keeping the costs low, the grid reliable and facilitating the energy transition. The problem is that the legislation and regulations do not change quickly enough, hence impede the energy transition, flexibility and sustainable innovation for the grid operator (Rutger de Croon, personal communication, 22 June 2017).

Box 5.3. The possibilities of electric transport for flexibility
“At the point of demand, behind-the-meter storage, demand management and managed charging can reduce the interaction and electricity needed from the grid, provide local small-scale back-up capacity, and provide the opportunity to provide grid services and for arbitrage, charging when prices are low and discharging when prices are high. In fact, if electrification of transport grows as fast as some forecast, grid services could be provided primarily from vehicles” (Accenture, p. 10, 2017).

Presently, the Dutch network operators are not permitted to have a battery to store energy, since they are also not allowed to supply energy (Rutger de Croon, personal communication, 22 June 2017). In terms of flexibility, the Dutch grid operators are neither allowed to do anything, except when permission is requested from the ACM, though this takes a long time and a lot of effort. This constraint also includes that no incentive for (in-front-of-meter) flexibility can be created (Mark van Kerkhof, personal communication, 24 April 2017). Legislation will have to react actively to new developments, and ambitious requests regarding the speed and scope of legislative changes are made to the Dutch House of Representatives. “The energy transition is a process of change that deeply affects economy and society in all sectors and at all levels. It is a complex process and the speed at which new developments occur is high. This involves that the developments in society will go faster than in the legislation can be adjusted” (Wiebes, p. 3, 2017). As been written in a letter to the House of Representatives about the legislation concerning the energy transition by the Minister of Economic Affairs and Climate of the Netherlands. Moreover, this is not only the case in the Netherlands, also in America for example, the biggest concern that the network operators over there have is whether the legislation can keep up with innovation - legislation in this context means what actions and tasks the network operator may execute (Mark van Kerkhof, personal communication, 24 April 2017).

The regulatory framework of the DSO must ensure that the grid is reliable, costs remain low and the energy transition to a sustainable system is facilitated. These three objectives may hinder each other. A network operator can increase the network capacity, and therewith facilitate the energy transition and a reliable network without flexibility. However, this is not favorable for society as the costs increase, as well as it is not guaranteed that for example electric cars run always on sustainable energy due to the lack of flexibility. Flexibility should be integrated the system so that the DSO can react in time in the case of nearly blackouts. For instance, if ten Tesla's all plug in at the same time and start charging, then this will require ten times as much power - the capacity of a network operator - as a normal household. In other words, if one hundred households all together start consuming at capacity in one go - as this is how much is demanded by ten Tesla’s – the DSO wants to be able to react at that moment and therefore flexibility is required. Then a choice must be made from the flexibility available at that moment. EV is one of the options, though it can also be a heat pump, or a heavy industry that will be (partly) shut down for a while. Accordingly, an agreement is reached on the compensation for the flexibility provided (Rutger de Croon, personal communication, 22 June 2017). Hence, legislation is limiting now flexibility is not allowed and no incentives for it may be created by network operators.

Sustainability is subordinated to affordability and reliability

As mentioned before, I noted that sustainability of the network appeared to be inferior to affordability and reliability. The ACM (2017) has published an English document which contains general information about its role as supervisor of electricity grid operators. Again, it is striking that sustainability is regarded not so important, as the word 'sustainable' and 'renewable' are only mentioned once. “Our regulation is technology-neutral – it facilitates efficient investments, regardless of their nature. System network operators are currently expected to make the investments that are necessary to contribute to a more *sustainable* and *renewable* energy chain, for example, infrastructure for solar panels or wind farms” (ACM, p. 6, 2017). Moreover, this is in the description of the regulatory goals of the incentive-based regulatory scheme. Hence, sustainability is not mentioned as a regulatory goal, nor as responsibility or task of the DSO. In addition, the goal from which this quote came from is “Allow network operators an appropriate return on investments”. However, investments are only facilitated by the regulation if seen as efficient, though the necessary long-term investments in a sustainable chain do not give profit quick enough to be considered as efficient by the ACM.

Does the current legislation have to change to enable smart charging?

PWC identified the institutional bottlenecks which hinder developing smart charging of EVs, as well as possible solutions for the urgent bottlenecks of great significance. Thereby, 'institutional bottlenecks' are defined as "obstructions arising from existing or non-existing legislation and regulations at national, regional or local level, relevant sector agreements, and established or still absent/implemented standards" (PWC, p. 3, 2017). Institutional bottlenecks block or slow down the scale up of smart charging cases presently tested in the Netherlands. The legislation and regulation do not act in accordance with the prerequisites associated with the new initiatives, and consequently possibly hinder the development of smart charging (PWC, 2017). For an overview, see the report.

Rutger de Croon of the Living Lab Smart Charging agrees with the institutional bottlenecks identified in the PWC report. In addition, he said "The most important bottleneck for network operators is, of course, that the network manager has no possibility to prevent grid congestion locally". Currently, this is only possible in pilot form, such as will take place in the provinces of Gelderland and Overijssel (Rutger de Croon, 6 December 2017, personal communication). In this three-year trial, smart charging with a variable charging profile is tested, this profile takes into account the availability of renewable energy on the electricity grid. When there is high supply of sustainably generated electricity or when there is little demand for electricity on the grid, the e-driver has the possibility to charge faster. In this way, the variable charging profile can contribute to reducing peaks in the electricity network (LLSC, 2018).

> "Some markets are developing regulation and market structures that support the move to batteries supporting the grid. The market regulation should change to allow batteries to participate directly in these markets will increase the number of new third parties entering the market and that can act as aggregators" (Accenture, p. 10, 2017).

5.5. Sustainability in the e-act and electricity grid code

The structure and rules of the electricity market are written down in European rules and the Dutch Electricity Act (e-act) 1998. The e-act establishes rules for the grid operator and the organization of the electricity market. The conditions and tariff structures of the network operators are fixed in further elaborations of the e-act, the so-called (grid) codes (VEMW 2018; ACM, 2018). Hence, the assessment of the grid managers by the ACM is enshrined in the act. However, it is unclear what sustainability means in this act. Also, the ACM does not supervise to what extent the network operator has contributed to sustainability.

Renewable electricity (art. 1u) and renewable energy sources (art. 1t) are defined in the e-act. However, sustainability is not defined in the e-law nor in the electricity grid code, though being one of the three objectives of the electricity market as defined in the e-act (art. 5b; art 20e, sect. 3). Sustainability is a broad concept which is not clearly defined (ACM, p. 2, 2013, consultatiedocument). The e-act refers to sustainability aspects such as energy saving, climate-neutral electricity and the environmentally responsible functioning of the electricity supply (art. 2, sect. 3b; art. 4, sect. 5d), yet this is only a description of the development. Still, the network operator does have to deal with renewable electricity, for an overview of articles mentioning this see Appendix.

Sustainability is often mentioned as a factor that must be taken into account when establishing the tariff structures and conditions; "paying attention to the importance of the reliable, sustainable, efficient and environmentally sound functioning of the electricity supply" (art. 20, sect. 2 & 3; art. 36, sect. 1b; art 41, sect. 1a & 1b; art. 42b, sect. 1; art. 94, sect. 1c). Note that this sentence in essence is an enumeration of the policy goals. The supervision and control of the ACM is clearly focused on affordability and reliability. No assessment criteria or output factors for sustainability are included in the legislation. The current method of tariff regulation leaves no room for ACM to explicitly take into account the consequences of the energy transition or to actively control the way in which the sustainability objectives set by the legislator must be achieved (ACM, p. 17, 2013). A grid operator who chooses for measures that promote sustainability should not be worse off than one who does choose an alternative with the current regulation (Netbeheer Nederland, 2013). Unfortunately, the opposite is true with measures that do not benefit in short term, which is the case with many sustainability initiatives.

Moreover, there is nothing in the e-law or grid code that explicitly ensures the promotion of sustainability in grid management. There is no check specifically on sustainability, but only on the reliability and affordability of the electricity network. For example, it is clearly described how tariff structures and associated conditions are established, whereby sustainability is also mentioned as a factor (art. 36, sect. 1b), yet it is unclear how the latter is guaranteed. It should be noted that the current tariff structures and conditions have been designed around the year 2000 and are not aimed at achieving sustainability objectives. The most encouraging article is that the grid operator must take account of demand control, sustainable electricity, energy saving and decentralized electricity production in the maintenance, restoration and renewal of networks (art. 16, sect. 1c). (Elektriciteitswet 1998).

5.6. Conclusion

The energy transition requires a new interpretation of energy legislation. Roles and responsibilities have to be clearly described. Besides, flexibility in the electricity- and energy system must be allowed, in order to maintain the reliability and affordability of the Dutch electricity supply. Therefore, market parties must be stimulated to develop business cases for demand management, storage, conversion and other forms of flexibility, thus incentives have to be created.

6. Smart Charging Institutionalization (Results sub question 5)

The former questions have elaborated on the attitude towards smart charging and the limitations of the regulatory framework of the DSO. In addition, it is interesting to get an idea about new good institutions that serve the development of smart charging. How can these good institutions be created? For instance, how can a positive attitude towards smart charging be ensured? Therefore, this chapter describes the results on sub question 5; "*In what way should the institutionalization of smart charging be encouraged?"*

6.1. The Future Electricity System

World Economic Forum (2017) published a report on the future of the evolving electricity landscape, as three major trends of grid edge technologies are transforming the electricity system, namely electrification, decentralization and digitalization. These technologies and innovation are disrupting the system. "The electricity landscape is a prime example of the Fourth Industrial Revolution as it undergoes transformation, becoming more complex than ever before, with rapidly evolving technologies, emerging innovative business models and shifting regulatory landscapes" (p. 3).

As made clear in the figure below, the three trends behave "in a virtuous cycle, enabling, amplifying and reinforcing developments beyond their individual contributions" (p. 4). Electrification is taking place in major sectors like transport and heating. It is of importance for the climate goals and is regarded for increasing the use of renewables. Decentralization is the consequence of distributed energy resources (DERs) that have become much cheaper, and it implies e.g. distributed generation and storage, energy efficiency and demand flexibility. Hence, customers become active components in the system and coordination is necessary. Third trend entails the digitalization of the electricity network, related technologies, increase in power-consuming connected devices and the arrival of the Internet of Things (IoT). The digitalization enables more control on electrification and decentralization, and thus supports the optimal use of production, consumption and interaction and communication with consumers (World Economic Forum, p. 4, 2017).

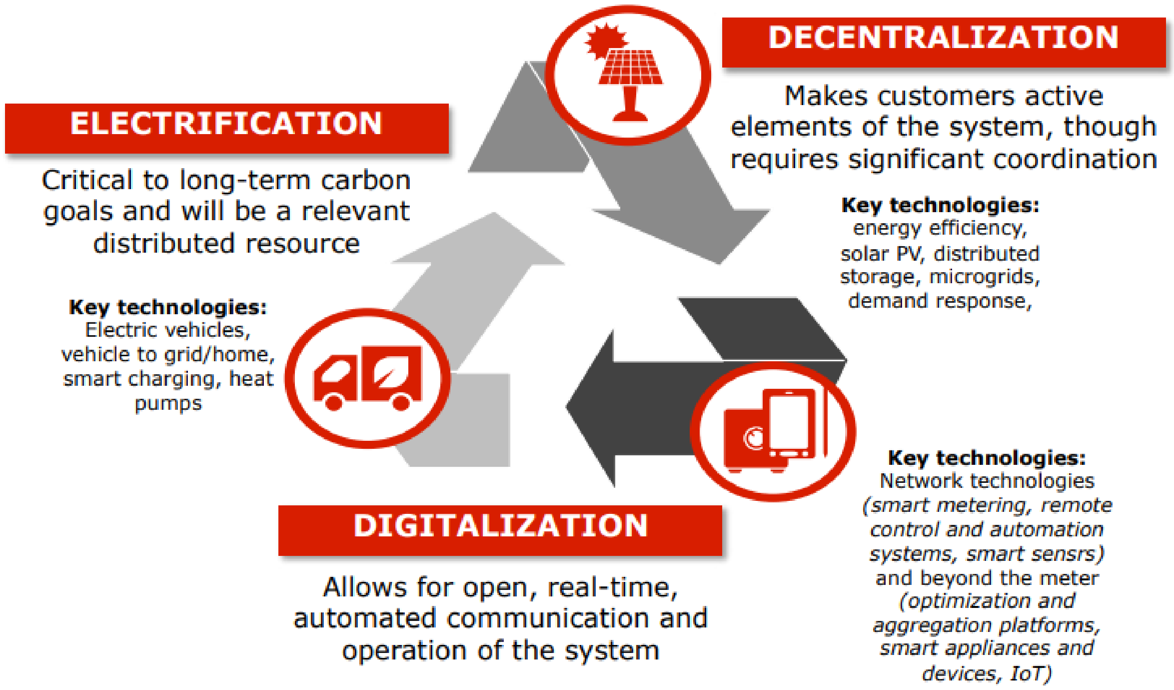

Figure 8. Three trends of the grid edge transformation. Source: World Economic Forum. 2017. *The Future of Electricity New Technologies.* Transforming the Grid Edge. p. 4. Retrieved from http://www3.weforum.org/docs/WEF_Future_of_Electricity_2017.pdf

The WEF (2017) did some recommendations to accelerate the development of these technologies and their associated social and economic benefits, and therewith secure a reliable, economically competitive and environmentally sustainable electricity system. Hence it is important to redesign the regulatory paradigm and deploy enabling infrastructure that takes away uncertainty about rules, so that the future energy system and new business models are given the authority and means to develop. Concerning the first mentioned – changing the rules, i.e. the institutional environment – the regulation should be improved so that DERs and innovation can be fully integrated, and distribution network operators are allowed to execute new and revise roles.

The future electricity network system is going to be bidirectional and new innovative solutions will make the electricity system more and more decentralized, with many wind turbines, solar installations and EVs. To use the new energy system efficiently, it is important to control and make use of the power of Internet, hence add the layer of information technology. Therefore, the separation of the physical – electric current in kWh –, contractual – dollars –, and information technology – in bits – should be clear and well defined. Besides being a technical topic, this concerns redistribution of power and money. Incumbents like the DSO and energy supplier will lose their leading role and have to fit in a new system. Possibly, in a much further stage the energy distribution will be democratized so that everybody can trade with anyone, and the "consumers become prosumers". Accordingly, smart grids need flexible energy markets to fit in all these developments legislation should adapt (Auke Hoekstra, 15 January 2018, personal communication).

Hoekstra emphasizes the importance of enabling network operators to reward flexibility from consumers. Not with a fixed amount for a fixed permissive value, but rather a higher reward for greater flexibility. This can for example be done with distributed ledger technology, which essentially is a list of verified peer-to-peer transactions that can be shared by anyone. An app, charge point, aggregator or your car can request, with an automatic message, to postpone your charging session. Reduce the peak in demand on the electricity grid, in return you are offered low-priced renewable energy during the night. The consumer determines the value of this and accordance on the price is reached, sequentially the agreement is documented in the ledger. The consumer can say for example: "My car stops charging now and starts charging again at midnight". Somebody else replies in the ledger with the price agreement. That is how it is recorded, whereby the ledger is a kind of contract (Auke Hoekstra, 15 January 2018, personal communication).

6.2. A focus on flexibility for the grid operator

Verheijen (2017) believes that the grid operator should focus on flexibility. A grid operator has to create the conditions in which market parties find it interesting to use for instance smart charging. Hence, the network operator can ask for flexibility, which the market can then offer and deliver. At present, the only business case for the market concerns capacity behind-the-meter, as there is no incentive for anything else. It is of great importance that the network operator creates an incentive for flexibility in-front-of-meter. Without incentive, market parties will not invest and therefore the grid operator will have continue increasing the capacity of electricity networks. If there is money to be made, market parties will invest and the desired services will come naturally. To do this, the legislation must be adjusted, market processes changed, the ACM will have to be convinced, and the network operators (in the Netherlands) must figure out how they will compete with their own 3x25 ampere agreement (Lennart Verheijen, personal communication, 24 November 2017).

Network operators must do research in smart charging to know how it works. However, they should not focus only on smart charging to tackle the future problem, since you never know what will be invented in three years' time. For this reason, a grid operator must concern contract forms in which those individual techniques (such as smart charging) come into its own, so that if something new is invented by the market, this can be fitted into the system. They must create the incentive for flexibility, so that market parties can tackle the problem and offer a solution. In addition, they must ensure that the law and regulations are adjusted, so that that flexibility may be allowed in the future (Lennart Verheijen, personal communication, 24 November 2017).

This does not mean that the grid manager only has to deal with flexibility, though smart charging also needs to be considered. If the network operator does not engage in smart charging, then it will become too expensive for society, since the market will try to play games with smart charging.

Network operators have to engage in research and development in order to prevent the grid from being used very clumsily, as that can cause a lot of costs. Thus, it is good that many network operators are already working on this. They wonder how they should deal with the emergence of fully electric cars - which load faster and faster - in combination with the evening peak, where there is relatively little space in the capacity on the low-voltage grid. For example, it could be a solution to offer a connection with less capacity in the evening hours and more outside, so that the cars are still sufficiently full again, while the network is not changed, which is also referred to as a variable connection (Friso Schuring, personal communication, 15 January 2018).

Despite the fact that practical examples show that sustainability can be achieved, experienced promoters perceive obstacles in legislation. Bottlenecks can be removed by making the facilitation of renewable energy with flexibility and freedom of choice possible. Thence, specialist traders (aggregators) can offer flexibility of a group of electric cars on the market on behalf of EV drivers. Financial rewards give value to flexibility and provide benefit to the energy supplier, DSO and the consumer. Free choice of different energy suppliers would make it possible to charge your electric car anywhere in the Netherlands with self-generated renewable energy. For example from solar panels on the roof. By far most of the time, EV drivers charge at home or at work, which means that free energy trading is needed at local level (Huygen & Hoekstra, 2017).

As mentioned before, network operators must be enabled to reward flexibility from consumers (Auke Hoekstra, 2018). In addition to flexibility, network operators have to engage in smart charging. "If the grid operator does not become involved smart charging, then - oversimplified - it becomes far too expensive for society. Then the market will behave in a playful way with smart charging without taking into account the social costs. Network operators have to think about smart charging timely, to prevent the grid from being used in a silly and inappropriate way, which can cause high social costs". Therefore, it is satisfactory that the DSO's are already building up a knowledge base and gain experience, the three largest DSO's of the Netherlands are also quite busy with it. They wonder how, as a grid operator, you should deal with the emergence of all-electric vehicles - which load faster and faster - in combination with the evening peak, where there is relatively little room for extra energy demand on the low-voltage grid. For example, they can offer a connection with less capacity during the evening hours and a higher capacity outside these hours, so that the EV's still will be fully charged sufficient enough, while the network does not have be changed. However, this has to be allowed by legislation (Friso Schuring, personal communication, 15 January 2018).

6.3. The social aspect and customer level

Before a market can emerge in future, smart charging should develop on the technical aspect, this implies, standardization, as well as that open protocols and security specifications have to meet the latest requirements. (Baerte de Brey, personal communication, 6 December 2017; Rutger de Croon, 6 December 2017, personal communication; Edwin de Veen, personal communication, 5 January 2018; Katja Gicklhorn, personal communication, 14 February 2018; Alexander Schuller, personal communication, 14 December 2017; Thomas Daiber, personal communication, 16 January 2018). Even more important is to stimulate the formation of a smart charging market is the social aspect of the customer. The EV driver will have to be put central to enable smart charging in future. Current smart charging development is mainly focused on the technical side, i.e. the possibilities. More consideration must also be given to the added value for the e-driver. It is therefore important to look at how developments can be beneficial for both the electricity grid and the e-driver (Jaap van Tiggelen, personal communication, 8 December 2017).

6.3.1. Awareness, acceptance and communication

In the Netherlands, the consumer is too spoiled with a reliable e-network, and we think that it is normal that electricity is always available, therefore the customer should become aware of the real situation and the importance of smart charging. People and society need become aware that the electricity grid also has its limitations, and that it is very expensive to charge a Tesla Model S very quickly 365 days a year. An EV driver probably does not realize that charging his car has a large impact on the electricity grid. This must be explained to the user and also the solution smart charging has to be offered. It will help to give the user insight into the positive effect of smart charging their car, for example through an application. Clear and simple contact with EV drivers essential for smart charging to be accepted by the general public. A party or consortium is needed that takes the lead here. Forces of stakeholders will have to be combined to ensure the social aspect of smart charging. So that, acceptance of the e-driver and social support of the general public can be created (Rutger de Croon, 6 December 2017, personal communication; Friso Schuring, personal communication, 15 January 2018; Jaap van Tiggelen, personal communication, 8 December 2017; Steven Mens, personal communication, 6 December 2017).

In addition, there must be more information and communication about what smart charging is, especially towards customers. What does it imply for the customer, what are the benefits and why it matters (Jaap van Tiggelen, personal communication, 8 December 2017). EV drivers must be prepared to charge their vehicle smart certain times and, if necessary, to make the battery available as a storage. Therefore, creating user acceptance is an important step (Katja Gicklhorn, personal communication, 14 February 2018).

6.3.2. Uniformity with smart charging methods

In addition to good communication about smart charging, it is important to ensure as much uniformity as possible. This is about uniformity where possible in the types of smart charging, otherwise the driver does not know what to expect. It is unfavorable for the social acceptance of smart charging when an EV driver, for example in ten different cities in the Netherlands encounters other smart charging methods or at least does not know that he would run into them. The rider must be involved with the different systems in different places in a simple way. For example, there is a different approach in The Hague and Amsterdam. In the Hague, the EV driver must download an application to overrule smart charging. If you visit The Hague and do not know that this is happening, it is an unpleasant surprise. Especially with the advance of electric driving this has to be taken into account (Jaap van Tiggelen, personal communication, 8 December 2017

6.3.3. Put the EV driver at the center

The adoption rate of EV will have to be increased by, for example, new additional rules, the removal of thresholds and sufficient charging infrastructure (Rutger de Croon, 6 December 2017, personal communication). In addition, the driver must take a central position in further deployment of smart charging. The mobility of the e-driver must be guaranteed, he must have control over his charging process at all times. A new market phase regarding electric cars begins. With a new kind of drivers who just want to drive and do not want to figure out everything related such as smart charging. These people want to drive to a charging point, are glad they found it, that the charging works and that the spot is not occupied by a plug-in or a petrol car. Then there should be no smart charging surprise. It is very important to be well aware of the sensitivity of the customers regarding the image of electric driving and smart charging (Jaap van Tiggelen, personal communication, 8 December 2017).

6.3.4. The customer acceptance and needs must be central

It is important to look at the expectations and wishes of the customer (Baerte de Brey, personal communication, 6 December 2017). Services should be created that benefit the customer. Take for instance that the smart phone became a success after a good product was launched with the iPhone (Rutger de Croon, 6 December 2017, personal communication).

You could present smart charging to electric drivers and ask how they see this. The image of electric driving is still fragile that one should be careful with offering these people a certain discomfort when the smart charging does not match their needs. It is very important to get in touch with driver groups to see what they think is important to have smart charging vehicles. For instance, how a driver's association (VER), or the car importers and manufacturers look at it. Since there might be a lot of information that should be given with the sale of an electric car. The experts in the field almost seem to forget what the knowledge of the masses is. Because the ordinary people are just interested in charging their electric vehicle. This is a point of attention and must be handled with great care (Jaap van Tiggelen, personal communication, 8 December 2017).

Respondent 16 also emphasizes the involvement of the EV driver. In any case, a sort of interest organization will have to be set up in which the most important players collaborate. The end user must of course also be represented here, for example by the association of electric drivers in the Netherlands (VER). “Smart" charging will mainly be "delayed" or "slower" charging in the short term, and the most important thing is that the end user knows what is going to happen. In addition, He thinks that the development of smart charging strongly depends on the law- and regulations, but also on how the interconnection of the network operator - charging manufacturer and charging station operator will develop (personal communication, 21 December 2017).

6.3.5. Financial incentives and intuitive application use cases

Financial incentive systems, business cases, and intuitive application use cases have to be created to make smart charging more attractive for companies and customers. (Thomas Daiber, personal communication, 16 January 2018) A customer shall not ask for smart charging but is willing to cooperate for a financial compensation. When the system is well designed with intuitive application use cases, smart charging can soon be part of the charging process without the driver even noticing it. (Edwin de Veen, personal communication, 5 January 2018).

Smart charging should at least be a financial advantage for many EV drives to be attractive enough to participate (Jaap van Tiggelen, personal communication, 8 December 2017). This also requires incentives that need to be created and thus appropriate policies must be put in place (Katja Gicklhorn, personal communication, 14 February 2018; Eric van Kaathoven, personal communication, 16 December 2017). And there must be clarity about the value of flexibility, so what does the customer get in return being flexible (Mereille Klein Koerkamp, personal communication, 30 November 2017).

6.4. Other institutional obstacles for sustainable energy

The social aspect of the customer is of main importance for further development. A number of components are clearly important, which can be seen as preconditions for enabling market for smart charging. Besides the acceptance and needs of the customer other institutional conditions exist. Such as the market characteristics and expectations, the regulation structures, the required growth of the number of electric cars, policy foundation, and information provision.

6.4.1. Market characteristics and regulation structures

Friso Schuring hopes that new actors in the market will take responsibility on some difficulties for the e-driver. All kinds of (market) parties want to do something with the battery in the car and offer services to the e-driver that influences charging the car. Therefore, the e-driver must get some sort of overview - or a party who arranges for them - how their car is charged exactly and a certain prioritization is made. So the market must come with a smart charging "platform", i.e. a sort of (computing) platform, a framework on which applications may be running, that helps prioritize. This can be done by an aggregator, however if there are private agreements available there might be an added component. Above all, there must be clarity for the e-driver, and he must easily be able to make choices about this himself if he wants to. This situation is elaborated in an example in the box below. An important aspect of such a platform is that network operators set good requirements and capture this in regulations, in order to guarantee the social interests of the network.

> Imagine you have a contract with the transmission system operator TenneT to help prevent imbalance in the transmission grid, and with your neighbors that if they have leftover solar power that you will charge your car, and also with the regional network operator Liander who can ask to postpone charging when the capacity of the network requires it. All these kinds of contracts are mixed up and a certain prioritization must therefore be put in place (Friso Schuring, personal communication, 15 January 2018).

Smart charging pilots currently cover only one aspect of the energy market, for which they offer flexibility. The market must develop in such a way that e-drivers must be able to benefit from all aspects of the energy market. The market must be completely open and lock-in effects, such as now, where you are bound to a fixed energy supplier for smart charging services, have to disappear. Therefore, a lot has to be changed in legislation and uniform communication protocols between market parties are necessary (Mereille Klein Koerkamp, personal communication, 30 November 2017).

In addition to the information about smart charging that OEMs will actually have to give to their customers, we almost skip another essential part. This was clear from Alexander Schuller's reaction to my question on how smart charging should develop in the future; "Well, smart charging should be implemented. Currently most OEMs seem to rather struggle with the initial swindle to e-mobility alone". This is almost taken for granted, but of course it is also important to keep the acceptance and needs of the car manufacturers in the back of our minds (personal communication, 14 December 2017). Clear communication with all stakeholders that have to deal with smart charging is important, so support must be created among all car manufacturers (Jaap van Tiggelen, personal communication, 8 December 2017).

6.4.2. Technical development

Eric van Kaathoven indicates that two aspects should be further developed, both smartly adapting demand, i.e. charging at adjusted speed and times to avoid peak load and optimally use solar and wind power, and smart storage for own use at home as well as for the grid (Eric van Kaathoven, personal communication, 16 December 2017). In addition, the intelligence related to smart charging and its applications must be integrated into the private, public and semi-public charging infrastructure (Thomas Daiber, personal communication, 16 January 2018). Edwin de Veen also goes a bit further in distinguishing between the development of charging points in the public domain and in semi-public areas. For the former (public). Further development is an extensive and complex process, for example through various stakeholder, privacy and infrastructure. For the latter this is (partially) already determined and relatively simple. Important hereby is further development of the OCPP / ISO protocols (personal communication, 5 January 2018).

6.4.3. Policy foundation and information provision

Concerning the policy foundation, it is no longer possible with radical innovation to base policy on past experiences. The best foundation is based on transparency, empiricism and taking change into account. If change is modelled, the designs must be bottom-up and open source. Recognized bodies like the IEA are constantly underestimating the rise of sun, wind and EV, as their models are still based on the past. Bottom-up regional plans that prioritize the locally available potential to improve both the business case and social cohesion. Independent public tests based on practice bring back reality and consumer confidence. There, standardized (total cost of ownership) information is of great importance for sustainable technology, as it is more expensive to purchase, yet is cheaper over its lifetime (Huygen & Hoekstra, 2017).

The second area is information provision. The possibilities of the Internet revolution have penetrated to the energy system, yet only to a limited amount. This creates the opportunity to the market and regulators to do this right at once. Therefore, the government has to accelerate the introduction of open standards. Laws and regulations need to be adjusted, to be supportive to the innovations. Not only for the reason that this leads to better market functioning, but as well because it is favorable for Dutch business. Governmental intervention is necessary and desirable for the (legislation) bottlenecks of cyber security and privacy (Huygen & Hoekstra, 2017). On the subject of privacy, Edwin de Veen thinks that if the network operators – especially the major three – join forces together, the further development must be possible. However, he expects that making the low voltage grid “smart” – and thus making smart charging possible from the side of charging infrastructure – will be the biggest challenge. Though, both are needed to enable smart charging (Edwin de Veen, personal communication, 5 January 2018).

6.5. Conclusion

The future electricity system will be characterized by electrification, decentralization and digitalization, which can support flexibility. Flexibility from consumers will be of major importance and should be rewarded. In the future development of smart charging - which is a way to deal with flexibility - the customers’ needs and acceptance of smart charging must be central. Besides, the market characteristics and regulation structures have to adapt, and the number of electric vehicles should increase. There are four levels that have to develop to help the future smart charging market emerge. The social aspect and customer level, technical, legislation and market level. Lastly, regarding the institutional obstacles for sustainable energy, the policy foundation, information provision and financing must change.

7. Conclusion

This research has investigated on the effect of institutions on sustainable innovation. Therefore, a close look has been given to the institutions related to the traditional energy system and their impact on the development of smart charging. It appears to be worthy to use the institutional perspective instead of the transition approach as it enables the deepening of structures such as the regulatory framework of the DSO. The elaboration of the step of regulatory reforms changing the regulation towards an output-based approach has uncovered the subordinated role for sustainability. And thanks to the institutional theory it is possible to put this in the broader perspective of the sustainable transition and related institutional structures.

In general terms, a positive and active attitude towards a new socio-technical system contributes to sustainable innovation. Institutions of the old socio-technical system can impede sustainable innovation and therewith the transition towards the new system. Thus, these must adapt as well as that new legislation must be made that serve and promote (the development of) the new system. Hence it is crucial to ensure a positive attitude towards the new socio-technical system, to improve institutions and regulation belonging to the old system as well as creating the necessary institutions to support the new socio-technical system. An open attitude to new developments, together with a high willingness to support this from the government are important.

In terms of the transition towards smart electric mobility, this implies that a positive attitude towards the smart charging is favorable for research and development and the enlargement the social acceptance of it. The market parties that have knowledge and are involved in smart charging development have a positive attitude. However, it is important to ensure that all parties, such as car manufacturers, are and keep being involved in the further development. After all, smart charging is not possible without electric vehicles. Moreover, two major institutional changes are necessary to enable the further development of smart charging. The policy makers have to adapt the institutional environment of the DSO, in which sustainability objectives have to be integrated. And the social aspect of smart charging and the focus on the consumer - who has to change his behavior – should be central. These conditions have to change to enable the energy transition to a sustainable system in which smart charging can connect the energy supply with electric mobility.

The government is considerably less concerned with smart charging innovation than companies and universities. However, the government will have to actively take up its role as a policy maker. It is very important that policy makers translate the sustainability goals into the energy market and provide an assessment framework for the ACM to control. If sustainability is not translated, as being the case right now, then affordability and reliability of the grid will seriously limit the possibilities to develop a future proof energy network. Moreover, the government is the less active with enlargement of social acceptance than companies and universities. Though this will be an important task to take up in future.

Even though awareness has to be created about the limitations of the electricity grid and the opportunities and solutions smart charging offers, the social embeddedness in the Netherlands seems to be in favor of the sustainable transition that combines sustainable energy supply and electric driving. The Dutch realize the seriousness of climate change and recognize the economic benefits that expertise in new clean technologies such as smart charging can bring. However, ignorance, a certain discomfort due to unexpected and unclear smart charging test cases and the fragile image of electric driving are a threat for further development of smart charging if these matters are not addressed now. The driver with his interests and expectations should put at center, uncertainties about charging have to be removed and services for the benefit of the consumer have to be created. Besides, awareness and acceptance with the customer about the real situation concerning the impact of the electric car on the grid and the importance of smart charging must be ensured. If this is guaranteed, then the consumer will certainly be willing to cooperate if financial incentives and intuitive application use cases are created. It is important to share information and to communicate well about what smart charging is, what it means, what the benefits are and why it matters.

8. Discussion and Reflection

The research group used in sub-questions one to three is too small to be representative of a part of the population, which is unfortunate. These sub-questions do give a nice indication of likely linkages, yet cannot be regarded as hard evidence. That is why it would be interesting to explore this extensively in future research. Besides, the starting point for the research group of the survey may have created a too positive picture of the market for smart charging. I specifically wanted parties that had already heard of smart charging or were working on it. This is of course not a good representation of society. For the reliability of these sub-questions, it would have been better to randomly select respondents. Though, now it does show how the parties in the market involved in the development are looking at smart charging. On the other hand, this pre-selection has created good chances for the last two sub-questions. Because in many cases the survey was an opening to ask a number of additional questions to experts who are at the heart of smart charging development. This has yielded very interesting insights, especially for the social aspect of the consumer. Before I started the research I had a suspicion that the added value for the consumer was part of the whole. However, I did not realize that this would be so important.

Institutions are embedded in the culture as well as geographical systems, such as country related norms and values and rules. Although this research is focused is on economic institutions, it is of importance to be aware of the possible impact of geography and culture. As there are originally three components (economic institutions and latter two mentioned) that encourage technological progress and therewith economic prosperity (Acemoglu, 2002). It would be interesting for future research to focus on the effect of geography, culture or even the intertwine of the three on sustainable innovation. One can think for instance of national resources, like that Norway is far ahead with renewables and even has a surplus due to water power. Or a look into institutional differences and possibly different working of the same set of institutions in different cultures. Cultural differences in urban and rural regions, as well as between countries. Even though neighbor countries as Germany and the Netherlands share similarities, differences might exist in the institutions and culture. People in rural areas might have a different attitude towards electric driving and renewable energy sources than the urban counterparts. Cultural differences are not part of this research, but it is interesting for future research to deepen de differences between drivers and inhabitants.

In relation to the subject of this paper, it would be interesting for further research to elaborate on the customer aspect and progress in the legislation. What is the best way to focus at the customer and enlarge social acceptance? Also, to what extent the "law VET" (Dutch law progress energy transition) and the new climate agreement contribute to an improvement of the law and regulations of the grid manager regarding sustainability and smart charging development. It is particularly interesting how policy makers after setting sustainability goals translate these into the energy markets and an assessment framework for the ACM.

9. Policy Recommendations

9.1. The institutional environment of the DSO

Sustainability aspects of the energy supply

The legislator will have to set legal frameworks for sustainability. In line with this, the ACM can be given a task to monitor sustainability aspects in energy supply, which is not possible without an explicit (legal) task in the field of sustainability. The transition to a sustainable energy supply will have to be described in the law, with attention also being paid to the role of the network operator.

Problems will arise in the energy transition wherefore no tailor-made solutions are laid down in legislation at that time. Therefore, ACM should be empowered to grant permission to deviate from the legal framework if necessary and to promote the energy transition. Adaptation of legislation at the moment the need arises would take too much time and frustrate the transition unnecessarily. Moreover, it is impossible to make a full-fledged legislation when an innovation is still in its infancy (ACM, 2013; Netbeheer Nederland, 2013).

An added value of the ACM may be the provision of further guidelines to ensure that the network operator dilemma (pre-investment versus efficiency) does not become an obstacle for the sustainable energy transition. Space for pre-investment if sustainable plans were appointed in the structural vision can be a good start (Nationaal Energieakkoord, 2013). However, since the considerations of network operators are still based on the same criteria, this will not yet provide a realization of efficient sustainability investments by the network operators. It must be prevented that the efficiency pressure on the network operators leads to a cautious approach regarding (pre-)investments for sustainable solutions. In concrete terms, the grid code must be supplemented with sustainability criteria for, among other things, reserve capacity of the distribution grids, flexibility and decision criteria that are linked to government plans. In the current legislation, sustainability is only mentioned as a criterion for efficiency (e.g. art. 20, sect. 2) (bron: elektriciteitswet). In order to deal with the energy transition and related investments in distribution networks, the sustainability aspect will have to be elaborated and standardized into criteria applicable in the distribution grid. The increasing degree of interdependence of various energy systems such as electricity and mobility will also have to be given a place in legislation, for example the developments in charging infrastructure for electric mobility (ACM 2013; Netbeheer Nederland, 2013).

Supervision with regard to sustainability

The ACM must follow the political and policy choices with regard to sustainability objectives and does supervise the goals and laws set by politicians and policy makers. Policy makers are responsible for: First, setting sustainability goals. Secondly, translating these objectives into the energy markets. Thirdly, providing a (legal) assessment framework for the way in which the ACM has to weigh sustainability against reliability and affordability (ACM, 2013). In order to integrate policy, implementation and supervision, the second and third mentioned will have to be elaborated.

In addition, the regulation of the network operators is characterized by 'output control', since the grid operator himself is responsible for carrying out his statutory task. That is why this statutory task with regard to sustainability (and smart grids) should be well defined. A definition for output factors of sustainability must also be laid down in the legislation itself, as well as a determination how this can be taken into account in the tariff regulation. Subsequently, the ACM will have to provide the right incentives so that network operators take their responsibility with regard to the statutory task for sustainability. Besides, in the supervision of (local) experiments, the ACM will have to let the interests of sustainability prevail wherever possible. Considering that the current legal framework offers no or insufficient possibilities to temporarily deviate from certain laws and regulations. While changes to legislation and regulations are not (yet) on the agenda or take too long. (ACM, 2014; ACM, 2013; Netbeheer Nederland, 2013).

Sustainability aspects in tariff structures and conditions

The current tariff system of electricity connections has to be changed. The legislator should allow grid operators to treat these connections separately from a normal home connection. As the network load of a car is much higher than that of a household, this must be differentiated. A distinction must be made between types of use, what implies more differentiation in the product and service offerings of the network operator (Friso Schuring, personal communication, 15 January 2018).

Besides, Grid operators need to be able to experiment with different than current tariff structures. Hence, the ACM will have to grant exemption from the tariff codes and other codes in order to contribute to initiatives for the desired energy transition. Presently, the grid operator has no resources to actively use demand response (art. 16, sect. 1c), in his tariff setting and conditions, for instance. In addition, there will no longer be a 'standard' customer in the future as a result of the energy transition. For this reason, there is a need among grid managers for opportunities to organize peak management at local level, for example by means of tariff differentiation or congestion management (ACM, 2014, Netbeheer NL 2013). At this moment, the network operator may only deliver connections with a fixed capacity, thus variable capacity is not yet permitted by law. Grid operators are not allowed to ask the end user to reduce the speed of charging or postpone the charge session (Friso Schuring, personal communication, 15 January 2018). Therefore, flexibility should also be integrated into the legislation, including the allowance for grid operators to create incentives.

Role and tasks of the network operator in relation to sustainability

In addition to the regulatory framework regarding small-scale electricity that needs to be changed, a possibility to trade flexibility must be created. So that market parties can also bid on the flexibility that the car offers and then a market force can arise, whereby that aggregator is needed. Market parties can then ask consumers what flexibility they have available at home, and this flexibility will be traded on the market (Friso Schuring, personal communication, 15 January 2018).

Market parties have insufficient interest in enabling sustainability initiatives and flexibility as long as there are no incentives. Grid operators as public companies - with their public shareholders and the nature of their legal duties and the existing supervision thereof - could take the responsibility to create the necessary incentives until market forces are sufficiently developed. The legislation will have to offer the opportunity for this. The ACM can make agreements with regional network operators (by means of an assessment model). For example, it can be determined when and for how long network operators are allowed to perform the relevant activities. In that case, ACM could monitor with use of reports from the regional grid managers. In this respect, the network operators could temporarily receive additional statutory tasks for which regulated tariffs would also apply. Or that (a part of) the costs of the relevant activities can be included in the tariffs of the already regulated services of the grid operator, in the initial phase. When market forces can create sufficiently incentives themselves, the grid operators will have to withdraw (ACM, 2014, Netbeheer NL 2013).

Investments in relation to sustainability

Finally, the current regime of special expansion investments is framed in such a way that no regional network operator makes use of this. The assessment as taking place in the context of the expansion investments should not be used for assessing sustainability investments. Sustainability investments deserve an appropriate coordinated assessment. Linked to the performance measures of output control concerning the sustainability task. (ACM, 2014; Netbeheer NL 2013).

9.2 The social aspect and customer level

The government should take up the task and provide a plan as well as free up money to create awareness about the limitations of the electricity grid. She is the designated entity to convey something like this. This should not come from the market or network operators, which creates mistrust. As well as that national unity and alignment can best be achieved with the use of a national entity. Awareness of the limitations of the electricity grid can be explained with use of an analogy between the congestion problem and traffic jams.

The Route du Soleil[1] is also not extended because of extremely busy traffic due to a mass holiday exodus, which only appears a few days a year, then it would be much too wide. There are only a few days a year that there is a problem on that road. And we all have to deal with it. That should also be the case with the electricity grid. It is not convenient to expand the electricity grid for a few hours of peak load per day. We must all take this into account. The cars can also charge at a different time or at a lower speed (Friso Schuring, personal communication, 15 January 2018).

The government should enforce the use of smart charging. This does not mean that the government should impose obligations on the manner of control, but rather create the framework within which flexibility can be opened up, grid congestion prevented, and so on. The government must offer incentives in the context of preventing additional social costs and mobility limitations (Rutger de Croon, 6 December 2017, personal communication).

Smart charging may not be optional for e-drivers, yet should be very easy. The implementation of smart charging must be focused on awareness and simplicity. The e-driver must be aware of the load on the net by his car, hence that this must be handled cleverly. This awareness can be created with, for example a SIRE advertisement. In addition, a user must be able to easily handle smart charging. An overview of the current load on the grid and the contribution of his electric car in the stabilization of the grid would also be nice to make the user more involved (Steven Mens, personal communication, 6 December 2017).

Concerning the various smart charging methods that an EV driver can encounter uniformity and good communication has to be pursued. Preferably top-down driven policy should make sure that the consumer is easily informed about the circumstances. This may be done with use of one accessible platform, application and/or website like “van A naar Beter”. Local governments should be obliged to provide clear information by means of this resource in collaboration with technical experts. To make sure that the consumer knows what he can expect and easily can control is own charging process if desired.

Last but not least, smart charging and an increasing number of electric vehicles do inherently depend on each other. Smart charging really only makes sense if there are lots of EVs, but lots of EVs actually make smart charging necessary to limit the EVs’ impact on the power grid (and integrating renewables). So, yes, supporting the adoption of EVs is necessary, but also continuing to strengthen energy production from renewables. Otherwise, EVs just use electricity from coal or other filthy sources, which does not create a substantial environmental benefit (Tobias Brandt, personal communication, 17 January 2018).

[1] A busy motorway route in France, with enormous traffic jams a few days a year as a result of a massive holiday exodus.

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