Powering the Future with Smart Grids

A Normative Framework for Moral-Political Problems

Master Thesis

Gijs van Leeuwen

1 September 2021

MSc Philosophy of Science, Technology and Society

University of Twente, BMS Faculty

First Supervisor: Dr. Yashar Saghai

Second Reader: Dr. Andreas Weber

Table of Contents

1. Introduction

The crucial importance of electricity for the life of people in developed societies cannot be understated. We need electricity to refrigerate our food, wash our clothes, charge our phones, and conduct payments, meaning that only very few people can live without it. Besides its use for daily activities, electricity is also required for services of logistics and mobility, as well as pervasive systems of communications and information management and industrial processes. Overall, the general functioning of developed economies and their institutions of governance are dependent on the reliable availability of electricity. Still, most of us tend to forget at times how much we rely on this energy carrier. Electricity has become so widely ubiquitous and pervasive that its consistent and abundant availability is largely unquestioned. Whenever we turn on the lights there is no doubt that they will illuminate, and when we shop for groceries we assume that we can pay electronically with our bank card.

While most of us tend to take electricity for granted, it is by no means generated out of thin air and delivered without effort. Behind the power socket lies extensive infrastructure that can span entire countries or even continents, and there are numerous institutions, companies and other organizations that work to keep the grid operational. They do so by ensuring that the generation of electricity matches the demand at all times, that the infrastructure is adequately equipped and maintained and that any failures or outages can be swiftly addressed without creating major disturbances in the system. All of this is done while keeping electricity supply affordable and reliable for everyone. Both the technological and societal structures that are in place are highly complex, consisting of many diverse interconnected technologies, procedures, protocols and services, making it very difficult for the layperson to wholly comprehend what is going on behind the scenes. While these technological and societal configurations are thus largely invisible, society as a whole is dependent on and shaped by their proper organization and structuring. Thus, because the grid is so indispensable for society and influential in its organization, a proper academic understanding of the grid, its functioning in society and its effect on the social world is warranted.

Infrastructures like the grid have been subject to academic study for some time, especially in the field of Science and Technology Studies and Infrastructure Studies. These fields aim to study how infrastructures shape and are shaped by society, as various scholars and historians have argued that infrastructures are constitutive of modern societies and their citizens. Notably, Paul Edwards describes how infrastructures provide the fundamental basis of modern societies and modernity as such (Edwards, 2003), Elizabeth Shove describes how infrastructures shape the everyday social practices of individuals (Shove et al., 2015) and Brian Larkin analyses how the act of defining and advocating a particular infrastructure can promote certain political views, moral behaviours or popular visions and fantasies (Larkin, 2013). Fossil fuel-based energy systems and infrastructures, including the grid, are among the most studied. Oil infrastructures in the 20th century have been used to promote the political system of Western democracy and further the interests of institutional and corporate actors (Mitchell, 2011). This was possible in part because oil is easy to transport and store using technological and capital means, centralizing control over the infrastructure with a small number of powerful actors. This centralized architecture, enabled by the physical properties of fossils fuels, is still present in today's energy infrastructures including the grid.

This fossil-fuel based architecture might be changing however because of several developments, most prominently the renewable energy transition which is driven by international goals of CO_2 emission reduction (European Council, 2014; UN, 2015). Unlike in fossil fuels, where chemical energy is stored in fluid or solid substances, renewable energy generation creates electricity at the site of production which is more difficult to transport and store. Furthermore, fossil-fuel based power plants can be quickly and easily ramped up or down while renewable energy generation is uncontrollable. To deal with the inflexibility of electricity storage and transportation, the grid infrastructure may require a range of new functions and features. In recent years, the concept of the "smart grid" has been proposed in scientific literature to cover a range of novel innovations that address these challenges (Amin & Wollenberg, 2005; Farhangi, 2010). Considering the societal status and indispensable social function of the grid, the new smart grid proposals and experiments requires further study and investigation.

This is because with the development of this novel infrastructure, there are important design decisions to be made in which different values with a moral and political character may be prioritized. The first publications on smart grids are from the engineering field, focusing on improving security, reliability and resilience of the grid using novel information and communication technologies (Amin & Wollenberg, 2005; Bouffard & Kirschen, 2008; Farhangi, 2010). In parallel with this digitalization, the authors describe how the grid could transform into a more decentralized form, an architecture that is so different that it could be considered as a new paradigm in the organization of this infrastructure. Besides security, reliability and resilience, the value of sustainability and integration of renewable energy has become increasingly important, with a large emphasis on flexibility within the grid to account of inflexible solar or wind generation (Driesen & Katiraei, 2008; Farhangi, 2010). Finally, more recently an increasing amount of attention is directed towards the study of social and societal implications, consequences and opportunities of electricity infrastructures, placing a large emphasis on decentralization, energy communities and topics of autonomy, self-sufficiency and citizen participation and engagement (Skjølsvold et al., 2015; Verbong & Geels, 2010).

Related to such societal consequences and developments in grid infrastructure, the renewable energy transition more broadly has been studied with regard to its political aspects and implications, particularly in the movements for and the scholarly literature on Energy Democracy and Energy Justice (Jenkins et al., 2016; Szulecki, 2018; Van Veelen, 2018). Both draw on insights from social and political science and philosophy and present normative views on desirable properties of the renewable energy transition. Energy Democracy advocates a more democratic energy transition by providing more agency and governance authority to individuals and local communities. In particular, the ideal citizen in this view is the 'prosumer', a citizen who derives political power from the ability to produce as well as consume energy (Szulecki, 2018). Energy Justice advocates a just transition in which no particular groups are favoured over others and all citizens receive fair and equal treatment and opportunities (Sovacool & Dworkin, 2015).

The conceptual frameworks provided by this literature can be used to study political problems within the field of energy, however an explicit connection with transforming energy infrastructures and smart grids has not yet been made. It is recognized that revolutionary changes in the energy system are taking place, driven by renewable energy integration and technological changes. Whilst Energy Justice and Energy Democracy advocate more just and democratic energy systems, it is not fully explored what the specific consequences are of the introduction of certain innovative technologies. In particular, whilst the relevance of renewable energy generation is extensively considered, there has not been research yet that analyses how smart grid infrastructure may contribute to or impair the realization of just and democratic energy systems.

It is this research gap to which this thesis aims to make a contribution. Smart grids have the potential to provide individuals and communities as well as utilities and energy service companies with novel capacities and modes of interaction. Such developments have the potential to empower or disempower these various actors and exacerbate or mitigate any inequalities between them. Because the grid is indispensable for many developed societies and shapes their structure and functioning to a large degree, I propose that the moral-political problems of this transforming grid infrastructure should be studied in greater detail. Therefore, the primary research question of this thesis is:

> What moral-political problems emerge in the development of smart grid infrastructure and what kind of normative framework can assist us in addressing them?

Within this question, moral-political problems are understood as morally controversial issues or questions that arise within the collective decision-making processes about the development and management of smart grid infrastructure. The term 'moral-political' is distinguished from 'political' to indicate the moral component of such issues, whereas political problems may pertain to matters of governance from an institutional or regulatory perspective. I will use both terms throughout this thesis.

To answer the question, I will build upon the academic discussions introduced above, drawing from Science and Technology Studies, Political Philosophy and Science and Engineering Studies from the fields of energy infrastructures, smart grids, democratization and others. The different insights from these fields are used to conduct a philosophical analysis provide normative guidance for further development and study of smart grids. I will build a normative conceptual framework to study and define the moral-political problems that may arise in the development of smart grids. I will use this framework to study an empirical case of local development of innovative energy systems and consider how the framework and the existing literature can be used to study problems found empirically. In the end, I will provide a normative recommendation on the desirable properties and aspects of smart grids and their development based on the findings and provide suggestions for further improving the framework and expanding on existing literature in future work.

To build the framework and provide the moral-political analysis I will break this thesis down into several steps and corresponding chapters. The second chapter serves to ground the present transformation of the electrical grid in a historical and societal context. I will consider what types of political problems have been studied and found empirically in energy infrastructures to elaborate the understanding of what constitutes a 'moral-political' problem in this context of collective decision-making in infrastructural development. I will argue that the notion of citizenship and issues of power, control and justice are central. To analyse these empirical, historical insights, I will expand upon the spatio-temporal dimensions within which these moral-political aspects must be understood since infrastructures are highly expansive and obdurate structures. In this way, the second chapter provides a conceptual baseline for building the framework and discussing the smart grid's present and future moral-political problems in later chapters.

The goal of the third chapter is to build a contemporary, rather than historical, conceptual framework by providing an overview of key innovations, features and developments in the new smart grid paradigm. In doing so, I will pay particular attention to the different public and political goals and functions that have been proposed for the smart grid. Furthermore, the chapter serves to describe the different conceptual parts in which the infrastructure can be divided for convenient discussion. In the end, I will use these insights to elaborate on the trend and concept of decentralization which is of considerable moral-political significance. Building on the insights from the first chapter, I will discuss how decentralization in smart grids should be understood politically while considering the extensive spatio-temporal dimensions of infrastructures. Smart grids are highly heterogeneous and customizable, with a large variety of different models and architectures that can exist in different local contexts. To enable the co-existence of such different local architectures, power and control can be delegated from large institutional and corporate parties towards a larger number of varied and smaller actors, including individuals and local communities.

In the fourth chapter I will consider how the potential moral-political problems I have identified can be further conceptualized and addressed. In doing so, I will provide a normative framework that is useful for studying such problems in present and future development of smart grid infrastructure. To build this framework, I will combine normative prescriptions from Energy Justice, Energy Democracy and American pragmatism. First of all, I will use Energy Justice and Energy Democracy for normative guidance at a macro, systemic level, where governments and other institutions may take action to implement certain smart grid models at the scales of a city, region or country. Then, I will use American pragmatism to provide guidance for micro-level, bottom-up governance in experimental contexts, which is especially important as smart grids are currently at an experimental stage of development. In this way, the normative framework can be a tool to conceptualize moral-political problems and thus guide development at the various levels that are connected by smart grid infrastructure.

In order to test the framework, I will use it to study an empirical case of a Community-based Virtual Power Plant (cVPP) project in the Dutch town of Loenen. By doing so, I will conceptualize the empirical findings as moral-political problems of power, justice and democracy. I will consider to what extent the normative framework is adequate for the empirical findings and analyse what the implications are for the greater system. I will argue that for considerations of power, justice, and democracy, it is desirable that grid development be decentralized in a controlled manner, where responsibilities and opportunities are extended to local actors whenever they are able and willing to take these up. I will identify two main problems that remain to be addressed in future work: the motivational problem, which states that people are often not inherently motivated to take responsibility and pro-active action in smart grid development and governance, and the epistemic problem, which states that people often lack the knowledge and understanding required to take part in local governance processes and technical infrastructural management.

2. Political Aspects of the Grid through Time and Space

This chapter will provide a historical and empirical background on the development of energy infrastructure and the grid in particular. The goal is to gain an understanding of typical moral-political issues that can arise in collective decision-making processes regarding infrastructural development and management. As an indication, Thomas Hughes describes how in the development of grid in the late 19th and early 20th century a considerable amount of control and political power was exercised by inventor-entrepreneurs who preferred a particular system design or function for the grid (Hughes, 1983). Furthermore, Timothy Mitchell analyzes in his book "Carbon Democracy: Political Power in the Age of Oil" how powerful corporations and governments have used the physical properties of oil to develop an infrastructure that served to spread the political system of their choice, to ensure their own profitability and to ensure that infrastructural control in overseas territories remained in their hands at the disadvantage of local populations and authorities (Mitchell, 2011). From these and other empirical and historical findings and understandings, I will argue that political aspects of infrastructures pertain to 1) power and control over the infrastructural components and their development, 2) the use of this control to promote certain political ideas, popular visions or notions of citizenship associated with the infrastructure, and 3) the fair and equal treatment and involvement for different stakeholders in infrastructure development as well as equal access to infrastructure services. By highlighting and explicating these elements, this chapter forms the basis for the normative framework that will be developed throughout this thesis.

As a conceptual lens for studying these issues in this chapter I will make use of literature from the field of infrastructure studies, in particular work by Paul Edwards (Edwards, 2003). Edwards describes the distinctive properties of infrastructures, where three complicating factors in development he describes are time, scale and agency. In general, it can be said that infrastructures are very large, heterogeneous, sociotechnical systems that take a long time to develop and persist for a long time after their completion (Edwards, 2003). This has several implications for a study of moral-political problems: design decisions at early stages must deal with disproportionately large uncertainties about the future course of events, and various scales should be studied including the systemic level and the end-user level. Furthermore, different local regions may have vastly different social, regulatory and geographical contexts leading to different, competing architectures and actor roles which must be reconciled. Section 2.1 will describe the conceptual approach that I will be using, section 2.2 describes the empirical and historical findings and develops an understanding of political aspects of infrastructures, and section 2.3. concludes the chapter.

2.1. Infrastructure as the Backbone of Modern Society

In this section I will present the conceptual lens which I will use to study moral-political issues that have been found empirically in energy infrastructures in the next section. Making use of work from Infrastructure Studies and Science and Technology Studies, I will describe how infrastructures are different from other technologies. These differences especially arise from their extensive spatio-temporal dimensions, their structuring function for daily life in developed societies, and their background function for enabling a wide range of services, institutions, and systems. An important dichotomy that should be recognized when studying infrastructures is that between the micro-scale of end-users and individual actors, and the macro-scale of the sociotechnical system. Both of these perspectives should be considered when infrastructures and their social and political implications are studied.

First of all, infrastructures can be conceptualised as sociotechnical systems that are composed of a large number of interconnected technologies and corresponding societal structures (Edwards, 2003; Ottens et al., 2006). When studying infrastructures as a whole, it is not sufficient to consider singular subcomponents of it, much less the particular technologies that end-users come in regular contact with. Rather a systems approach is required, something that was already recognized in the early days of the electrical grid by Thomas Edison (Hughes, 1983). The definition of a sociotechnical system is not limited to its technological substrate: the societal configurations of institutions, procedures, services and various stakeholder groups that surround it are equally important. In this sociotechnical system, neither the technology nor the social world are taken as fundamental starting point. Instead, both pillars are seen as co-constitutive and co-evolving (Geels, 2005). This means that changes in sociotechnical and infrastructural systems are attributed to systemic dynamics and emergent, evolving processes rather than individual agents and their intentions.

Besides being a sociotechnical system, infrastructures have been described as providing the fundamental background conditions for the existence of modern, developed societies (Edwards, 2003). This is precisely because infrastructures connect macro and micro scale entities and processes into a single system. Infrastructures function to stabilize and regulate the natural environment and constitute an artificial environment, and enable all activities and experiences that we associate with modernity (Edwards, 2003). To further distinguish infrastructures with other types of technologies, Paul Edwards describes three tensions that make infrastructural development particularly complicated, namely time, scale and agency (Edwards et al., 2007). First of all, the development of infrastructures requires long-term planning and consistent efforts, and after its completion they remain in place for a long period of time. This can be recognized with the electrical grid which has existed in approximately the same form for roughly a full century. Secondly, because of the large scale different parts of the infrastructure develop at different speeds leading to asymmetries in the technology and issues of interoperability (Edwards, 2003). Such asymmetries can be societal as well as technological as for example regulatory frameworks may be different in various regions. When different standards and protocols in different infrastructural segments have to be made commensurate, this can lead to what Hughes called reverse salients, which can be understood as sociotechnical bottlenecks (Hughes, 1983). Thirdly, because infrastructures develop in an emergent, co-evolving fashion, it is difficult for any actors to exercise full control over the development of the system.

In contrast with the systemic nature of infrastructures described above, typical citizens will only interact with infrastructures at particular entry points where the underlying systems are invisible or opaque. Such entry points typically exist where the infrastructure fulfils a primary societal function or purpose that is useful for the citizens. For the electrical grid, the wall-socket is where people benefit from the its provision and delivery of electricity. By providing such services, infrastructures enable citizens to perform certain activities or social practices. Elizabeth Shove describes how infrastructures enable interconnected patterns of social practices for connected citizens (Shove et al., 2015; Shove & Walker, 2014). In this way, infrastructures do not only structure modern society as a whole but also the daily lives of individual modern citizens, and they connect different practices and parts of citizens' daily lives. In the case of energy infrastructures this is particularly evident because a significant portion of social practices and activities use energy in some form or another (Shove et al., 2015). Any activity that requires transportation by car requires petrol – or electricity for electric vehicles – and any electronic devices require electricity to function.

2.2. Political Dimensions of Grid Development

Using the conceptual lens for infrastructures described in the previous section I will discuss various historical and empirical findings for energy and particularly electricity infrastructures to consider what types of political issues have been commonly identified in infrastructures. I argue that such aspects of infrastructures pertain to 1) power and control over the infrastructural components and their development, 2) the use of this control to promote certain political ideas, popular visions or notions of citizenship associated with the infrastructure, and 3) the fair and equal treatment and involvement for different stakeholders in infrastructure development as well as equal access to infrastructure services. I will carry over these findings to later chapters within the conceptual framework that I will use to study moral-political problems of smart grids and their development.

I will start this section by describing how power and control of a political character was exercised in the early development of the electrical grid, between approximately 1880 and 1930 (Hughes, 1983). In particular, this narrative shows how influential individuals had the ability to influence the course of grid development in the early stages. On the other hand, this ability was mitigated in later stages when infrastructure development was of a more emergent, systemic fashion. In later chapters, similar things could be said for smart grids which are also at an early stage.

This history starts in the 1870s with Thomas Edison. Edison is described as an "inventor-entrepreneur", someone who was able to direct the entire process from the identification of a problem to the introduction of a usable solution into the market (Hughes, 1983). While Edison is best known for his invention of the light bulb, Hughes describes him as a holistic thinker and conceptualiser who was from the beginning determined to develop not only the light bulb but also the system of the direct-current distribution network. Edison had several reasons for this: by creating a coherently functioning system himself he could be independent from the designs of other inventor-entrepreneurs, thus retaining the freedom to implement his own ideas and control over innovation (Hughes, 1983). Being one of the earliest pioneers, Edison had a disproportionate amount of control over the development of the grid system. This was possible because the system was small enough that individual actors could create intentional change and influence the future course of developments. Such power and control could be exercised through the technical expertise and visionary ideas of such individuals, allowing them to develop technological solutions that were deemed superior to others and adequate to address existing needs.

Besides technical expertise, connections with influential officials and institutions and a practical understanding of socio-political relations and regulatory constraints were equally important and relevant. As Edison's focus shifted more from individual components to the system-level work of increasing complexity, the focus also shifted more from purely technical and scientific innovation to an increasing amount of work on economic and legal matters, for which purpose he partnered with up with others (Hughes, 1983). In one example, his legal associate Grosvenor Lowrey arranged for the New York mayor and aldermen to be theatrically introduced to a lavish dinner by lighting Edison's incandescent lamps, after which they gave him permission to lay the first commercial Edison lighting system in New York (Hughes, 1983). This was an important step in Edison's career, enabled not only by the technological quality of his system but also by the political savviness of his associate. Transferring the system to other locations required adaptation to the local legislative and regulatory frameworks. This involved plenty of networking with political representatives: in Great Britain for example, a certain Edward Johnson was particularly successful in promoting Edison's system with British aristocrats and scientists who were influential with politicians (Hughes, 1983), leading to the system's diffusion to Britain. Still, this was not without problems as his adaptation of the New York station system to the Holborn Viaduct Station in London was unsuccessful in the end. This failure is largely attributed to the Electric Lighting Act of 1882, which provided the state with significant regulatory powers over electric lighting systems and put limitations on private ownership, diminishing the success of the Holborn Viaduct Station system for Edison. Overall, these findings show that power and control over infrastructural development was, for Edison, in important part constituted by influence and leverage in political decision-making procedures. This influence was not provided by his technological expertise but required different types of social skills.

As the infrastructure grew in size and complexity however, development proceeded in a co-evolutionary fashion with emergent, systemic change, and individual agency was mitigated. In its swift growth, Edison's system encountered various problems and competitors. Hughes dubbed the term reverse salient to describe typical bottlenecks in this situation, situations of stagnation in which a complex interplay of social, economic and technical factors in a small part of the system inhibits growth of the entire structure (Hughes, 1983). In the case of Edison's direct-current system, the reverse salient was related to the high cost of transmission over long distances. Despite numerous efforts by numerous entrepreneurs and inventors, the problem persisted for several years until the invention of the transformer by inventors Gaulard and Gibbs, the foundational technology for the alternating-current (AC) electrical distribution system. This new system is considered as fundamentally different from Edison's DC system as their conflicting benefits and weaknesses resulted in a "battle of the systems" (Hughes, 1983). Gaulard and Gibbs never set out to develop the new AC system as a whole: rather their transformer was developed as a singular component to address the reverse salient in the existing DC system. Because of this, other inventor-entrepreneurs adopted and adapted their ideas to make them interoperable with their own technology, leading to many conflicts about ownership and patents of the technology (Hughes, 1983). Gaulard and Gibbs were never able to truly capitalize on their invention for this reason and unable to exercise the control that Edison held in preceding years. Such reverse salients demonstrate how emergent change in different parts of the infrastructure may be difficult to reconcile, as different local contexts give rise to different sociotechnical configurations and infrastructural models. Furthermore, the grid had reached a certain level of complexity, where the amount of interconnected technologies and actors precluded any individual agents to shape the entire system according to their own ideas. The fact that Gaulard and Gibbs were unable to capitalize on their invention and control its implementation shows that the agency of individuals is limited when the complexity and scale of the infrastructure increases.

While the battle of the systems between DC and AC proceeded throughout the 1880's and 1890's, Edison and others again made use of political influence and power to promote their own system (Hughes, 1983). In one grisly effort, Edison and his associates influenced the New York State legislature to adopt a more "humane" execution of the death penalty than hanging: namely, electrocution by AC electricity. In doing so, AC could be framed as a deadly, killer-current to the masses (Hughes, 1983). In the end, the battle-of-the-systems did not result in a resounding victory for one party: rather, both systems synthesized, merged and coupled over the course of decades, on the technical, economic and institutional levels.

While the above narrative describes how individuals could influence early system development at a micro-level, large actors such as corporations and governments are better able to exercise control at a macro, system-level of the infrastructure. This is also shown historically by Timothy Mitchell, who describes how such powerful actors made use of the physical properties of oil to gain control of global networks of crude oil extraction, transportation and refinement at the expense of smaller governments and local labour workforce (Mitchell, 2011). He does this first of all by contrasting oil-based systems with the preceding coal-based infrastructure. The mining, transportation and processing of coal was a highly labour intensive task, as many people were needed for mining and for operating much of the specialised machinery and industrial equipment that was required in the process. This created numerous opportunities for the workforce to exercise political power. The formation of labour unions and other political organisations allowed workers to take collective action, since the functioning of certain critical systems and industries was highly dependent on the labour of these workers. In this way, the coal-based system emerged in parallel with early democracy and socialist movements in the late 19th century.

The fact that oil is a liquid rather than a solid energy carrier has various consequences which limit the political influence provided to those involved in its production (Mitchell, 2011). Unlike coal, oil does not have to be mined but flows to the surface naturally by underground pressure. This reduces the number of workers that is required, and the workers that remain are located above surface under strict supervision. Furthermore, oil is easy and convenient to transport through pipelines or in large container ships which do not require much human labour. While political power derived from human labour would lie in the hands of the local population, as in the case of coal, oil infrastructures were established and maintained through capital investments made by globally-operating, systemic actors (Mitchell, 2011). This provided these actors pervasive control over the entire system of oil production and supply, allowing them to exercise strong control to reduce the quantity of oil production to keep prices and profits high. Overall, as manual labour was replaced by technological infrastructure, political power in decision-making processes moved from production and processing sites to boardrooms and offices. Thus, it is clear that the nature of the energy carrier can have significant implications for political systems. In chapter 3, it will be discussed how renewable energy has consequences of a comparable magnitude, although instead of centralizing control as is the case with coal, renewable energy enables decentralization of control and political power.

As Mitchell describes, the control exercised by these powerful actors served not only to secure economic profits but also to spread the system of Western Democracy to many other countries (Mitchell, 2011). The infrastructures surrounding the production, transportation and refinement of crude oil have been used to spread institutions and systems of democracy to different countries while inhibiting actual bottom-up democratisation of populations. Understood in this way, the notion of democracy is constituted by certain procedures and political institutions that can be easily copied from one country to another (Mitchell, 2011). It is an abstract understanding of democracy that does not encompass cultures or ways of living of a country’s inhabitants: rather it serves to build international alliances and gain political influence. It is a top-down imposition of a "democratic" political system that subjects the population to that system. By spreading a political system of a particular form, the infrastructure also serves to spread an associated notion of free, democratic citizenship. This can be considered as one of the political goals or purposes of controlling oil infrastructures throughout the 20th century, according to Mitchell (Mitchell, 2011). For smart grids, the top-down imposition of certain political ideals may be a risk in particular when it comes to empowerment and decentralization, as will be discussed later.

Besides concrete consequences such as taking away labourers opportunity to strike, infrastructures may also serve to promote political visions and ideas by mere association through their poetic or aesthetic qualities (Larkin, 2013). From a range of anthropological research, Brian Larkin describes how the sheer ambiguity of defining an infrastructure can produce fantasies, desires and beliefs that bind a political public together for a common purpose. In this way infrastructures become symbolic, as they represent a particular way of life or an ideal type of society. Importantly, the infrastructure and the ideas connected to it may be used by authorities to mobilize populations to adopt those views (Larkin, 2013), promoting a certain model of ideal citizenship. As an example from the city of Mumbai, Anand describes how the interplay between the technical infrastructure of water supply systems and the social networks within slums produced a form of "hydraulic citizenship" (Anand, 2011, p. 545). In smart grids, the "prosumer" – i.e. producer and consumer of energy - has been proposed as an ideal citizen.

Such political visions were also associated with the European electricity grid in the 20th century. Bolton et al. describe how the integration and growth of the continental grid came about by a combination of pragmatic policy-making at the national level and grand visions about a united European grid (Bolton et al., 2020). Such grand visions were founded upon the economic and engineering ideals of maximizing efficiency by integrating national systems as well as high-level political ideals of European unity. After the First World War, electricity became increasingly recognized as a key public utility and beneficial resource for society, leading to a politicization of the system and larger government involvement. Lagendijk further describes how the vision of the European grid is intricately connected with engineering logics of maximizing efficiency (Lagendijk, 2021). The European grid was commonly accepted as the most rational scale of system integration. At the same time, this interest in the European-scale grid contributed to a growing interest of national governments and international organisations such as the League of Nations in European matters

(Lagendijk, 2021). Thus, whether intentional or not, the electricity grid and the associated beliefs about its optimal functioning were closely connected to grand political ideas about European integration.

So far, it has become clear that control over infrastructure and its development for certain actors may result in an increased power for those actors to pursue their own political goals and interests, either intentionally or not. Besides concrete political consequences that result from the nature of the technological infrastructure, such goals may involve political visions, views and ideas for the society and citizens connected by the infrastructure. From these findings, I argue that there is a considerable risk that different groups of people connected to the infrastructure can be affected in inequal and potentially unfair ways. This follows from the notion that infrastructures are very large, heterogeneous systems that extend far in time and space. The types of people and actors that are stakeholders in an infrastructural system is very large. On the one hand, these stakeholders can be separated by their role in the system: for example, in the grid system a distinction can be made between regulatory authorities, utility companies, energy service companies, electricity producers, electricity consumers and more. Furthermore, stakeholders can be divided by their geographical region as stakeholders in one part of the country may have different wishes, needs and desires than consumers in other parts of the country. Finally, electricity consumers today will not be the same as electricity consumers decades into the future. Regulations may change over time and corporategoals and structures may shift equally so. It is clear that there is a vast range of stakeholders in an infrastructural system with different desires, wishes and needs.

Any design or development decisions in the infrastructure are likely to affect multiple groups in different geographical regions or temporal timescales. Because of their heterogeneity, there is a risk than any broader political ideas or visions on which the infrastructure is based or that are promoted through the infrastructure are not desirable for all groups involved. Furthermore, when any single or small number of actors have disproportionate control over infrastructure development there is a risk that certain stakeholder groups are outside of their scope and neglected, either intentionally or unintentionally. For these reasons there is a risk that inequalities are created between different groups as socio-economic or political (dis)advantages are not equally distributed. I will consider this the third aspect that must be studied in political decision-making in infrastructures.

2.3. Conclusion

In this chapter, I have described the distinctive properties of infrastructures and discussed various empirical, historical insights that describe the political implications that infrastructures may have. Infrastructures are sociotechnical systems that extend far in time and space, connecting a large variety of stakeholders with very heterogeneous capacities, wishes and needs. When studying the political implications in later chapters, these considerations should be borne in mind and both the macro and micro scales should be considered.

For the historical findings, I first of all discussed how in the early stages of the development of the electrical grid, inventor-entrepreneurs such as Edison had a disproportionate amount of control over the course of its development, both through technological expertise and socio-political efficacy. As smart grid development is at a similarly early stage, the influence and actions of such individuals should also be considered. Secondly, I discussed how at a systemic level certain Western governments and large oil corporations had the power to control global oil networks to impose and spread a political system of Western democracy to various countries, thereby securing political influence and economic profits. Thus, the power of systemic actors in controlling and shaping entire systems is potentially problematic for smart grids and the nature of the energy carrier may have various consequences. Thirdly, I discussed how infrastructures may be associated with political ideas and visions, and may be used to spread a certain ideal of citizenship. From these findings and the observation that infrastructures are very large, heterogeneous systems, I concluded that there is a significant risk that different stakeholder groups may be affected by such political problems in an inequal and unfair fashion.

For future chapters, I will take all these considerations and describe how they apply in the context of smart grids. By doing so, these findings provide the basis of the conceptual framework that I will be building to conduct an analysis of the moral-political implications of smart grids.

3. The Paradigm of the Smart Grid

Having discussed the historical political aspects of the grid in the previous chapter, this chapter will describe the expectations surrounding its future evolution. I will do so by studying the proposed functions of smart grids, which contain implicit moral values and political goals. These different functions or goals are important building blocks of the conceptual framework for studying moral-political implications of smart grids. While the primary function of the grid is delivering cheap electricity reliably which remains unchanged, I aim to show that in various engineering and social science research, two new functions are being attributed to the grid: (1) reducing CO_2 emissions by facilitating renewable energy generation, and (2) empowering citizens by providing access to novel energy technologies or services. I argue that these two new functions, as well as the existing and historical function of reliable delivery of electricity, are central to the new paradigm of the smart grid. The literature suggests that all three functions require a transition towards more decentralized grid architectures which I consider a crucial development for the political implications. I will study this trend of decentralization in smart grids using the conceptual lens of the three political aspects of infrastructures that were formulated in the previous chapter: power and control over infrastructure components, the promotion of political ideas or visions and the equal or inequal treatment of various stakeholder groups.

The first section 2.1. will describe the changing functions of the electrical grid and what the smart grid concept typically entails in terms of concrete trends and innovations. I will discuss how scientists' focus on the different functions lead to different focus areas and innovations for smart grid architectures. Furthermore, I aim to show how all different functions involve a transition from centralized grid architectures to decentralized architectures. From the concrete developments described in 2.1., the second section 2.2. will describe the new paradigm in a holistic manner as a smart and segmented electrical grid. I will distinguish between three conceptual layers for convenient discussion: 1) the physical infrastructure, incorporating distribution and transmission lines, energy generators and storage systems; 2) the digital infrastructure, composed of energy data management systems, AI algorithms and other digital control systems; 3) the economic infrastructure, covering the procedural arrangements and techniques that govern the exchange of electricity and electricity services between different actors. Finally, in section 2.3 I will discuss the trend of decentralization as it has been discussed in the literature through the lens of the different political aspects of infrastructures as formulated in chapter 1. Decentralization is a crucial element of the conceptual framework for studying moral-political implications of smart grids.

3.1. Functions and Political Purposes of Smart Grids

3.1.1. The secure and reliable supply of affordable electricity

Until now, the sole and primary function of the electrical grid has been to deliver affordable electricity in a secure and reliable manner. This is reflected in the use of fossil fuels, which are relatively cheap, flexible and easy to use, as well as the current architecture of the electrical grid which is adapted to fossil fuels. It is characterized by top-down centralized control, one-way electricity flows and hierarchical network topologies. While this function of delivering affordable and reliable electricity remains unchanged, scientists have indicated that several changes to the grid's technological infrastructure are required to continue to fulfil this function. Technical control over the grid should be distributed over numerous independent control stations rather than a central control point, leading to a grid architecture where blackouts or other failures can easily be isolated, preventing the cascade of catastrophe throughout the entire system. (Amin & Wollenberg, 2005; Defeuilley, 2019; Mehigan et al., 2018). Therefore, a continued delivery of electricity requires a transition to decentralized grid architecture. In this context, this should be understood primarily as decentralization of technological systems rather than political power, which I will discuss more in later sections.

In order to fulfil this first function, some of the earliest and most influential publications on smart grids focus primarily on issues of resilience, security and reliability. This is because the purpose of efficient electricity delivery is primarily a technical problem to be solved using engineering methods and values. In their 2005 publication "Toward a Smart Grid", Amin and Wollenberg focus on the security, robustness and reliability of electrical grid infrastructure and describe how innovative information and communication technologies can help to face challenges in these dimensions (Amin & Wollenberg, 2005). It is emphasized that the electrical grid is a critical infrastructure that is highly interconnected with other systems and that deregulation of the sector has led to increased risks and vulnerabilities. In this situation, any failures within the infrastructure can cascade throughout the whole system quickly and cause severe damage. According to Amin and Wollenberg, this problem could be addressed by allowing "power grids and other infrastructures to locally self-regulate" through advances in computation and communication technologies (Amin & Wollenberg, 2005, p. 36). It is described how this would require all components of the grid, including power plants and substations, to be equipped with their own independent processor and coordination unit. Connecting these independent stations in plug-and-play fashion allows problematic sections of the grid to be isolated and technical failures to be solved locally. In this way, it is described how the grid as a whole can become self-monitoring and self-healing, leading to significant benefits in maintenance and resilience of the infrastructure.

The issues of resilience and system vulnerabilities – for the purpose of continued delivery of electricity - are also emphasized in other early smart grid studies. Bouffard and Kirschen describe how a key weakness of centralised energy supply systems is their vulnerability to failures in crucial locations of the supply chain (Bouffard & Kirschen, 2008). By dividing the system into smaller, modular components, such vulnerabilities can be greatly mitigated. It is not only by decentralisation that such risks are decreased: in the 2010 study "The Path of the Smart Grid", Farhangi describes how the smart grid should "provide the utility companies with full visibility and pervasive control over their assets and services" (Farhangi, 2010, p. 19). Thus, the use of ICT technologies would allow for total monitoring and control of all system components, allowing system failures to be quickly detected and addressed with intelligent systems. Besides increasing resilience and reducing system vulnerabilities, the smart grid would also be a much more efficient system, making maximum use of the available energy by reducing losses to a minimum (Fang et al., 2012). This would allow for a lower electricity price, making the smart grid more able to deliver cheap electricity than its analogue predecessor.

3.1.2. Facilitating the transition to a renewable energy system

Whereas the main focus in early smart grid publications was on resilience, security and efficiency, the issues of sustainability and CO_2 reduction have become more dominant as the global issue of climate change received widespread attention. In 2015, 196 countries signed the Paris agreement which aims to limit global warming to less than 2° Celsius in 2050 as compared to pre-industrial levels (UN, 2015). In order to attain this goal, the European Union aims to become the first climate-neutral continent by 2050, while reducing emissions by 40% by 2030 (European Council, 2014). These are ambitious goals that require a deep decarbonisation of all sectors of national economies, especially the energy sector. Countries around the world are planning to gradually phase out of a fossil fuel-based energy provision system in favour of a larger share of renewable energy sources (WEC, 2013). As sustainability and CO_2 emission reduction can be considered as political goals, I will consider this also as a political purpose of the smart grid.

In order to achieve these goals the electrical grid must facilitate the integration of renewable energy sources, which comes with particular challenges (Chu et al., 2016; Kabir et al., 2018). Solar and wind energy generation is intermittent and unpredictable and converted into electricity on-site in often remote and dispersed locations. In order to compensate for this, the grid must be equipped with electricity storage and other flexibility options, which is often expensive and relatively inefficient. For these reasons there are numerous adaptations required to the current fossil-fuel based grid architecture (Driesen & Katiraei, 2008; Farhangi, 2010; Rahimi & Ipakchi, 2016). Transporting inflexible green electricity to a place where it is needed at that very moment is a complex coordination task, as is the efficient storage of electricity. Smart monitoring, sensing and control systems provide new capacities for this coordination, allowing the inflexible renewable energy streams to be directed more efficiently. For example, smart control systems would be able to automate the charging and discharging of batteries to maintain power balance when there is an excess of electricity supply or demand respectively. Furthermore, as wind and solar generation is dependent on the weather, the use of advanced and accurate weather prediction systems will be increasingly important (Sweeney et al., 2020). Integrating such systems in grid infrastructure would make for more efficient planning and scheduling of electricity transmission and distribution.

Other challenges arise from the fact that renewable energy generation is located in the fringes of the distribution system as well as residential areas. Electricity now flows in two directions where it previously only ran one-way – for example in households that own solar panels. Decentralized control in the form of independent control and processor units could be more beneficial and efficient for locally managing the grid in such places (Farhangi, 2010). Also, because currently the only usable renewable energy carrier is electricity, it is expected that several key technologies will be electrified, especially electric vehicles. In line with this expectation, electricity demand is projected to rise significantly in the coming decades (WEC, 2013), straining the grid even further. Overall there are many studies from the past decade that emphasize how sustainability and reduction of emissions will and should be at the heart of future infrastructural development (Burke & Stephens, 2018; Goldthau, 2014; Karger & Hennings, 2009; Poudineh & Peng, 2017; Rosenbloom et al., 2018; Wentland, 2016). Integrating green energy should thus be regarded as a primary function, and political purpose, of the electrical grid, one that may become even more important in the coming years.

3.1.3. Citizen empowerment in a changing actor landscape

The developments described in sections 3.1.1 and 3.1.2 have been primarily technological in nature, yet their significance extends well into the social and societal domain. From the field of sociotechnical transition studies, it is known that technological developments in large system transitions both cause and are caused by social and societal dynamics in a process of co-evolution (Skjølsvold et al., 2015; Verbong & Geels, 2010). As a sociotechnical system, the grid connects a large and varied amount of actors with different interests, goals and capacities, and a paradigmatic shift in its architecture would be just as significant in the social domain as it is in the technological domain (Goldthau, 2014). Therefore, in parallel with the developments described above it is expected that the actor landscape of the electricity system will change substantially, with changing roles for existing actors such as utility companies (Fox-Penner, 2020) and the rise of new types of actors such as prosumers and autonomous energy communities (Eurelectric, 2015; Lavrijssen & Parra, 2017; Van Der Schoor & Scholtens, 2015). These developments are likely to be accompanied by shifts in the relative political power of these different actors which have been studied commonly in social and political science research (Healy & Barry, 2017; Milchram et al., 2018). Such political power shifts can potentially be created – or inhibited – by the technological innovations that fall under the smart grid paradigm, and are closely connected with the trend of decentralization. For these reasons, I consider the empowerment of citizens to be the third primary function and political purpose of the smart grid development. For the present purpose I will refrain from discussing the concepts of power and empowerment in more detail, which I will do in chapter 3: rather I will use the term heuristically in line with its common occurrence in academic writings.

A fundamental difference between the renewable and fossil-based energy system is that individual citizens and collectives can now have access to their own source of energy, primarily through solar energy (Van Der Schoor & Scholtens, 2015). People can use their own solar-generated energy to power their homes, charge their cars and cater to other needs, making them less dependent on the grid and perhaps even completely self-sufficient. It may also be possible to sell excess solar energy to the grid, creating a new source of revenue for households. Methods like demand response, which is essentially a time-of-use pricing method that adapts the electricity price to the availability of green energy within the grid, are often described to create more active energy citizens (Siano, 2014). In fact, energy consumers are described to become prosumers as they both produce and consume energy (Lavrijssen & Parra, 2017). Numerous methods and economic schemes are being proposed to create opportunities for prosumers, so that both the citizens and the greater grid can benefit (Michaels & Parag, 2016). Technological innovations may provide completely new capacities: for example, households may be equipped with home energy management systems, a household battery system, rooftop solar panels and electric car charging (Pratt et al., 2016; Saad Al-Sumaiti et al., 2014). Overall, there appears to be a clear potential for the empowerment of individual citizens by such developments.

The largest potential of locally self-generated energy emerges when people group themselves into collectives or communities. By bundling their forces and cooperating, energy communities could share access to communal storage systems, exchange solar electricity and potentially manage their own local infrastructure (Lüth et al., 2018; Van Der Schoor & Scholtens, 2015). Such communities are much more likely to be self-sufficient than individuals, as investments in energy assets can be shared and energy generation and consumption patterns tends to average out over larger numbers of households, making for more stable and predictable grid management. The political power that can be wielded by such a community would be much larger than for individual citizens. There are many different forms in which such collectives can exist: they can either be fully self-organized, independent entities that operate as a single actor in the greater system, or loose collectives of individual actors that merely cooperate instrumentally to further their individual interests. In scientific research, many concepts and economic schemes are being proposed in the domain of local electricity markets that can govern and regulate the local trading of electricity between neighbours or community members (Lavrijssen & Parra, 2017; Morstyn et al., 2019).

As opportunities for participation in the system and responsibilities for local infrastructure management are extended to individuals and collectives, it is inevitable that these are relinquished elsewhere or that their integration is supported and permitted by incumbent actors. In fact, it is the utility companies that currently centrally administer the infrastructure and system, and who would inevitably play an important role in this process. New forms of cooperation and mutual agreement must be found between citizens and utility companies, which are likely to go along with negotiations of a political character.

In novel smart grids, the role of utility companies could be very different from what it is currently (Fox-Penner, 2020). The business model of utility companies currently rests on selling an ever-increasing amount of kWh to electricity consumers, which has been in line with the grid's historical function of supplying reliable and affordable electricity. With the new functions of reducing emissions and empowering stakeholders the utility companies must revise their business model (Fox-Penner, 2020). Fox-Penner distinguishes between two potential new business models: The Smart Integrator (SI), and the Energy Service Utility (ESU). In the SI business model, the utility company would provide a platform where numerous unregulated energy service companies or aggregators can provide a variety of products and services, facilitating a highly fragmented electricity market with thousands of small actors. In contrast the ESU utility company would itself be in a direct service relationship with individual actors. The company would have much more extensive control over the system which is likely to be heavily regulated. The SI model would be more fitting for a deregulated, free market system, which may be more efficient and provide maximum benefits to actors with high access to energy assets. This model could result in aggravated socio-economic inequalities between more and less affluent actors, however. On the other hand, the ESU model would be more fitting to implement egalitarian or otherwise desirable regulations and policies. Still, it might be very inefficient for the utility company to be in central control of coordinating a highly complex, decentralized grid system with thousands of small actors and assets. It is evident that the different potential utility company models may have implications for the political relations within the system and its actors.

Because of all the developments described above, with emerging communities and prosumers and new roles for utilities, many authors have argued that political power relations, interests and goals are of important relevance in the electricity system, as well as the greater energy transition (Avelino & Wittmayer, 2016; Brisbois, 2020). I will consider this as the third primary function and potential political goal of smart grids. The empowerment of citizens and communities is highly interconnected with a process of decentralization of political power, which I will discuss further in section 3.3.

3.2. Architecture of Smart Grid Infrastructure

Depending on the degree to which and manner in which the expected developments actually become reality, the electrical grid could undergo such fundamental transformations that it is appropriate to speak of a new infrastructural paradigm. Unlike the current fossil fuel-based structure, the smart grid is not characterized by a single, monolithic grid architecture:

rather it encompasses a wide variety of potentially functional grid architectures that can co-exist and co-evolve, and that can be independent as well as interdependent. In order to describe the potential infrastructural components that make up this new paradigm, I will distinguish between three conceptual layers of the smart grid:1) the physical infrastructure, incorporating distribution and transmission lines, energy generators and storage systems, 2) the economic infrastructure, including the procedures, regulations and techniques that govern the exchange of electricity and electricity services between different actors, as well as pricing mechanisms, and 3) the digital infrastructure, composed of energy data management systems, AI algorithms, software platforms and other digital control systems. In this section, I will describe what the smart grid looks like in these layers and how they are connected, and consider how relative prioritization of the three functions described above may lead to different grid architectures. Distinguishing between these layers serves to discuss implications of decentralization of the infrastructure in section 3.3.

3.2.1. Physical infrastructure

The physical infrastructure of the grid refers to all material, physical, technological components of the grid, including transmission and distribution lines, battery systems, transformation stations, as well as energy generators such as solar panels, wind turbines and power plants. The architecture of the physical infrastructure would accommodate a large variety of energy sources. Sustainability would be ensured by the prominence of wind turbines and solar panels in the system, as well as the use of carbon capture and storage for any gas-fired power plants that remain. Reliability and security of power supply can be ensured by incorporating a mix of uncontrollable renewable generation as well as flexible fossil-fuel plants and consistent nuclear power plants. The grid could incorporate a large variety of energy storage options, including batteries and conversion to hydrogen. It would include large numbers of electric vehicle charging stations in urban areas, with the potential use of Vehicle-to-Grid technology which allows the use of electric vehicle batteries as storage systems that can support grid power balance. Overall, the grid would incorporate a large amount of distributed energy resources, including renewable generators, storage systems, electric vehicle charging stations and more.

In the decentralized architecture that is expected, the architecture of the physical infrastructure could be very different in different geographical contexts. Depending on the geographical and social conditions of a neighbourhood, city or region, grid infrastructure and energy generation mix could be adapted and customized to fit such circumstances (Fox-

Penner, 2020), making use of decentralized, independent control stations as discussed before. In this way, the grid could be segmented in neighbourhood-size microgrids, organization-level nanogrids and grids that span cities or regions. By optimizing local energy management in this decentralized way, efficiency would be improved, local renewables would be integrated and local actors would be empowered. Such different scales of grid architectures would be nested and able to operate independently from each other, while also being able to interact when necessary or desirable. This concept of segmentation is a fundamental, paradigmatic change in grid architecture, which is most visible in the physical infrastructure.

3.2.2. Economic infrastructure

In the economic infrastructure, various types of market structures and trading agreements would able to cater to a wide variety of stakeholders with very different needs: bulk industrial consumers, individual prosumers, small commercial aggregators, autonomous communities, energy service companies and more. It would enable a wide variety of energy services to be provided according to the needs and wishes of stakeholders as well as the constraints and opportunities of local geographical contexts. Some citizens may wish to prioritize costs and reliability, opting for a service where cheap electricity is delivered at all times for the same price. Other citizens may prioritize sustainability, receiving green electricity with fluctuating costs according to availability. Engaged and pro-active households may use their own solar panels, battery systems and home energy management systems to take full control over their own energy use, maximizing efficiency and selling solar energy back to the grid at favourable times.

In some neighbourhoods, microgrid-based communities may form that engage in political organization, with a formal decision-making structure and adopting serious responsibilities in local grid management for full autonomy. In other places local electricity markets may form, where hundreds of households are loosely connected on marketplaces where auctioning and sales and purchases of electricity happen automatically (Fox-Penner, 2020; Morstyn et al., 2019). Such marketplaces may be run by energy service companies or utility companies, and numerous small businesses with new business models may emerge. Such businesses could offer communities grid management services, they could offer EV (dis)charging services to car owners and public charging stations and they could aggregate green energy generation in larger quantities to sell in the bulk market. In order to do so, tools such as dynamic pricing, demand response and even gamification methods may be used to engage citizens and persuade them to make their energy assets available for grid management (AlSkaif et al., 2018; Siano, 2014). The extent of such marketplaces or economic structures may correspond to the scope of the underlying physical infrastructure: i.e., a marketplace will be connected to a particular grid segment. In a segmented grid various types of markets could co-exist, and I suggest that the nature and structure of these markets are highly relevant for the political power of different actors. I will elaborate more on this in section 3.3.

3.2.3. Digital infrastructure

In order to enable all of the above developments, an extensive digital infrastructure would be required that could include a wide variety of innovative technologies. On the one hand, coordination of electricity flows requires sophisticated digital control systems which already exist and are in use. Such control systems are typically linked to underlying physical infrastructure segments and would be controlled by the same party, typically the utility company. Furthermore, the large increase in distributed energy resources means that coordination complexity increases very strongly, which may require systems of big data analytics, machine learning and artificial intelligence (Fox-Penner, 2020). Moreover, numerous types of electricity markets and exchange systems co-exist in different grid segments, such systems would have to be facilitated by digital platforms on which the different cooperating actors are connected. Such platforms can allow prosumers or other participants to participate in electricity markets, providing access to required data, information and communication channels. As a final disruptive digital technology, blockchain has been proposed to facilitate all of these different digital system, providing transparent and immutable records of all data that is used an collected, whether for coordination of electricity flows or for trading mechanisms.

Control over the digital infrastructure could rest with various actors, most likely utility companies or other systemic actors that are authorized to do so. It is also possible however that in local contexts, smaller entities like communities or organizations manage platforms that are tailored to their specific needs and geographical context. Control over digital infrastructure is a relevant issue to consider, as it may have various implications for privacy cyber-security and more (Döbelt et al., 2015; Milchram et al., 2018b). I will elaborate on this in the next section.

3.3. Decentralization and its Importance for Moral-Political Problems

As already indicated at several points, a trend that is of particular importance to smart grid infrastructure development is decentralization, a concept that is often mentioned as a key characteristic of novel smart grid infrastructure. In this section, I will discuss in more detail this concept of decentralization in the infrastructure and argue that it should be at the heart of a further study of the political problems of smart grid infrastructure. In order to do so, I will consider how decentralization relates to the three political aspects of infrastructures that were discussed in chapter 1. Firstly, decentralization of control over infrastructure components involves a transfer of power derived from that infrastructure to a wider variety and larger number of actors. Secondly, ideas and visions of political decentralization are promoted through the smart grid concept and involve a new notion of energy citizenship in the form of prosumers and energy communities. Thirdly, while decentralization can mitigate existing inequalities by moving opportunities from incumbent to new actors, it is also possible for new inequalities or injustices to emerge in a more deregulated system.

Before discussing the moral-political implications, I will first elaborate on the concept of decentralization itself. Fundamentally, I will define decentralization as the delegation of control – i.e. the ability and authority to make changes to the system – from a single actor or small number of actors to a larger number of actors. Such actors can be technological systems, institutions, organizations, corporations, communities, individuals, communities and more. In the context of infrastructures, those actors are likely to widely geographically dispersed. In the smart grid, a decentralized architecture is likely to be highly heterogeneous with a strong need for local customization and differentiation. The grid caters to a very wide range of present and future stakeholders with very different wishes, needs and desires, many of which are yet unknown. The range of potential energy services and applications is likely to be greatly expanded, making it difficult for any single concept or vision to fully capture all wishes and needs of all stakeholders under the smart grid paradigm. On top of this, the development of infrastructure is a process that takes decades, making the uncertainties relatively large. Decentralization is a process that happens occurs over an extended period of time during development, resulting in a decentralized state that persists after completion. It is likely that any present needs and wishes of stakeholders will change over time in ways that are difficult to foresee, and change in the system will likely be of an emergent and uncontrollable nature.

To discuss the moral-political problems, I will start with considering decentralization as a political vision or idea associated with the infrastructure. I will then consider how this vision or idea can be implemented and become manifest, and what types of issues could arise in the process. When decentralization is considered as a political goal or vision for smart grid infrastructure, it can be implemented in different ways. First of all, a particular decentralized infrastructural end-state may be envisioned and desired for any number of reasons, be it sustainability, infrastructural resilience or empowerment of local actors. The process towards this decentralized end-state can potentially be steered from the top-down by central controlling actors. Opposed to this end-state view, the focus may be on the decentralization of the development process itself. Local actors are encouraged to take control and contribute to the development of local infrastructure without having any top-down goals imposed by controlling actors. I will discuss the potential consequences for both options, keeping in mind the different functions that the smart grid may have and different ways in which decentralization may happen in various parts of the infrastructure.

When expectations of decentralized infrastructure are formed this often involves an envisioned end-state of the smart grid. By envisioning such end-states, powerful actors may retain control over infrastructural development in their hands in order to steer the development of the infrastructure in this direction. For example, because of the increasing importance of CO_2 emission targets governments may prioritize the goal of integrating renewable energy. Because the targets for CO_2 emissions are implemented on a national or European level, a prioritization of this goal would require some type of policy at these levels that ensure that the grid is adequately equipped to reach this goal. This is even more true because CO_2 reduction targets extend well into the future for a number of decades, overlapping with the expected infrastructural development time. Ensuring that such targets are met would require extensive planning, years ahead into the future. If too much control over infrastructural development is delegated to local actors it is possible that the system fails to meet CO_2 reduction targets because the local actors are not held accountable. Therefore, sustainability targets would likely require some form of centralized decision-making and control at least in the domain of policy-making, even though the integration of renewable energy requires some degree of decentralization.

Similar things can be said for the case where utility companies aim to improve technical efficiency and resilience of the infrastructure to ensure consistent and affordable electricity delivery. While the goal itself may be considered political, the task is mostly technological and logistical so that decentralization of technical control may occur without decentralization of political control and power. It has been noted that some degree of technical decentralization in the physical infrastructure is likely and desirable in the form of grid segmentation. Still, technical control can be delegated from a single central station to numerous substations while political control remains in the hands of a single, centralized actor who manages all substations and separate grid segments. It is possible that technical decentralization is accompanied with institutional decentralization of governance, but this is not necessary. While technical decentralization in the physical infrastructure may enable further innovations that are more tangible and implicatory for end-users, the technical decentralization by itself may be largely invisible for those end-users. This decentralization may be fully or completely steered from the top-down, with utilities and other controlling actors planning infrastructure for years or decades ahead.

When decentralization is implemented from the top down with policies and regulations being imposed by governments, it is also more possible to ensure that harmful inequalities or injustices between stakeholder groups are mitigated. When the development process itself is decentralized with no controlling actor, it is possible that a free-for-all ensues in which wealthy, powerful and self-interested actors take control and develop grid architecture according to their own wishes. In fact, it is possible that a new form of centralization takes place as powerful corporate actors may obtain a monopoly position, the difference with government monopoly being that corporations may be less likely to ensure that less advantaged groups are catered to and that injustices are mitigated.

While there are clear benefits to centralized control over development, it may be more difficult to ultimately realize decentralization of political power in this case even if this is one of the initial goals. For example, a government may implement policies that incentivize a certain type of grid infrastructure that would empower citizens. It is possible that the wishes of all citizens are collected in a democratic and accurate way and synthesized into a comprehensive conception of citizen empowerment. If this is true, the outcome of a politically centralized development process may be a truly politically decentralized system. Still, it seems difficult to ensure that the conception of empowerment in such end-state visions is in full alignment with the real wishes and needs of all actors that are supposed to be empowered. This is because, as has been discussed, the new grid architecture is likely to be highly heterogeneous with a strong need for segmentation and local differentiation. Reaching such a level of local customization and differentiation with centralized control may be inefficient at best and impossible at worst. Besides the plausibility that a fully top-down development process leads to comprehensive and satisfactory empowerment of local actors, there is also a risk of power abuse. Controlling actors may take advantage of their position to put forward a narrative of empowerment and notion of citizenship that ultimately serves their own goals and purposes.

On the other hand, it is possible for decentralization in the physical grid infrastructure to be accompanied with parallel decentralization in institutional ownership and control, i.e. political decentralization. In such a case, the process itself would be decentralized as well as the end result. From the initial phases of development, control over infrastructural development would be delegated to more local actors. An example of what this could look like is described in a study of a shifting actor network in decentralized energy infrastructure (Goldthau, 2014). Overall, the article argues that infrastructure governance needs to be polycentric to allow experimentation and innovation to happen in local contexts, which can then be adapted to fit other parts of the system. In a system of polycentric governance, different actors and organizations residing at different scales (i.e. national, regional, local) or segments of the grid are provided political decision-making power. This would lead to more innovation, experimentation and learning at the local level. Overall, the polycentric governance view appears to fit well with the paradigm of the smart grid as a segmented infrastructure. It can be imagined how, for example, microgrid-based communities may govern their own grid segment, allowing for the community to innovate their own preferred form of grid architecture that suits their local context and particular needs and preferences. Thus, when institutional control is delegated to such a local actor, new grid architectures may emerge that are wholly unique and different from the rest of the grid.

When considering how decentralization will happen, an important aspect to consider is the economic infrastructure. How participants on independent grid segments cooperate, and how separate grid segments interact with each other would be very much dependent on the nature of the economic infrastructure. For example, it is possible for a microgrid community to share electricity for free among its members, optimizing for technical efficiency. This would allow the community to act as an economically autonomous entity in the greater grid, creating the appearance of political decentralization and empowerment. This is not necessarily true however, as there are many ways in which such communities may be dependent on utility companies or other institutional actors to provide them with certain services. For example, it is possible that the community is dependent on the greater grid for the sale or purchase in the circumstance that there is an excess or deficit of energy within the community. Even if this is not required, there may be monetary benefits or efficiency gains in cooperating with the greater grid. Furthermore, the community may rely on the utility company or energy service company to provide physical grid maintenance services or grid control software. The degree to which such a community can be completely autonomous is dependent on whether the community has the ability to do such things for themselves.

This is even more true for individual prosumers or local free-market electricity trading schemes, which are often described as key components in grid decentralization. Prosumers are often described as being empowered relative to consumers because they can produce as well as consume energy. Individual prosumers however are likely to remain dependent to a great degree on utility companies or energy service companies, for example through demand response programmes. While they may sell some energy to the grid at certain times, they are unlikely to be fully self-sufficient and even more unlikely to be able to maintain the necessary hardware and software. Furthermore, in such schemes where the main focus is on economic profits and individual actors maximizing their interests, it is likely that the wealthiest actors will benefit the most. Those with the most renewable energy generation and the most flexibility options (e.g. batteries) will have a distinct advantage over those who do not, making the potential for actor empowerment and real political decentralization across the board questionable. While it may be possible to devise schemes that provide more benefits to less wealthy participants, such schemes may be dependent on a central regulating authority.

Finally, decentralization in the digital infrastructure may be the most difficult to achieve yet still important for true decentralization of political control. As has been discussed, the digital infrastructure would comprise large amounts of energy management and grid control data gathered throughout the system. Furthermore, large and complex data management systems are required for this data and sophisticated control algorithms are needed to coordinate electricity flows. It stands to reason that such software systems are likely to be controlled by the same actor who controls the physical infrastructure as both are highly intertwined. Due to the complexity of this back-end grid management software, control over such systems is not easily delegated or decentralized to new actors. As grid management becomes more dependent on insights gathered from big data and potentially artificial intelligence, these technologies provide further benefits of scale to large actors with an extensive reach who have access to large amounts of data.

Besides control systems for physical infrastructure, new types of software platforms may emerge as part of the economic infrastructure. For example, an autonomous community may have their own energy management platform where all members can interface with the community and the system. Local electricity markets may run on digital marketplaces where participants can see and participate in real-time energy auctioning and transactions. If such control systems or trading platforms are managed by a central actor, this may place much power in the hands of this actor who can control the flow of information on this platform as well as control access to the platform for anyone who wishes to participate. A potential solution for the decentralization of digital systems has been proposed in blockchain technology, which allows all participants or stakeholders in a platform to access all data, and makes it unable for any singular actor to make changes without consulting the rest of the network. Still, blockchain technology is at an early stage of development and it is unknown how real implementation would function and how power relations would be impacted.

These descriptions should illustrate the difficulty of conceiving of an end-state vision of smart grid development that is fully politically decentralized. The smart grid concept incorporates a vast range of potential and proposed technologies and innovations, the ultimate form of which is difficult to foresee and implausible to fully steer.

3.4. Conclusion

In this chapter I have discussed the paradigm of the new and emerging smart electrical grid. By distinguishing between the functions of reliable and affordable electricity, sustainability supply and actor empowerment I have intended to show that the grid can be used for multiple purposes by those who control its design and development. Depending on the political goals and intentions of such actors, grid design may favour any or multiple of these goal. The function of actor empowerment is especially interesting and relevant, as this function by itself should bring about a change in political power relations, making it of special interest for discussion in the next chapter.

Next, I have discussed in more detail the smart grid infrastructure and described some of the numerous innovations and technologies that are being proposed as part of the new paradigm. I have grouped these innovations in the physical, economic and digital infrastructure layers to indicate the main parts of smart grid infrastructure. I have described the trend of decentralization and how it is expected to potentially manifest in the different infrastructural layers. In general, the amount of innovations in these domains is much larger than can be discussed here, and the future evolution of all these technologies is all but certain. Therefore, I have argued that an attempt to steer innovation in the different infrastructural domains is problematic, in particular for the purpose of actor empowerment and political decentralization. This is especially the case for infrastructural development because the time-span and technological scope is much larger than for other technologies.

The different functions and goals of the grid, the different layers and the concept of decentralization form the basis of the normative framework that I will present in chapter 4. The desirability of the different goals will be discussed using normative frameworks, and it will be considered in more detail in what ways decentralization is desirable or not.

4. A Normative Framework for Just and Democratic Smart Grid Infrastructures

So far, I have described that the smart grid is an infrastructure that extends far in time and space where potential issues in collective decision-making pertain to control over infrastructural components and development, the promotion of certain political ideas and visions associated with the infrastructure, and the relative advantages provided to different stakeholder groups. I have argued that the trend of decentralization should be central to a discussion and normative framework of moral-political problems, since it is itself a political ideal that involves a delegation of infrastructural control which may lead to shifting political relations in the system and relative empowerment of various stakeholders. The three main political goals of this decentralization in smart grids are delivery of electricity, CO_2 emission reduction and empowerment of local stakeholders.

In this chapter, I will further define and conceptualize these issues in terms of power, justice and democracy, and evaluate to what extent the Energy Justice and Energy Democracy literature offers an adequate normative framework for identifying and addressing these issues in decentralized smart grids. I will start by arguing that Energy Justice develops an appropriate top-down systemic perspective that can be used by governments and other controlling, institutional actors to ensure that all stakeholders within the smart grid system are treated equally with respect to delivery of electricity services, legal procedures and other aspects. I will expand the framework and argue that Energy Democracy provides an appropriate framework to judge and assess the value of decentralizing infrastructural control by delegating governmental capacities and infrastructural management to local actors such as prosumers. Still, Energy Democracy does not provide any guidance for how such local bottom-up actors should conduct their moral decision making. For this purpose, I will complete the normative framework with ideas from American pragmatism on micro-level political decision-making, distribution of power and democratic experimentalism. Pragmatism is used to provide normative guidance at the bottom-up level where citizens cooperate and experiment within their local communities and contexts.

I will use the resulting framework to study an empirical case of a Community-Based Virtual Power Plant (cVPP) project in Loenen, The Netherlands. In this project, scientists, citizens, utility companies, and other parties cooperate to develop a new innovative community-based energy management platform. By doing so, I will contextualize the study within the current early stage of smart grid development that is characterized by local experimentation rather than system-wide implementation. For this reason, the aspect of the normative framework based on American Pragmatism will provide the main conceptual lens to conduct this empirical study. In this view, democracy is not considered from a governmental and institutional perspective: rather, democracy is considered as a way of life that is characterized by pro-active citizen participation at the local level, where people cooperate and communicate to solve practical problems that they collectively encounter in the world. By conducting this empirical case study, the aim is to test the extent to which the proposed normative framework can assist us in identifying and addressing the moral-political issues and conundrums that individuals encounter when working on smart grid innovations within democratic communities at the local level. Thus, the empirical study can reveal gaps in the proposed framework and new directions for future research and framework improvement.

4.1. Power, Justice and Democracy

In this section I will consider to what extent the issues raised and described so far can be studied and further conceptualized using literature from Energy Justice, Energy Democracy and pragmatism. By doing so, the goal is to build a normative framework able to identify and address moral-political issues that might arise in the development of smart grids. This is done by reconceptualizing the potential issues in smart grids in moral-political terms, paying attention to aspects where the current literature is not fully adequate. Starting with Energy Justice literature, I will first consider a top-down systemic perspective and then zoom in to the micro, bottom-up level with Energy Democracy and pragmatism.

4.1.1. Energy Justice and Energy Democracy

Energy Justice is a research direction that recently emerged as a means to cross boundaries between theoretical, philosophical and ethical considerations of justice on the one hand, and practical application to energy systems and policy on the other hand. Energy Justice can be considered as a tool to be used for various purposes, including 1) providing links between the concerns of individuals and those of larger publics, 2) distinguishing between preferable and non-preferable outcomes with regard to justice in decision-making, and 3) understanding how certain values are implemented in practical and technological energy system solutions (Sovacool & Dworkin, 2015). In these different ways, the Energy Justice framework can be useful to both identify justice-related problems in smart grid development and provide normative guidance for decision-making.

I will now discuss the central tenets of Energy Justice and consider how they connect to the issues identified in this thesis. Justice is a multifaceted concept, and Sovacool & Dworkin distinguish between eight principles in Energy Justice that should be considered (Sovacool & Dworkin, 2015). The first two of these are availability and affordability of energy, which are also a central political goal of the smart grid infrastructure. These aspects are the most basic elements and primary purposes of the infrastructure for people's daily lives, and I will consider them sufficient to describe the goal of delivering electricity. The two next principles - due process and good governance - are more explicitly political. Firstly, due process means that any stakeholders should be able to participate in political decision-making processes proportional to how much they are affected by the decision. Secondly, good governance means that all stakeholders should have access to sufficiently trustworthy and transparent information to minimize corruption. These principles, especially due process, can be considered as contributing to the goal of empowering stakeholders since they are attributed further opportunities for participation as well as information that may open new courses of action for those stakeholders. The next two principles cover the goal of CO_2 emission reduction: Sustainability and responsibility. Sustainability refers to a reduced reliance on fossil fuels and increased use of renewables, and the principle of responsibility holds that governments and institutions have a responsibility to minimize externalities and environmental damage. Finally, the principles of inter- and intragenerational equity hold that all stakeholder groups distributed through time and space have equal rights with respect to the distribution of beneficial and harmful consequences of the infrastructure. These two principles can be used to cover any concerns that might be raised regarding problematic inequalities that arise as a result of decentralization.

While these principles of justice cover the various political goals of smart grids, they only do so from a top-down perspective. When using these principles of justice as guidance to develop a smart grid system or to normatively judge existing systems or proposed designs, an institutional viewpoint is assumed where there are, for example, the capacities to increase equity among widely different stakeholder groups, to ensure that a fair legal process is extended to all stakeholder groups, and to ensure good governance by creating transparency and minimizing corruption. Operationalizing these principles requires a central agent that is actually in control of the legal process and bodies of governance, and that holds independent authority from all other stakeholder groups in order to be able to treat them equally. While this perspective is certainly useful and very necessary, I argue these principles of justice cannot be used to study and normatively guide decentralization or the full empowerment of local stakeholders.

Next, I will consider to what extent Energy Democracy can complement Energy Justice, and be used to study and provide normative guidance for decentralization and empowerment of local stakeholders. Energy Democracy is a concept and research field that is used both to describe existing examples of democratization in energy systems as well as the normative goal of a more democratic energy system in the transition towards renewable energy (Szulecki, 2018). In this way, Energy Democracy is an explicitly descriptive as well as normative tool that focuses on the role of prosumers, local collectives, and municipalities in the energy transition. Energy Democracy is not concerned with constitutional, representative, parliamentary democracy: rather it advocates more decision-making and control at the micro level, shifting responsibility and accountability from systemic to local actors. In this way, Energy Democracy appears to be closely connected to the ideas of local citizen empowerment and decentralization.

Energy Democracy is conceptualized as a political vision or imaginary that is very strongly connected with the notion of prosumer as the ideal citizen (Szulecki, 2018). In this way, Energy Democracy is very closely connected to renewable energy systems, smart grids and other technological innovations. Ideally, the prosumer is a citizen that is highly pro-active, conscious and involved in the functioning of the energy system, gaining political power through ownership of the means of production – i.e., renewable energy generation. Still, it is suggested that prosumers are new types of political agents in a rapidly changing environment, meaning that new types of governmental techniques may emerge. The prosumer citizen and the ideal mode of political engagement is elaborated upon along three dimensions: 1) Popular sovereignty, 2) participatory governance and 3) civic ownership (Szulecki, 2018). For the current purposes, I will discuss the latter two dimensions and consider their relation to smart grid systems.

Participatory governance refers to an increased participation by local actors in collective decision-making processes. An emphasis is placed on public deliberation, decision-making for practical purposes and citizen participation more generally. In this way, an argument in favor of public participation is made with an appeal to the democratic legitimacy of decision-making. The question is whether participatory decision-making would lead to qualitatively better decisions for technical infrastructure management than the current, more technocratic system. Under this current sociotechnical system of the grid, societal and social involvement is meant to be limited. As such, lay people would be considered uninformed and ignorant about the technical issues and how they are to be solved. Therefore, access to information, energy education and increasing awareness among citizens are seen as key components of participatory governance (Szulecki, 2018). In this way, it can be recognized that while responsibilities are delegated to local stakeholders, it is implied that there is also a responsibility for governments, utilities and other systemic actors to provide this information, education and awareness. I argue that this responsibility should be more explicitly considered when studying the desirability of decentralization in smart grids, and that it should be part of the normative framework. When responsibilities for participation are extended to local stakeholders without the necessary awareness, education, or information, it is possible that the stakeholders will be overburdened and misguided as well as unmotivated. Thus, reducing epistemic asymmetry should be part of a compelling normative framework. Furthermore, the framework should be able to deal with motivational problems where local stakeholders fail to initiate necessary steps and take necessary actions for local governance. I will expand on these problems later on.

Besides participatory governance, greater democratization is also associated with increased civic ownership over means of energy generation and distribution (Szulecki, 2018; Van Veelen, 2018). Such democratization is not just considered as a means to enhance the integration of renewable energy and provide local social benefits, but also as a way to fundamentally restructure societal, political and economic relations in the energy system. Such restructuring is not guaranteed to be beneficial or successful, however: Whether or not such civic ownership is more democratic actually depends on the type of governance that is in place locally for the control of energy infrastructure (Van Veelen, 2018). First of all, when acting as a single entity the community must be guided or motivated by some kind of shared interest among its members. This means that any dissent or contrasting opinions may be marginalized or ignored, as homogeneity and consensus is preferred. Secondly, communities may become sites of internal power struggles just as much as larger political structures. Therefore, I argue that, besides increasing awareness and education about substantive matters of smart grid development and management, local actors should also be competent in matters of local governance, deliberation and collective decision-making. Resources should be extended to these local actors to aid them with these processes. This should be part of a normative framework on moral-political problems in smart grids.

If local stakeholder groups are not adequately equipped to successfully organize politically, they may be beset by various problems. For example, while communities or other groups may strive to attain greater inclusion and diversity, this is not always easy or possible to attain. The majority of decisions is typically made by a small number of knowledgeable people (Van Veelen, 2018). Furthermore, even when there is the intention to hold this small number of decision-makers accountable to the rest of the community, there may be barriers as deadlines and increasing organizational complexity can lead to quick decision-making without consulting the rest of the organization (Van Veelen, 2018). In these ways, it is clear that localized and decentralized control should not simply be conflated with democratization. While accountability, consensus-building and a plurality of views are often at the heart of a community's goals and ideals, power struggles, exclusion and conflict are also found to be part of the reality, making the community a site of political processes. The desirability of democratization, decentralization and empowerment of local stakeholders is thus, as I argue, dependent on the quality of these collective decision-making processes at the micro-level. In the next section, I will explore what moral-political problems might arise in such processes, and how they might be studied and conceptualized in smart grid systems.

4.1.2. American pragmatism: decision-making, democratic experimentalism, and power

Pragmatist political philosophy centers very much around democracy, which is not understood in terms of institutions, states and governments, but as constituted by the everyday practices of all citizens that make up the democratic society (Talisse & Aikin, 2008). For pragmatists, ideal democratic citizens are pro-active, rational and intelligent agents that participate in collective processes of deliberation, decision-making and experimentation (Wolfe, 2012). This collective process is one of practical problem-solving, the core task of a democracy according to pragmatist thinking (Talisse & Aikin, 2008). Democracy is considered superior to other systems of government, not because of its inherent characteristics but simply because it is most effective and efficient at solving practical problems. In this way, Pragmatist political philosophy is not concerned with formulating answers to grand societal challenges such as climate change or social inequality, but with the collective process and method by which such solutions are formed (Talisse & Aikin, 2008). Therefore, I will consider the political ideals of decentralization, the prosumer as an ideal citizen and citizen participation in local energy systems through the lens of pragmatism to consider the preconditions for citizenship within smart grid systems, and consider where potential moral-political problems could arise. In doing so, I will not focus on substantive issues such as justice, but rather on process-related problems such as might arise when there is a problematic asymmetry of power distribution between actors.

As pragmatist democracy is strongly concerned with method and process, I will describe some of the typical steps that are part of this democratic method. This is not considered as a rigid framework but rather as loose guidelines. The first step in the problem-solving process is the observation of practical, real-world problems. As part of a collective process, different members of a democratic community must deliberate and come to an agreement about what the observed problem is. Once a shared awareness about a problem and the need for addressing it has become established among a group a people, a democratic "public" is formed (Shook, 2010). In facing their common challenge, pragmatism holds that the public may be assisted by experts, scientists or others who are either internal or external to the public.

As a central contribution to the normative framework, I argue that in smart grids stakeholders at different levels form democratic publics as they come together to address the common challenge of infrastructure development. Because the infrastructure is so pervasive and connects many people together, a fair and democratic process would require that all stakeholders collaborate and work together. In smart grid systems, different democratic publics could exist on different levels depending on the systems that are being developed and the challenges that are being addressed. On the one hand, the goal of CO_2 emission reduction is typically pursued at national levels creating a democratic public throughout a nation. On the other hand, people may come together in local communities to develop collective energy systems that are customized and tailored to their local needs, creating a local democratic community. Furthermore, any democratic public aiming to develop smart grid systems will require significant expertise because of the technological complexity. While the ideal prosumer citizen may be informed about their own energy assets and local management, such as their own solar panels and home energy management system, the coordination of complex transmission and distribution systems as well as the associated IT architecture would require specialist knowledge. Overall, I argue that pragmatist democratic principles thus hold not only in local experimental contexts but also in larger publics. These different publics must then communicate and cooperate to form an even more comprehensive public with an overarching goal.

As a second step in the "democratic method", the members of the public cooperate in identifying the particular problematic elements and engage in a process of experimentation to find a solution (Shook, 2010; Wolfe, 2012). When problematic conditions or causes are identified, the public may proceed to form hypotheses about how to solve the problem. Such hypotheses may then be tested and implemented within the social world, where the consequences of implementation are observed and interpreted. Social and political experimentation in this way is at the heart of any functioning democracy within pragmatist thinking. It is interesting to consider how such experimentation would play out in smart grid systems: it appears to be especially suited for local systems and democratic publics that are small, adaptable and agile. Experimentation at levels of country or region sized grids would be infeasible since time and resource investments would be too large to take large risks at failure. Furthermore, the stakes at such levels are much higher: any system that is too experimental might endanger the reliable delivery of electricity for entire regions or cities. Rather, experimentation at the community or neighborhood level appears to be more appropriate and desirable, especially as different experiments with different sociotechnical models of smart grid systems might be conducted in different locations. Prosumers in local communities can mobilize their entrepreneurial resources and collectively owned energy systems to innovate and explore novel sociotechnical configurations and solutions. In this way, the different solutions may be compared so that the best models for the overarching systems may be found.

In order to expand somewhat on the central role of experimentation in pragmatist democracy, I will provide a brief discussion of Democratic Experimentalism (Sabel & Simon, 2017). Democratic Experimentalism is a set of ideas within political theory inspired by pragmatism and holds that the formation of practical solutions requires a constant questioning and reconsideration in a social setting. This core philosophy is a response to the problem of uncertainty, i.e. the inability to predict how the world will develop in the future, which is particularly relevant in the case of infrastructural development and smart grids where uncertainties are still very high. By adopting several pragmatist principles Democratic Experimentalism advocates for governmental structures that are loosely organized and not overly rigid and bureaucratic (Sabel & Simon, 2017). Such loose governmental structures are characterized by several features: for example, its members are encouraged to act in the spirit of the rules rather than the letter, and members at the bottom of hierarchies are considered to have a particular knowledge and expertise that is unavailable to those at the top. Overall, the proposed governmental architecture is composed of a central party, i.e. a type of governing entity, and connected local units. While the central party forms rules or norms in very general terms, the local units are free and autonomous to adopt and interpret such norms in the way that they see fit. In return, local units will report on their experience and share insights with the broader community to facilitate the broader process of consensus forming, deliberation and problem solving.

I argue that such an architecture could be well suited to smart grid systems in some cases, and thus should be considered within the normative framework. Since smart grid infrastructure will potentially be segmented in numerous smaller grids that all have their own particular energy generation systems, market structures, actor configurations and cooperation agreements, following a specified, rigid set of rules and protocols across the entire system seems impractical. Still, for the smaller grid segments to be able to interact there must still be a common protocol or technological standardization to which all segments can connect, otherwise there would be no interaction possible.

Besides democratic practice, I will consider how the concept of power is understood in pragmatism and how it can be used to define moral-political problems within the normative framework. In doing so, I will consider how the concept of "empowerment" for local actors should be understood in smart grid systems and how problems can arise when power is not equally distributed in the system. I will focus on the account of John Allen, who provides an account of power within classic and contemporary pragmatist thought (Allen, 2008). He describes that, in Dewey's and James' thought, power is the capacity to intervene in events and make a difference. Conceived in this sense, power can be regarded as a practical tool that, just like other tools, can be used by humans to intervene in world events. Just like tools, power is a means to an end, meaning that there is always a goal or purpose associated with the use of power. Such a goal can be considered to be political, for better or worse. Thus, even though power is not inherently wielded over others, it can still be used to impose constraints on others depending on the goal. Power is thus exercised when an agent desires to attain certain practical purposes, meaning that this power is constantly changing and fluctuating according to the changing goals of this agent. It is by no means true that 'power to act' precludes any actions that discredit, constrain or oppress others (Allen, 2008). This can be either intentional or unintentional, but what counts is the recipients' experience of any impositions on the part of others.

When power is defined as "the capacity to intervene in events", I argue that political power in smart grid systems is primarily derived from 1) control over infrastructural components and their development, 2) control over the political ideals, visions and narratives that are put forward in conjunction with smart grid infrastructure and 3) knowledge and expertise about the functioning and development of smart grid systems. For 1), when actors have the control over the physical, economic, or digital infrastructure they have the capacity to determine the design, the degree to which other actors' wishes are incorporated and the administrative and legal status of the infrastructure. They also have the capacity to influence how the infrastructure is managed and how its functions are executed after it is in place. In this way, controlling actors have the power to prioritize any of the different political goals with which infrastructures are associated, and the power to create or mitigate inequalities. When infrastructural control is distributed in the process of decentralization, power is also distributed in parallel. Still even when infrastructural control is decentralized, some degree of centralized power can still be retained by actors who control the political narrative in 2). This can be recognized in a scenario when a central, powerful actor pushes a particular ideal of decentralization and prosumer-citizenship. While control may be delegated and decentralized, the particular form of this decentralization can vary according to the political vision that is put forward, as discussed in chapter 3. Actors that are 'empowered' in the process may be tasked with extra responsibilities that can be experienced as burdens. Finally, as I have argued it is very important in a process of decentralization that stakeholders are provided with necessary information, education, and awareness. This information must be extended by knowledgeable actors that have access to the necessary expertise. These expert actors have control over the process of information provision and education, which grants them power in the process. After all, such experts can decide which information they provide and which information they withhold, and by doing so they can influence the course of events and infrastructural development.

4.2. Case Study: cVPP Loenen

Next, I will describe the empirical case study conducted, the goal of which is to apply and test the developed framework and analyze what problems arise that are not yet covered by the framework. The case study will contextualize the philosophical analysis of smart grids in the current system, which is at an early phase of development and characterized by experimentation. I will use the framework developed in preceding sections to study what issues are found empirically, and in the next section I will consider what changes are desirable to the framework and how the framework can be used to provide normative guidance for smart grid development.

4.2.1. European cVPP Consortium

As an empirical case I will consider the Community-Based Virtual Power Plant (cVPP) project in Loenen, a town of about 3000 residents in the municipality of Apeldoorn. This project is part of a larger European consortium that is composed of three different cVPP projects in Loenen, Gent (Belgium) and Templederry (Ireland) (van Summeren et al., 2020). TU Eindhoven acts as a lead partner within this consortium and cooperates with local partners in the different regions to develop a scientific model of the cVPP and its development (Wieczorek, n.d.). The project aims to use innovative technology to allow local communities to engage in their own local energy management with small scale energy generation and thereby to empower these communities and their individual members. In this way, the cVPP project is intended to contribute to the democratization of energy markets and create more awareness and public engagement in the energy transition (van Summeren et al., 2020). Funding is provided by Interreg North-West Europe, a European cooperation and funding program that aims to support economic prosperity, innovation and sustainability in different European regions. This is done by funding projects that create transnational collaborations and thus improve territorial cohesion with North-West Europe.

The cVPP concept emerged from a combined understanding of community energy and Virtual Power Plant (VPP) concepts and applications. Whereas VPP is an existing application that works by aggregating and coordinating a variety of energy resources on an ICT platform, cVPP is a novel concept of which this European research project aims to provide a definition based on the three local community efforts. Therefore this project can be considered to engage in experimentation at different levels: as communities and other local actors experiment to develop a cVPP that is in line with the local needs and context of the community, the research consortium as a whole experiments with a new concept and solution in the domain of smart grids that serves the goal of democratization. Ultimately, based on the findings from the three cases the cVPP was defined as follows:

> *A cVPP is a portfolio of DER aggregated and coordinated by an ICT based control architecture, adopted by a (place- and/or interest-based) network of people who collectively perform a certain role in the energy system. What makes it community based is not only the involvement of a community, but also the community-logic under which it operates (van Summeren et al., 2020, p. 4).*

Conceptualized in this way, there are three condition to which the local activities must conform as part of the cVPP project (van Summeren et al., 2020). There must be 1) decentralized, community-based generation and use of energy, 2) digital connection of this energy generation and use, and 3) aggregation of energy flow patterns into a single entity. Within these parameters, local communities have freedom in their community organization and system design. From these descriptions, it is evident there is a large emphasis on citizen empowerment in the top-down requirements for participation in the cVPP project. The project is intended to provide room for experimentation and local organization and aims to provide few restrictions for local communities to do so.

Reference	Date	Interviewee
CL1	22-06	Project leader municipality Apeldoorn
CL2	23-06	Board member energy cooperative Loenen
CL3	28-06	Initiator cVPP Loenen

4.2.2. cVPP Loenen

For the purposes of this research I will zoom in on the cVPP project that was conducted in Loenen, The Netherlands. Citizens in Loenen, a town of about 3000 inhabitants in the municipality of Apeldoorn, initiated local sustainability and energy projects in 2013. Loenen's community has been involved in the cVPP project since 2017 and has founded a local energy cooperative association that not only assumes ownership and management of the cVPP, but also of other community energy projects (van Summeren et al., 2020). The cVPP Loenen initiative includes not only residential participants but also industry, SMEs and public partners such as schools. I will make use of literature but have also conducted several semi-structured interviews with local stakeholders. To conduct the case study, semi-structured interviews were conducted with three participants closely involved with the cVPP project in Loenen. Each of these interviews took about 45-60 minutes. The three interviewees are listed in the table below. Unfortunately, covid-related restrictions precluded a visit of Loenen and conducting ethnographic research. Therefore, these interviews were conducted online.

Before the cVPP project in Loenen was started, the community was already quite active in the domain of local renewable energy management (CL3). The role of pioneers and was found to be important in this process, as people with the knowledge, drive, connections and community trust played a pivotal role in activating and motivating the community (CL2),.

The engaged citizens from Loenen were driven by a number of motivations (van Summeren et al., 2020): the desire to generate more renewable energy locally and to contribute to a better integration of DER an local management of the grid. Other important values include autonomy, self-sufficiency, the adoption of responsibility over energy transition challenges and an increased control over decision-making with regards to the siting and scale of local energy generation (CL3). Finally, another important motivation was the increased revenue and retainment of economic benefits for the local community. Overall, from the beginning the explicit goal of the cVPP Loenen was to engage in both technical and social innovation (CL3). This social innovation encompasses an empowerment of prosumers in the energy system of the future, where citizens finance, manage and take ownership of local renewable energy projects (CL3).

While the initiative in Loenen is clearly motivated from the bottom-up, this is not true in all cases. Unlike in Loenen, where it was not found to be necessary to organize any activities to motivate or activate the citizens, the municipality of Apeldoorn made considerable efforts to find other communities in the municipality who would be willing to take up the cVPP project (CL1). This was for example done through a so-called ‘energieregisseur’, a local citizen hired by the municipality to build a bridge between the government and the community. This was a complex and time-intensive process. In the end, citizens were motivated by organizing a competition in which different communities could enter with their particular CVPP design and win a prize (CL1).

Both in Loenen and in the other communities in Apeldoorn, workshops were organized to identify the needs and wishes of citizens for the cVPP design (CL1, CL3). In these workshops, participants were presented with dilemmas that represented contrasting values and choices for the design of the cVPP. All citizens were invited to partake in these workshops. During these workshops, groups of citizens engaged in discourse and conversation and ultimately made their decisions based on a collective consensus in each group (CL3). In these workshops expert knowledge and guidance would be offered and potential design options were narrowed down to fit three potential purposes or choices (CL1): financial cost reduction, sustainability and social cohesion. In Loenen, the highest priorities from these workshops were found to be self-sufficiency and autonomy (CL3). After this, sustainability was prioritized and after financial gains. It is reported that very good discussions arose in the workshops, as citizens with differing views exchanged their views in an attempt to come to agreement (CL3). With the expert guidance, citizens were able to make their choices in a very informed manner. There were examples of citizens being convinced to take positions and adopt designs that were opposite to their initial thoughts through the discussion (CL3). Still, it was also found to be difficult to inform everyone in the sessions because of the topic's complexity and a number of citizens were happy to follow the majority decision.

Besides partaking in the design of the system through workshops, citizens in Loenen are also encouraged and invited to engage in governance and decision-makingdecision-making processes through the energy cooperative (CL2). The energy cooperative is intended to take full ownership of the cVPP system after the project ends. The cooperative has a board that consists of 4 people as well as different working groups with volunteers who work on various projects (CL2). The total amount of members is 120. While the board is in charge of daily operations, all members can vote on important decisions where a majority-vote structure is adopted. Such voting procedures are especially used to determine whether and where new renewable energy generation units will be installed and how benefits from these units and energy management are distributed among the community. The members of the cooperative have final say in any decision-making, the board serves the members (CL2). At the same time, sometimes there are unpopular measures that may still be necessary or beneficial. It is reported that there is a tension here between an open and participatory governance structure and demands made by politicians to expand the project and take further actions (CL2).

As an outcome of the design process, the technical composition of the cVPP Loenen is a digital information interface that contains data about energy flow patterns throughout the community (van Summeren et al., 2020). Citizens can see how much energy the community is using and generating at different times throughout the day, as well as access their personal energy use patterns in their own household and privately owned assets. Based on this information, flexible loads such as charging of EV's and heat pumps can be activated at favorable times for balancing the demand and supply in the local grid. Such actions are made quite simple for individual citizens using innovative technology (CL2). For example, scheduling of EV charging to relieve the grid can be done simply with an *if-then-else* statement using a user interface that is installed with the smart meter (CL2). Overall, providing value to citizens by giving them insight into their energy usage is an important property for the cVPP design (CL2). This enables citizens to make more informed decisions in their personal energy management. While the cVPP itself only consists of the digital platform that gathers data from existing assets such as batteries, EVs and solar panels, the utility of the cVPP is greatly expanded with the amount and diversity of assets that are available.

The value of autonomy was found to be a particularly important aspect for the community members (CL2, CL3). This includes autonomy of the community with respect to the greater system, but also autonomy of individual citizens with respect to the community and the cVPP platform. Some people do not like that the system may automatically control their domestic devices and would like to retain free choice in their utilization of such devices (CL2). Still, the interviewees believe that resistance would be larger if energy companies were involved (CL2). Furthermore, a key benefit of community self-sufficiency is that all revenue remains within the community (CL3). From other cVPP communities within Apeldoorn it was found that different communities had very different priorities even within the same municipality, according to the local context (CL1). For example, a low-income community with inefficient electric boilers focused on financial gains and social cohesion, a solution that worked for every citizen. Another, higher-income community that was already cooperating on other fronts focused on sustainability.

From the results of the various cVPP projects, researchers from TU Eindhoven found that while the CVPP projects provide a challenge to the status quo in the current energy system, the local communities were also severely constrained and limited in the options by existing regulations and structures (Van Summeren et al., 2021). For example, P2P trading is prohibited in the Netherlands (CL1, CL3) and large scale, centralized energy generation units are favored for participation in energy markets under the current regime. This severely limits the ability of communities to trade and exchange electricity at the local scale. Therefore, the local cVPP projects were more or less forced to cooperate more with incumbent actors than they would have originally liked. The focus shifted from maximizing self-consumption and supporting community values towards supporting integration of DER in the greater grid (van Summeren et al., 2020). Thus, there is a clear tension that is found between community values and needs of the greater system.

Still the researchers also concluded that the use of ICT by the CVPP communities served to enhance their agency in the energy transition, for example by supporting integration of DER in the grid and by allowing communities to participate in energy markets (Van Summeren et al., 2021). The strategies adopted by the communities in their ICT usage are characterized as ‘fit and transform’ strategies, where ICT is used for the communities to fit in the incumbent system but also intended to transform it over the longer term. Furthermore, ICT is used to enable and reinforce collaboration between individuals at the local level by connecting and collectively coordinating energy resources. Besides enhancing agency, ICT was also found to give rise to new challenges such as the strong reliance in cyber infrastructure, increasing vulnerability against cyberattacks (Van Summeren et al., 2021). Another large issue was found to be interoperability between different system components (CL3). Overall, it is concluded that experimentation with ICT creates opportunities for energy communities to participate and co-design in the energy system.

For a future outlook and prospects for the cVPP in Loenen, the interviewees report that it is difficult to look very far ahead in the energy transition (CL1, CL2, CL3). There are several regulatory barriers and it is uncertain how this will change in years to come. It is not easy to design a local energy system while keeping in mind a 10-year period. Planning out all the individual steps and details is not practical, rather it is better to know the general preferred direction and be flexible and prepared to adapt (CL1). In Loenen, the current focus is on adding more renewable energy generation in the system as well as more flexibility options (CL2, CL3).

4.2.3. Insights from Loenen and Other Local Projects for the Normative Framework

In this section I will use insights gained through the case study to reconsider the normative framework for future smart grid development. To start off, I argue that the pragmatist ideas of experimentalism and democratic publics describes well the mode of cooperation and technology development within the cVPP project. This experimentation occurs at different levels, most notably the level of the European consortium and the level of the local communities. At the European consortium level, various researchers and community representatives are cooperating to develop new innovative solutions for local energy management, for which the main goals are to empower local communities and citizens, and to create awareness for (and thus accelerate) the sustainability transition. The cVPP is a new concept and the project aims to explore what this concept could entail by experimenting with solutions in different local contexts. Consortium partners experiment with the development of the cVPP platforms in different ways, where different types of designs are implemented and considered. Feedback is provided between the different places, and in a process of collective deliberation and conversation, knowledge is shared in order to improve the local systems. At the community level, experimentation is more concrete and tangible as community members and other parties collaborate to develop an energy management system that is fitting and suitable for their own local context. These activities are in line with pragmatic theory of experimentation and deliberation. In this way, different democratic publics form: one at the higher level of the consortium, and one at the level of the local community. Within certain constraints, these publics are free to develop their own method, approach and solution towards the problem that they are facing.

At the same time there are certain top-down requirements, guidelines and goals that must be met and followed by the consortium. The goal of the consortium is to contribute to the democratization of energy markets and to empower local actors by providing innovative solutions for their own energy management. Furthermore, through the funding by Interreg North-West Europe the project is indirectly supposed to create more economic activity and prosperity in the respective participating regions. When such goals are translated to concrete requirements at the local level, the local communities were required for example to reduce CO_2 emissions by a certain amount, produce a certain amount of solar energy, and involve a certain amount of citizens in the project (CL3). In this way, goals that are formulated and imposed from the top-down create constraints within local actors must operate. These goals are typically connected to one or more of the three functions or political purposes of smart grid infrastructures and may be necessary to address various justice-related concerns.

While interviewees in Loenen reported that these goals were easily met and not restrictive, this can certainly be a risk in other situations. In such cases, local communities may be inhibited in their wishes and desires because certain goals (e.g. sustainability goals) require a certain system design that is otherwise not preferable. According to the pragmatist view of power, which is the ability to act freely and steer events, citizens' power could thus be constrained. Still, the model of having fairly loose conditions that are not overly difficult to meet is desirable from the viewpoint of democratic experimentalism, where a central governing body provides guidelines that are loosely interpreted by smaller, semi-independent units. Furthermore, a key characteristic of the cVPP project is the exchange of knowledge and experiences between the different initiatives, which is also desirable in pragmatism and democratic experimentalism.

In Loenen and the other local communities in Apeldoorn, it was found that local pioneers and initiators played an important role in mobilizing community members to engage in collective energy management. Such individuals could either be intrinsically motivated, as in Loenen, or employed by the municipality such as the energieregisseurs in Apeldoorn. The different approaches bring along different implications. In the first case, it was observed that in Loenen the main pioneer and initiator of the project was involved in different ways. Not only was he a board-member of the energy association in Loenen, but he was also the owner of an energy consultancy company that partnered in the cVPP project. He is well known and respected by many of Loenen's community members and well connected with local politicians. When a single person has this much influence, this can also provide him more power within the democratic process of decision-making and consensus forming. This is because the person will have required expert knowledge about the infrastructure or access to contacts with this expertise, as well as political influence. This allows him to influence the course of events to a greater degree than others. In Loenen it appears from interviewee responses that this power was used for the right purpose with the best interests of the entire community at heart, however there may also be potential conflicts of interests that arise under such circumstances, especially when commercial interests are involved. The moral compass and actions of such influential people are therefore of significant political relevance. This is an important finding for the normative framework that fundamentally arises from asymmetries in motivation and expertise between actors.

With the energieregisseurs in Apeldoorn who were hired to mobilize communities, the individuals have authority not because they are inherently respected but because they represent the municipality. In these cases, the community initiative is not truly bottom-up as the government is the initiating actor. While the situation in Apeldoorn was not found to be problematic it could bring certain problems, as the municipal employee could have certain limited instructions or information that is provided to the community members. The municipality thereby derives power from their control over the provision of information and political vision that is put forward to motivate the inhabitants. In motivating a local community to participate in the project, it could be initiated in such a way that the governmental authority provides a certain initial direction or impulse, constraining the options for local community actors. While deliberation may be happening in a seemingly democratic way, the government actor could have more power and control in steering the direction of the project than participating citizens. The moral-political problem identified is similar to the case of Loenen and also arises from asymmetry in motivation and knowledge.

The provision of expert information and activation and motivation of participants remained important throughout the development process. For all the different projects within the CVPP consortium, including Loenen, workshops were organized in which the participating citizens were provided information, assistance and tools to help them with developing a system design of their choice and preference. The different priorities of sustainability, economic profits and social cohesion were pre-determined and provided by the experts and align well with the three political functions of smart grids. The workshops had a strong focus on deliberation and collective consensus and agreement, and it was reported that good discussions came about which made some citizens change their views or better understand their fellow participants. This is desirable in the pragmatist ideal of democracy, where a group of people cooperates to address a common problem that confronts them. At the same time, some people were reported to simply side with the majority because of the complexity of the information that was provided. The prompts and dilemmas that are provided to the citizens for making design choices and the expert guidance and information that is given appear to be very important, as this can strongly influence the choices that decisions make and how they understand the subject matter.

The energy cooperative of Loenen provides a way for all community members who are willing to decide on important decisions that are made regarding local energy management, which is desirable from the perspective of pragmatism and Energy Democracy. In particular, the aspects of participatory governance and civic ownership are covered under the cooperative structure. At the same time, it is reported that there is tension for the cooperative board between facing external pressure and conforming to the proper decision-making procedures. For example, Loenen is considered as an exemplar for local energy management within The Netherlands which led to pressure from local politicians to adopt more renewable energy generation, in particular solar farms. Solar farms were unpopular with the population of Loenen, creating a difficult conundrum for the cooperative board. In the end, it is reported that the board always conforms to the decision of the cooperative members. It can be imagined however that situations may arise, in cooperatives similar to Loenen, where external pressures and wishes are prioritized over community decisions. This is also reported by Van Veelen who emphasizes the importance of governance practices in energy communities (Van Veelen, 2018).

Other issues may arise from the fact that a cooperative, also the one in Loenen, typically has a small amount of members who are disproportionately active and influential. Such members are more knowledgeable and may be more opinionated than the average community member, and they do more work for the cooperative as volunteers in working groups. Because of their knowledge these community members may be disproportionately influential in shaping others' opinions and collective consensus forming. In this way, these members have more power and control within the community than others. This does not have to be problematic, but it can lead to internal power struggles or issues. In any case, it might be unfair to say that the community is wholly democratic in the sense that every member has an equal amount of power and control over decision-making, even if voting rights are equally distributed.

When considering the influence of the technology itself rather than the process of its development, the cVPP was reported to provide citizens more options and thus greater power and control in their energy management. By being able to adapt energy use and generation patterns to the local status of the grid, citizens are better able to pursue any personal goals they may have in saving energy, saving costs and unburdening the local grid. These benefits best constitute what is commonly meant with 'citizen empowerment' in the context of renewable energy systems. Still, this empowerment was primarily limited to the local level of the individual households and the community. In fact, it was not found or otherwise inferred that the local community and its members were empowered in their ability to influence the course of events in the greater system, or that they were particularly empowered in their position to negotiate with systemic and incumbent actors such as energy companies, governments or utility companies. In fact, it was found by the cVPP consortium researchers that these incumbent interests still preceded and constrained local interests.

4.3. Conclusion

In this chapter I have study in more detail the moral-political problems and consequences associated with smart grid development. This study has resulted in a normative framework of various components which can provide guidance for smart grid development at various levels. First of all, Energy Justice provides substantive principles by which it can be ensured that different stakeholder groups, which vary by time, space and role in the system, receive fair and equal access to electricity and proper governance processes, and that harmful environmental consequences are minimized equitably. These principles are particularly useful from a top-down perspective where institutions have the capacity to implement proper measures. Then, the framework is expanded with ideas from Energy Democracy where active bottom-up citizen participation and civic ownership is promoted. By viewing the prosumer as an ideal citizen, democratization and decentralization of smart grids can be better discussed and studied. To further study and conceptualize such micro-level, bottom-up decision making procedures I have made use of American pragmatism. Using pragmatism, I have argued that democratic, deliberative publics form at different levels in smart grid systems besides merely the local level. Furthermore, the heterogeneity of smart grid infrastructure can be studied using Democratic Experimentalism and pragmatism provides a useful lens to study asymmetries of power derived from control over infrastructure and political narratives as well as technical knowledge and expertise.

From the empirical case study on the cVPP, the problems of epistemic and motivational asymmetry become especially evident. The experimental projects under study were dependent on the initiative of either knowledgeable and self-motivated individuals or government-hired officials. Furthermore, significant expertise and assistance was required both within the Loenen cooperative and in the cVPP development process. I conclude that these problems require further study in future research. In the last chapter, I will connect these findings to the previous chapter and

5. Conclusion

The research question of this thesis was: '**What moral-political problems emerge in the development of smart grid infrastructure and what kind of normative framework can assist us in addressing them?'** In an attempt to answer this question, I have adopted a multidisciplinary approach.

In chapter 2 I have made use of STS literature to explore what political infrastructures have been studied historically, and what their relevant distinctive properties are. These findings are relevant for the development of smart grids today: in the same way that Edison and other inventor-entrepreneurs could exercise considerable influence over the grid, pioneering and knowledgeable individuals in experimental, pilot settings have a disproportionate influence over the deliberative, political process in smart grid development. Additionally, in the same way that Western governments and oil corporations could control whole systems of oil infrastructure to spread democracy, governments nowadays may take control over smart grid infrastructure to ensure that sustainability goals are met.

In chapter 3 I described a range of recent scientific research from various disciplines to indicate the range of innovations, functions and technologies that are covered under the smart grid concept, as well as the goals of electricity delivery, sustainability and citizen empowerment. Taking into account their expansive scale, I have argued that smart grid systems are highly heterogeneous as local systems must be customized to fit local social and geographical conditions. The concept and trend of decentralization, which involves delegation of infrastructural control, is central to smart grid infrastructure.

In chapter 4 I have provided a normative framework by which moral-political problems in smart grid systems can be better studied and addressed. I have done so by making use of principles and ideas from Energy Justice, Energy Democracy and Pragmatism, focusing on problems of justice, democratization and power imbalances. The framework provides tools to study issues at various levels, including top-down and bottom-up perspectives and consideration of heterogeneous grid systems in different parts of the infrastructure. From the case study of the cVPP in Loenen, the problems of epistemic and motivational asymmetry became especially apparent. In this concluding chapter, I will elaborate on the implications of these findings for greater infrastructural system of smart grids and provide recommendations for future research.

5.3. Implications for the Greater System

While the previous discussion in section 4.2.3. pertains to issues that arise in local contexts from the findings of the CVPP in Loenen, these findings have implications for the more comprehensive, nation-spanning infrastructure. It is possible that at some point a broad infrastructural development plan is required or desirable for smart grids at levels of national government. In such a development plan it would be necessary to consider the entirety of the system and the interaction between all the different parts, time horizons would be longer and uncertainties would be larger than for smaller projects. Potential issues would have to be considered from the top-down rather than the bottom-up, and be addressed through regulations. To discuss these systemic implications I will focus on the different goals that may be prioritized: electricity delivery, sustainability and citizen empowerment.

While there are three distinct functions of the smart grid, it is likely that any practical implementation of smart grid systems will aim at a balance of all three functions. In this balancing of the three functions, I first of all argue that there is a potential tension between the goal of empowering citizens on the one hand, and the reduction of CO_2 emissions and cheap and reliable supply of electricity on the other hand. These latter topics are typically considered at the level of national government, which may implement certain taxes, subsidies or other policies that incentivize the use of renewable energy and ensure that economic inequalities between different groups are mitigated. Such policy tools, coming from a central authority and being imposed from the top-down, may cause certain types of smart grid systems to be preferably adopted over others. This may be favorable in terms of Energy Justice, since egalitarian socio-economic policies and prevention of problematic climate change can only be implemented at such higher levels. Also, it is important to note that in the domain of sustainability, goals for CO_2 emissions are already set for decades in advance – in particular 2030 and 2050. Therefore, considering the multi-decade long infrastructural development time, it is possible that governments and other controlling actors would have to act at an early moment ensure that the future energy infrastructure is suitable for meeting these emission goals. In this way, planning for this infrastructure would require a top-down, end-goal oriented approach that can account for the large uncertainties inherent in the process and likely emergent changes to the system.

Such end-goals and centrally organized policies stand in some contrast to the views of democracy that exist in pragmatism and Energy Democracy, as well as the overall idea of decentralization. This view of political decentralization and democratization gives preference to local organization, decision-making and experimentation. In smart grids this would particularly involve local energy communities or cooperatives that have freedom to design and manage their local infrastructure. This would include the option to operate on an independent, islanded section of the grid and the ability to choose between various methods of energy exchange, monetary or non-monetary, optimizing the system for the needs and preferences of that particular group, as well as the particular geographic circumstances. When the system is designed from the top-down, this leaves little space for local differentiation which is so necessary in infrastructures with such high complexity and such a large scope in geography, range of potential technological configurations and timespan. Furthermore, when the government has primary control over system development it may also have the capacity to push for a particular type of citizenship or political model that is associated with smart grids.

Besides top-down policies that may be restrictive, there are also other barriers for such decentralized development, particularly related to the nature and complexity of the technological infrastructure of the electrical grid. As described in chapter 2, the electrical grid can be conceptualized as composed of several interconnected layers, all of which require high-level expertise. The physical infrastructure, composed of distribution lines, transformation stations, EV charging stations, solar panels and other hardware must be installed and maintained by mechanics, electrical engineers and other technicians. In the economic infrastructure, market mechanisms and trading schemes have to be designed by economists and game theorists which are adaptable to the local context. In the information infrastructure, local energy management data, control algorithms and more must be secure as well as accessible and transparent for stakeholders. If energy communities or other locally organized groups want to take responsibility for infrastructure management in truly democratic fashion, then these groups must have access to the knowledge and expertise described above to take full advantage of adapting the infrastructure to their local needs and context. If the group does not have this required knowledge it must resort to adopting a standardized model or configuration that can fit in many contexts but may be poorly adapted for any single specific local situation. Furthermore, individuals, groups or other actors that have access to this expertise are particularly empowered as they can decide who they provide this expertise, and for what price.

5.4. Controlled Decentralization with Centralized Support

In this final section I will describe the guiding directions provided by the normative framework developed throughout this thesis. From the framework, it can be concluded that decentralization and democratization is desirable in smart grids for various reasons: prosumers and local communities become empowered by their ability to self-govern, and local grid systems can be customized and tailor made to fit specific local needs and geographical contexts. When a specific infrastructural model for smart grids is imposed from the top down by a central controlling actor, the sheer scope, scale, and technological heterogeneity means that a significant amount of stakeholders are likely to be excessively and needlessly restricted. Even when this top-down imposition is associated with a vision of decentralization, such as the ideal of prosumer-citizenship, it is quite plausible that this ideal is not in accordance with the actual needs and wishes of many people. For example, many people may be unwilling to take up any responsibilities or tasks that come with the ideal of prosumer-citizenship. For this reason, some degree of decentralization of the development process itself is advisable and desirable.

The normative framework also suggests, however, that complete decentralization in anarchistic fashion where the government adopts a "hands-off" approach is not desirable. When this is done, it is possible that infrastructure adaptations will be unable to meet sustainability goals or that powerful corporate actors seize control and form problematic market monopolies. Such events could result in unjust distribution of affordability and availability of energy, as well as environmental damages and potentially barriers for less advantaged actors to participate. Because of the interconnectedness of the grid it is necessary that all sections remain able to interact and exchange energy in the case of outages, shortages or excess of supply, something that could be inhibited if sections are free to be fully isolated and self-sufficient. Therefore, it is necessary that there is a general protocol or model for the entire system by which independent sections can exchange and interact, and by which it can be ensured that renewable energy integration is sufficiently integrated in the entire system.

Furthermore, in a scenario of complete decentralization, actors that are motivated, wealthy and knowledgeable have a very significant advantage when it comes to development of local systems. When local groups choose to take matters in their own hands, it is likely that they must rely heavily on external advice and resources because of the technological complexity, meaning that they are dependent on external parties such as governments, utility companies or commercial actors, to provide them with accurate and helpful information for their local purposes. When such consultation is left to the free market, large inequalities may emerge as wealthy citizens can hire experts to provide them this assistance. This would allow such groups to gain more opportunities in attaining their goals for sustainability, economic profits and empowerment, while more disadvantaged groups would be unable to do so. Furthermore, in that case it cannot be ensured that the services provided by such companies are actually in the best interest of the local prosumers. For these reasons, it is necessary that either the government or another central entity plays an important role in providing such aid to local initiatives, or that the market is regulated. Besides technological expertise, assistance should also be available for the social and political organization in local initiatives.

The optimal model for smart grid development therefore lies between the two extremes, where decentralization occurs and centralized support is also provided. There should be a variety of ways in which local communities or citizens can choose to give substance to their prosumer-citizenship: strong local engagement and participation can be encouraged, but it should be equally acceptable to not participate and simply stick to an economic relationship of energy consumption and production. For further research, I recommend that the problems of motivational and epistemic asymmetry should receive further attention. Successful decentralization and democratization in smart grid systems is highly dependent on resolution of these problems, as inequalities may likely emerge if they are inadequately handled.

References

Allen, J. (2008). Pragmatism and power, or the power to make a difference in a radically contingent world. *Geoforum*, *39*(4), 1613–1624. https://doi.org/10.1016/j.geoforum.2007.06.004

Amin, M., & Wollenberg, B. (2005). Toward a Smart Grid. *IEEE Power and Energy Magazine*, *3*(october), 34–41. https://doi.org/10.1109/MPAE.2005.1507027

Anand, N. (2011). PRESSURE: The PoliTechnics of Water Supply in Mumbai. *Cultural Anthropology*, *26*(4), 542–564.

Avelino, F., & Wittmayer, J. M. (2016). Shifting power relations in sustainability transitions: A multi-actor perspective. *Journal of Environmental Policy and Planning*, *18*(5), 628–649. https://doi.org/10.1080/1523908X.2015.1112259

Bolton, R., Lagendijk, V., & Silvast, A. (2020). Grand visions and pragmatic integration : Exploring the evolution of Europe ' s electricity regime. *Environmental Innovation and Societal Transitions*, *32*(May 2018), 55–68. https://doi.org/10.1016/j.eist.2018.04.001

Bouffard, F., & Kirschen, D. S. (2008). Centralised and distributed electricity systems. *Energy Policy*, *36*(12), 4504–4508. https://doi.org/10.1016/j.enpol.2008.09.060

Brisbois, M. C. (2020). Shifting political power in an era of electricity decentralization: Rescaling, reorganization and battles for influence. *Environmental Innovation and Societal Transitions*, *36*(August 2019), 49–69. https://doi.org/10.1016/j.eist.2020.04.007

Burke, M. J., & Stephens, J. C. (2018). Political power and renewable energy futures: A critical review. *Energy Research and Social Science*, *35*(March 2017), 78–93. https://doi.org/10.1016/j.erss.2017.10.018

Chu, S., Cui, Y., & Liu, N. (2016). The path towards sustainable energy. *Nature Materials*, *16*(1), 16–22. https://doi.org/10.1038/nmat4834

Defeuilley, C. (2019). Energy transition and the future(s) of the electricity sector. *Utilities Policy*, *57*(March), 97–105. https://doi.org/10.1016/j.jup.2019.03.002

Driesen, J., & Katiraei, F. (2008). Design for Distributed Energy Resources. *IEEE Power and Energy Magazine*, *june*. https://doi.org/10.1109/MPE.2008.918703

Edwards, P. N. (2003). Infrastructure and Modernity: Force, Time, and Social Organization in the History of Sociotechnical Systems. *Published in Philip Brey, Arie Rip, and Andrew Feenberg, Eds., Technology and Modernity: The Empirical Turn (Cambridge, MA: MIT Press, Forthcoming 2002)*, 185–226. http://citeseerx.ist.psu.edu/viewdoc/summary?doi=10.1.1.97.2776

Eurelectric. (2015). Prosumers – an integral part of the power system and the market. *Eurelectric*, *June*, 15. https://doi.org/D/2015/12.105/15

European Council. (2014). EUCO 169/14. *European Council*, *October*, 1–15.

Fang, X., Misra, S., Xue, G., & Yang, D. (2012). Smart grid - The new and improved power grid: A survey. *IEEE Communications Surveys and Tutorials*, *14*(4), 944–980. https://doi.org/10.1109/SURV.2011.101911.00087

Farhangi, H. (2010). The path of the smart grid. *IEEE Power and Energy Magazine*, *8*(1), 18–28. https://doi.org/10.1109/MPE.2009.934876

Fox-Penner, P. (2020). Power After Carbon: Building a Clean, Resilient Grid. In *BMC Public Health* (Vol. 5, Issue 1). Harvard University Press. https://ejournal.poltektegal.ac.id/index.php/siklus/article/view/298%0Ahttp://repositorio.unan.edu.ni/2986/1/5624.pdf%0Ahttp://dx.doi.org/10.1016/j.jana.2015.10.005%0Ahttp://www.biomedcentral.com/1471-2458/12/58%0Ahttp://ovidsp.ovid.com/ovidweb.cgi?T=JS&P

Geels, F. (2005). Co-evolution of technology and society: The transition in water supply and personal hygiene in the Netherlands (1850-1930) - A case study in multi-level perspective. *Technology in Society*, *27*(3), 363–397. https://doi.org/10.1016/j.techsoc.2005.04.008

Goldthau, A. (2014). Rethinking the governance of energy infrastructure: Scale, decentralization and polycentrism. *Energy Research and Social Science*, *1*, 134–140. https://doi.org/10.1016/j.erss.2014.02.009

Healy, N., & Barry, J. (2017). Politicizing energy justice and energy system transitions: Fossil fuel divestment and a "just transition." *Energy Policy*, *108*(May), 451–459. https://doi.org/10.1016/j.enpol.2017.06.014

Hughes, T. P. (1983). *Networks of Power: Electrification in Western Society*. The John Hopkins University Press. http://library1.nida.ac.th/termpaper6/sd/2554/19755.pdf

Jenkins, K., McCauley, D., Heffron, R., Stephan, H., & Rehner, R. (2016). Energy justice: A conceptual review. *Energy Research and Social Science*, *11*, 174–182. https://doi.org/10.1016/j.erss.2015.10.004

Kabir, E., Kumar, P., Kumar, S., Adelodun, A. A., & Kim, K. H. (2018). Solar energy: Potential and future prospects. *Renewable and Sustainable Energy Reviews*, *82*(August 2017), 894–900. https://doi.org/10.1016/j.rser.2017.09.094

Karger, C. R., & Hennings, W. (2009). Sustainability evaluation of decentralized electricity generation. *Renewable and Sustainable Energy Reviews*, *13*(3), 583–593. https://doi.org/10.1016/j.rser.2007.11.003

Lagendijk, V. (2021). *Ideas , Individuals and Institutions : Notion and Practices of a European Electricity System*. https://doi.org/10.1017/S0960777318000115

Larkin, B. (2013). The Politics and Poetics of Infrastructure. *Annual Review of Anthropology*, *42*(1), 327–343. https://doi.org/10.1146/annurev-anthro-092412-155522

Lavrijssen, S., & Parra, A. C. (2017). Radical prosumer innovations in the electricity sector and the impact on prosumer regulation. *Sustainability (Switzerland)*, *9*(7), 1–21. https://doi.org/10.3390/su9071207

Lüth, A., Zepter, J. M., Crespo del Granado, P., & Egging, R. (2018). Local electricity market designs for peer-to-peer trading: The role of battery flexibility. *Applied Energy*, *229*(May), 1233–1243. https://doi.org/10.1016/j.apenergy.2018.08.004

Mehigan, L., Deane, J. P., Gallachóir, B. P. Ó., & Bertsch, V. (2018). A review of the role of distributed generation (DG) in future electricity systems. *Energy*, *163*, 822–836. https://doi.org/10.1016/j.energy.2018.08.022

Milchram, C., Hillerbrand, R., van de Kaa, G., Doorn, N., & Künneke, R. (2018). Energy Justice and Smart Grid Systems: Evidence from the Netherlands and the United Kingdom. *Applied Energy*, *229*(September 2017), 1244–1259. https://doi.org/10.1016/j.apenergy.2018.08.053

Mitchell, T. (2011). Carbon democracy: political power in the age of oil. In *Verso* (Vol. 49, Issue 10). https://doi.org/10.5860/choice.49-5932

Morstyn, T., Teytelboym, A., & McCulloch, M. D. (2019). Designing decentralized markets for distribution system flexibility. *IEEE Transactions on Power Systems*, *34*(3), 1–12. https://doi.org/10.1109/TPWRS.2018.2886244

Ottens, M., Franssen, M., Kroes, P., & Van De Poel, I. (2006). Modelling infrastructures as sociotechnical systems Maarten Ottens , Maarten Franssen , Peter Kroes and Ibo van de Poel. *International Journal of Critical Infrastructure*, *2*(2), 133–145.

Poudineh, R., & Peng, D. (2017). Electricity market design for a decarbonised future. In *Oxford Institute for Energy Studies (OIES) Paper: EL 26* (Issue October). https://doi.org/10.26889/9781784670948

Pratt, A., Krishnamurthy, D., Ruth, M., Wu, H., Lunacek, M., & Vaynshenk, P. (2016). Transactive Home Energy Management Systems: The Impact of Their Proliferation on the Electric Grid. *IEEE Electrification Magazine*, *4*(4), 8–14. https://doi.org/10.1109/MELE.2016.2614188

Rahimi, F., & Ipakchi, A. (2016). Using a Transactive Energy Framework: Providing Grid Services from Smart Buildings. *IEEE Electrification Magazine*, *4*(4), 23–29. https://doi.org/10.1109/MELE.2016.2614181

Rosenbloom, D., Haley, B., & Meadowcroft, J. (2018). Critical choices and the politics of decarbonization pathways: Exploring branching points surrounding low-carbon transitions in Canadian electricity systems. *Energy Research and Social Science*, *37*(May 2017), 22–36. https://doi.org/10.1016/j.erss.2017.09.022

Saad Al-Sumaiti, A., Ahmed, M. H., & Salama, M. M. A. (2014). Smart home activities: A literature review. *Electric Power Components and Systems*, *42*(3–4), 294–305. https://doi.org/10.1080/15325008.2013.832439

Sabel, C. F., & Simon, W. H. (2017). Democratic experimentalism. *Searching for Contemporary Legal Thought*, *549*, 477–498. https://doi.org/10.1017/9781316584361.026

Shook, J. R. (2010). Pragmatism applied to democracy. *Revue Francaise d'Etudes Americaines*, *124*(124), 11–28. https://doi.org/10.3917/rfea.124.0011

Shove, E., & Walker, G. (2014). What Is Energy For? Social Practice and Energy Demand. *Theory, Culture & Society*, *31*(5), 41–58. https://doi.org/10.1177/0263276414536746

Shove, E., Watson, M., & Spurling, N. (2015). Conceptualizing connections: Energy demand, infrastructures and social practices. *European Journal of Social Theory*, *18*(3), 274–287. https://doi.org/10.1177/1368431015579964

Skjølsvold, T. M., Ryghaug, M., & Berker, T. (2015). A traveler's guide to smart grids and the social sciences. *Energy Research and Social Science*, *9*, 1–8. https://doi.org/10.1016/j.erss.2015.08.017

Sovacool, B. K., & Dworkin, M. H. (2015). Energy justice: Conceptual insights and practical applications. *Applied Energy*, *142*, 435–444. https://doi.org/10.1016/j.apenergy.2015.01.002

Sweeney, C., Bessa, R. J., Browell, J., & Pinson, P. (2020). The future of forecasting for renewable energy. *Wiley Interdisciplinary Reviews: Energy and Environment*, *9*(2), 1–18. https://doi.org/10.1002/wene.365

Szulecki, K. (2018). Conceptualizing energy democracy. *Environmental Politics*, *27*(1), 21–41. https://doi.org/10.1080/09644016.2017.1387294

Talisse, R. B., & Aikin, S. F. (2008). *Pragmatism: A Guide for the Perplexed*. Continuum International Publishing Group.

UN. (2015). *Paris Agreement* (Vol. 2, Issue 4).

Van Der Schoor, T., & Scholtens, B. (2015). Power to the people: Local community initiatives and the transition to sustainable energy. *Renewable and Sustainable Energy Reviews*, *43*, 666–675. https://doi.org/10.1016/j.rser.2014.10.089

van Summeren, L. F. M., Wieczorek, A. J., Bombaerts, G. J. T., & Verbong, G. P. J. (2020). Community energy meets smart grids: Reviewing goals, structure, and roles in Virtual Power Plants in Ireland, Belgium and the Netherlands. *Energy Research and Social Science*, *63*(December 2019), 101415. https://doi.org/10.1016/j.erss.2019.101415

Van Summeren, L. F. M., Wieczorek, A. J., & Verbong, G. P. J. (2021). The merits of becoming smart: How Flemish and Dutch energy communities mobilise digital technology to enhance their agency in the energy transition. *Energy Research & Social Science*, *79*, 102160. https://doi.org/10.1016/j.erss.2021.102160

Van Veelen, B. (2018). Negotiating energy democracy in practice: governance processes in community energy projects. *Environmental Politics*, *27*(4), 644–665. https://doi.org/10.1080/09644016.2018.1427824

Verbong, G. P. J., & Geels, F. W. (2010). Exploring sustainability transitions in the electricity sector with sociotechnical pathways. *Technological Forecasting and Social Change*, *77*(8), 1214–1221. https://doi.org/10.1016/j.techfore.2010.04.008

WEC. (2013). *World Energy Scenarios: Composing energy futures to 2050*.

Wentland, A. (2016). Imagining and enacting the future of the German energy transition: electric vehicles as grid infrastructure. *Innovation*, *29*(3), 285–302. https://doi.org/10.1080/13511610.2016.1159946

Wieczorek, A. (n.d.). *Community Energy 2 . 0 A support tool for advisers and process moderators*.

Wolfe, J. (2012). Does Pragmatism Have A Theory of Power? *European Journal of Pragmatism and American Philosophy*, *IV*(1), 0–19. https://doi.org/10.4000/ejpap.775