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Max Joel Staib Ramalho

The role of Public Policy and Regulation in the transformation of the Electricity Sector: The case of the Germany Energy Transition

RIO DE JANEIRO
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Dissertação de Mestrado apresentada ao Programa de Pós-Graduação em Economia da Indústria e Tecnologia, Instituto de Economia, Universidade Federal do Rio de Janeiro, como requisito parcial à obtenção do título de Mestre em Economia.

ORIENTADORA: Profª. Dra. Marina Honorio de Souza Szapira.

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A minha avó, Lucília, e meu avo Jether.

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ABSTRACT

RAMALHO S., M.. *The role of Public Policy and Regulation in the transformation of the Electricity Sector: The case of the Germany Energy Transition*. 2017. Dissertation (Master in Economics of Industry and Technology) – Economics Institute, Federal University of Rio de Janeiro, Rio de Janeiro.

This dissertation analyses the German energy transition, in order to debate the importance and challenges associated with pursuing such a transformative project through mission oriented policies.
The Energiewende is a long-term economic strategy by the German government in which it aims to transform its energy system towards a low-carbon, electrified and renewable one. It does so by pursuing ambitious goals and implementing at times radical policies in order to create market incentives to drive forward this process. In the course of this, the energy transition has faced several challenges and in recent years has demonstrated modest progress. One of the areas in which most progress has been observed is in the diffusion of renewable energy technologies. The country implemented a famous remuneration program for renewable electricity, which has propelled it to the global forefront of renewable energy technologies. During this period, the incentive program has undergone some major transformations, strongly influenced by political pressures and technological progress. By taking a closer look at the promotion of photovoltaic energy in Germany, this dissertation hopes to shed some light on the difficulties facing policy makers when implementing and supporting emerging, fast changing technologies. While this work will argue for the importance of government intervention in creating markets and investment incentives for new and promising technologies, a major challenges remains in designing these policies to be flexible to change, while offering continuity.
As the German example of photovoltaic energy demonstrates, a key task for future policy makes will be in creating the environment and framework which will allow for a flexible and independent promotion of new innovative technologies and thus guarantee the success of transformative ‘missions’.

Keywords: Renewable Energy, Photovoltaic Energy, Innovation, Public Policy, Energiewende, Mission Oriented Policies, Techno-Economic Paradigm.

ABSTRACT

RAMALHO S., M.. *The role of Public Policy and Regulation in the transformation of the Electricity Sector:The case of the Germany Energy Transition*. 2017. Dissertation (Master in Economics of Industry and Technology) – Economics Institute, Federal University of Rio de Janeiro, Rio de Janeiro.

Esta dissertação analisa a transição energética alemã, a fim de debater a importância e os desafios associados à busca de um projeto transformador através de políticas orientadas para a missão.
A Energiewende é uma estratégia econômica de longo prazo do governo alemão que procura transformar seu sistema de energia para um de baixa emissão, eletrificação e energia renovável. A partir disso, observa-se que o país se colocou objetivos ambiciosos, implementando políticas radicais para criar incentivos de mercado que possam impulsionar esse processo de transformação da estrutura energética. A transição energética enfrentou vários desafios e nos últimos anos demonstrou um progresso modesto. A área em que a maior evolução foi observada foi na difusão de tecnologias de energia renovável. Isso foi possibilitado através da implementação do *Renewable Energy Sources Act* (EEG), um hoje famoso programa de remuneração para eletricidade renovável, que o impulsionou para virar um líder global na difusão de tecnologias de energia renovável. Durante este período, o programa de incentivo sofreu algumas transformações importantes, fortemente influenciadas pelas pressões políticas e pelo progresso tecnológico. Ao analisar de perto a promoção da energia fotovoltaica na Alemanha, esta dissertação espera esclarecer as dificuldades enfrentadas pelos decisores políticos ao implementar e apoiar tecnologias emergentes e em rápida mudança. Embora este trabalho defenda a importância da intervenção do governo na criação de mercados e incentivos ao investimento para tecnologias novas e promissoras, continua a ser um grande desafio projetar essas políticas para serem flexíveis a mudanças, mas ao mesmo tempo oferecendo continuidade. O exemplo da trajetória de energia renovável na Alemanha demostra que a tarefa fundamental para futuras políticas será a criação de um ambiente e um arcabouço politico que permitirá uma promoção flexível e independente de novas tecnologias inovadoras e, assim, garantir o sucesso de "missões" transformadoras.

Palavras chave: Energia Renovável, Inovação, Energiewende, Políticas Mission-Oriented, Paradigma Tecno-Econômico.

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LISTA DE ABREVIATURAS E SIGLAS

RET	Renewable Energy Technologies
EEG	Erneuerbare Energien Gesetzt
FiT	Feed-in Tariff
ROI	Return on Investment
BMUB	Federal Environment Ministry
BMWi	Federal Economics Ministry
BNetzA	Bundesnetzagentur
Fraunhofer ISI	Fraunhofer Institute for System and Innovation Research
Fraunhofer ISE	Fraunhofer Institute for Solar Energy systems
EV	Electric Vehicles
VDMA	German Engineering Association
BDI	Federal Association of German Industry

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1 Introduction

The 21st century is experiencing the beginning of a fundamental shift in the structure and organization of the economy, rivalling that of the industrial revolution nearly two centuries ago. Just like the industrial revolution, which transformed transportation, energy generation and production, we are witnessing a similar tectonic shift. Some are referring to these structural as a “third industrial revolution” (RIFKIN, 2008). This transformation is of a systemic magnitude and will be characterized by a greater participation of renewable energy, digitalisation and e-mobility, among others.

On the other hand, growing environmental concerns, including global warming, have brought governments together in an attempt to curb global CO2 emissions. Thus, it is undeniable that an important part of the answer to these challenges will be found in the energy sector. As a consequence, renewable energy will represent central pillar of future economic development. In response to this, more and more countries pursuit the ideals of an innovation-led and sustainable economic model. In this context, a wider discussion is re- emerging over what role the state should play in light of this paradigm change.

Confronted with these challenges a growing number of scholars discuss the importance of the state in pioneering, incentivizing and supporting this transformation. One of these proponents, Mariana Mazzucato, argues that the role of modern Government is “... about identifying and articulating new missions that can galvanize production, distribution, and consumption patterns across sectors” (MAZZUCATO, 2015, p.14). In other words, the state is not restricted to the role of a facilitator, but in fact plays an important part in shaping and driving this process.

In this respect, Germany is making headways by pursuing a transformative project known as the Energiewende. In essence, this ‘mission’ represents nothing short of a major overhaul of the nations economic structure towards an emissions free, green economy. In order to accomplish this, the country has implemented a number of policies and identified specific goals, in order to advance this transformative process. In principle, this ‘mission’ is to be accomplished through a greater diffusion of renewable energy and an increase in energy efficiency. Yet in practice, the Energiewende incorporates a systemic change which affects a wide range of areas including transportation, electricity, heat, construction, urban development, digitalisation, among others.

The German experience offers several examples of the importance of a proactive state. Particularly, the rise of renewable energy generation is emblematic of this. The country has played a pioneering role in the research and diffusion of renewable energy sources, especially in the fields of wind and solar energy. The speed and quantity of installed solar power generation has been tremendous and the role of public policy in this process attracts little controversy today.

Within an incredibly short period of time, the country has been able to generate, accumulate and apply incredible levels of know-how to the field, ultimately fostering one of the worlds most advanced industries in renewable energy technologies. Germany "ranks among world champions in the deployment of renewable technologies, being the second country in the world with total renewable power capacity per capita" (WWF, 2016). On May 8th 2016, renewable energy generation reached a new record high, providing 87.6 % of domestic electricity consumption[1] (WWF, 2016).

This incredible transformation did not occur in a political vacuum, nor was it solely the result of market forces. The speed and quantity of installed solar power generation has been tremendous and the role of public policy in this process has been central. Yet, today's outcome was by no means self-evident and as a result, an analysis of the contributing factors to this success can be very relevant for understanding the trajectory of renewable energy in Germany, and in particular, the role of the state in this process.

A particular milestone for the deployment of renewable energy technologies (RET) was the "Renewable Energy Sources Act" (EEG) which was signed into effect on the first of April, 2000. Particularly, the feed-in tariff (FiT) introduced through this law, has turned out to be a crucial policy mechanism to incentivize investment in RET and thus represents an important example for the active role of Government in creating and shaping markets for new and promising technologies. This means, that public policy was able to shape and direct private investment into creating a robust market and demand for RET.

[1] On that given day, wind and sun conditions were particularly favourable, while demand was low.

This dissertation intends to argue for the importance public policy in shaping the process of economic transformation. More specifically, this dissertation will investigate the important role of mission oriented policies in enabling economic transformation. This will be done by presenting the *Energiewende* as a mission oriented policy, intending to bring about a paradigmatic change to the countries energy system. Furthermore, in order to better understand the success and challenges of pursuing a 'mission', this work will use the specific case of policy support for photovoltaic and its evolution over time. In addition, this example will help illustrate some characteristics in policy making which help explain the progress and/or stagnation in certain areas.

The specific example of photovoltaics was chosen because it represents a technology with particularly disruptive potential due to its wide applicability and because it is characterized by fast technological and innovative dynamics. As a consequence, this example can be of considerable value as it offers an insight into the challenges to creating effective support policies.

To complement this discussion and as a necessary prerequisite in order to evaluate the progress of such a 'mission', the countries institutional and innovative structure will be considered. In that sense and to better contextualize the different elements which contribute to the example of the German Energiewende, this dissertation will illustrate some important aspects of the countries National Innovation System. Just as the Energiewende did not occur in a political vacuum, so did it not evolve independently of the countries existing institutional and innovative landscape.

Finally, this work will attempt to add to the discussion over the merits of 'mission' oriented policies and the challenges and difficulties such systemic, long term projects face. In particular an emphasis is made in illustrating the complexity and systemic nature of such processes, and the difficulty of identifying and implementing effective policies for completing them. As a consequence, this analysis will touch upon the challenges presented by incumbent player and political discourse.

The dissertation begins by presenting and drawing on a multitude of theoretical frameworks, particularly the National Innovation System (NSI) model and the discussion on mission oriented policies and techno-economic paradigm shifts. This will serve as the basis for better identifying the *Energiewende* as a 'mission' oriented policy, while outlining the complexity of the contributing factors for its success and challenges, through the systemic lens of the NSI model, and barrier to change, through the discussion on techno-economic paradigms.

Subsequently, chapter two introduces the *Energiewende* as a German mission oriented policy, giving a brief overview of its goals and systemic nature. The different pillars of the energy transition are presented, together with some important policy initiatives, in order for the reader to gain a sense of the magnitude of this 'mission'. To complement this, the second half of the chapter offers a short summary of some of the more important elements of the German National Innovation System related to photovoltaics. While the list is not exclusive, it aims at illustrating the systemic effort of the energy transition, and the multitude of actors involved. The final chapter presents the evolution of the EEG (the main support policy for photovoltaics) in order to discuss its impact and change over time. This will be used to explore some of the characteristics of the policy implementation which help explain its success and failures. Consequently, a short comparison will be drawn to the case of e-mobility, in order to exemplify some of the lessons of the EEG.

Finally, the conclusion will situate the findings of the analysis of the EEG and the Energiewende within the theoretical framework. The trajectory of the EEG and the progress of the *Energiewende* offers an abundance of important narratives on the importance and challenges of 'mission' oriented policy and techno-economic paradigm shifts. The theoretical framework proves insightful for understanding the progress of the German energy transition.

2 Chapter I

2.1 Introduction

In order to better understand and discuss the German energy transition (Energiewende) as a whole, and in particular, the implementation of the Feed-in tariff, this dissertation will utilize a broad range of academic literature discussing innovation processes and the role of government. Specifically, the following theoretical discussion will attempt to shed light on the following questions:

Which circumstances (environments) best foster and incentivize innovation?

What elements help explain the successes or difficulties of adopting innovative technologies?

What role do Governments, Institutions and Public Policies play in supporting innovation and the adoption of new technologies?

These questions will be explored through the application of the following theoretical lenses and concepts: National Innovation System Approach, Techno-Economic Paradigm, Mission Oriented Policies and the *Entrepreneurial State*. Furthermore, in order to situate this debate within innovation, technological change and public intervention, other concepts and theoretical discussions will also be presented/included. Thus, it can be helpful to begin this theoretical exposition by exploring some of the origins of innovation theory.

The following chapter will begin by exploring some of the origins of innovation theory which still inform most of the contemporary academic debate on innovation processes. After presenting some of Schumpeters earlier contributions to this topic, and introducing the linear approach to innovation, this chapter will offer an overview to the development and characteristics of a systemic approach to innovation and technological change. Particular attention will be paid to the National Innovation Systems approach and the discussion on technological-paradigms. Finally, the chapter will shift its attention to the role of the state in economic progress, with special emphasis on Mariana Mazzucato's conceptualization of an "Entrepreneurial State".

2.2 Origins of Innovation Theory

Many of the origins of innovation studies today, can be traced back to the works of Joseph A. Schumpeter and other research traditions outside the mainstream of economics, such as institutional economics, development economics, and most notably, evolutionary economics. Yet, while Schumpeter recognized the central role of innovation in economic progress, he made little effort to understand the process itself. Thus, a central concern of innovation studies has been to more effectively explain technological growth within an economy.

The roots of much modern debate on innovation today, go back to the ideas and works of Joseph Schumpeter during the first half of the twentieth century. In his conceptualization, he divided the process up into three stages: invention, innovation and diffusion. This model is often referred to as the “linear model” of innovation, which proceeds through the steps of basic research to applied research to technology development and diffusion. In its essence, this framework implies that advances in scientific understanding determine the rate and direction of innovation. Following this argument, putting/feeding more resources into Research & Development (R&D) results can increases the output of new technologies. This dynamic is often referred to as technology- or science- push.

As previously mentioned, initial theories describing the process of innovation conceived it as a linear process following certain “stages”. These successive stages were usually identified as; basic research, applied research, development, production and diffusion (CASSIOLATO AND LASTRES, 2005). In this sense, the discussion involving the driving forces behind the innovative process revolve around two conceptualizations, the earlier mentioned science push, which emphasizes the importance of scientific advances in “pushing” innovation, and demand pull, affirming the relevance of pressure through demand for new technologies in “pulling” the innovation process.

A first attempt at theorizing innovation was advanced within the neoclassical economic theory by Robert Solow’s work on recognizing the macro-economic importance of understanding innovation and its relative contribution to the growth of national economies (SOLOW, 1957). Through his efforts, he came to the conclusion that the largest contribution to growth did not, as traditionally assumed, derive from an increase in labour or capital productivity, but rather from a residual element which he identified broadly as technical change i.e. advances in knowledge resulting in economic applications. Thus, while his line of argument established the importance of innovation and technological progress within the greater debate of economic growth, he contributed little to understanding the dynamics and mechanisms behind explaining innovative processes.

Consequently, early popularization of innovation theory was driven by the recognition that empirical investigations seemed to suggest that innovation and technological change were central to explaining economic growth and that investment was required for innovation. Initially it was the works of Nelson (1959) and Arrow (1962) which identified the challenges faced by innovation through the nature of scientific knowledge (the challenges of 'appropriating' or owning it) and the logic of the market (a firm expending costs that will equally benefit rivals is not making a rational economic decision since the rivals can free ride and obtain a cost advantage while not having to make the research expenditure).These insights would represent the basis for justifying public support for *a component* of innovation, i.e. discovery and invention (SCHOT AND STEINMUELLER, 2016). As a consequence, it can be said that the study of innovations only began to emerge as a separate field, differentiating itself from economics, in the 1960s (SHARIF, 2005).

While Schumpeter's more linear and unidirectional approach to innovation continued to exert its influence, it came under growing criticism by newer innovation theorists who found that it was no longer compatible with more complex conceptualizations which incorporated aspects of interactions, networks and feedbacks (NEMET, 2007). Consequently, while the relevance of both linear approaches of innovation driven by technology-push and demand-pull policies, continued to be recognized, the importance of complex, systemic feedbacks between supply and demand grew in influence (FOXON, 2003)

Nelson and Winter attempted to build a more general theory of innovation by identifying two important characteristics of the innovation process (NELSON, 1977; 1982):

i. Innovation is essentially marked by uncertainty. This is especially present during the incipient stages of innovation when there is diversity of options for addressing a technological problem or user needs.

ii. Institutional structures play an important role for providing incentives or creating barriers to innovation.

Scholars came to recognize that innovation was essentially characterised by different kinds of uncertainty: about future markets, technology potential and regulatory environments. Consequently, firm's expectations of these factors has an impact on the directions of their innovative searches and investments; and furthermore, these expectations are often implicitly or explicitly shared between firms in the same industry, which helps to explain why technologies follow particular trajectories (FOXON, 2003). This element of uncertainty is particularly influential for innovation decisions related to emerging technologies, i.e. technologies that are still in an early phase of development (MEIJER ET AL., 2007). This uncertainty is not only related to the future success of the technology itself but is also linked to the socio-institutional environment in which this new technology will be embedded.

This latter element is associated with the fact that current regulation has developed in such a way as to be aligned with established technologies. Consequently, it may prove to become a hurdle for emerging technologies, as the regulation may not provide room for their introduction. This, as mentioned before, is partly to do with the presence of uncertainty about which institutional regulations and support mechanisms will emerge for the new technology. A matter that will be discussed in greater detail later on, dynamics related to technological paradigms and lock-ins, contribute to a socio-institutional inertia, which obstructs and slows down change and adaptation to new technologies, ultimately requiring "critical pressure" (PEREZ, 2004).

In this sense, Freeman and Perez (1988) offered a useful categorization of different innovation processes which is helpful in understanding approaches to innovation theory based on a more complex, systems-based framework for the innovation process:

i. *Incremental innovations* occur continuously in any industry or service activity, often as a result of learning- by-doing or learning-by-using, rather than because of specific R&D activity.

ii. *Radical innovations* refer to innovation which emerges from outside the current mainstream. Perhaps best understood as the counterpart to "incremental innovation", this type of innovation can bring about structural change. Nonetheless, their economic impact is relatively small and localised unless a whole cluster of radical innovations are linked together in the rise of new industries and services.

iii. *Changes of 'technology system'* on the other hand represent far-reaching changes in technology. This is the result of a wider, inter-related innovation process, combining clusters of radical and incremental innovations, together with organisational and managerial innovations consequently affecting a wider number of firms.

iv. *Changes in the 'techno-economic paradigm'* ('Technological revolutions') go beyond engineering trajectories for specific process or product technologies, and affect the cost structure and conditions of production and distribution throughout an economic system.

2.3 Emergence of the Framework for Systemic Innovation

Accordingly, in the following decades, scholars began to analyse innovation not merely as an isolated act, but as a cumulative, non-linear process, with local and institutional specificities. This revision, was initiated by two prominent empirical research programs, the SAPPHO Project coordinated by Chris Freeman at Sussex University and the Yale Innovation Survey. The two empirical studies, for the first time, demonstrated the importance of formal and informal innovation networks; for many, including Cassiolato and Lastres (2005), they represent the basic pillar upon which most of the innovation theory of the past 30 years has been built.

The 1980s also witnessed the emergence of a more holistic systemic approach to innovation, particularly through the contributions of Chris Freeman and Bengt-ÅkeLundvall. Curiously enough, these advances had their roots as much in policy as in academic institutions. In this sense, the Directorate for Science Technology and Industry (DSTI) of the OECD made significant contributions through its publication of "Technical Change and Economic Policy" (OECD, 1980), the "Sundquist Report" (OECD, 1988) and "Technology and the Economy: The Key Relationships" (OECD, 1992b). Simultaneously, in the world of academia, works such as Freeman (1987), Lundvall (1985,1992), Dosi et al. (1988) further propelled the development of innovation theory. Nonetheless, as Cassiolato and Lastres (2008) observe, since its inception during the 1980s, the systemic approach to innovation has had a particular affinity to informing and guiding policy recommendations.

As mentioned at the beginning of the chapter, much of this discussion was rooted in earlier efforts of understanding innovation. Schumpeter's "The Theory of Economic Development" (SCHUMPETER, 1934) and "Capitalism, Socialism, and Democracy" (SCHUMPETER, 1962), already argued against the prevailing trend among economists to define the core subject matter of the discipline as firm behaviour, prices, and quantities under conditions of equilibrium. He made it clear that the most important feature of capitalism was its role as an engine of economic progress (NELSON, 2004). Taking this as their cue, both Freeman and Lundvall felt dissatisfied with the lack of attention mainstream economic theories accorded to knowledge, technology, and technical change (SHARIF, 2005). Influenced by Schumpeter's earlier analysis, both Freeman and Lundvall, along with other contemporary economists studying technological advances agreed that innovation, technological or otherwise, could not be understood within the confines of a theory that assumed stable equilibrium. Consequently, as Sharif (2005) points out, Lundvall affirmed that his own motivation for carrying out the NIS work was due to dissatisfaction with standard economics. This also explains why in some policy circles, the ideas brought forward by Freeman were perceived as "too much trouble" (SHARIF, 2005). Sharif (2005, p.13) explains that the conflict arose because "Freeman had identified a role in the process of technological change to be played by factors outside of the classical neoclassical framework". Deriving from this was not only a necessity to provide an alternative explanation for the innovation process, but to recognize the key role that innovation plays in explaining the appearance of new technological paradigms which drive the evolution of capitalism (CASSIOLATO AND LASTRES, 2005).

Thus, the systemic perspective of innovation, offers an overarching conceptualization, or an underlying framework, for the different innovation study areas which emerged over time. An important characteristic that they all have in common is their vision that the innovation journey is a collective and cumulative achievement that requires key contributions from entrepreneurs from both the public and private sectors (VAN DE VEN ET AL., 1999, p. 149). Thus, it could be said, that one of the most novel contributions of the systemic approach to innovation, has been its rejection of the traditional linear understanding of innovation processes, towards a recognition of the interactive character and to the importance of (and complementarities between) incremental and radical, technical and organizational innovations and their different and simultaneous sources (CASSIOLATO AND LASTRES, 2008).

2.3.1 Innovation Systems

Freeman (1988) and Lundvall (1992) employed the term national systems of innovation. The national systems of innovation approach directed its attention to the various configurations of organisations concerned with the generation and utilisation of scientific and technological knowledge. Central to the idea of national innovation systems was that some configurations might be much more effective than others. These might contribute substantially to the explanation of why very uneven rates of productive and innovative performance were observable throughout the world.

While Freeman's (1987, 1988) version of national systems of innovation emphasized the differences in institutions and policies, Lundvall (1985, 1988) concentrated his attention on the differences country specific organisations involved in learning capabilities. Their justification for focusing on national systems were two-fold: institutions and policies are largely established at a national level and knowledge does not travel easily outside the socio-cultural milieu in which it is created.

Thus, the concept of a national system of innovation was first utilized in the late 1980s in a study of the then successful Japanese economy. Freeman's (1987) work on Japan, had a strong emphasis on public policy and governance, much of the literature which evolved from then, recognizes the importance of an active contribution from public institutions. It was in this work, that he offered a strong definition of National System of Innovation*, "... the network of institutions in the public and private sectors whose activities and interactions* *initiate, import, modify and diffuse new technologies" (*FREEMAN*, 1987).*

Therefore, an essential element of NIS theory is the emphasis on the positive role of government - working closely with industry and a science base - to provide:

- direction and support for development and marketing of advanced technologies;
- an integrated approach to R&D, design, procurement, production and marketing within large firms;
- a high level of education and scientific culture, combined with practical training and frequent up-dating in industry (FREEMAN AND PEREZ, 1988).

Consequently, for the purposes of analysing the contribution of public policy to the innovation process, the "national innovation system" seems particularly adept. This is partly due to the fact that its inception occurred somewhere in between the spheres of academia and policymaking. On the other hand, scholars such as Freeman are of the opinion that the "national" domain is particularly adequate to accommodate the policy dimension of the concept (SHARIF, 2005). As such, while the national innovation systems approach incorporates all the systemic conceptualizations of the innovation process, recognizing the multiplicity of contributing factors, it offers itself well for analysing in more detail, the contribution of public policy.

In their discussion, Cassiolato and Lastres (2008, p.8) present some key characteristics for understanding the 'broader' conception of innovation systems, propagated by Freeman and others. Two of their arguments warrant particular emphasis:

i. "innovation capacity derives from the confluence of economic, social, political, institutional and cultural specific factors and from the environment in which they operate, implying the need for an analytical framework broader than that offered by traditional economics (FREEMAN, 1982, 1987; LUNDVALL, 1985);

ii. the number of firms or organizations such as universities and research institutes is far less important than the habits and practices of such actors with respect to learning, linkage formation and investment. These shape the nature and extensiveness of their interactions and their propensity to innovate (JOHNSON, 1998; MYTELKA, 2000, JOHNSON AND LUNDVALL, 2003)."

Furthermore, they emphasize the importance of the localized characteristic of innovation systems, since many of the elements of knowledge and relationships between institutional and organizational frameworks are not easily transferable from one place/context to the other (CASSIOLATO AND LASTRES, 2008). This helps explain one of the advantages of focusing the analysis of innovation systems on a national context. “The diversity of NISs is a product of different combinations of their main features that characterize their micro, meso and macroeconomic levels, as well as the articulations among these levels. (CASSIOLATO AND LASTRES, 2008:8)”

Today, there are a variety of different approaches to innovation systems, which vary according to the subject and the perspective of analysis. This means, that the innovation systems has been conceptualized at still other levels. During the same period Lundvall (1988; 1992) pursued a similar framework, yet emphasizing the role of interactions between users and producers, facilitating a flow of information and knowledge linking technological capabilities to user needs. Even other approaches have emphasized the technological, territorial (local, regional), sectorial, or transnational level. Depending on the subject of investigation, these different approaches can be more useful. Malerba (2004) offers some conceptualizations of sectorial innovation systems, while Carlsson and Jacobsson (1997) focus on technological innovation systems. None the less, a core idea remains the recognition that the capacity to innovate is the product of a coming together of political, institutional, social and cultural factors which constitute the environment in which economic agents operate (CASSIOLATO AND LASTRES, 2008).

With the advances of systemic approaches, and the recognition of the importance of the public sector in innovation the role of institutions at all levels in establishing and maintaining the “rules of the game” became a key theme. To this was added the argument that institutions may constrain choices, driving innovation along certain - possibly sub-optimal - paths, while often throwing up barriers to more radical change (FOXON, 2003).

2.3.2 Techno-economic paradigms

Within the theory of evolutionary economics, the concept of technological paradigms has proven to be very valuable for the debate on innovation (DOSI 1982). The concept partly stem from need to respond the persisting resistance to study technology (being considered exogenous) and institutions and social organizations in economics, since they are 'outside the domain of economic theory' (PEREZ, 2009). In their essence, they build on our earlier discussion of technological regimes and path dependency, by highlighting the limitation of market forces in providing direction to economic development. A change in technological paradigms should be understood as a deep and gradual process of change in ideas, organizations, behaviours and institutions, related to technical change (PEREZ, 2004).

Thus, the paradigm approach to technology systems, argues that market signals have limited effectiveness in terms of providing direction to techno-economic development, since their logic is restricted to the parameters of the paradigm. In other words, market signals induce the rate of change rather than its direction.

This can also be associated with the fact that once paradigms are established they have a strong "exclusion effect", i.e. some technological trajectories are ignored due to their incompatibility with the prevailing paradigm and consequently become "invisible" to agents. In other words, such a techno-economic system of innovation may be locked into a self-reinforcing, path-dependent trajectory (DOSI AND NELSON 1994). So the mix of "…mutual adaptation between technological systems and the economic, cultural and institutional environment tends to make the whole structure self-reinforcing, both in its development and in its exhaustion, in its inclusion and in its exclusion mechanisms. (PEREZ, 2004, p.225)". Perez (2009, p.198) goes further, using the term organisational inertia to describe the "phenomenon of human and social resistance to change". She points out that while in the market economy inertia is overcome by competition, this motivation and drive is naturally lacking in most public institutions.

In order to overcome these lock-ins, mechanisms and new institutions have to be established to support the diffusion of the new paradigm. Mazzuacto (2015b) argues that in the past, "…governments have led the process of institution-building that allowed new techno-economic paradigms to replace the old ones". In addition, Perez (2004) makes a case for the importance of diffusion of technologies when she states "… the fact with the most far-reaching social consequences is the process of massive adoption. Vast diffusion is what really transforms what was once an invention into a socio-economic phenomenon."

When considering the direction and possibility of technological change, the ideas articulated by Dosi (1982) 'technological paradigms and trajectories', allows for an analysable and relatively predictable course of incremental technological change. The often-cited example for this has been the evolution and change of microprocessors. In addition, Chilton's Law which stipulated that doubling plant capacity increases investment cost by only two-thirds, allowed for an easier predictability of dynamics behind obtaining scale economies.

Consequently, the public sector plays the central role in creating a new "vision" which will rally and coordinate cognitive efforts of different public and private agents and direct their actions to areas beyond the existing paradigm. Yet as Mazzucato argues, policies should not be understood as specific answers to problems, but instead facilitate and enable learning and emergence. Consequently, the adequate policy will emerge from experimentation and trial and error. In line with this idea, Stirling (2008) points out the necessity for a bottom-up participatory processes to ensure the directionality is taken seriously and shared amongst stakeholders.

These ideas can be recognized when Perez (2004) identifies several interconnected processes of change and adaptation which can be observed as part of the establishment of new technological systems:

1. The development of surrounding services (required infrastructure, specialized suppliers, distributors, maintenance services, etc).
2. The 'cultural' adaptation to the logic of the interconnected technologies involved (among engineers, managers, sales and service people, consumers, etc).
3. The setting up of the institutional facilitators (rules and regulations, specialized training, education, etc).

Overall, these elements create strong feedback interactions between social, institutional and economic actors, reinforcing the technological paradigm (PEREZ, 1983). Thus the newly established techno-economic paradigm matures, imparting new rules and organizational structures.

2.4 The Role of the State in the Innovation Process

As may have become clear up to now, the discussion of innovation (and necessarily economic growth), essential involves a deliberation on the role of government and public policy. The *justification* for pursuing innovation policies has changed over time. While during the 1950s and 60s, military considerations predominated, the 70s and 80s saw the emphasis shift towards improving economic and competitive position of countries. In addition, the 1980s witnessed the popularization of market failure theory in legitimizing greater public intervention in innovation. Accordingly, a large part of today's innovation polices still retain their legitimacy based on the 20th century supply-driven rational of competition between nations and support for R&D and national systems of innovation as the main entry points for policy making. None the less, the debate on the impact public policy and regulation has on innovation is diverse, offering a multitude of perspective.

Yet critiques of this more "classical" approach to conceiving the role of government has grown in recent years. Mazzucato (2016), for example, argues that classical approaches are often limited in offering an explanation for instances during which policy is required to dynamically create and shape new markets i.e. "transformation." Thus there is a need for for addressing innovation and societal challenges that require the kinds of transformative, catalytic, mission-oriented public investments (FORAY ET AL., 2012, MAZZUCATO AND PENNA, 2015) that induce new sectors and technologies that did not previously exist.

Mazzucato (2013c) proposes that an alternative framework to public intervention in innovation which requires that "the market itself must be redefined as an *outcome* of the interactions between different agents, including public policy-makers". As such, when considering the role of the state as a transformative and a market-creating agent, one needs to draw from a diverse body of literature which have attempted to address this issue, notably:

(a) development economics research on the *developmental state*;
(b) evolutionary economics research on shifts in *technological trajectories and the emergence of techno-economic paradigms;*
(c) science and technology policy research on *mission-oriented* policies;

(d) research on the *entrepreneurial state*, which looks explicitly at the risk-taking role of different actors (MAZZUCATO, 2013a).

With the concepts of technological trajectories and techno-economic paradigms having been previously discussed, in the following pages, this composition will focus on the concepts of mission-oriented policies and the entrepreneurial state in order to discuss the active role played by the state in pursuing economic progress.

Mission oriented state

While the concept of mission-oriented policies has traditionally been associated with the military driven policy initiatives of the 50s and 60s, contemporary scholars have called for such an outcome oriented approach in tackling the "grand societal challenges" (MOWERY, NELSON AND MARTIN, 2010). In this sense, the *Maastricht Memorandum* (SOETE AND ARUNDEL, 1993:50) formulated a detailed description of the differences between old and new mission-oriented projects, showing that:

> "Older projects developed radically new technologies through government procurement projects that were largely isolated from the rest of the economy, though they frequently affected the structure of related industries and could lead to new spin-off technologies that had wide-spread effects on other sectors. In contrast, [contemporary] mission-oriented environmental [and other] projects will need to combine procurement with many other policies in order to have pervasive effects on the entire structure of production and consumption within an economy."

2.4.1 Entrepreneurial state

Borrowing from the activist nature of the mission-oriented perspective, Mazzucato[2] (2013) built a strong argument for the need of an "Entrepreneurial state". In essence, these two approaches focus on shedding light onto the role of states within economic progress, transition and the innovation process.

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[2] The Entrepreneurial State: Debunking Public vs. Private Sector Myths.

Mazzucato in her writings emphasizes the importance of an active state and public policy plays in achieving economic progress and transformation. A firm's decision to enter a market is driven by its expectations about future growth opportunities (DOSI AND LOVALLO, 1998). Mazzuato (2013a, 2015) argues that these technological and market opportunities have historically been driven and shaped by government investment. She calls it the "entrepreneurial state", the one who is willing to invest in and envision new high-risk areas ahead of the private sector.

This state sees its role no longer restricted to the traditional areas of innovation policy: (1) to support basic research, (2) aim to develop and diffuse general-purpose technologies, (3) develop certain economic sectors that are crucial for innovation, and (4) promote infrastructural development (FREEMAN AND SOETE, 1997). This view of public policy as having a passive or reactive role in innovation, has been a characteristic of the market failure approach, as much as the evolutionary approach which limits the role of public intervention in relation to fixing system failures (LUNDVALL, 1992). This has contributed to the idea that the public sector can only facilitate change, rather than lead it. Instead, the state plays a more active role in directing resources towards a previously identified mission, in order to lead and structure the necessary transformational changes (MAZZUCATO, 2016). Furthermore, Mazzucato (2015b) points out that while the *systems of innovation* perspective have emphasized the importance in building and understanding horizontal linkages between actors, this came at the cost of neglecting the important role of vertical policies required for a *direction* of change.

Consequently, Mazzucato identifies that a crucial role of modern states, has to be their willingness to take risks and invest in markets and technologies which venture capital deems too risky. Thus, for her, the entrepreneurial state agenda has sought to challenge the notion of the entrepreneur being embodied in private business, and policy-making being an activity outside of the entrepreneurial process (MAZZUCATO, 2013a). She goes further to describe her ideas:

> "Historically, such technological and market opportunities have been actively shaped by government investment – what Mazzucato (2013a) refers to as "the

entrepreneurial state"; that is, a willingness to invest in, and some- times imagine from the beginning, new high-risk areas before the private sector does…. Business has tended to enter new sectors only after the high risk and uncertainty has been absorbed by the public sector, especially in areas of high capital intensity" (MAZZUCATO, 2016:149).

This mission oriented approach seems particularly adequate when tackling "grand societal challenges" (MOWERY, NELSON, AND MARTIN, 2010), of which global warming and environmental protection is certainly a good contemporary example. In addition, Foray, Mowery, and Nelson (2012) contrasted missions of the past, such as putting a man on the moon, with such contemporary missions as tackling climate change. They identified that due to the nature of contemporary missions of addressing broader and more persistent challenges, they require long-term commitments to the development of technological solutions (see the earlier cited Maastricht Memorandum).

At the core of Mazzucato's arguments over role of the "entrepreneurial state", lies the idea that most revolutionary innovations were enabled through early, daring, capital-intensive investment by the state. As a consequence, an important characteristic of investment in the sphere of innovation is that it needs to be "patient", i.e. able to accept that innovation requires time and is marked by high levels of uncertainty (MAZZUCATO, 2013a). This "patient capital" can come in different forms, such as the example of the German feed-in tariff (FiT) policy to support the long-term growth of renewable energy markets (LAUBER AND MEZ, 2006). On the other hand, state development banks have emerged as suppliers of 'patient' finance. They too take up the role of providing early, and risky, investments into infant or incipient technologies (MAZZUCATO AND PENNA, 2014).

It is argued that the case of clean technologies, such as renewable energy, exemplifies the need for state support in order to overcome the sunk-cost advantages of incumbent technologies, which often at times has been accumulated over a long period of time (UNRUH, 2000). Interestingly enough, the case of the energy sector also shows, that the energy industry has tended to develop by favouring the stability and reliability of the energy system over the rapid adoption of new technology (CHAZAN, 2013). In other words, established systems and stakeholders, tend to favour the status quo and thus are not necessarily inclined naturally to adopt innovative new technologies (which usually have a disruptive effect on the sector). The case of renewable energy technologies plays particularly well into Mazzucato's example of a transformative process which can benefit from mission oriented policy making and an active, participating state.

Mazzucato (2015) argues that the hurdles confronted by renewable energy technologies are seldom simply technical; instead, they are political and social, requiring greater commitments of patient capital by governments and businesses. “R&D works, but it is not enough. Nurturing risky new industries requires support, subsidy and long-term commitments to manufacturing and markets as well.” (MAZZUCATO, 2015). Consequently, she argues that these clean technologies would not develop ‘naturally’ through market forces, partly due to existing, embedded energy infrastructures, but also because of the difficulty of markets to value sustainability and put a price on waste and pollution.

In her commentaries, Mazzucato (2015b) has argued for the need to recognize the important role of public policy in the economy, as providing a direction and mission-oriented approach. More specifically, she distances herself from the traditional role attributed to public policy, as limited to facilitating, incentivizing and/or de-risking the private sector. Rather, government has been required to take risks by choosing the particular direction of change (MAZZUCATO, 2013a). Yet, as she also emphasizes, such directionality was not the product of a top down approach, but rather through decentralized groups of public agents, i.e. “developmental network state” (BLOCK AND KELLER, 2011).

As a consequence, her argument is less directed at how governments should pick or choose the technological trajectories or innovations, but in enabling an environment which emphasizes learning and adaptation in order to evade systems from getting locked into suboptimal circumstances.

2.5 Conclusion

What has become evident over the last chapter is that innovation theory has come a long way since its first formulations by Schumpeter during the first half of the 20th century.

A particularly noteworthy trend has been the evolution from a linear conceptualization of the innovation process, towards a more systemic, multilevel understanding. Representative of this, has been the concept of National Innovation Systems which started appearing during the late 1970 and particularly 1980s. This model of innovation introduced some very important ideas; the first being that the process of innovation is the outcome of a wider interaction of different agents; social, political, institutional and economic circumstances, all of which contribute and influence the direction, the effectiveness and subsequently the outcome of this process. The second idea, stems from the origin story of this innovation model, which has sought its inspiration and purpose in policy making. This has lent itself to be particularly useful when discussing and analysing public policy and/or innovation policy. Simultaneously, this suggests that the National Innovation Systems model recognizes an important role played by government in at least enabling innovation, if not outright steering and promoting it.

To shed better light on the role of government in the innovation process, this chapter has borrowed from Marina Mazzucato's concept of the "Entrepreneurial State", in order to bridge the gap between the innovation systems and a systemic framework, and mission oriented public policy. Her argument propagates an active role of government in innovation and economic transformation through a mixture of risk taking, entrepreneurial activism and directionality. This last point illustrates an important contribution made by Mazzucato. She sees herself contributing to the debate on innovation processes, by complimenting the systemic view with a proactive role of government in directing and shaping this process. The importance of this becomes clearer, when taking into account the debate on technological paradigms.

The debate on technological paradigms, techno-economic paradigms and paradigm shifts, discusses the dynamics and challenges of greater transformational changes. This is the result of a number of contributing factors, which involve institutional inertia, technological 'lock-ins', path dependency, among others. In other words, one of the great contributions of this debate has been the identification and recognition that paradigm shifts face strong economic, institutional, political and social resistance which needs to be overcome in order to succeed.

Consequently, the greater debate on technological change, innovation processes and technological paradigm shifts, necessarily involves a discussion on how to overcome hurdles and how to steer this development. In agreeing with this, Geels (2014) points out that there exists a necessity to conceive means of directly disrupting incumbent systems given their monopolisation of resources and domination of visions of what is possible and desirable, i.e. their active resistance to system change. On the other hand, Mazzucatos articulates the importance of having a state which can break with traditional structures in order to allow for more transformational and revolutionary changes in the economy. This, as she puts it, does not necessarily imply a policy approach which disregards the possibility of diversity but instead incentivizes overall openness to trial and error. Schot and Steinmueller (2017, p.18) points out that "…this means that a fundamental transformative change is required, one that involves the democratising of control over innovation production and diffusion and the creation of negotiation spaces or market niches for alternative technologies to become established, capture imaginations and win constituencies among actors that would otherwise be excluded."

3 Chapter II

3.1 Introduction

This chapter's objective is twofold: on the one hand, it will introduce the *Energiewende*, its main objectives, areas of activity and its current progress. This will be done, not only to familiarize the reader with the policy, but in order to illustrate the complexity, vastness and more importantly inter sectorial nature of the energy transition. It hopes to show that the *Energiewende* is a complex broad transformative project consequently depending on a mirage of stakeholders and institutional structures which determine its success.

On the other hand, the chapter will outline some important elements of the German National Innovation System which contributes to the successful implementation of the energy transition. The innovation system approach offers itself for analysing the contributing institutional structure for this energy transition, as it recognises the multidimensional nature of such radical innovations. In other words, the decentrality of this process, together with the necessary interaction and synergy between different elements of a country's economic and institutional framework, are an essential component of the NSI concept.

It is important to note, that the exercise of this chapter is focused on providing a sense of the complexity and diversity of the policy goals, instruments and actors which contribute to this transitory process. In other words, it is a transformation of systemic proportions, which can only be pursued and understood as a systemic effort.

On the other hand, this chapter aims to provide the basis for a more specific discussion of the challenges of implementing the energy transition, with the example of promotion of renewable energy in Chapter Three. In addition, it will allow for a more in depth analysis of the progress and difficulties of this paradigmatic shift.

3.2 German National Innovation System

As discussed in the previous chapter, the National Innovation System is composed of a multitude of elements and interactions between different agents. In light of this, the following section will highlight some of these elements of the German National Innovation System which contribute to the process of the *Energiewende*. The section will begin by illustrating some aspects of the German political system which characterize the political decision making process in the country. Next, some important political institution will be presented, focusing on the main ministries involved in implementing the different policy areas involved in the energy transition. Finally, this section will outline some of the main elements involved in research and education, which contribute in generating knowledge and identifying new solutions to the challenges faced by the Energiewende, along with educating and training the workforce for the requirements associated with this economic shift.

3.2.1 Political System

When analysing the German National Innovation System, particularly in the context of the *Energiewende*, one needs to have a basic understanding of the country's political system. In this sense, special attention should be paid to the nature of political decision making and the process through which legislation is passed.

Germany is a federal democracy, divided into 16 regions or *Länder* (the equivalent of states). The federal laws apply to the whole of Germany, while other laws are only applicable to the *Länder*. In tune with Article 31 of the Basic law, federal laws take precedent over *Länder* laws.

The country's pattern of political decision making can be considered as a voting-system which combines characteristics of the British, winner-takes-all approach iconic with Anglo-Saxon countries, combined with a proportional representation system which enables small parties to enter parliament (THE ECONOMIST, 2013). In Germany, the vote is divided into two parts, one for district representative (of which there are 299 districts), and one for choice of political party. If parties pass the 5% threshold, they occupy their share of second votes.

Legislative Process

The German political system is characterised by a high number of veto opportunities through the two-chamber parliament system consisting of the *Bundestag* and *Bundesrat*, the coalition government, comprehensive judicial review by a strong constitutional court, continuous election campaigns resulting from the federalist system and a corporatist tradition. All of this causes radical policy changes to be a rarity and hinders reform processes. Aside from these institutional constraints, the nature of the federal system provides greater opportunities for interest groups to influence policy making, often resulting in a greater necessity for interest mediation during the legislative process.

In the first chamber of parliament, the *Bundestag*, incumbent parliamentary groups typically provide a reliable and sufficient majority for governmental law proposals, due to fairly high group discipline. The Bundestag is therefore only ascribed with low veto power, if any (TSEBELIS, 1995; SCHMIDT, 2007), thus considered "not a veto point due to majority governments and strong party discipline" (SCHULZE AND JOCHEM, 2006).

The *Bundesrat* is the second chamber of parliament and represents the governments of the 16 *Länder.* Each state government appoints a number of representatives ranging from three to six, relative to population size and privileging smaller states. The *Bundesrat* has 69 members, in which an absolute majority of 35 members is needed to pass a decision.[3]

When analysing the actual legislative process, a particular dynamic is worth noting, as the entire process follows a set pattern: after legislative initiatives are passed by the *Bundestag*, the *Bundesrat* is given an opportunity to vote on the legislation. Should a law not pass in the *Bundesrat*, a mediation committee[4] (*Vermittlungsausschuss*) is convened in order to find a compromise. In the case of *mandatory consent* legislation, should the committee fail to agree on a compromise, the legislation process will be stopped. On the other hand, in the case of *non-mandatory consent* legislation, the absolute majority of the *Bundestag* can overrule the rejection, resulting in the law coming into force.

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[3] Abstentions from voting are considered as 'No'.

[4] The Mediation Committee consists of 16 members of the Bundesrat and an equal number of Members of the Bundestag who are appointed according to the relative strengths of the parliamentary groups.

3.2.2 Ministries

When discussing the political system, one cannot overlook the central role played by the different ministries in conducing the energy transition by coordinating, influencing and implementing policies. They are an essential element not only in the application of policies and laws, but also in their formulation. This latter aspect is worth some further elaboration. Much of the legislation passed by parliament relies on and is elaborated by the ministries responsible for topic. Their bureaucratic structure, guarantees them greater access to know-how and specialists, which becomes increasingly relevant with the growing complexity of policy initiatives. In response, this means that the ministries' policy proposals have a greater chance of being successfully implemented.

On the other hand, as mentioned before, one of the major responsibilities of the ministries lies in the implementation of policies and the pursuit of wider development strategies. While there are a multitude of ministries responsible for different areas of the county's economy, an essential characteristic of this institutional landscape is 'policy overlap' i.e. ministries may directly or indirectly be responsible for policy areas which overlap. Of course, this has the desired effect of incentivizing ministries to collaborate and develop joint strategies on how to best pursue certain policy outcomes. On the other hand, these overlaps of responsibility can provoke competition between different ministries, and have allowed for the monopoly over policy areas by certain ministries to be broken.

A curious example of this can be observed in the area of energy policy and more specifically renewable energy. While this example will be explored in more depth in Chapter Three, it can be said that rivalling views between the Environmental and the Economics Ministry characterized much of the policy debate at the time. This example is also interesting, as it will show how the responsibilities of the ministries can shift, in response to party politics and coalition government agreements.

In the following section, a number of ministries will be presented in more detail. The examples chosen pursue policies which directly align with the goals of the *Energiewende* and/or contribute to the production of scientific knowledge and innovation which does so. In this sense, the following exposition serves the purpose of illustrating the diversity of pursued policy initiatives, the policy overlap between the institutions and gives a sense of the scope of policy initiatives necessary to implement such a vast project as is the case of the 'Energiewende'. The three ministries which will be explored are The Federal Ministry for the Environment, Nature Conservation, Building and Nuclear Safety (BMUB), Ministry for Economic Affairs and Energy (BMWi), and Federal Ministry of Education and Research.[5]

The Federal Ministry for the Environment, Nature Conservation, Building and Nuclear Safety (BMUB)

An important institutional structure for environmental policies was established with the creation of the environmental ministry in 1986, as a response to the Chernobyl catastrophe. Through this institutionalisation an important and influential actor was created who has had direct influence on energy policies. This was particularly true during the period between 2002 and 2013, when the competences of renewable energy development were transferred from the Economic Ministry to the Environmental Ministry (HIRSCHL, 2008).

Since 2013, the ministry has been responsible for urban development, housing, rural infrastructure, public building law, building, the construction industry and federal buildings. The ministry is responsible for overviewing some of the previously described policy initiatives which deal with energy efficiency of buildings (new buildings and renovations), urban planning and energy consuming products. These areas have become particularly important as part of the effort to advance the energy efficiency objectives of the Energiewende.

In addition, the ministry also has funding for research and development. In particular, it supports the market launch of innovative technologies by financing or co-financing (often in cooperation with the KfW bank) pilot and demonstration projects. In the case of renewable

[5] This list of ministries is not exclusive and as a consequence the contribution of other ministries towards the Energiewende should not be underestimated. In this sense, particular mention should be made of the Federal Ministry of Finance which is responsible for establishing the annual budget of the different ministries, consequently having the power to accentuate certain areas of importance, and the Federal Ministry of Transport and Digital Infrastructure, which among other things, play a key role in guaranteeing the infrastructure for the successful digitalization of the economy and the deployment of e-mobility.

energy, in the past the ministry had been involved in supporting various demonstration projects for photovoltaics going all the way back to the late 1980s. These economic support programmes are financed through taxes and revenues from emissions trading. Funding is available to the general public, associations, companies and municipalities to obtain financial support for specific projects.

Finally, as implied earlier, the ministry plays an important role in preparing policy initiatives for the government and overseeing the energy transitions progress. The former is best exemplified through the *Klimaschutzplan* 2050 (Climate Protection Plan 2050) in which the ministry organized and elaborated a roadmap for carbon neutral economy until 2050, while the latter can be illustrated through the annual *Klimaschutzbericht* (Climate Protection Report)[6].

Ministry for Economic Affairs and Energy (BMWi)

The ministry sees its central task in "reinvigorat[ing] the social market economy, stay innovative in the long term and strengthen the social fabric in Germany" (BMWi, 2017). More specifically, the ministry sees its responsibility in a wide range of activities including: stimulating public and private investment, fostering a scientific infrastructure to support the development and deployment of lead technologies, promote infrastructural modernization, improving vocational training. In terms of the Energiewende, the BMWi is the primary institution responsible for coordinating, planning and evaluating the progress of the energy transition. This is partly the consequence of the ministry's role in promoting renewable energy expansion.[7] In addition, the institution focuses on advancing energy reforms focusing in equal measure on climate and environmental sustainability, security of supply and affordability (BMWi, 2017).

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[6] Through this report, the ministry evaluates annually the progress of the *Aktionsprogramm Klimaschutz 2020* (Action Plan Climate Protection 2020) which articulates initiatives in order for the country to cut carbon emissions by 40% (compared to 1990 levels) by 2020.

[7] During 2002-2013, the responsibility for renewable energy had been shifted to the environmental ministry. With the new government in 2013 responsibility was given back to the BMWi.

The BMWi divides its activities into three areas of activity Energy and Sustainability, Innovation, Technology and New Mobility, and SMEs. While all areas contribute in different ways to the goals of the Energiewende, the former two are of particular interest.

Energy and Sustainability

In the area of energy and sustainability, the ministry has allocated a budget of 2.6 billion euros for 2017. This includes a budget of 466 million euros for research and development, focusing on energy efficiency, renewable energy and safety for nuclear reactors. In addition, an initiative for increasing energy efficiency has been allocated 41 million euros in addition to the already available funds provided through the energy and climate fund (*Energie- und Klimafonds* – EKF).

This is also the case for funds allocated to the MAP program which, among other things, promotes the application renewable energy for heat generation, especially from geothermal and biomass. Also, 455 million euros are being made available to the KfW promotion program for energy efficient construction and renovation called “CO2-Gebäudesanierungsprogramm" (loosely translated into CO2- building renovation program). In addition, it should be noted that a considerable 1,162 million euros has been allocated to subsidise the phasing out of hard-coal and the renovation and recultivation of these coal mining areas.

Finally, the ministry is responsible for the Federal Network Agency for Electricity, Gas, Telecommunications, Post and Railway (BNetzA). One of the primary tasks of the Federal Network Agency is to regulate electricity and transmission grids. This includes the approval of network fees and integration of electricity producers. Since 2011, the Federal Network Agency has also been responsible for the faster expansion of the electricity grid through implementation of the *Grid Expansion Acceleration Act*.

Innovation, Technology and New Mobility

With an overall budget of 2.7 billion euros the ministry finances initiatives that include market integration programs for promising emerging technologies, support for innovation and technology transfer, investment in research, development and application of new mobility technologies and digitalisation. Overall, a substantial budget is reserved for supporting activities in research and development with a particular emphasis on application. These include efficient energy conversion research such as fuel cells and hydrogen (alternative fuel sources).

Specifically, in relation to electric mobility, the ministry's target is to make the country a market leader for electric mobility. Part of this goal is to have 1 million electric vehicles on German roads by 2020. In order to succeed, the ministry is implementing temporary purchase incentives, additional funding for the expansion of the charging infrastructure and more efforts regarding the purchase of electric vehicles by public authorities.

Federal Ministry of Education and Research

In short, the ministry is responsible for promoting education and research. For its budget of 2017, the ministry's budget has been increased to 17,6 billion euros. Nonetheless, some of its earliest activities of public research into alternative energy sources can be traced back to the 1970s. In particular, in 1972 the ministries responsibilities were restructured introducing a number of key areas of activity such as technology, development and innovation, and nuclear technology and research. Part of this reform meant that the ministry promoted the research and development of renewable energy considerably (NITSCH, 2007). This promotion of non-nuclear energy began as part of the "Energy research framework program" and gained continuity ever since (BRUNS ET AL. 2009). [8] In this sense, the ministry research emphasis has been on photovoltaics, followed by wind energy (HIRSCHL, 2008). In addition to research, the ministry has played an important role in financing and organizing pilot and demonstration projects. These have been crucial in helping establish and support a number of research institutions, but also for the emergence of companies (to supply the demand for these technologies).[9]

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[8] For example, in response to as the government pursued the goal of accelerating the process of substituting fossil fuels with other sources of energy through the "First energy research program" (1977-1980) in response to the oil crises (NEU, 2000).
[9] In this regard, particularly the 100 MW-Programm (later increased to 250MW) for wind energy and the 1.000 roofs programm for phovotoltaics in 1989 are prominent examples (HIRSCHL, 2008).

With regard to education, even though German school and university education is mainly dictated by the Länder, the federal ministry supports these areas through funding and scholarships. In the field of vocational training, training assistance and continued education, the federal government shares responsibility with the states.

A particularly important role is played by the ministry when it comes to research. The implementation of a 'High-Tech Strategy' aims at making Germany a leader in providing scientific and technical solutions to the challenges in the fields of climate/energy, health/nutrition, mobility, security, and communication. In addition, the Excellence Initiative and the Pact for Research and Innovation are supporting the existing research community and promoting young research talent.

3.2.3 Financing

Providing financing to various aspects of the Energiewende, the KfW Development Bank plays a crucial role within the greater German economy, and the Energiewende in particular. The bank was initially founded in 1948 to support the reconstruction of war-torn Germany after World War II as part of the efforts of the Marshall Plan. Today, the bank's domestic programs are developed either on demand from the government (including government subsidies) or through their own assessment of market needs. Nonetheless, the bank requires approval by the Environment Ministry and the Economic Affairs and Energy Ministry.

The KfW plays an important role in financing the major energy transformation associated with the *Energiewende*. In this sense, its domestic activities include financing Small and Medium Enterprises (SMEs), start-ups (primarily investments including innovation, as well as climate and environmental protection within companies, such as renewables and energy efficiency), private customers (including energy-efficient construction and refurbishment of residential buildings, renewable energy), as well as municipalities to finance communal infrastructure and environmental protection.

To succeed, the bank's main financing mechanism is the provision of loans at cheaper interest rates possible through the bank's triple AAA credit rating. This has allowed them to cheaply access funds from capital markets. Nonetheless, the bank loans are not given distributed, but instead through financial intermediaries (*Hausbankprinzip*). These financial intermediaries assume the risk, and consequently they have a contract with both, the KfW specifying the terms of the loan and with the client (GRIFFITH, 2015).

To contextualize the bank's impact, in 2014, the KfW Group held assets worth 558 billion dollars making it one of the largest development banks in the world. Its role in the energy transition has been staggering, having covered at least one third of total funding of the Energiewende in Germany. This proportion was at times even higher: in 2012, the bank funded $11.4 billion of renewable investment, which represented over 50% of renewable investment in Germany, and over 50% of solar PV in the country. In fact, during 2007-2009, all investment in solar PV was funded by the KfW (GRIFFITH, 2015).

3.2.4 Research and Education

A discussion focused on the German National Innovation System would not be complete without taking into consideration its institutional landscape of higher education and research. This aspect of the country's NIS is renowned for pushing the barrier of scientific knowledge and an exceptional output of innovation, but also for providing the country with highly trained human capital. In this sense, the following section will highlight some characteristics of the German university system, in order to consequently investigate the country's network of research institutions and associations.

3.2.4.1 Education: Universities and Vocational Training

The success of the German energy transition, as well as the effectiveness of the countries innovation system ultimately depends on the economy's access to a workforce which is qualitatively and quantitatively adequate. In other words, having access to skilled professionals is key to innovation, competitiveness, growth and employment. Nonetheless, there are growing concerns over the lack of graduates, particularly in the fields of science, technology, engineering, and mathematics. This lack is being felt as much in the technical professions as in the academic/research sector. Consequently, this skilled workforce is the backbone of the country's industry, as well as its scientific and technological research institutes.

An essential element of the German NIS which has traditionally addressed the industry's continuous need for skilled professionals, has been its renown system of vocational education and training (VET). As a quote by Schmoch et al. (2006) illustrates, it is often merited for contributing to the country's economic success: " In terms of the NIS, VET schemes in Germany provide firms and industries with workers with the skills that can help to maintain competitive advantages." In its earlier form, these training programs were organized by the large industrial companies themselves. While today the government has taken over organizing and standardizing the VET, "…[t]he input of employers in designing training programs has remained a key feature of the system and has ensured the continuing relevance of the skills provided by it" (SCHMOCH ET AL., 2006).

The Federal Ministry of Education and Research (BMBF) together with the Federal Institute for Vocational Education and Training are principal institutions responsible for the VET. Together with employer and employee representatives (unions etc.) they establish the broad parameters within which the different actors operate.

The VET represents a vocational training and education system, which emphasizes a very practice oriented learning process. One of its most emblematic characteristic being its principle of dual training. This dual system promotes for collaboration between companies and teaching institutions, during the implementation of learning curricula, as much as during its creation. In other words, companies participate in the education of the students, as much as in the creation and adaptation of new teaching curricula. Together with the ministry's efforts to standardize and universalize the certification, the quality and broad acceptance of the VET is guaranteed across industries. All of this has played an integral role in guaranteeing that the German economy has access to a well trained, practice oriented workforce.

As a consequence of the growth of the renewables industry, the VET has been tweaked and altered regularly in order to respond to the new sectors' demands. Yet overall, the implications of the *Energiewende* is putting pressure on the vocational system to adapt to future demands. It will require the combination of new skills, such as combined expertise in energy and IT, as well as expertise in technical branches, such as renewable energy production, power supply management, smart grid transmission, storage technology, cogeneration, and e-mobility, among others. Consequently, through the VET, the country must train and retrain its workforce to handle this complex transition.

On the other hand, Germany has a long history of higher education and its system has undergone some substantial transformations. Today Germany has a proximately 240 state institutions and 139 private institutions for higher education, of which 207 are universities of applied science. This illustrates two interesting characteristics of the German system: on the one hand, higher education is predominantly public, having enrolled 95% of students. On the other hand, the country has always shown a tendency towards hard and applied natural sciences and technical sciences (this is further exacerbated by the VET system) (KEHM, 2012).

In order to strengthen universities international competitiveness and quality, the German government adopted the *Bologna reforms*[10] and an *Initiative for Excellence*[11] . These efforts aimed at addressing two major issues: "While the solution for the problems in teaching and learning is sought in the implementation of the Bologna reforms, the solution for the problems in research was sought in a steeper stratification of the system by identifying top research universities and providing them with considerable extra funding. (KEHM, 2012, p.94)"

In relation to the efforts of the *Energiewende*, the university system fulfils a dual role: firstly, similar to the VET, the universities contribute to the supply of skilled professionals for the private and public sector. And secondly, these institutions of higher education

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[10] Through this, an undergraduate- graduate system was introduced leading to a major overhaul of existing curricula, ultimately enabling the creation of a tertiary degree structure (with undergraduate and graduate programs).

[11] With the implementation of the *Initiative for Excellence* a vertical differentiation within the German university landscape was pursued, as an attempt to increase the quality of research conducted. As a consequence, a number of universities were identified to receive additional funding, with the ultimate goal of improving their research quality and international competitiveness.

significantly contribute to research in a great number of areas important for the energy transition. These encompass as much traditional natural sciences, as well as social sciences and the arts. As the *Energiewende* represents a systemic project, it benefits from ideas in areas as wide as urban development, architecture, physics and chemistry and IT, among others. Thus, the German university system is an important contributor to informing and transforming the strategies of the energy transition.

3.2.4.2 Research Institutions

Aside from university efforts in the sphere of research, Germany has a sophisticated network of research institutions. These cover a wide range of research demands, with particular attention paid to bridging the gap between basic and applied research while balancing public and private funding. The latter point is also illustrative of an emphasis in creating public-private partnerships, and aligning research efforts to industry demands, while at the same time not neglecting the need for basic research.

There are an abundance of research institutions and associations which make up this institutional landscape, such as the Max Planck Society, Hermann von Helmholtz Association of Research Centres and the German Research Foundation (DFG), to name just a few. Yet to better understand how these institutions contribute to the efforts of the Energiewende, it is helpful to exemplify this by analysing a specific institute. Consequently, the following section will give a brief overview of the activities of the Fraunhofer Society focusing on areas particularly relevant to the energy transition.

The Fraunhofer Society evolved from an institution initially focused on a largely advisory and administrative role channelling public funds to researchers, to an institution which performs its own research. Today it is one of the leading institutions for applied research in Europe, containing 69 institutes and research units throughout Germany and employing a staff of 24,500 (FRAUNHOFER, 2017). In 2016, its research budget totalled 2.1 billion euros. Its links to industry are purposely stronger than those of other research institutes in Germany and it tries to bridge a gap between these two spheres. In other words, the institute aims at focusing on more applied research compared to most universities and other research institutions, but more basic research than that commonly found in companies. Through its different research units, the Fraunhofer covers a wide range of research areas. In regards to the Energiewende, the Fraunhofer Institute for Systems and Innovation Research (ISI) and Solar Energy Systems (ISE) are particularly noteworthy (FRAUNHOFER, 2017).

The Fraunhofer Institute for Solar Energy Systems (ISE)

The institute was founded in 1981 as the first non-university-affiliated solar energy research institute in Europe. Today, with a staff of 1,150 it is also the largest solar research institute in Europe. The ISE develops technical solutions to use renewable energy sources economically and to increase energy efficiency, while focusing on a holistic, systemic approach. Its research focuses on energy conversion, energy efficiency, energy distribution and energy storage. In these areas, the institute is involved in investigating and developing materials, components, systems and processes (FRAUNHOFER ISE, 2017).

The Fraunhofer Institute for Systems and Innovation Research (ISI)

Since its inception in 1972, Fraunhofer ISI has been influential in shaping the German innovation landscape. The ISI is one of the leading innovation research institutes in Europe focusing on an integrated analyses of technology developments and society's needs, in order to suggest systemic solutions. In other words, the institute considers socio-technical and socio-economic framework conditions in order to contribute to developing solutions that help to tackle the overarching societal, ecological and economic challenges. Its work offers political and industrial actors strategic consultation. As an example, the ISI studies electric mobility. Specifically, it conducts research in areas such as market evolution scenarios, new mobility concepts and business models, user acceptance in the private and commercial sectors, among others (FRAUNHOFER ISI, 2017).

3.3 The Energiewende

The *Energiewende* is a term describing a long-term 'mission' oriented policy by the German government to transition its energy system and consequently the economy towards a low-carbon, low-emission system. The principal political objectives of this project are:

"…fighting climate change (through a reduction of CO_2 emissions), phasing-out nuclear power, improving energy security (through a reduction of fossil-fuel imports) and guaranteeing industrial competitiveness and growth (through industrial policies targeting technological, industrial, and employment development). (AGORA, 2017, p.9)"

The term *Energiewende* roughly translating into *energy transition*, illustrating the central role which a transition of the current energy system takes within this greater transformative process. In addition, an important characteristic of the energy transition is its ambitious and concrete mid- and long-term targets, encompassing all energy sectors (electricity, heat, and transportation), and going as far forward as 2050.

While the *Energiewende* has gained much attention over the last years, its origins can be traced back to the 1970-80s in the form of public opposition to nuclear power, the sustainable development movement and climate protection. In terms of policy impact, the 1986 Chernobyl disaster marked a turning point in energy policy, through the discontinuation of the construction of new nuclear power plants with in Germany. These controversies, especially in relation to nuclear energy, triggered a search process for alternative energy paths which were of fundamental importance for today's *Energiewende*.

In terms of policy initiatives, the 2002 *Energiewende – Atomausstieg und Klimaschutz* (energy transition – nuclear phaseout and climate protection) conference can be regarded as the starting point for this energy transition policy. From that moment on, the process no longer included only the electricity industry, but also the mobility sector, the heat market and energy efficiency gained significant attention as fields of activity (BRUNS ET AL., 2009).

As such, the energy transition is best understood as a dynamic formation process, instead of the centralized application of a grand master plan. Not until recently, this mission was lacking a holistic formulation (or approach) of this transition effort. As a response, in 2010 the German government published a long-term strategy paper, in which it called for a low-emission economy by 2050. This report was known as *Energiekonzept* (energy concept) and it articulated a framework and roadmap to implementing the *Energiewende*.

The plan is to develop a virtually emission-free energy supply by 2050, by setting the ambitious target of reducing GHG emissions by 80-95%. In order to do so, the transformation of the current energy system is based on two pillars: increased energy efficiency in all sectors and mass deployment of renewable energy technologies. At the time of its publication the goals formulated in the Energiekonzept had been unrivalled on the international stage. It demonstrated the government's commitment not only to a long-term horizon, but also more ambitious targets than EU lead targets (20-20-20)[12].

The Energiekonzept (energy concept) formulates the vision of Germany becoming one of the most energy efficient and environmentally friendly economies of the world, while maintaining competitive energy prices and a high level of welfare. Furthermore, the paper recognises that these goals are a central prerequisite for maintaining Germany as a competitive industrial country in the long run (BMWi, 2010, p.3).

The paper illustrates the government's desire to articulate a framework for the energy transition, while emphasizing the importance to maintain flexibility, in order to adapt to changes in technological and economic development (BMWi, 2010, p.3). This is to be accomplished by pursuing an ideology free, technologically open and market oriented energy policy, which includes multiple sectors and dimensions such as electricity, heat and transport. Consequently, it is recognized that the approach necessarily needs to integrate a wide range of different components into an overarching strategy.

3.3.1 The Pillars of the Energiekonzept

The Energiekonzept report identifies eight different areas of action, which encompass energy efficiency, R&D, renewable energy and nuclear energy, among others. The following section will outline some of the main policy goals associated with these eight areas, mentioned in the report.

[12] The "20-20-20" represents goals formulated by the European Union that its member should increase the participation of renewable energy to 20% of overall consumption, reduce emissions by 20% (compared to 1990) and improve energy efficiency by 20%.

Renewable energy

One of the most successful pillars of the energy transition, has been the dissemination of renewable energy technologies and its growing importance within the overall electricity sector. Consequently, the *Energiekonzept* report aims at continuing the growing diffusion of these technologies, while at the same time tackling some of the challenges identified over the last decade. These challenges among other things involve:

- Strengthening the use of renewable energy for generating heat;
- Ensuring a cost efficient expansion of renewable energy;
- A better integration of RE into the energy supply system;
- The greater expansion of off-shore wind energy;
- Improving the development and support for storage technologies.

As a consequence, the continued expansion of RE is the goal, with particular attention being paid to strengthen the pressure on innovation and cost reduction.

Energy efficiency

In terms of energy efficiency measures, the government aims to focus its efforts on creating economic incentives and improving access to information and consultation. This is hoped to increase business and private consumer's motivation to utilize the potential of energy efficiency to save on costs.

The report exemplifies this by citing an economic study which identified an annual savings potential within the German industry of 10 Billion Euros spent on energy. Consequently, part of the efforts will also concentrate on supporting individual initiatives by the industry to invest in energy efficiency (BMWi, 2010). Part of this overall effort will be met by improving the effectiveness of low interest credits and subsidies for efficiency measures by the SMEs.

Nuclear energy and fossil fuel

The government recognises the future challenge of adapting the traditional electricity market design to a future in which renewable energy sources will play an ever more dominant role. This inevitable reorganisation will be identifying the changing role played by conventional energy sources, the need for energy conservation, balancing and backup energy markets as well as wider European market integration.

Part of this effort includes prolonging the operating period of operational nuclear power plants by an average of 12 years up until 2032[13], and negotiating an agreement with the owners of these plants to utilize the access profits resulting from this extension to finance *Energiewende* related efforts. Sufficient investments need to be made in reserve and balancing capacities, particularly through more flexible lignite and gas power plants (BMWi, 2010).

The government plan also identifies carbon capture and storage (CSS) technologies as a potential element to contribute to the reduction of CO2 emission. Particularly the exploration of CSS technologies for future exportation is mentioned as a motivating factor.

Grid Infrastructure for Electricity and Integration of Renewable energy

In regards to the necessity of new investments into infrastructure, the government recognises two spheres of action: the need to expand current grid infrastructure, particularly in transmission, and upgrade/modernise existing grids in order to allow for a "smarter" infrastructure. In order to accomplish this, the government aims to identify incentive mechanisms and planning measure to accelerate this investment into the grid.

While in the transmission sector, some concrete plans have already been articulated, such as the need to increase the countries North-South connection, the issue of 'smart grids' and demand management were still being explored. In this sense, the government articulated the need to experiment and investigate a roadmap for the modernisation of the grid, taking into account the need for better and greater reactiveness of distribution grids. Nonetheless, the report recognises the central role that digitalization and information technologies will play in the future (BMWi, 2010).

A greater extension of this grid infrastructure will also be crucial in the process for greater intra-European electricity integration.

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[13] Originally the phase out of nuclear energy was set to 2022, the year in which the last of the nuclear reactors would be taken offline.

Energy building renovation and energy efficient construction

Another central area which the report identifies as a priority, is the increase of energy efficiency in buildings through renovation. The goal being that by 2050, nearly all buildings in the country are 'climate neutral'. That is to say, buildings only require a very small amount of energy which they predominantly generate from renewable energy technologies.

To enable this change, the government articulate the need for an appropriate and reliable legal framework, time and money. To that effect, the existing policy instruments (the EnEV and EEWärmeG)[14] have been deemed insufficient, thus policy action is required. Nevertheless, the government emphasizes its goal to rely on incentives to renovate, rather than obligation (BMWi, 2010).

Mobility

In the case of mobility and transport, the report clearly states the goal of having one million electric cars by 2020, and 6 million by 2030. In addition, a strong emphasis is put on fostering the development of a national innovation program for hydrogen and fuel cell technologies (BMWi, 2010).

Furthermore, the government recognises the importance of articulating well defined efficiency goals for new vehicles in order to guarantee planning security for the economy, and to incentivize more CO2 efficient cars. A funding initiative will also be implemented with the goal of developing and testing technologies for the production of so called second generation biofuel. This will contribute to the government's goal to continue increasing the biofuel component in fuel.

Energy Research for Innovation and new Technologies

Another important pillar of the energy transition identified in the report, was the central role of research and innovation. The government reinvigorates the need for not only basic research, but particularly applied research and development into renewable energy and efficiency technologies. The emphasis lies in accelerating the transition from development

[14] more details in the next section.

to market introduction. These efforts aim to reduce the cost of existing energy Technologies, as well as identifying and developing new Technologies for future implementation.

Through greater financial commitment to research and development, the German government hopes to guarantee a leading position for German companies in the near future. In addition, the government plans to articulate a comprehensive energy research program for the period up to 2020. Part of this effort will be the further development of application oriented research, while at the same time expansion and greater networking of the national research institutes.

In order to guarantee an integrated energy research policy, the government will expand the *Koordinierungsplattform Energieforschungspolitik* (coordination platform for energy research policy). This aims at coordinating efforts among different federal institutions, funding activities of the Länder and from European funding institutions (BMWi, 2010).

Finally, the report recognises the importance of maintaining high quality levels in research and particularly in the capacity building and education of professionals in the area of engineering and natural sciences.

Energy supply within the greater European and international context

In regards to international pursuits of greening the economies and promoting greater cooperation, the German government sees its role in helping emerging economies formulate effective 'energy transition' action plans. As the report states, this is seen as an important attempt of encouraging the creation and development of new markets for 'green' technologies.

On the other hand, greater integration of the European energy markets is seen as an integral element in guaranteeing the successful and efficient transition towards a sustainable energy sector. This involves not only investments in better grid integration among the member countries of European Union, but also the articulation and implementation of regional policy instruments, such as the European Emissions Trading Scheme (EU-ETS).

Transparency and Acceptance

Finally, the report recognises the importance of making the *Energiewende* a participatory process which is characterized by transparency and a broad popular consensus. This societal participation is to be achieved through convening different stakeholders from all areas of society to participate, inform and accompany the decision process. One activity to promote this, will be achieved through the creation of an online information and dialog platform called *nachhaltige Energieversorgnung* (sustainable energy supply), monitored and run by the federal economics ministry (BMWi, 2010).

This last point on the need for public involvement and transparency should not be underestimated. As mentioned before and as will be argued further in the discussions to come, the participation of the public in different aspects of the *Energiewende* is considered a major characteristic of its success. Sonnenschein and Heinnicke (2015) emphasize this when they write:" And let's not forget that the active participation of citizens – resulting from the democratization and decentralization of the energy system – is by no means a nice-to-have side-effect, but the key pillar on which the *Energiewende* and its public acceptance."

3.3.2 Policies for the Energiewende

As mentioned before, the energy transition needs to be understood as a multi-faceted policy effort necessarily involving various dimensions. Consequently, it is difficult to identify a singular 'Energiewende policy' which would summarize all policy efforts. While the *Energiekonzept* report described previously, sets goals and identifies strategic areas, the actual implementation of the energy transition is pursued through a wide range of different policy instruments. As mentioned previously, the energy transition follows two basic objectives: the increase of renewable energy and energy efficiency. The following section will begin by presenting some of the most important policies and programs related to the 'greening' of the electricity sector, i.e. expansion of renewable energy. This will consequently be followed by a brief overview of other important policies related to energy efficiency, in order to illustrate the systemic and widespread nature of the *Energiewende*.

Renewable Energy Act with feed-in tariffs and auctions

The principal policy tool utilized to progress the primary pillar of the *Energiewende* - the dissemination of renewable energy technologies - was the feed-in tariff (FiT), or more specifically, the Renewable Energy Act (EEG). An initial version of this incentive mechanism was introduced in the early 1990s as the *Stromeinspeisungsgesetz* (StromEinspG). Yet, it was the 2000 reform which implemented the now famous EEG and ushered in a new dynamism in renewable energy diffusion.

In a nutshell, the policy implements a remuneration for electricity generated by renewable energy systems (i.e. a feed-in tariff), whose remuneration rate is differentiated between renewable sources and system sizes, revised on a regular basis and with the law undergoing a review and amendment process every 3-4 years.[15] In addition, renewable energy sources are guaranteed access to the grid, grid operators are required by law to purchase renewable power, and the remuneration levels for approved systems are guaranteed for 20 years.

The rationale behind determining the feed-in tariffs is quite straightforward: the cost of a system per kilowatts-hours is determined by taking the cost of a particular system and dividing that by the number of kilowatt-hours the system can reasonably be expected to generate over its service life (generally 20 years). To that is added a return on investment (ROI), which in the case of Germany is usually targeted at around five to seven percent (MORRIS AND PEHNT, 2016). As mentioned before, a "degression rate" (i.e. scheduled tariff reductions) is established for the different renewable system types, depending on the maturity of the different technologies.[16] The costs of paying for the feed-in tariffs is passed on to electricity consumers. This is done through a surcharge on electricity consumed which in 2016 amounted to 6.4 cents per kilowatt-hour, or nearly a quarter of the retail power price (MORRIS AND PEHNT, 2016).

Another important element of the EEG is its outcome oriented approach. Since its implementation, the law has articulated specific renewable energy goals to be met at specific

[15] Some details of the policy have changed over time, but this will be discussed in further detail in chapter 3.
[16] The mechanism utilized to determine the rate of degression has also undergone major changes, which will also be revisited in the following chapter.

deadlines. These have changed and adapted with the success of the policy, and today aim for the country to get at least 40 to 45 percent of its power from renewables by 2025, and at least 80 percent of its power from renewables by 2050. This constitutes a legal requirement for the government to attain specific levels of renewable energy diffusion.

Nuclear phase-out

An integral part of the energy transition in Germany, has been the debate over the role nuclear energy will play in it. A strong impetus for the whole motivation behind transitioning into a 'greener' economy has always been a particularly strong opposition within the population towards nuclear energy. Thus a phase out of nuclear has been a serious political goal since the 1980s, with the ascension of the "Greens" into parliament, and with the support of the Social Democrats (SPD) after the Chernobyl catastrophe in 1986.

A "Nuclear Consensus" struck in June 2000, between the then red-green[17] government of Gerhard Schröder and Joschka Fischer with major stakeholders (including the four big energy companies EnBW, RWE, Eon, and Vattenfall of Sweden) represented a binding decision for the abandonment of nuclear energy and a roadmap for retiring the existing nuclear reactors (BRUNS ET AL., 2009). The agreement stipulated an average service life of 32 years for nuclear plants, fixing 2022 as the years in which the last reactors would be shut down. At the time, the country had 19 nuclear plants with commissions that had not expired.[18]

As of 2016, the country had closed eleven of its 19 reactors still in commission in 2000. In 2017, the German government reached an agreement over how and what would be done with the final waste repository, after the last nuclear plant will go offline in 2022.

Other Energiewende Initiatives

[17] Social Democrats (red) and Greens (green).

[18] An attempt was made in 2009, under the new conservative government of Christian Democrats (CDU) and Liberals (FDP), to alter the 2000 accord by prolonging the phase out date. The law was passed at the end of 2010 but strong popular opposition to these plans, amplified through the Fukushima Daiichi nuclear catastrophe in Japan, pressured Merkel Government to double back on her plans. Consequently, the government reinstated the original phase out timeline and in addition commanded the immediate closure of eight nuclear plants.

As mentioned before, the Energiewende encompasses a wide variety of sectors and thus, such a systemic transformation requires a broad range of policies to address these changes. While the previous section emphasized some of the policies which affected the transformation of the German electricity sector, there exists a great majority of policy efforts focused on energy efficiency and heat generation, among others. Table 1*: Important Energiewende Policies* offers a brief overview of some of the more prominent initiatives passed by the German government, in order to accomplish its ambitious goals.

While the environmental taxation and emission trading focus on incentivizing (through pricing and/or taxation) changes in demand, the Energy-Conservation Ordinance and the Ecodesign/ErP Directive emphasize improvements in efficiency and thus a reduction of energy consumption. Beyond the ones described previously, there are a number of initiatives which aim at incentivizing the use of renewable energy for heat (Cogeneration Act and Renewable Energy Heating Act), but also a more general improved integration of renewable energy sources to the grid (Act on Accelerating Grid Expansion).

Table 1: Important Energiewende Policies

Emissions trading	The European wide Emissions Trading Scheme's (EU-ETS) objective has been to cap the emissions for different sectors, particularly the industry and electricity sector, by pricing carbon emissions.
Environmental taxation	Introduced by the under Gerhard Schroeder introduced the 'eco-tax' (Ökosteuer) is applied not only to gasoline and diesel for vehicles, but also to heating oil and fossil fuel (natural gas, coal, oil, and liquefied petroleum gas) used to generate electricity. The tax was designed to be 'revenue-neutral' meaning that it would off-set a revenue stream somewhere else. More specifically, the revenues from the eco-tax were used in part to fund renewables, but the majority of it was utilized to lower payroll taxes.[19]

[19] Germany has been an early proponent of 'energy taxes'. It has implemented a petroleum tax (renamed in 2006 into 'energy tax') as far back as 1951. In comparison to other countries the taxation levels are quite significant, having been stipulated at 65.45 cents per litre of gasoline in 2007 (the last time it was changed). To put this into perspective, Morris and Pehnt (2016) draw a comparison to the United States affirming:"

Cogeneration Act	Similar to the 'traditional' FiT, the law sets a bonus for each kilowatt-hour of power produced by the cogeneration unit, in addition to that power having priority on the grid. A first amendment of the law in 2009 defined a goal of having 25 percent of its electricity supply originating from cogeneration units by 2020 (compared to 14.5 percent in 2010).
Renewable Energy Heating Act and Market Incentive Program (MAP)	In 2009 the Renewable Energy Heating Act was passed, with the aim of increase the share of renewable heat to 14 percent by 2020. As an effect, new building owners were obligated to obtain a certain share of their heat from renewable energy. Market Incentive Program (MAP) was instituted in 2000, which was to support renovations of heating system.
Act on Accelerating Grid Expansion (NABEG)	Passed in 2011 the act calls for the evaluation of the requirement to expand the North-South transmission grid, emphasizing the viability for application of underground cables and a process for greater public input and transparency at an early stage of planning to increase public acceptance. Of the 1,800km of new lines planned, only about a quarter had been completed by mid-2015.
Energy-Conservation Ordinance (EnEV)	Energy Conservation Ordinance (EnEV) which introduces requirements for energy audits, replacements for old heating systems, and improvements in the quality of renovation. The EnEV also specifies energy consumption standards for new homes. In particular, two elements have been recognised as requiring improvement: (i) the rate of renovation in the country (currently at around 1% per year), and (ii) the quality of renovation and technology used. This is done through a program of facilitating access to information and financial support. More specifically, the KfW (the German development bank) provides special low-interest loans for energy-efficient renovations.
Ecodesign/ErP Directive	The 2005 Ecodesign Directive (renamed in 2009 to the Energy-related Products Directive (ErP)) traces its origins back to the European Union. Its main objective is to regulate the efficiency of energy-consuming products (with the exception of buildings and cars), by setting minimum standards

…Germany's petroleum tax alone costs roughly the same as gasoline itself does in the United States, for instance, and we still need to add on sales tax!" Since its implementation, the consequent reduction of payroll taxes by 1.7 percent is estimated to have have led to the creation of 250,000 new jobs (MORRIS AND PEHNT, 2016).

	for many different product categories. As a consequence, the program expects to reduce power consumption within the EU by 12 percent by 2020, in comparison to a business-as-usual scenario.

Source: (MORRIS AND PEHNT, 2016).

3.3.3 Energiewende: Successes and Challenges

While the *Energiekonzept* paper was only published in 2010, the process of the *Energiewende* goes back a lot further. Thus, when evaluating the current progress of the energy transition, it is useful to remember its two main pillars, renewable energy and energy efficiency, as points of orientation. This is because up to now, the energy transition has been slightly lop sided, demonstrating enormous progress in the dissemination of renewable energy technologies, while falling short of taking greater advantages of energy efficiency gains.

Since its initial tentative support policies for renewable energy at the beginning of the 1990s, the power sector has undergone some major transformations. While renewable energy only represented 3.6 per cent of the power production in 1990 it had risen to 29.5 per cent by 2016, corresponding to 32.3 per cent of national power consumption, as can be seen in Table II (AGORA, 2017).

Table 2: German *Energiewende* Targets

		Status quo	2020	2025	2030	2035	2040	2050
Green-house gas emissions	**Reduction of GHG emissions in all sectors compared to 1990 levels**	-27% (2016)*	-40%		-55%		-70%	-80 – 95%
Nuclear phase-out	**Gradual shut down of all nuclear power plants by 2022**	11 units shut down (2015)	Gradual shut down of remaining 8 reactors					
Renewable energies	**Share in final energy consumption**	14.9 % (2015)	18%		30%		45%	min. 60%
	Share in gross electricity consumption	32.3 % (2016)*		40 – 45%		55 – 60%		min. 80%
Energy efficiency	**Reduction of primary energy consumption compared to 2008 levels**	-7.6 % (2015)*	-20%					-50%
	Reduction of gross electricity consumption compared to 2008 levels	-4% (2015)*	-10%					-25%

Source: adapted from Agora (2017)

At a closer look, the overall landscape of power generation has changed dramatically. An important contributing factor has been the decision to phase out nuclear energy, which has resulted in nuclear power dropping from 27.7 per cent of domestic power production in 1990 to 13.1 per cent in 2016. At the same time, lignite power production has remained almost constant over the last twenty years while hard coal has slowly declining. Much of this decline has been offset by increasing renewable and natural gas production. A definitive mile stone was reached in 2014, after which point renewables have produced more electricity than lignite, completing its evolution from a niche technology into a major pillar of the power system (AGORA, 2017).

On the other hand, when looking at energy efficiency, the *Energiewende* has shown timid success. Over the last ten years' power consumption has decreased by a moderate rate of about -0.5 per cent annually (AGORA, 2017). As Table 1 illustrates, most of the energy efficiency targets are at a risk of not being met. Consequently, as mentioned earlier, reaching the Energiewende targets greatly depend on the governments capacity to tap into energy efficiency potentials. In addition, while energy transition has made great strides in the power sector, a lack of stronger sector coupling, particularly with the heat and transport sector, has slowed down progress in CO2 emission reduction. In other words, a considerable electrification of the transport and heating sector needs to take place, in order to decarbonise the sectors. In both areas, the structural adaptation needed has been slow and an effective policy instrument is lacking. As an example, the case of E- mobility has gained much attention recently (not least because of the Emission scandals by large German car manufacturers), yet the sector hasn't gained any significant momentum even with a policy implementation to subsidize e-car purchases.

With this in mind, the tendency is that the power system will take an ever more important role within the whole energy supply. Thus, an overall reduction of electricity is unlikely in the short, as other sectors increasingly switch to electricity as their major energy input. This long term increase in overall power consumption will also be triggered by the prospect of using excess electricity generation for hydrogen and other power-to-gas technologies. Scenarios have been developed in which by 2060 in excess of a third of all renewable power will be used for hydrogen production alone (SONNENSCHEIN AND HEINNICKE, 2015).

This means that not only a greater diffusion and integration of renewable energy technologies will be important, but also an adequate expansion and adaption of the grid infrastructure. Wind energy and solar PV are the two renewable energy technologies with the largest growth potential in Germany, yet gridlocks in grid infrastructure pose a serious problem for their future deployment. Particularly the case of Wind and off-shore Wind which have shown that adequate access to transmission grids are essential for their effective use. Yet, as mentioned earlier, the efforts to meet the growing need for particularly transmission grid expansion, have been slow. Thus, while the past decade and a half have witnessed a great expansion of renewable energy, recent developments are putting into question if this progress will continue.

3.4 Conclusion

To summarise, this chapter sought to give a brief sense of the magnitude and characteristics of the German energy transition. It is important to understand what a paradigmatic shift the *Energiewende* represents, and consequently how it requires a systemic approach in order to succeed. More specifically, the progress of this 'project' ultimately requires a strong and coherent policy framework which demonstrates some important characteristics: an effectiveness in mobilising enough investment in order to drive forward and implement different programs, the ability to guarantee policy continuance, effective coordination and inter-disciplinary sector cooperation, and a responsiveness to changes.

There exists a common misconception that the *Energiewende* is primarily dependent on a higher participation of renewable energy in its electricity matrix. Yet as this chapter has illustrated, the energy transition taking place in Germany today, requires a great many elements in order to be successful, one of the most important being improvements in energy efficiency. These gains in efficiency are pursued in many areas, ranging from buildings, to heat generation, all the way to electric appliances. Furthermore, the electrification of the heating and transport sector represent a complete overhaul of a status quo which has persisted for nearly a century. More importantly, all of these elements of the Energiewende are necessarily linked and require extensive and creative ways of collaboration. Consequently, as this chapter has tried to argue, the countries innovation system is essential for the success of the *Energiewende* 'mission'. The German energy transition represents nothing short of a systemic transformation of the German economy, and consequently it requires a holistic policy framework, strengthened by an elaborate institutional and innovation infrastructure.

In addition, another integral part of this energy transition is the creation of competent innovative infrastructures which strengthen the transition though legitimacy, innovative solutions, a competent and highly trained workforce and a continuous output of new or improved technological tools.

This chapter also highlighted some aspects of the German National Innovation System related to renewable energy, which contributes to the implementation of the *Energiewende*. While perhaps the contribution of its research and education infrastructure is more easily deduced, attention should be paid to the role of the political framework, and the public institutions. As Chapter Three will argue, the implementation of public policy which promotes the energy transition is best understood by taking into account the institutional and political struggles underlying it.

Finally, when analysing the current progress of the *Energiewende* it becomes evident that aside from the diffusion of renewable energy technologies, many of the areas of actions still lack considerable progress. Unlike the EEG, the German government has had difficulties in formulating and effectively implementing policies to drive forward the others pillars of the transition, such as electrifying the transport and heating sector, and increasing energy efficiency of buildings.

In the next chapter, the example of the EEG and its impact on the expansion of photovoltaic electricity will be used to illustrate the discussion over the success and challenges of the Energiewende as a whole, and renewable energy expansion in particular. As a consequence, an attempt will be made to identify some of the challenges of designing effective policies that aim at advancing the deployment of specific technologies.

4 Chapter III

4.1 Introduction

The EEG can be considered a cornerstone of Germany's "energy transition" and in particular, its aggressive promotion of renewable energy technologies. From its introduction in 2000, to its latest reform in 2017, the policy has undergone a great reform process in response to the fast-paced technological progress of renewables as much as changes in policy debate and focus. Particularly photovoltaic energy technologies are emblematic of this process, as their technological progress and their political controversy have been outstanding. While the EEG incorporates a variety of renewable energy technologies, for this discussion I will focus on the trajectory of the EEG for photovoltaics. This reform process and the accompanying political debate, can help exemplify the challenges of creating support policies for dynamic, disruptive and fast changing technologies, while also illustrating the inevitable political, institutional and societal struggle and debate accompanying any such support policy and potential economic paradigm shift.

The following chapter will begin by presenting the historic trajectory of the EEG, focusing on the policy changes occurring between 2000-2017 (more specifically; 2000, 2004, 2009, 2012, 2014 and 2017) and the political and economic debate accompanying these reforms. Consequently, this reform process will be discussed in light of the wider theoretical framework presented in Chapter One, contextualizing the institutional, political and societal challenges and support within the greater debate on National Innovation Systems and techno-economic paradigm shifts. In addition, the arguments presented in Chapter Two in relation to the mission oriented policy of the German "Energiewende", will be revisited with the example of the EEG in order to debate the opportunities and challenges of creating effective and long term policies for the pursuit of wider economic change.

4.2 The evolution of EEG

The 1998 elections in Germany represented a hallmark for renewable energy policy in the country. The elections saw the Social Democrats (SPD) and the Greens securing enough votes to form a coalition government. It was the first time, that the Green Party participated in federal government, and this coalition would come to initiate some of the major policy advances in favour or renewable and solar energy promotion.

The government dedicated special attention to introducing a paradigm shift in energy policy, which focused on the support for renewable energy technologies and culminated in the adoption of the Renewable Energy Sources Act (*Erneuerbare-Energien-Gesetz*, short: EEG). The Act came into force on April 1st, 2000, effectively replacing the 1991 Electricity Feed-in Act[20].

Building on previous experiences, the EEG introduced and maintained a number of important policy measures. Firstly, the EEG maintained the right for independent renewable energy producers access to the electricity grid if a grid connection was "necessary and economically feasible" (HOPPMANN ET AL., 2014, p.6). Secondly, for the first time, the law included technology specific remuneration at which grid operators had to purchase (costs passed onto consumers)[21] the generated electricity over a guaranteed period of 20 years. Thirdly, this remuneration was decreased in regular intervals (applying to new installations) in an effort to exert cost pressure on energy generators and manufacturers and to accompany the accomplishments in efficiency and cost reduction caused by technological progress. This digression was put at an annual 5% of the FiT for newly installed plants as of 2002.[22] While the EEG encompassed a wide range of renewable energy technologies, for the sake of this

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[20]As a reaction to the 1986 nuclear disaster and growing mounting political pressure, the German government passed a Grid Feed-In Law in 1991 (in short StromEinspG). It stipulated a remuneration at a level of 90% - the average customer purchasing price for the energy generated by renewable technology systems, around 0.17 DM (JACOBSSON AND LAUBER, 2006). While this feed-in tariff had some positive effects on investment in wind energy, the law "had no measurable effect on the use of photovoltaic power" (BUNDESTAG, 2007). The technology was still much too cost inefficient to be an attractive investment, given the financial incentives offered by the StromEinspG.

[21] The costs of the feed-In tariff are passed on to consumers through an extra levy on their electricity bill. This is also hoped to incentivize a reduction in overall electricity consumption due to elevated prices..

[22] It is important to emphasize that these changes in FiT only affected new installations, i.e. plants are guaranteed the FiT at the time of their installation, for a duration of 20 years (irrespective of any legislative changes later on).

argument, this section is going to refer itself specifically to photovoltaics.

As already being part of the agreement of the EEG in 2000, the law was reformed in 2004, taking into consideration the challenges and limitations it had encountered during the past four years. This reform was particularly important for photovoltaics since it represented the first point at which the FiT for photovoltaics was strong enough by itself. Recognizing a necessity for greater remuneration levels for photovoltaic systems, due to a discontinuation of low interest loans, the tariff for rooftop-mounted PV systems was increased relative to the systems size (57.4ct below 30 kW, 54.6ct below 100 kW, 54.0ct above 100 kW)[23].

In its 17 years since implementation, the EEG has contributed tremendously to the diffusion of renewable energy in general, and photovoltaic in particular. This becomes evident, when considering that photovoltaic capacity in 2000 was 114 MW and a decade and a half later had skyrocketed to 41,275 MW (BMWi, 2017).

As described in more detail in Appendix 1, this period has seen the EEG (particularly for photovoltaics) being constantly reformed and refined in order to address perceived challenges and obstacles. One important element of this reform process, was the design and implementation of appropriate degression rates, in order to accompany cost reductions of photovoltaics. As Graph I illustrates, this has meant a progression from a fixed annual degression rate, towards a monthly, more dynamic, capacity growth related, degression (from 2012 onwards).

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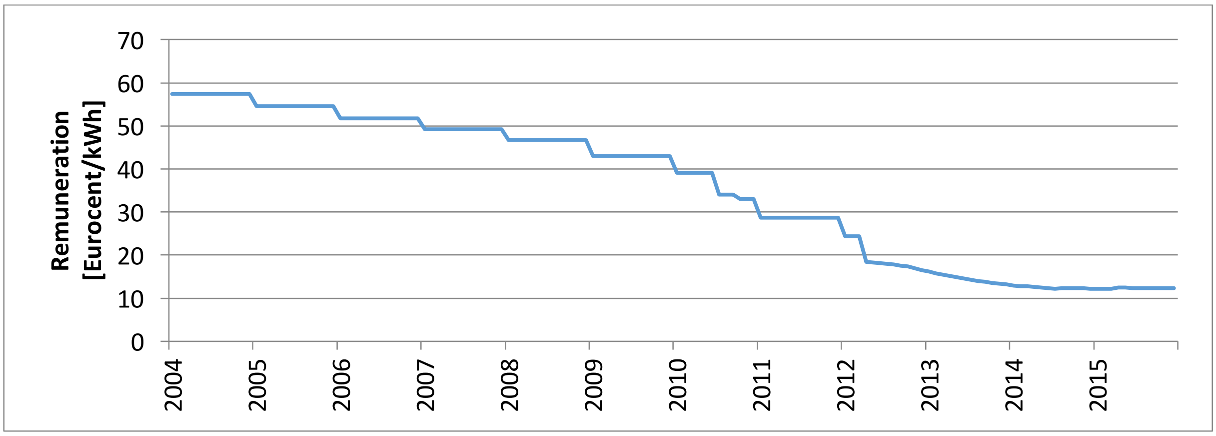
[23] An additional bonus of 5.0ct for integrated facade systems.

Graph I: Development of remuneration for photovoltaic system with a capacity inferior to 30kW.

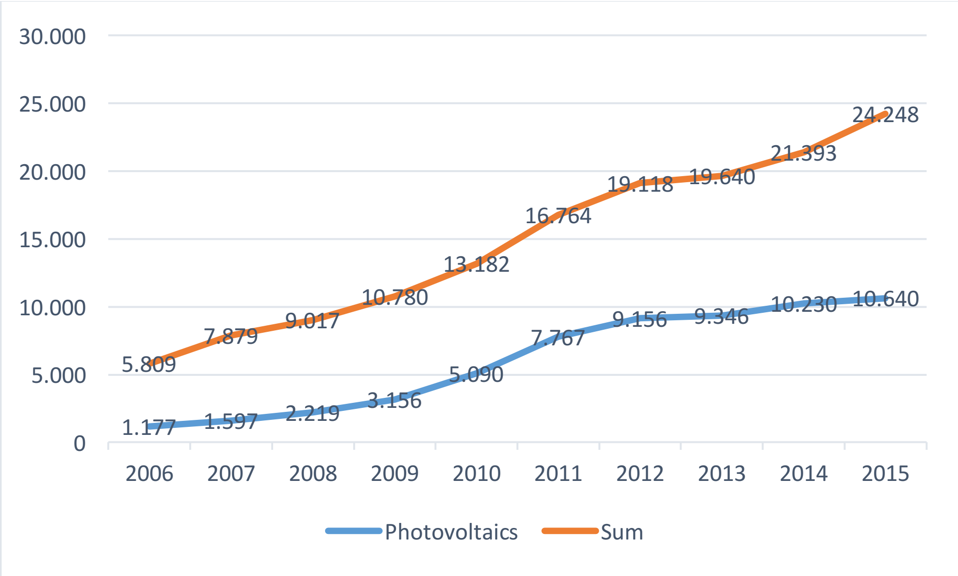


Source: Own elaboration based on Quaschning, 2011 and BNetzA, 2016.

The difficulties in predicting cost developments of photovoltaics were partly caused by uncertain market developments, supply and demand issues, technological progress and advances in manufacturing. Thus, while the period between 2004 and 2006 was marked by a stagnation and even partial increase of PV market prices, mainly due to high demand caused by shortages in production, the following years saw an accelerated decrease in PV system prices, mainly driven by cheap imports from China. In 2009 alone, prices dropped by approximately 30% (GRÜNDIGER, 2017).

One of the major challenges identified by policy makers, were the rising costs associate with the EEG. The accelerated increase in capacity growth translated into increases of the FiTs surcharge. This meant that only between 2004 and 2008, the FiT costs increased by 600% (comparing 2004 to 2008 levels) (HOPPMANN ET AL., 2014). This amounted to 2 billion euros worth of FiTs paid for PV installations alone in 2008. As Graph II illustrates, this rapid growth of the EEG costs has continued since, and the costs associated with photovoltaic growth represent the lions share.

Graph II: Development of Financial support for photovoltaics and renewables as a whole.



Source: BNetzA, 2015

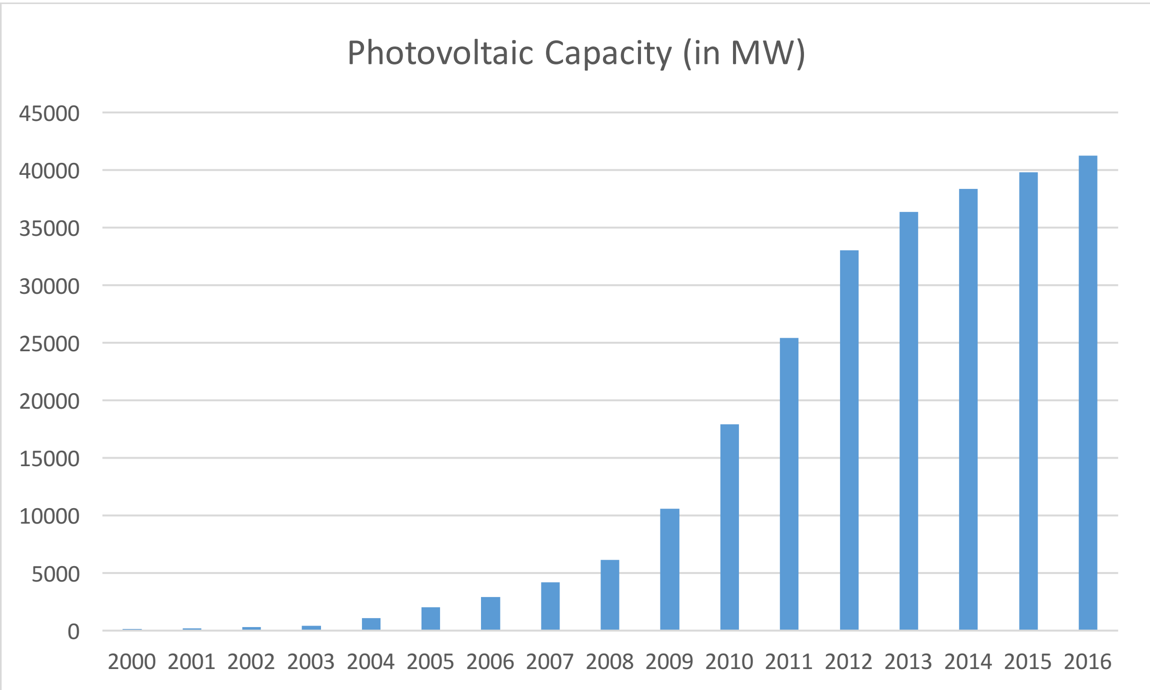
Contributing to this accelerated increase in FiT costs was the difficulty of predicting these cost developments. The Federal Association for Renewable Energies (BEE), an advocacy group for renewables, for example completely underestimated the cost development forecasting costs to reach €4.4 bn. in 2010 and €7.0 bn. in 2020 (BEE, 2004). In contrast, these numbers had reached €8.2 bn. in 2010 and €20.4 bn. in 2013 (BMU, 2013).

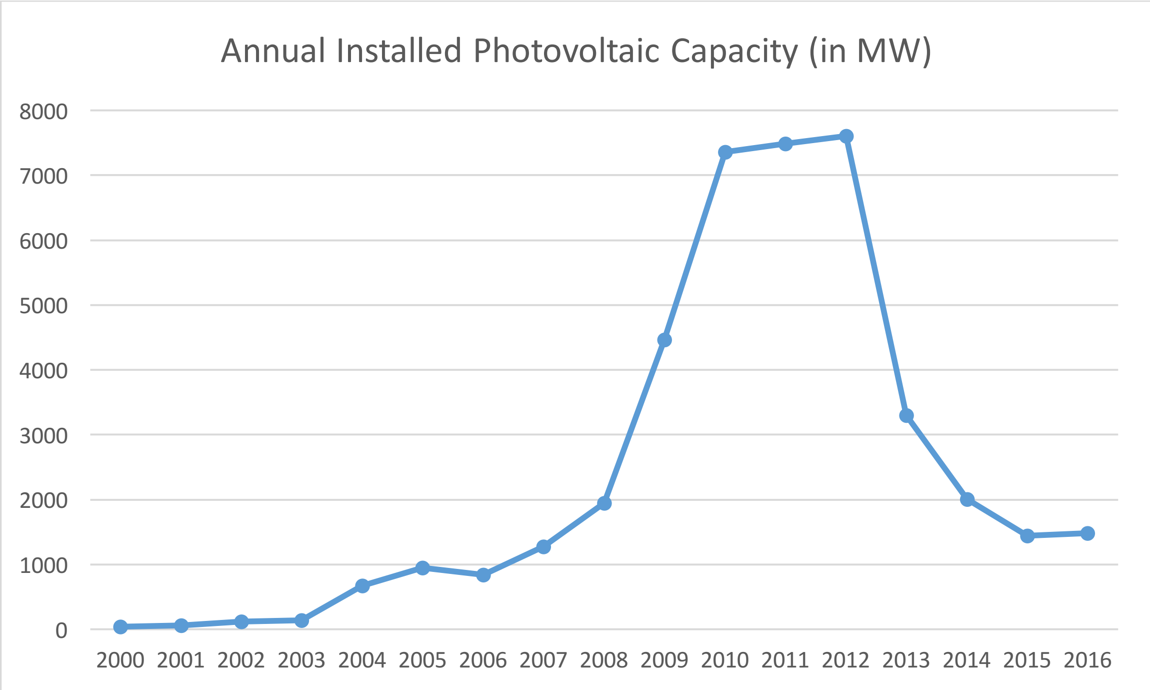
At the same time, this unpredictability could also be observed for the growth of photovoltaic capacity. The Environmental Ministry's 2008 Lead Study forecasted a growth of 1,300 MW for the following year, while in actual fact 2009 saw a capacity growth of 3,800MW (nearly three times as much). This had also occurred in 2008, when capacity growth was 1,933MW while estimations had predicted it as 1,250MW (BMU, 2008; BNETZA, 2012).

Thus, by 2008 it had become undeniable that photovoltaic energy was the costliest renewable energy. Its high tariffs accounted for 24.6% of total EEG remuneration payments, while only supplying 6.2% of renewable electricity in that same year (RWI, 2009). This helps explain why many considered the subsidization 'inefficient' i.e. too much money for too little return. Aggravating this, was the fact that enormous demands coupled with undersupply in solar panel production, meant that the industry was making huge profits. Of course, this growing demand could directly be traced back to the generous tariffs.

As a response to these rising costs, the EEG underwent a number of tariff cuts and the implementation of market integration mechanisms. This included the introduction of the feed-in premium in 2012 as well as the recent implementation of an auctioning system for larger projects to be eligible for financial support. Thus, the costs associated with photovoltaics have decelerated. Nonetheless, this deceleration can also be observed in the capacity growth over the last few years. Graph III offers an overview of the growth trajectory since the implementation of the support policy in 2000.

Graph III: Accumulated Photovoltaic Capacity installed and Annual Photovoltaic Capacity growth.





Source: BMWi, 2017

Yet initially, despite considerable tariff cuts, as a response to pressure on improving cost reduction, photovoltaic expansion continued to accelerate (7,400 MW new capacity has been installed in 2010 (BMU, 2011a). With this, the EEG levy increased culminating in photovoltaics, in 2011, being responsible for a share of 56% of total remuneration costs, while representing only a 20% share of renewable electricity production[24] (BMWi/BMU, 2012, p. 36).

As a consequence, mounting pressure to reduce these costs culminated in the PV Act 2010, which introduced drastic tariff cuts, ranging from 8-13% depending on the system type. An additional cut by 3% was done in a second step which came into effect during the second half of that same year. With this also came a tighter growth-dependent degression rate of 1-12%, in addition to the basic regression by 9%. Should capacity growth fall below the growth corridor, the ordinary degression is relaxed in accordance. The 2012 PV Act continued this trend and introduced major tariff cut of up to 30%.

[24] In comparison, onshore wind constituted a share of 14% of remuneration costs while contributing 44% of renewable electricity production (BMWi/BMU, 2012, p. 36).

The years of 2012 and 2013 marked the first time, in which the principles and the existence of the EEG were seriously questioned. This was exemplified by the Environmental Minister Peter Altmaier (CDU) (a ministry traditionally in support of the EEG) expressing in an interview his concerns over the costs of the support for renewables. It caused him to controversially claim that the programme would run up costs of 1 trillion euros by 2040[25]. While the debate over the costs of the EEG had been debated for years, political pressure was rising. Gründinger (2017, p.335) observes that: "This intense cost debate reinforced the public image of PV as expensive form of electricity production, although prices had already dropped."

As a consequence, while the years following 2008 witnessed an unprecedented increase in annual capacity growth for photovoltaics, after 2012 this was followed by a rapid deceleration. Between 2010 and 2012, average annual growth was approximately 7,5 GW. This momentum was reversed resulting in a growth rate between 2014 and 2016 of less than 2 GW, falling short of the government's own growth goals. The notable drop in photovoltaic capacity growth in 2013 was criticized by many stakeholders.

Considerable resistance to tariff cuts also mounted from regional governments. In order to evade delays during the reform processes, state governments were increasingly invited to contribute during the policy formulation. During these processes it became clear, how the growth of the solar industry had affected the different regional governments. All five of the former East-German state governments had expressed their dismissal of severe tariff cuts for photovoltaic. In all of these regions, the industry had gained significant economic importance and there were considerable concerns with the economic repercussions of major promotion cuts.

Nonetheless, during the same period, the country's photovoltaic industry underwent some dramatic transformations. Until the end of the last decade, the sector witnessed unprecedented growth, carried by high demand and strong policy incentives. A combination of the EEG, regional investment support and research backing meant that the country

[25] After harsh critique from the opposition (particularly the Greens), pointing out the lack of evidence for this figure, the ministry distanced itself from these claims.

developed into a leading manufacturing location, boasting the number one internationally ranked company in terms of production volume (WIRTH AND SCHNEIDER, 2017).

Yet growing competition from outside markets (especially from Asia), later accompanied by the previously mentioned decline in capacity growth, threw the industry into existential crises. As Table III illustrates, while the industry initially experienced a strong growth, recent years have seen a considerable collapse in industry employment. The country's solar PV industry fared poorly, suffering a 38% decline in sales in 2014. Employment decreased by 32%, reaching 38,300 jobs at the end of the year. In the meantime, the German PV sector was marked by insolvencies and companies exiting the market (O'SULLIVAN ET AL., 2015).

Table 3: Employment in the PV Industry in Germany

	2004	2007	2012	2013	2014	2015
Number of People	25.100	49.200	113.900	68.500	49.300	30.000
Variation		+96%	+132%	-40%	-28%	-41%

Source: O'SULLIVAN ET AL., 2015

In parallel, the reform process continued and the 2017 EEG introduced a tendering system for photovoltaic installation with a capacity that exceeds 750kW. The design of the auction model had previous been tested through a pilot program which was initiated in 2015. In essence, it meant that eligibility for receiving a floating[26]feed-in premium (for the duration of 20 years) is determined by a tendering process under which only the most competitive projects were chosen. Systems with a capacity inferior to 750kW continue to be eligible to the/for the traditional remuneration model (feed-in or premium).

The reform can be considered one of the most controversial in recent years, not alone

[26] A floating premium unlike a fixed premium, is adjusted in relation to the fluctuation of the electricity price.

for its abandonment of feed-in tariffs for the majority of system sizes and types. While some saw the changes as a step in the right direction (IW, 2016), many within the pro-renewables coalition and the political opposition argued that it jeopardised the future of renewable energy development, and the *Energiewende* as a whole. This provoked the President of the BEE to asses: “Until now, the EEG was an engine for the development of clean energies, but with today’s reform, it serves mainly to preserve fossil energies, and to significantly slow the speed of the *Energiewende*. (BEE, 2016)”

Aside from the policy mechanisms related to the promotion of photovoltaic discussed previously, it is worth briefly mentioning the introduction of the *special equalisation scheme* in 2004. The scheme represents a cost relief clause for electricity-intensive industries. Essentially the justification for this was based on the EEGs effect on rising electricity costs, which, as argued by the industries, negatively affected the competitiveness of certain sectors. As a consequence, criteria were established for companies to be exempt from paying the EEG surcharge (or only paying a fraction of it). Initially encompassing 330 enterprises and railroad companies the clause was reformed over years, allowing for the inclusion of more and more companies (BRUNS ET AL., 2009). Over the period of 2012 to 2014 alone, the number of companies exempt from paying the full costs of the EEG surcharge increased from initially 734 to 2098 (MAYER AND BURGER, 2014). In terms of monetary exemptions, this increased from 2,7 billion euros in 2011 to 5,1 billion euros in 2014 (MAYER AND BURGER, 2014). While the policy is not directly related to the promotion of photovoltaics, as much to the reform processes as of late were at least party motivated with concerns over the growing costs of the EEG, it is interesting to recognize the multitude of elements which contribute to these costs.

As a consequence, the evolution of the EEG was not solely a response to changes that were of a techno-economic nature. In order to better comprehend the aspects informing and motivating these reform processes, one needs to investigate the political dynamics and debates behind the diffusion of photovoltaic energy. Consequently, the next section will try to provide an overview of some of the important changes and shifts in the political landscape and discussion surrounding the politics of renewable energy and more specifically photovoltaics in Germany.

4.3 The Energiewende in Practice: Lessons from the EEG

This dissertation began by trying to give the reader an understanding of what constituted the *Energiewende*. It is an ambitious project which represents nothing less than a paradigmatic shift and a transformational process which encompasses a multitude of areas and sectors of the German economy. As previously argued, the success of such a transformation requires the contribution of a wide range of different stakeholders and elements. Furthermore, as the *Energiewende* requires changes to occur in many sectors of the economy, it cannot be reduced to a single policy.

With the introduction of the *Energiekonzept*, Chapter Two attempted to illustrate that the German government has committed itself to a set of ambitious goals, setting a worldwide precedent for an industrial economy of this magnitude. Yet, the difficulty of pursuing such a transformational project lies not so much in setting the goals, but in identifying effective ways of implementing them. This can become apparent when considering that the energy transition has thus far, had mixed results.

Undeniably, the area in which Germany has been able to present the most progress, has been in the diffusion of renewable energy technologies. The most important policy, which has supported this trend, has been the feed-in tariff introduced under the EEG. While a rich and important debate exists, over which mechanisms constitute the most effective policy for RE deployment, and while the feed-in system is not without its critiques, the growth of renewables in Germany from representing 6,2% of electricity production in 2000, to 32% in 2016, speaks for itself (ENERGIEN-STATISTIK, 2016). Thus, the example that the EEG offers in itself can be used to analyse some of the difficulties and challenges faced by such a promotional policy. Furthermore, focusing on the example of photovoltaics allows us to illustrate the challenges of creating a policy framework which promotes a technology characterized by innovation and technological progress. This contributes to the necessity of policy makers to deal with the uncertainties associated with this.

As is the case with any political agenda, the difficulties present themselves in the process of implementation. Thus, it is argued that the challenges of a mission oriented policy could be divided into two parts: (a) identifying and formulating a mission, and (b) its implementation. The case of the German *Energiewende* could be seen as the successful completion of the first step, i.e. the government was able to identify and articulate a transformational project, the energy transition, and set out ambitious goals.

Interestingly enough, unlike traditional examples of mission oriented policies (such as putting a man on the moon), the example of the *Energiewende*, is emblematic of a wider, more recognized phenomenon associated with climate protection and global warming. Thus, the German example is perhaps one of pioneering a stronger commitment to a mission, by implementing a series of policies, rather than the identification of a "novel" mission.

Nonetheless, the German case is particularly interesting when trying to understand the particular challenges of realizing the "missions" goals. Of course, these will differ depending on each area and policy initiative, but as it is argued in the following, two characteristics are of importance for any policy framework to be successful: (a) coherence/stability and (b) adaptability. Initially, these traits might seem paradoxical, which illustrates its difficulty, but as the EEG has shown, on the one hand, (a) enabling the development of a public, institutional and economic framework which supports new sectors through consistent and reliable policy, is fundamental in order to overcome potential institutional inertia and structural barriers. On the other hand, in order for these policies to be successful, they require a more (b) open-ended, flexible design which allows for an adaptation to potentially fast paced market developments.

A) The development of a public, institutional and economic framework

As the trajectory of the EEG has demonstrated, the ministerial structure and political alignments have played an important role in determining the development of the policy. Part of the reason for this, stems from an increased dependency of policy makers with ministerial expertise in formulating and designing complex policies. Thus, depending on the party affiliation and jurisdiction, these institutions have played a central role in informing the reform processes of the EEG (for a more detailed discussion, see Appendix 2). In particular, when looking at the feed-in tariff, one could observe a dispute between the Environmental

Ministry and the Economic Ministry on how to address reform necessities. Additionally, during the same period, these two ministries responsibilities shifted, often in response to party politics. Thus, the responsibility for renewable energy shifted from the Economics Ministry to the Environmental Ministry in 1998, with the newly elected Green Party heading the Environmental Ministry. In 2013, this shift was reversed, when responsibility for renewable energy was given back to the Economics Ministry. During this period, the two ministries defended opposing ideas on the future of the EEG and necessary reforms. Nonetheless, the balance between these two institutions was important in counterbalancing more radical calls for remuneration cuts.

Of course, these disputes were a strong reflection of cross party disagreements on how to best pursue greater renewable energy diffusion. Yet, what is striking in this example, is that environmental concerns are not an issue which follows a strict party divide along traditional lines. In fact, inner party dispute over if and how to advance renewables support may indicate that cross party agreements became more common place.

This was perpetuated by the different degrees in which the renewable energy industry gained economic relevance in the different regions and the different voter groups in the country. For example, the strong economic ties of the solar industry in former east German *Länder*, meant that regional governments voted in opposition to their party in the Bundestag, when they felt that their regional industries were being jeopardised. On the other hand, stronger investments into renewables (especially bioenergy and solar) by farmers, meant that conservative parties were held accountable for defending renewables interests by their voters[27].

Public concern over environmental protection has been a characteristic of the German political landscape, anticipating the recent growth of renewables. Particularly the anti-nuclear movement in the country, which has played a pivotal role in advancing environmental agendas and Germany is one of the first countries to have a Green Party in parliament (mid-1980s). As the sector has grown, it has "…allow[ed] for the formation or the strengthening

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[27] The case of Bavaria with its considerable agricultural sector, and the CSU (conservative party) are a striking example.

of a technology specific advocacy coalition, which may gain enough strength to influence the institutional set-up" (JACOBSSON AND BERGEK, 2004, p.214). While the origins of this peculiar affinity/concern for the environment would deserve a discussion of its own, its importance should not be underestimated. After all, the basis for the impressive renewables expansion during the 21st century, was laid out by the first coalition government which included the Green Party.

Aside from these party issues, the nature of renewables expansion (photovoltaic in particular) has brought about an increased decentralization of the electricity sector, and has initiated a discussion over the *democratisation of energy* (BECKER AND NAUMANN, 2017). What has undoubtedly occurred, is a greater participation of the public, in electricity generation. The FiT has mobilized great amounts of private capital to be invested in renewables. This has resulted in nearly 50% of renewable capacity belonging to private investors (citizens and farmers), while the traditional energy companies make up only 12% (in 2012, the latest data available) (AGORA, 2015). Thus, this aspect of the energy transition has been very much led by the citizenry (in the form of micro systems on roof tops as much as through citizen cooperatives). As a result, public support for renewables has been strikingly high, even in light of the rising costs of the FiT system and controversies of windfall profits for the solar industry.

As discussed earlier, a contributing factor, as much as a result of this, has been the greater organization of renewables and solar associations and lobbying groups. An important development for the political effectiveness of the industry has been its efforts to organize and mobilize support for its agenda among different environmental organizations, unions and industry associations. This represents an integral part in the maturing of an industry and has been an important, if not completely uncontroversial, part of gaining political support.

Many of these earlier mentioned aspects, are at least partly a result of the growing economic importance of renewables and the solar industry. A considerable part of its ability to mitigate reform cuts is based on the industries growing economic relevance. In 2014, the renewables industry is estimated to have employed 355,000 people, without considering its earlier discussed regional weight (O'SULLIVAN ET AL., 2015).

B) Flexible Design

The design of the EEG has played an important role in understanding its success and the nature of renewables expansion in the country. It has also been the source of much criticism, especially by proponents of a more market oriented, cost effective approach. An important characteristic of the feed-in tariff as introduced in 2000, was its differentiated remuneration level for different technologies. This enabled the creation for an even playing field among the different technologies, which found themselves in different levels of technological maturity. Photovoltaic stands out, for having received the highest remuneration level, due to its still substantial costs at the time. This became even more evident, when in 2004 the remuneration level was increased in order to compensate the phasing out of the financing program for roof top systems. Critics at the time pointed out that wind energy provided a much more cost-effective alternative to photovoltaic and thus argued that the differentiated remuneration structure was not market oriented enough.

Nonetheless, an integral part of the role of the EEG was to create opportunities for a wide range of renewable energy technologies, promoting diversification and evading a selection bias. This was also part of an effort to create the space for the development and growth of new technologies, which were deemed promising. Therefore it should be noted, that from its inception, the EEG has attempted to create an "open minded/ended" policy. In a similar way, the policies approach in dealing with and adapting to technological progress and cost reductions has represented the need for designing a flexible policy framework. While the earlier versions of the EEG have tried to address this through fixed annual degression rates[28] for remuneration, this later developed into a more sophisticated system with monthly degression rates linked to capacity growth rates. This latter design, allowed for a much more organic adaptation of remuneration rates.

Growing concerns with a better market integration of renewables, has also informed a substantial part of the reforms. Much of this has been debated in response to mitigating policy costs but as a result, the feed-in tariff has undergone some substantial transformations.

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[28] Representing an estimated rate of technological progress.

The introduction of a feed-in premium which requires system operators to sell their electricity at the stock market was a first attempt to incentivize greater market integration and the creation of better market for commercialization. The latest substantial change came about with the introduction of an auctioning system for larger renewable projects. This aimed at increasing the competitiveness of remuneration rates.

On the other hand, the growing need for grid expansion has shown the urgency for more systemic approaches to policy implementation. Today, concerns about the lack of appropriate grid infrastructure, have begun to throttle renewable energy expansion in parts of the country.

As earlier illustrated, the EEG has undergone some substantial reform processes in an effort to address new challenges. If looking at photovoltaics, the policy has undergone nine different reforms. This demonstrates the difficulty in designing support policies for technologies characterized by high levels of innovation, technological progress and cost reductions. One of the major challenge lies in allowing for enough flexibility within the policy framework in order to address the uncertainties innate to this process.

4.4 The Energiewende: Obstacles to Success

As mentioned in Chapter Two, many other areas of the Energiewende are still struggling to make considerable and necessary progress. Understanding some of the reasons for this, can help strengthen the lessons learned from the successes of photovoltaics and renewable in general.

A particularly interesting example can be seen in the case of e-mobility. The electrification of the transport sector in Germany is one of the cornerstones of the energy transition, yet also one of the areas in which the country has made the least progress. This is especially interesting, considering that Germany is home to the biggest car manufacturers in the world and 10 percent of the country's industrial employment is directly and indirectly dependent of this industry (FALCK ET AL., 2017). The government formulated a goal of increasing the total number of electric vehicles (including hybrids) to 1 million by 2020 and 6 million by 2030 (IRENA, 2015). Yet by 2016, there were only 25,502 pure electric cars registered in the country (more if hybrids are included) (CLEW, 2016).

Given the importance of the industry and the governments goals to promote e-cars, it seems strange that smaller manufacturer such as Tesla (THE TELEGRAPH, 2014) and recently Volvo (THE GUARDIAN, 2017a) are leading the way in adapting to these future markets. At the same time, this inertia is reflected in the federal government's timidity in articulating more ambitious policies in order to guarantee its goals. Its policy of building loading stations and car premium[29] have yet to stimulate a growth in the e-cars market[30]. Other countries such as Norway, France and recently Britain, have articulated more ambitious goals of banning new diesel cars by 2025 (INDEPENDENT, 2016) and 2040 (NEW YORK TIMES, 2017a), increasing the pressure on the automobile industry.[31]

Part of these difficulties stems from the industries inertia to change, which is amplified by the industries strength and economic weight. A transition to a completely e-car oriented production structure, would represent a revolution of the current industry, with all its sophisticated value chain. The existing economic and political weight and vested interests represent an enormous challenge to be overcome. To underline these claims, a recent study commissioned by the Association of the Automotive Industry (VDA) argues that a diesel ban by 2030 would have detrimental effects on the job and value creation of the industry. The study by the Institute for Economic Research (Ifo) predict that a total of 620.000 jobs would be affected (426.000 of this directly in the automobile branch) (FALCK ET AL., 2017).

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[29] To kick-start e-mobility, the German government introduced a buyer's premium of up to 4,000 euros in the spring of 2016 (ZEIT ONLINE, 2016). As part of the *National Platform for Electro mobility* (NPE) the German government formulated plans to increase investment into charging infrastructures (NPE, 2015).

[30] The country has 25,502 cars, compared to Norway 100.000 (with 40% of newly registered cars being EV).

[31] In addition, France and the UK offer of up to 6,300 euros, as well as tax breaks. In comparison, Norway offers tax cuts and benefits including an exemption from tolls and parking fees, free recharging stations, and the use of bus lanes. Another interesting policy approach is that of California which offers rebates of 2,500 dollars for EVs and requires a quota of EV by car manufacturers which for 2025 is aimed at 10%. (CLEW, 2016)

Given the recent Emission[32] (NEW YORK TIMES, 2017b) and Cartel[33] (NEW YORK TIMES, 2017c) scandals, the sector has demonstrated a strong willingness to maintain “business as usual”. This is perpetuated by a considerable degree of political apathy and even support. In response to the allegations of cartel activities and software manipulation, both the Economics and Transport ministers expressed their rejection of calls for more decisive action, such as ban of diesel cars (DER SPIEGEL, 2017a). The ‘Diesel Summit’[34] which took place in August of 2017 confirmed the governments light stance towards the car industry with the main result being a mandatory update of car software, instead of hardware upgrades or car restrictions (DER SPIEGEL, 2017b).

With Federal government hesitant to enforce stronger signals for the car industry, opposition is stirring. Similar to the case of RE, manifestation of this opposition and a push for more radical policies can be identified on regional and municipal levels. Discussion involving the Ban of Diesel in Stuttgart[35] (DER SPIEGEL, 2017c) and other cities, exemplifies once again the possibility for regional pressure. Public pressure has hired judicial help to enforce stricter control on CO2 emissions in the absence of political activity. Environmental organizations such as the *Deutsche Umwelthilfe* (DUH) for example, are spearheading law suits in 16 different cities, forcing through the implementation of driving bans (DUH, 2016).

Thus, one can observe, that other areas of the Energiewende are struggling to make headway. The challenges faced in these areas can in some ways be compared to that of the expansion of renewables (and photovoltaics in particular). A tendency to resist radical change

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[32] The Emissions Scandal refers to a number of high-profile cases in which car manufacturers (including Volkswagen, Daimler and BMW) were caught programming engine software to dupe regulators about nitrogen oxide emissions.

[33] The German magazine *Der Spiegel* uncovered that for decades Volkswagen, Daimler and BMW had colluded to hold down the price of key technologies, including emissions equipment.

[34] As a response to elevated nitrogen oxide levels in cities, and looming diesel bans in those areas, the German government called for a summit with automobile industry leaders to discuss possible solutions.

[35] In the case of Stuttgart, a city renown for high levels of air pollution, environmental organizations have successfully brought a case to court, calming the governments insufficient efforts for guaranteeing cleaner air for their citizens. The first judgement was in favour of the environmentalists, claiming that a diesel ban in the city might be inevitable in order to attain adequate emission levels.

and a weak policy framework obstruct the necessary transformational adjustments needed to accomplish the ambitious goals set out by the energy transition.

4.5 Conclusion

As was attempted to show, these reforms of the EEG were not simply the result of a need for improving the policy, but also represented a dispute of economic and political interests. While this is an inevitable process, in any democracy, and also a result of vested interest, it demonstrates the importance of strengthening the 'sectors' ability to defend itself.

In the case of the EEG, particular attention should be paid, to the role of disputing ministries (particularly the Environmental and Economic Ministries), the sectors ability to lobby and mobilize support within the public and organization (unions etc.), regional government support, across party environmental coalitions, among others. As Jacobsson and Bergek (2004) argue, it is important to "…foil attempts by incumbent vested interests to capture the state and hinder an institutional alignment simply by having more resources at their disposal than the representatives of infant industries and underdeveloped markets." As a whole, they enabled the overturning or minimizing of political efforts to undermine the EEGs economic potency.

In addition, this also illustrates the necessity of considering the importance of institutional, innovation and political subsystems. The evolution of the EEG also demonstrates the need for the development and strengthening of an innovation system, in order to guarantee policy continuation and to allow for the emergence of new industries and stakeholders.

At the same time, the policy has come under increasing threat, by a growing discussion over its economic burden. The simple example of the equalisation scheme demonstrates how incumbent players have influenced the development and implementation of such a policy. Their influence has risen over the years, and it is argued by some, that the recent developments of the EEG is moving towards creating a more favourable environment for big investors. It should be noted, that these developments have come about under the guise of economic reason, i.e. cost reduction and economic effectiveness. This is particularly interesting, as much of the dispute over rising costs of the EEG subsidy is not as clear cut, as the political debate makes it out to be. For example, a recent study by the Öko-Institut argued, that a reform of the industry exemptions set out by the EEG could decrease the surcharge costs for consumers by 20%, just by adopting the European Union's categorization of energy intensive industries which are exposed to international competition (thus drastically reducing the number of industries exempt) (ÖKO-INSTITUT, 2014).

Thus, this illustrates an important and undeniable aspect of the *Energiewende*, which should not be underestimated: The energy transition is as much a project to increase climate protection, as it is an industrial policy to develop, prepare and position the German economy for the future. Consequently, an economic rationale is an essential and very conscious component behind much of the policy making.

At the same time, these challenges, while very real and observable in the example of renewable energy diffusion, they can help understand the development (or lack of) in other areas of the Energiewende. The closing section of this dissertation, will explore some of the implications of the discussion in this chapter for the successes and challenges for the *Energiewende* as a whole.

5 Conclusion

This dissertation has analysed the case of the German *Energiewende*, in order to further the debate on the role of the state in promoting transformative change. Furthermore, the aim was to shed light on the challenges and difficulties in the design and implementation of effective policies for the promotion of innovative technologies characterized by uncertainties. As a consequence, the first step of the exposition involved describing the "mission" (i.e. the energy transition) and presenting its characteristics and elements. In addition, some of the contributing elements of the German National Innovation System were presented. This was done in order to illustrate how such a systemic transformation, as is the *Energiewende*, depends on the quality and interaction of a multitude of actors. Such a process does not occur in a vacuum, and analysing the success of the German energy transition just by looking at a singular policy initiative would be over simplistic. The country's renown research and education infrastructure, just like its political and institutional landscape, among others, play a fundamental part in explaining the country's success and advancements.

Aside from systemic contribution, this dissertation explored the more punctual contribution of specific policies. This was illustrated using the EEG policy for photovoltaics, emphasizing the policies trajectory over the years, and the political and institutional framing of the reform necessities.

Finally, the following discussion has tried to identify some of the important characteristics of the German EEG experience, which help explain its success. These have been broadly categorized into two groups: those related to (i) policy design, and those (ii) involving political and institutional dispute.

(i) Design

The frequency of reforms of the EEG illustrates the need for greater flexibility in policies. The days are gone in which policies addressed fixed and static issues, characterized by slow or no change. This is particularly true when policies are dealing with sectors and markets involving fast paced technological progress. The case of photovoltaic promotion through the EEG serves as a good example of this. The market growth and maturity over the past 15 years was incredibly difficult to reliably predict and thus required an adaptive policy framework. Yet besides the need for potentially more frequent reforms, the example of the EEG also illustrates the power of policy design.

The open-endedness of the policy, refraining from betting on a particular renewable technology, but instead providing for a more even playing field was very important. This is the case, not only for particular policies, but certainly for the "mission" as a whole. Schot and Steinmueller (2016, p.17) echo this when they write: "Mission oriented policies may even be counter-productive if the missions are not formulated in an open-ended way that encourages creativity and diversity."

A central mechanism of the EEG is its feed-in tariff. Mazzucato (2015) describes it as a "…good form of public 'patient capital' supporting the long-term growth of renewable energy markets." Several studies have concluded that the FiT mechanism is particularly effective at reducing prices and investment risks (MENDONCA, 2007, TOKE AND LAUBER, 2007). In addition, the German's FiT scheme's 20-year guaranteed remuneration contributes by "…reducing market uncertainty and boosting investor confidence…" (MAZZUCATO, 2015). Furthermore, the time limit somewhat anticipates the possibility for lobbying efforts to extend subsidies beyond the economically sensible given a previously chosen phase-out.

The EEGs example of degression rates for remuneration and temporal limits also have interesting implications. The former, which was refined over the years, exemplifies a policy design which not only acknowledges but goes a step further to incorporate the need to adapt to changes provoked by technological progress. In other words, creating policies which incorporate adjustment mechanism is crucial in order to have a framework more reactive to real world changes.

Nonetheless, recent years have seen a deceleration of renewables expansion. Critics point out that some of the policy changes, such as the implementation of a growth corridor and a growth cap have contributed to this. At the same time, the 'greening' of the electricity sector is not solely based on an expansion of renewable energy, but requires a complete fundamental transformation of the system. Thus, part of the obstacles for greater progress in this area can be linked to the need for advances in grid expansion, new market designs, digitalisation of infrastructure, etc. In this sense, the Heinrich Böll Foundation concludes that "…even the strongest proponents of Energiewende agree that Germany needs to reform its energy system to accommodate the next influx of renewable energies." (SOPHER, 2015). Thus the trajectory of the EEG is also characterized by trial and error, and it cannot be dismissed that the motivation behind certain policy changes are not political.

(ii) Policy

This brings the discussion to another important aspect, which the experience of the Energiewende in general and the case of photovoltaic promotion in specific, can illustrate. While on the one hand, these policy frameworks require an ever growing need for flexibility and adaptability, they also need continuity and stability. Yet this continuity goes beyond a more simplistic aspect as the 20-year guaranteed remuneration, to involve a certain level of security, that policies will be pursued in the future. Groba and Breitschopf (2013, p.15) affirm this when they write "…several studies find that the stringency, commitment and consistency of policies may be more influential than the policy type." On a rudimentary level, this means that the 'mission' will not be abandoned half way through, but in its intricacy this idea has implications on what is required for the successful catalysing of investment and market creation.

So ultimately one of the important questions is: how to strengthen policy stability? In this sense, the case of the EEG for photovoltaics holds some particularly relevant insights. As the political discussion over the promotion of photovoltaics demonstrated, there was no innate political consensus as to the questions of 'if' and 'how' to promote renewables as a whole and specifically, photovoltaic. Nonetheless, the country was able to implement an aggressive policy for the promotion of photovoltaics, and until recently, maintain and defend these strong incentives.

On the one hand, this success can be explained by the very strong public support for the expansion of renewable energy in Germany. Recent polls continue to show that even though households pay the second highest electricity price in Europe[36], 95 percent see the expansion of renewables as important or extremely important (AEE, 2017). This public support is not only the result of a particular 'cultural' affinity to climate protection or nuclear resentment, but also a direct result of a high level of public participation in renewables (as mentioned previously). As Schot and Steinmueller (2016, p.17) argue, a transformational process requires "...civil society [to be] engaged in this process, both in deliberating and setting the 'direction' and in taking part of the partnerships…". In addition to the strong public participation, there has been a growing organisational and professionalization of industry advocacy groups and lobbyist in renewables. Their collaboration with the civil society and unions has contributed significantly to the industries capacity to influence policy makers.

Undoubtedly, these trends have contributed to a stronger alignment of party policies with regard to renewable energy and climate protection. This is further helped by the fact that these issues offer themselves to stronger cross party coalitions. In the German case this has also been demonstrated through the differentiated policies pursued by the *Länder* governments. This political competition could also be observed among the ministries. Particularly the division of responsibilities between the Environmental Ministry and the Economics Ministry, which played an important role in understanding the articulation of the reforms. In summary, these characteristics of the German political and institutional landscape created a more disputed and decentralized arena, which strengthened the conditions for policy continuity through direct and indirect veto powers.

In summary, a major challenge to effective policies lies in the fact that on the one hand many comparative case studies demonstrate, long-term, reliable government commitment is decisive (HAAS ET AL., 2008, KLEIN ET AL., 2008), while on the other hand, policy needs to strike a balance between being able to overcome opposition from established actors, while also being able to adjust or phase out support when it is no longer desirable (NILL AND KEMP, 2009).

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[36]Nearly, 1/3 of household electricity prices is related to the EEG surcharge which finances the feed-in tariff. For an average household with a consumption of 3,500 kW/h this represents 20 euros a month (AEE, 2017).

Bringing the discussion back onto a more macro level of the "mission", the case of the *Energiewende* exemplifies the complexity of architecting a systemic transformation. While the expansion of renewables since the beginning of the century has been exemplary, challenges to the future progress of this pillar of the energy transition are mounting. Aside from the discussion over the necessity for grid expansion, the current policy has contributed to a steep deceleration of capacity growth. At this pace, experts warn that the *Energiewende's* renewable goals will not be met.

In fact, the majority of the goals stipulated by the *Energiekonzept* in 2010 are currently in jeopardy of not being met. This is especially a consequence of the governments inadequate progress in efficiency gains and electrification of the heating and transport sector. The latter is a particularly interesting case, as previously discussed, due to the presence of a leading automobile industry and the success and political commitment to reform in other countries. Additionally, this is not seen as a marginal by-product of the energy transition, but the decarbonisation of the transport sector is a central pillar - on a par with green power generation, energy efficiency, or the nuclear phase-out. Thus, the lack of advances in this area is also emblematic of the discussion involving the challenges of paradigm shifts and the difficulties of overcoming incumbent/established industries. It should be seen as an example of what was earlier introduced as institutional inertia to changes in the techno-economic paradigm.

These obstacles to change, were and are still present in the transformation of the German electricity system. Nonetheless, the expansion of renewables and their implication for the traditional stakeholders demonstrates the progress of this transition in the electricity sector. One simple case of incumbent interests can be seen in the example and evolution of 'industry exemptions' for the EEG surcharge. Still, perhaps a greater example with which to illustrate the discussion on techno-economic paradigms can be found looking at the *Energiewende's* progress in promoting an increase in electric cars.

The current progress of e-mobility in Germany could be seen as a cautionary tale of the challenges and difficulties facing such a transformative 'mission' as the Energiewende. As Mazzucato (2015, p.27) argues, the "challenges faced by clean technologies are therefore seldom just technical; they are political (and social) …". As a consequence, such transformative projects require mechanism to overcome this institutional inertia, and self-reinforcing structures (PEREZ, 2004).

In this sense, the case of renewables demonstrates that these hurdles can be overcome, and that adequate, bold government actions are important in providing a discontinuity/ break with established economic structures. One way to accomplish this, is by increasing the rate of deployment of new technology. This strategy of greater deployment is particularly important in order to accomplish the goals of the Energiewende, as Mazzucato (2015) argues: "Clean energy is a paradigmatic example of technology that needs to be widely deployed in order for the green industrial revolution to succeed." This also demonstrates what had been argued in Chapter One regarding the need for the adoption of new technologies in order to enable a paradigm shift (PEREZ, 2004).

Nevertheless, while the example of the EEG has greatly contributed to increasing the diffusion of renewable energy technologies and creating a market for the industry to grow, public policy investment on its own is not sufficient. There exists a necessity by governments to conceive means of directly disrupting incumbent systems given their monopolisation of resources and domination of visions of what is possible and desirable (GEELS, 2014). As was discussed in the previous chapter, when one considers the differing quality, in regards to dominance, between the electricity and the automobile industry, perhaps one can better comprehend their resilience to change.

Overall, by committing to the goals of the Energiewende, the German government has been able to mobilize substantial efforts in order to succeed in its transition. The 'mission' represents nothing short of a radical transformation of the great parts of the country's economy. As a consequence, it requires a holistic, systemic approach which enables the pursuit of a multitude of strategies, while formulating very specific metrics for evaluating success. Emblematic of a greater 'mission', while the implementation of the EEG galvanized the expansion of renewable energy, the origins of the transformation of the power sector can be traced back as far as the 1980s. This demonstrates how such a process depends on a multitude of policy initiatives, whose final results might only be apparent in decades to come.

Thus, such an energy transition inherently depends on policy making with a very long-term perspective.

The long-term approach illustrates another characteristic of such a transformative 'mission': it needs to be foresighted i.e. formulating and conceiving a mission such as the Energiewende necessarily needs to consider the question of 'what will be possible' rather than 'what is possible'. This is indicative of policy making involving dynamic, fast changing technologies. In this sense, the evolution of renewables should be seen as an example. At the beginning of the 21st century, these technologies were considered economically and technically impractical. Today they serve nearly one third of Germany's electricity demand.

In addition, it is important to bring attention to the countries innovation system, and its contribution to the Energiewende. While the EEG and its FiT have played an important role in unleashing demand for photovoltaics, Chapter Two illustrated the important contribution of subsystems of Germany's National Innovation System to the success of the energy transition. The country's institutional and innovative infrastructure are integral elements in explaining the *Energiewende's* accomplishments. In other words, one cannot understand the country's progress in pursuing the energy transitions goals just by focusing on singular policies. As a systemic transformation, it is necessarily dependent on a strong innovation system, boasting a diverse institutional infrastructure. The various elements of an innovation system, especially its ability to respond and address the demands of such a mission, are a vital contribution to the accomplishment of the Energiewende. Thus, the strength of the NIS is crucial for the success of the Energiewende.

Finally, the case of the German Energiewende illustrates the importance, yet difficulty of pursuing a mission oriented policy. A tremendous amount of opportunities are associated with the transformation to a 'green' economy. At the same time, this process represents a radical shift from 'business as usual' and thus, as the literature on techno-economic paradigm shifts argues, a considerable amount of resistance to be overcome. Thus pursuing a more active and goal oriented policy can contribute to overcoming this inertia, by stimulating and incentivizing change.

Overall, the future of this energy transition is still open and the coming years will demonstrate if the country will be able to effectively shape and implement this transformation. Nevertheless, the case holds many important insights into the difficulties and advantages of pursuing a mission oriented policy. Without effective policy making and wide political commitment, progress will be cumbersome and slow.

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Appendix 1:

The evolution of EEG

The 1998 elections in Germany represented a hallmark for renewable energy policy in the country. The elections saw the Social Democrats (SPD) and the Greens securing enough votes to form a coalition government. It was the first time, that the Green Party participated in federal government, and this coalition would come to initiate some of the major policy advances in favour or renewable and solar energy promotion.

The government dedicated special attention to introducing a paradigm shift in energy policy, which focused on the support for renewable energy technologies and culminated in the adoption of the Renewable Energy Sources Act (*Erneuerbare-Energien-Gesetz*, short: EEG). The Act was adopted by the Bundestag on 25 February 2000, supported by the SPD, Greens and PDS (Left Party), in opposition to CDU/CSU and FDP. After the EEG passed through the Bundesrat, it came into force on 1 April 2000, effectively replacing the 1991 Electricity Feed-in Act.

Building on previous experiences, the EEG introduced and maintained a number of important policy measures. Firstly, the EEG maintained the right for independent renewable energy producers access to the electricity grid if a grid connection was "necessary and economically feasible" (HOPPMANN ET AL., 2014, p.6). Secondly, for the first time, the law included technology specific remuneration at which grid operators had to purchase (costs passed onto consumers) the generated electricity over a guaranteed period of 20 years. Thirdly, this remuneration was decreased in regular intervals (applying to new installations) in an effort to exert cost pressure on energy generators and manufacturers and to accompany the accomplishments in efficiency and cost reduction caused by technological progress. This digression was put at an annual 5% of the FiT for newly installed plants as of 2002.[37]While previously, the remuneration rate was coupled to the electricity market prices, the new rules

[37]It is important to emphasize that these changes in FiT only affect new installations, i.e. plants are guaranteed the FiT at the time of their installation, for a duration of 20 years (irrespective of any legislative changes later on).

stipulate a specified absolute value, differentiated between the different technologies. The reform process, also introduced more specific energy expansion targets, which in the case of renewables included at least a doubling of the share of renewables in total energy production until 2010. In the following years, the EEG in general, and for photovoltaics in specific underwent a number of changes and reforms. While most of the reforms had been previously planned, some were a direct reaction to market developments and political pressure.

The reform in 2004, saw an increase in remuneration of PV. Recognizing a necessity for greater remuneration levels for photovoltaic systems, due to a discontinuation of low interest loans, the tariff for for rooftop-mounted PV systems was increased relative to the systems size (57.4ct below 30 kW, 54.6ct below 100 kW, 54.0ct above 100 kW)[38]. During the same time specific expansion targets for renewables were articulated. These included an increase of the renewable share of overall electricity production to at least 12.5% until 2010 and to at least 20% until 2020.

The 2009 reform of the EEG was not only a response to the quantitative growth of renewables, but stemmed from a growing necessity to address market distortions, better concepts for market and grid integration and economic efficiency. As a result, the regression rate was increased from previously 5%, to 8-10% (again depending on the system size). In connection to this a “flexible cap” was introduced which tied the degression rate to growth in solar capacity. In other words, an annual growth corridor was established of about 1,100MW – 1,900MW for solar which should it be exceeded, the degression rate would increase by 1%, while it would decrease, should the growth be below. Renewables target were also increased to at least 35% in total electricity production by 2020 (up from 20% previously), 50% by 2030, 65% by 2040 and 80% by 2050.

In 2010, through the PV Act 2010 drastic tariff cuts were implemented, ranging from 8-13% depending on the system type (8% for converted land areas installations, 12% for other freestanding systems, 13% for buildings installations). An additional cut by 3% was done in a second step which came into effect during the second half of that same year. On

[38] An additional bonus of 5.0ct for integrated facade systems.

the other hand, the flexible cap was increased to a growth corridor of 2,500 and 3,500 MW per year. With this also came a tighter growth-dependent degression rate of 1-12%, in addition to the basic regression by 9%. Should capacity growth fall below the growth corridor, the ordinary degression is relaxed in accordance.

As part of the 2012 reform which cumulated in the EEG 2.0 an optional feed-in premium was introduced in an effort to drive forward market integration of PV systems. The premium was calculated as difference between the EEG tariff and the average stock market price. In addition, a management premium was added to compensate for administrational costs and alleviated market risks.

Shortly after, the 2012 PV Act introduced major tariff cut of up to 30%. As a result, tariffs ranged from 13.5ct (for freestanding systems) to 19.5ct for roof systems. Furthermore, the tariff categories along system sizes was reformed: below 10kW, below 40kW, below 1000kW and below 10,000kW. A limit of 10MW for freestanding systems was established.

In addition, the standard degression rate was set up to equal 1% per month, or 11.4% per year, in effect substituting the previous bi-annual adjustment. Added to this, was a mechanism through which degresssion rates would rise to a maximum of 2.8% if new capacities over exceed the corridor (the growth corridor itself remained unchanged). Furthermore, a *hard cap* was introduced amounting to 52GW (27GW of PV capacity existed by mid 2012) after which, new installations lose eligibility for EEG promotion. This measure reflected the existing growth target of PV representing 8% of total electricity production (BUNDESREGIERUNG, 2010).

The 2014 reform established that installations with a capacity inferior to 500 kW before 2016 and 100kW from 2016 onwards, continue to receive the traditional FiT while other systems are only eligible for feed-in premiums (LANG AND LANG, 2015). In addition, a pilot project was implemented for photovoltaics which tested auctioning systems to determine eligibility and remuneration level for large scale systems. These are organized by the grid regulator (BNetzA) three times a year and for the years 2015-2017 the volume to be auctioned will be a total of 400MW per year.

The reform also establishes growth targets for the share of renewables in the gross electricity consumption, they being 40-45% by 2025; 55-60% by 2035; and 80% by 2050 (LANG AND LANG, 2015).

The 2017 EEG builds on the 2014, by keeping many things the same, but by also introducing some important fundamental changes for photovoltaic energy promotion (and renewable energy as a whole). The latter is primarily the result of the introduction of a tendering system for photovoltaic installation with a capacity that exceeds 750kW. The design of the auction model had previous been tested through a pilot program which was initiated in 2015.

In essence it means that eligibility for receiving a floating[39]feed-in premium (for the duration of 20 years) is determined by a tendering process under which only the most competitive projects were chosen. Systems with a capacity inferior to 750kW continue to be eligible to traditional remuneration model (feed-in or premium).

Aside from the policy mechanisms related to the promotion of photovoltaic discussed previously, the introduction of the *special equalisation scheme* in 2004 is worth briefly mentioning. The scheme represents a cost relief clause for electricity-intensive industries. Essentially the justification for this was based on the EEGs effect on rising electricity costs, which, as argued by the industries, negatively affected the competitiveness of certain sectors. As a consequence, criteria were established for companies to be eligible to be exempt from paying the EEG surcharge (or paying a fraction of it). This clause was reformed over years, allowing for the inclusion of more and more companies. Alone over the period of 2012 to 2014, the number of companies exempt from paying the full costs of the EEG surcharge increased from initially 734 to 2098 (MAYER AND BURGER, 2014). I terms of monetary exemptions, this increased from 2,7 billion euro in 2011 to 5,1 billion euro in 2014 (MAYER AND BURGER, 2014). While the policy is not directly related to the promotion of photovoltaics, as much of the reform processes as of late were at least party motivated with concerns over the growing costs of the EEG, it is interesting to recognize the multitude of elements which contribute to these costs.

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[39] A floating premium unlike a fixed premium, is adjusted in relation to the fluctuation of the electricity price.

Appendix 2:

Political and Institutional Context

During the period since its implementation, the EEG has come under reformes by four different government coalitions, over 5 legislative periods (see Table 4). The responsibility for renewables has changes ministries three times, and the growth of the photovoltaic industry translated into a more professionalized lobbying infrastructure. In addition, evolution of the EEG was closely accompanied by political debate, which saw a shift in party lines and increased relevance of regional politics. The following section will outline some of the political developments during the past 17 years, in relation to growth of photovoltaics and the debate over the future of policy support.

Table 4: Coalition Governments and EEG/PV Reforms

SPD/Greens (1998-2005)		CDU/CSU/SPD (2005-2009)	CDU/CSU/FDP (2009-2013)			CDU/CSU/SPD (2013-2017)	
EEG 2000	EEG 2004	EEG 2009	PV Act 2010	EEG 2012	PV Act 2012	EEG 2014	EEG 2017

Source: Own elaboration

SPD/Greens (1998 – 2002)

In their pursuit of a more dedicated renewables policy, the Green/SPD parliamentary groups faced resistance from the economics ministry run by former RWE/VEBA energy manager Werner Mueller[40] and who was responsible for energy policy, including renewables. On the other hand, at the time the environmental ministry under Jürgen Trittin (Greens) was

[40] independent, links to SPD

not given any significant influence in this area. As a result, the economics ministry would come to reject many of the propositions elaborated by the parliamentary groups during the drafting process. In addition, Mueller sought to suspend the reform process pointing out judicial issues under EU state law, which required clarification before any law could go into effect.

None the less, building on the existing draft, the parliamentary group launched its own proposal in December of 1999, using for the first time, the new name "Renewable Energy Sources Act". The abandonment of the earlier name "electricity feed-in Act" was meant to emphasize the fundamental shift from simple grid regulation to a broader renewables promotion framework.[41]

Among the coalition partners, the SPD was less committed to the EEG as the Greens, yet as they also underestimated the market potential of renewables, they were not worried about the implementation costs. In addition, they recognized the EEGs potential contribution to climate protection and job creation (AEE, 2010). On the other hand, as had already become clear during the implementation of the previous electricity feed-in Act, members of the environmental wings of the opposition parties (CDU/CSU and FDP) were also in favour of the EEG reform, positioning themselves in a joint declaration in support of the reform. (HIRSCHL, 2008).

The feed-in tariff systems developed and implemented on communal levels, also contributed to the design and formulation of that similar system on a national level. This caused Gründiger (2017, p.279) to observe: "Policy heritage therefore created new path dependence with positive feedback effects."

The state of Thuringia which was home to many solar cell factories, early on recognized that solar promotion was of economic interest for the state. Consequently, environmental politicians and local industries effectively lobbied the government to support the EEG.

None the less, the German renewable energy sector had already transformed into

[41]

being a world leader. By the end of 2002, the country was host to more than one-third of the global stock of wind turbines—12,001 of 32,037 MW installed capacity, in addition to having approximately one-ninth of the stock of solar cells, around 275 MW_p of 2,403 MW_p (JACOBSSON AND LAUBER, 2006). In addition, the booming market attracted a significant array of new entrants which enlarged the industry further. By 2000, Germany was considered the world leader in roof mounted solar cells (MAYCOCK, 2000)

The coalition of advocacy groups and sympathizers with photovoltaic energy came to include the traditional renewables branch associations (such as the BEE) and environmental organizations, but also the metal worker's union (IG Metall), the Farmers Association, and solar citizens' initiatives and churches. Most remarkably, with the German Engineering Association (VDMA), also an important conventional industry sector was among those on board.

SPD/Greens (2002 – 2005)

With the re-elections in 2002, Wolgang Clement (SPD) assumed the head of the economics ministry, while Juergen Trittin (Greens) remained the environmental minister. In addition, as an acknowledgement to the electoral gains the Greens had made during the 2002 elections, the responsibility for renewables policy was shifted from the economics ministry to the environmental ministry (held by the Greens). This was an important victory for the pro-renewables alliance and would greatly impact the formulation and negotiations over the 2004 EEG reform. "[W]hen authority over the renewable energy sector switched from the BMWi [i.e. the economics ministry] to the BMU [i.e. the environmental ministry] in the early 2000s, the Green-led BMU rapidly expanded its expertise with the help of renewable energy advocates and it has since then dominated the periodic revisions of the EEG. The BMU also forced its way into the energy summits that are irregularly convened by the Chancellery and brought with it representatives of the renewable energy sector. It thereby opened the last bastion of the traditional energy sector" (STEFES, 2013, p.15-16).

As had become apparent earlier, the ideological conflict between the economics ministry and the environmental ministry greatly influenced the EEG reform. Among other things, the economics ministry pushed for greater exemptions for industry. The economics ministry dedicated special effort to push for the enlargement of industry exemptions (HIRSCHL, 2008) and sought to influence further aspects.

Yet the great popularity of the EEG among both government parliamentary groups, resulted in the economics minister Wolfgang Clement being strongly criticised for his anti-EEG stance, ultimately resulting in him being isolated within his SPD party (SCHEER, 2003; LAUBER AND MEZ, 2004). This example is striking because it demonstrated an interparty support for the EEG and renewables, which superimposed itself on inner party loyalties and consistency. The SPD parliamentary group collaborated with the Green environmental minister against their own SPD economics minister. This would come to be one of many examples of important role which the parliament played as a basis for the pro-renewables coalition.

Both members of the SPD and Green party pushed for faster progress of the EEG draft process, which was moving ahead idly, due to the conflict between the two ministries. The SPD environmental wing openly criticised their Minister for his pro-coal stance and his aversion to the EEG. The economics wing of the party, did not come to his defence, having been satisfied with the inclusion of protective clauses for electricity intensive industries (SCHEER, 2003).

In the meantime, the EEG had already reached a level of high complexity and parliamentarians were dependent on the expertise of the environmental ministry to design the new reform. This meant that the economics ministry was largely left out of the formulation process, it having become the product of a collaboration between the parliamentary groups and the environmental ministry (LAUBER AND MEZ, 2004).

Even with these growing cost relief measures, the EEG remained highly contested, particularly among parts of the industry and the big energy corporations. Boasting with strong economic power and financial resources, these groups utilized their ties to policymakers stemming from the corporatist tradition of interest intermediation in order to influence and direct the development of energy policies in their favour.

This is not to say, that they were in principle against a positive stance towards renewable energy technologies. "…for the sake of climate protection and explicitly encouraged temporary state subsidization and the establishment of a domestic market for the development, testing and production of renewable technologies, though primarily meant for the export to foreign countries with better geographical conditions (GRÜNDINGER, 2017, p. 295)"

Yet finally, even with mounting pressures from great part of the German industry and power supply companies to increase exemptions for industrial consumers, the strict criteria finally established under the reformed law, allowed only for a low two-digit number of companies to be eligible for exemptions.

On the other hand, the Federal Association for Renewable Energies (BEE) opposed the "Special Equalisation Scheme", arguing that it unequally distributed the costs of the EEG, essentially violating the polluter-pays-principle. Equally, the German Confederation of Skilled Crafts (*Zentralverband des DeutschenHandwerks*, ZDH), while recognizing the economic potential of renewables for skilled crafts, disagreed to the privileges for large consumers at the expense of smaller ones. Another group, the electrical engineering association (ZVEI) and the engineering association (VDMA), had a positive outlook on the EEG, mainly concerned with avoiding the potential cost burdens of the policy.

Curiously enough, Angela Merkel, the then parliamentary chairwoman of the CDU/CSU group expressed similar concerns after the ratification of the new EEG, stating:" It is hardly realistic to raise the share of renewables in electricity consumption to 20%. I believe that it is unrealistic to expect that renewable energies can close a gap that would be opened by the early shutdown of nuclear power" (MERKEL, 2005). In her defence, there was much confusion at the time about the future development of the renewables market and the EEG. The Federal Association for Renewable Energies (BEE), an advocacy group for renewables, completely underestimated the cost development forecasting costs to reach 4.4 billion euros in 2010 and 7.0 billion euros in 2020 (BEE, 2004). In contrast, these numbers had reached 8.2 billion euros in 2010 and 20.4 billion euros in 2013 (BMU, 2013).

During that time, the renewables industry, which was initially characterized by fragmentation, weak organizational structures and financial 'light weight', began to deliberately professionalize its lobbying efforts and consolidate its strength. Of course a positive contributing factor, was the sectors growing economic and financial strength which went hand in hand with the growth of renewables. A materialization of these efforts could be seen in the increasingly coordinated statements and direct political lobbying by the DFS, UVS, and BSE associations.

One of the forerunners of this movement could be seen in the solar industry lobby. In 2003, in order to increase its effectiveness, the DFS and BSE merged, establishing the German Solar Industry Association (*BundesverbandSolarindustrie*, BSi). In addition, the BSi moved its headquarters to the countries capital, Berlin, setting up its offices in the same building as the UVS. The two associations (BSi and UVS) increasingly coordinated their activities through the "ARGE Solwarwirtschaft" working group and ultimately merged in 2006.

In parallel, efforts were also made to strengthen the collaboration within the 'Environmental Coalition'. This cumulated in the creation of the "Alliance Renewable Energies" (*AktionsbündnisErneuerbareEnergien*) on 1 September 2003, which encompassed a broad group of stakeholders from business, unions and environmental movements, including BEE, Eurosolar, the Farmers Association, the German Association of Small and Medium-Sized Businesses (*BundesverbandMittelständischeWirtschaft*, BVMW) and the unions Ver.di, IG Metall and and IG BAU. By presenting renewables as a motor for growth and jobs, they hoped to mobilize small investors and homeowners in favour of these new technologies, not from a purely idealistic belief but through a private economic objective. They understood, that these groups needed the opportunity to partake in these profits and invest, in order to firmly cement the cause of renewable energies in the midst of society (BSW, 2012).

Notably, the incumbent parliamentary groups pursued the strategy of securing a cross-party consensus with the CDU/CSU, to maintain the tradition of renewables policies being a cross-party project as was the case of the previous Electricity Feed-in Act in 1990/91. At the same time, the CDU/CSU opposition had already begun to lighten up on its opposition against the EEG and to look to approximate itself with the pro-renewables coalition (REICHE, 2004, p.142).

Differently to the Bundestag, the Bundesrat (chamber of states) was ruled by a CDU/CSU-led majority. In May of 2004, they called for a mediation committee in order to discuss the reform proposal of the EEG, in effect delaying its initial implementation of 1 June 2004. This delay and potential political uncertainty, threatened the investment security for renewables. The Bundesrat sided with the large energy suppliers, who also owned large parts of the grid, and wanted to avoid increasing shares of wind power. In addition, concerns were expressed, particularly by the states of Bavaria and Baden-Württemberg, over the negative impacts of Wind farms on the natural scenery (BR, 2004, doc. 290/04). While the Bundestag had the right (could have) to overrule the appeal, pushing through their original version of the reform, the SPD/Greens were willing to seek a consensus in order to strengthen cross-party support for the EEG.

One interesting outcome of these negotiations, was the heterogeneity in positions and preferences towards the EEG and individual technologies, among CDU/CSU-led state governments and the state associations of the parties. Certain patterns became clears, such as a preference and stronger support for bio-energy in agriculturally strong states, a consensus among Northern coastal states in favour of wind power, and priority in photovoltaic energy in the sunnier southern states of Bavaria and Baden-Württemberg.

The latter was a result of solar energy coming to be recognized by farmers as a promising economic investment, resulting in stronger political pressure in favour of those technologies, in state such as Baden-Württemberg and Bavaria, traditionally strongholds of CDU/CSU (who were predominantly against solar subsidies) (DAGGER, 2009; EVERT, 2005).

As had become clear during the Bundestag debates over the EEG reform, proponents of the law had created their own constituencies, strengthening the overall conflict capacity of the environmental coalition. This was partly due to the fact that the pro-renewables lobby could demonstrate impressive employment figures and regional economic relevance, on top of the traditionally held high trust level among the public.

Thus, substantial parts of the CDU/CSU group began supporting the EEG, in parts due to the historic role the party has played in the implementation of the EEGs predecessor,

"…a success story that they did not want to sacrifice to the political opponents…" (GRÜNDINGER, 2017, p. 303), but also as a reaction to shifting pressure and interest in their electorate. This development, brought Gründinger (2017, p. 303) to asses that "Self-reinforcing path dependence effects tracing back to the political heritage of earlier, seemingly minor reforms can be clearly observed." The federal government pursued a consensus based solution, making concessions to their original formulations, in order to secure the collaboration and support of states in the implementation of the law and future amendments.

CDU/CSU/SPD (2005-2009)

The outcome of the Federal election in 2005 resulted in a change in government. The CDU/CSU formed a grand coalition with the SPD, with Angela Merkel as Chancellor. In the coalition agreement, both parties assured their commitment to "the environmentally and economically sound expansion of renewable energies" as an "important element" of energy policy (DAGGER, 2009, p. 101-103; HIRSCHL, 2008, p. 168-171).

The new Chancellor convened three energy summits on the 3 April 2006, 9 October 2006 and 3 July 2007 (DAGGER, 2009; HIRSCHL, 2008) in order to involve a greater number of stakeholders in the preparation of the new energy strategy. Among those invited were the ministers of environment, economics and research, in addition to representatives from unions, the scientific community, energy suppliers, industrial and private electricity consumers. An important political signal was given with the invitation of representatives of the renewables branch, which many interpreted as a signal by the new Government that renewables would represent an integral part of future energy policy and planning.

The central issues that were discussed during the first summit were related to security of supply, competitive energy prices, research, energy efficiency and renewables. Furthermore, the government used this opportunity to confirm the earlier established renewable energy expansion target of 20%, going further by mentioning that it was technically, economically and politically realistic to adopt a more progressive target of 25% (BUNDESREGIERUNG, 2006).

Subsequent to the G8 and EU presidency by Germany, the German government announced its Integrated Energy and Climate Programme (*IntegriertesEnergie- und Klimaprogramm*, IEKP) at the third energy summit. The IEKP was not limited to renewables but also included cogeneration, energy efficiency, modern coal power plants, CCS among others (BUNDESREGIERUNG, 2007). The program was launched ahead of the UN Climate Conference in Bali, Indonesia at the end of 2007 (BMWi/BMU, 2007).

An explosion in oil prices reinvigorated the debate over climate change and renewables in the country. In light of the circumstances, the SPD elaborated a strategy paper "Moving Away from Oil" and claimed a National Action Plan for Renewable Energies, which included ambitious expansion targets for renewables (SPD, 2009).

This was part of an effort to regain political ground within the renewables energy/climate protection debate. In the parties' view, the CDU/CSU with Angela Merkel as their leader, had managed to portray herself as champion of renewables and the "Climate Chancellor". Thus, in order to strengthen their stance as the 'leading environmental force' in government, environmental minister Gabriel (SPD) and environmental politicians in the parliament pressed ahead with a clear profiling in energy and climate policy (DAGGER, 2009).

CDU/CSU/FDP (2009-2013)

This conviction is best exemplified by the letter from Rolf Hempelmann, chairman of the working group on energy, to the parliamentary group: "Energy and climate policy is no longer a niche topic. [...] Especially in the election (campaign) year 2009 it must concern us [...] to present our- selves as the driving force for energy policy in the coalition. This implies that we self-confidently bring up for which government agreement we consider more ambitious goals to be achievable" (HEMPELMANN, 2008, p. 9),

At the same time, in an attempt to claim the success of renewables promotion as their own, the CDU/CSU parliamentary group not only explicitly supported the EEG (JUNG, 2014, interview), but also agreed upon ambitious expansion goals which surpassed their rivals the SPD. Nonetheless, in their articulation, the emphasis remained on the *economic and social compatibility* of these energy policies (CDU/CSU-BUNDESTAGSFRAKTION, 2007).

Simultaneously, the FDP, a long time opponent of the EEG, reversed their position on renewable subsidies through a controversial vote in party congress, which narrowly won a majority, in opposition to the party leadership (GRÜNDINGER, 2017). An important factor for this shift, had been aggressive lobbying efforts by the solar industry in order to convince members of the party to support the EEG.

Yet during the same period, some have observed that the renewables branch began defending its subsidies in the same manner as traditional industries (such as the coal industry) has done, thus positioning it as a "normal" industry that has lost its idealistic drive (SCHRÖDER, 2013).

By 2008, it had become undeniable that photovoltaic energy was the costliest renewable energy. Its high tariffs accounted for 24.6% of total EEG remuneration payments, while only supplying 6.2% of renewable electricity in that same year (RWI, 2009). This helps explain why many considered the subsidization 'inefficient' i.e. too much money for too little return. Aggravating this, was the fact that enormous demands coupled with undersupply in solar panel production, meant that the industry was making huge profits. Of course this growing demand could directly be traced back to the generous tariffs.

The energy-intensive yet innovation-driven industries demonstrated an interesting position towards solar energy, since the rising electricity costs affected them negatively, while some of them such as chemical corporations, glass producers, the electronic industry acted as suppliers to them.

Another turn of events, was the withdrawal of support by the VZBV (the consumer organization). While they had been in support of the EEG and were naturally distrustful of the conventional big electricity companies, they were critical towards the rising promotion costs which the EEG represented for private households and the excessive windfall profits for the solar industry. This was seen to have been achieved at the cost of consumers, and thus the VBZV lobbied for stronger tariff cuts and degression rates.

The political establishment recognized the importance of creating a political framework which would foster a stable environment for investment. In addition, the positive contributions of the solar industry were quite apparent, industry jobs and the branches promising potential were apparent to most. On the other hand, politicians also recognized the need to tackle increases in electricity prices and the growing costs associated to the promotion of the industry. A compromise which had been found, meant that small PV systems (which represented the majority of the market) would be spared substantial cutbacks, while larger systems would take the brunt of the cuts. In addition, the idea of a flexible cap was adopted, an idea originally elaborated by Green politicians (GRÜNDIGER, 2017).

The conflict between the economics ministry and the environmental ministry continued. Growing confidence by the environmental ministry meant that its advocacy for renewables and the political competition which resulted from it, strengthened the environmental party wings and pro-renewables interest groups. This went as far as the economics ministry being openly criticised, by State secretary Michael Müller (SPD), for wasting taxpayer's money for superfluous studies in fields outside its tasks (BMU, 2007).

Again, in an effort to create consensus among policy makers, during the formulation of the EEG reform state government were invited to contribute. This was done in order to evade any further delays to the implementation of the reform through appeals in the Bundesrat. During this process it became clear again, how the growth of the solar industry had affected the different regional governments. All five of the former East-German state governments had expressed their dismissal of sever photovoltaic cuts. In all of these regions, the industry had gained significant economic importance and there were considerable concerns with the economic repercussions of major promotion cuts.

Gründiger (2017) describes the governments position writing: "Both major mainstream parties CDU/CSU and SPD explicitly accepted and actively endorsed the feed-in model and moved closer to the positions of the Greens – quasi a "grand green coalition" for renewables. "It should be noted that both parties had reconsidered their stance towards renewables, moving towards a "greener" standpoint.

With the increasing complexity of the EEG, the ministerial expertise became invaluable as support for policy makers and parliamentarians who were struggling to cope with heavy workload. Consequently, the ministries ability to influence and advice the reform processes grew.

In 2010, the new government presented its ‘National Energy Concept’ (*Energiekonzept*). While it gave continuation to the ambitious goals for renewables of of 35% until 2020, 50% until 2030, 65% until 2040 and 80% until 2050 (BUNDESREGIERUNG, 2010), it put a strong emphasis on the need to design this expansion to be more cost-effective.

The growth of photovoltaic capacity continued to be difficult to predict. The environmental ministry’s 2008 Lead Study forecasted a growth of 1,300 MW for the following year, while in actual fact 2009 saw a capacity growth of 3,800MW (nearly three times as much). This had also occurred in 2008, when capacity growth was 1,933MW while estimations had predicted it as 1,250MW (BMU, 2008; BNetzA, 2012).

The BSW which regularly published predictions of photovoltaic capacity growth, also systematically underestimated the results. Its 2008 projections had forecast a build up of 682 MW for 2009, while the actual growth amounted to 3800MW (approximately 4 times higher). The association justified its inaccurate forecasts with high market uncertainties.

This period also witnessed a number of solar companies suffering from financial difficulties. As a result, 2009 witnessed the bankruptcy of one of the leading manufacturers of large solar power plants, City Solar.

At the time, the dominant feeling was that tariffs need to be adjusted, yet market uncertainties made it difficult to determine how far-reaching these reductions could and should be. This hesitation from policy makers paved the way for lobbies to influence the decision making.

Gründiger (2017, p.335) observes that: “This intense cost debate reinforced the public image of PV as expensive form of electricity production, although prices had already dropped.” Nonetheless, a survey by Forsa (a polling firm) at the beginning of 2010 showed, that public opinion remained supportive of the EEG and the solar industry. In the survey, 71% of respondents stated that they were willing to bear an increase of the EEG levy from 3% at the time to 5% in their electricity bill within the next five years (FORSA, 2010).

Building on a consensus that tariffs needed to be reduced, the principal debate concentrated on determining the extend of these cuts. The environmental minster Norbert Röttgen presented his plans in early 2010, proposing a cut of 15% for roof systems. In opposition, the economics minister Rainer Brüderle (FDP) argued for more severe cuts by 17% for roof systems (DER SPIEGEL, 2010).

In the course of these negotiations and debates, an inner party rift on the topic of renewables became clearer. While the FDP parliamentary group was considered more favourable to renewables than the FDP-led economics ministry, the environmental wing of the CDU/CSU supported by the CDU-led environmental ministry, was able to prevail against the parties economic wing, which had favoured higher cuts.

A discrepancy became clear, as the federal government identified the need to control increases of the EEG levy, while state governments in the Bundestag were focused on protecting their regional industries. Thus the Bundestag proved to be an important veto power, as their demand for lower cuts (only 10%), resulted in compromise under which a cut of 13% was established from 1 June with an addition 3% coming into effect from 1 October onwards.[42]

Policy decision making was informed by high uncertainties in regards to the current market situation and future market development. As a consequence, policy makers had to cope under conditions of time pressure – react to the fact-paced market changes and cost increases – and limited access to information about the very volatile and dynamic market environment.

At the same time this decision making process was overshadowed by the governments nuclear policy decisions. In 2010, the government decided to extend the lifetime of nuclear power plants, together with introducing a nuclear fuel tax. Shortly after, as a result of the nuclear disaster in japan in 2011, this extension was withdrawn (whereas the nuclear fuel tax was maintained). During the same period Gründiger (2017, p.343) identifies a trend which he resumes as: “Climate protection disappeared from public debate and ceased to play a major argument in the reform process. Security of supply and cost-effectiveness advanced to the top priorities.

Despite strong tariff cuts, as a response to pressure on improving cost reduction,

[42] This was the case for roof systems. In the case of freestanding systems in open space, the cuts were 15%.

photovoltaic expansion continued to accelerate (7,400 MW new capacity has been installed in 2010 (BMU, 2011a)). With this, the EEG levy increased culminating in photovoltaics, in 2011, being responsible for a share of 56% of total remuneration costs, while representing only a 20% share of renewable electricity production[43](BMWi/BMU, 2012, p. 36).

The solar industries strong lobbying activities, together with the BSW frequently inaccurate forecasts damaged the credibility of photovoltaics. As a consequence, some environmental and the consumer protection organizations turned away their support for some of the industries claims. This was acerbated by the image that the solar industry was gaining high profit margins at the expense of electricity consumers.

The FDP economics minster Rösler called for a fundamental reform of the EEG, pushing for restrictive growth corridors and substantial solar tariff cuts. In particular, he lobbied for a growth target reduction from 3,000 MW to 1,000 MW, as a way of effectively curbing the promotion costs (RÖSLER, 2012).

On the other hand, the states demanded less severe cuts, lighter degression rates among others. The Thuringian government together with the local solar industry published a joint paper asking for a large growth corridor of 5,000 to 7,000 MW, an energy storage bonus and more research funding. These dispute manifested themselves in the remarkable decision by the Bundestag to veto governments plans to cut back solar benefits, by a 2/3 majority. It send out a strong signal, that "… state governments have turned into political protectors of the energy transformation, independent from party composition, and use the Bundesrat to give thrust to their demands and preserve the status quo against regress. (GRÜNDIGER, 2017, p.379)"

CDU/CSU/SPD (2013 – 2017)

The years of 2012 and 2013 marked the first time the existence of the EEG were

[43] In comparison, onshore wind constituted a share of 14% of remuneration costs while contributing 44% of renewable electricity production (BMWi/BMU, 2012, p. 36).

seriously questioned. This was exemplified by the environmental minister Peter Altmaier (CDU) (a ministry traditionally in support of the EEG) expressing in interview his concerns over the costs of the support for renewables. It caused him to controversially claim that the programme would run up costs of 1 trillion euros by 2040[44]. While the debate over the costs of the EEG had been debated for years, political pressures were rising.

The coalition government of SPD and CDU/CSU which came into power in 2013, identified as one of their priorities, an impactful reform of the EEG. Already in march of 2014, the policy proposal, known as EEG 2.0, was passed by the Bundestag, ultimately going into effect in august. One of the principal elements introduced by the policy, was a pilot project for photovoltaics which would test auctioning mechanisms for the determination of remuneration eligibility for future projects. This represented a first step in the major overhaul of the feed-in system, which was predicted to take place 2 years later.

The EEG 2.0 was condemned by a majority of environmental groups for failing to continue to provide a strong incentive framework for renewables. The continuation of growth corridors for photovoltaics (and other RET) was seen by many as counterproductive to the governments energy transition goals.

Overall, the pro-renewables coalition articulated their concerns over the one sided cost debate associated with the EEG. The Renewable Energy Act has been reduced to a one-sided cost debate, depicting the costs for the development of renewables as a burden, instead of an investment in the future. This was echoed by suggestions for new ways of addressing the costs associated with the EEG. The VZBV for example suggested a new approach to covering the costs for the support for renewables, by introducing a state fund to cover some of the costs, thereby lowering the EEG surcharge. The Öko-institute[45] suggested that an overhaul of the EEG-surcharge exemptions for industries, could decrease the surcharge by 20% (ÖKO-INSTITUT, 2014).

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[44] After harsh critique from the opposition (particularly the Greens), pointing out the lack of evidence for this figure, the ministry distanced itself from these claims.

[45] The Öko-Institut is one of Europe's leading independent research and consultancy organisations focusing on sustainable development.

On the other hand, representative of the traditional industry, energy companies welcomed the changes implementation by the reform, as an important step for stronger market integration, the introduction of more competitiveness and more security the grid infrastructure.

As a continuation of the efforts of the 2014 reform, the EEG again underwent some changes in 2016. The reform, known as EEG 2017[46], saw the overall introduction of an auctioning mechanism for all renewables. Following the rationale of the previous reforms, the political agenda behind the changes were to streamline the growth of renewables and to reduce costs for consumers.

The reform can be considered one of the most controversial in recent years, not alone for its abandonment of feed-in tariffs for the majority of system sizes and types.[47] While some saw the changes as step in the right direction (IW, 2016), many within the pro-renewables coalition and the political opposition argued that it jeopardised the future of renewable energy development, and the *Energiewende* as a whole. This provoked the President of the BEE to asses: „Until now, the EEG was an engine for the development of clean energies, but with today's reform, it serves mainly to preserve fossil energies, and to significantly slow the speed of the *Energiewende*. (BEE, 2016)"

Many of these critiques were more concerned with the different mechanisms introduced to control and curb renewable expansion, than with particular cuts in remuneration levels. Particularly the auction system was seen as adding to the expansion cap. Experts argued, that the could be exacerbated by the fact that annual expansion caps did not take into consideration if projects were actually implemented (BWE, 2015) and did not take into account decommissioning of older systems. As a result a study argued that by 2023, the the entire planned expansion volume will be used for replacing phased-out installations,"[48], ultimately resulting in net-decreases in capacity (BWE, 2015).

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[46] As it came into effect in February of 2017

[47] Se section "EEG Reform", in chapter 3, for more details.

[48] The study focused on the case of on-shore wind. Yet the critique of gross and net value increases of capacity continues to be relevant for photovoltaics as well, particularly once the first 20-year feed-in contracts end.

The concerns over the negative effects of RE expansion due to the EEG 2017 reform also overlapped with discussions about the feasibility of the Energiewende goals. Experts pointed out the future need for greater renewable electricity, in order to support the growing electrification of the transport and heating sector. At the same time, the increased industry exemptions were counterproductive as long as they were not coupled with energy efficiency demands.