

MES-Perspektiven 1/2016

**Coevolutionary business model  
innovation through distributed  
energy systems within Germany's  
Energiewende**

A European role model?

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*Mit einem Vorwort von Dr. Matthew Hannon*

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## **MES-Perspektiven 01/2016**

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### **Redaktion dieser Ausgabe**

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### **Erscheinungsdatum**

31. Mai 2016



## Abstract

*„Energy has become a core issue for the European Union. However, the EU does not have an exclusive competence in this field“* (Morris and Pehnt 2012: 53). Die europäische Energiepolitik zielt unter anderem auf die Integration des europäischen Energiemarktes als Schlüssel für eine kosteneffiziente Dekarbonisierung der Energieversorgung. Dies umfasst beispielsweise den Ausbau der Übertragungskapazitäten im Stromsektor, die fortschreitende Kopplung der Märkte sowie die Entwicklung gemeinsamer Regeln. Hierbei erlebt jüngst vor allem das Stromversorgungssystem mit regenerativen Ressourcen einen regelrechten Innovationsschub, der zur Transformation des Energiesektors in Europa beiträgt.

Deutschland gehört mit seiner nationalen Energiewende zu den Pionieren eines hochkomplexen Systemwechsels, dessen Erfahrungen zur Einbettung der Energiewende in den europäischen Kontext beitragen können. Unter anderem zeigt der deutsche Entwicklungspfad, wie einst fest etablierte, zentralisierte Stromsysteme, meist bestehend aus fossilen und nuklearen Großkraftwerken, einem zunehmenden Verdrängungswettbewerb durch dezentrale Stromsysteme mit dargebotsabhängiger Erzeugung aus Sonne und Wind gegenüber stehen. Gekennzeichnet durch verteilte, kleinteilige Erzeugungsstrukturen in unmittelbarer Verbrauchernähe stellen die dezentralen Stromsysteme konventionelle Wertschöpfungsstufen in Frage. Zum einen hat das einschneidende Folgen für den Erfolg etablierter, auf zentralisierte Stromsysteme orientierte Stromversorger und ihre Geschäftsmodelle und zum anderen ruft es innovative Wettbewerber ins Feld, die sich mit neuen Geschäftspraktiken auf dezentrale Stromsysteme spezialisieren, über die jedoch nur wenig bekannt ist.

Daher gibt diese Arbeit Antworten auf zwei Fragen: (1) Wie lassen sich die Geschäftsmodelle der auf dezentrale Energiesysteme spezialisieren Energieunternehmen in Bezug auf die derzeit überforderten, etablierten und auf das zentralisierte Stromsystem fokussierten Energieversorger einordnen? und (2) Welche Rolle spielt das selektive Umfeld für die weitere Entwicklung von Geschäftsmodellen, die auf dezentrale Energiesysteme spezialisiert sind?

Ausgehend von einer koevolutionären Beziehung zwischen den genannten Geschäftsmodellen und ihrem Umfeld, wird zur Beantwortung der Fragestellung ein koevolutionärer Geschäftsmodellrahmen aus der evolutionären und soziotechnischen Transitionsforschung hergeleitet und angewendet.

Im Ergebnis werden drei verschiedene Module von spezialisierten Geschäftsmodellen für dezentrale Energiesysteme hergeleitet. Diese erzeugen unter anderem einen Kannibalisierungsdruck auf das Ertragsmodell etablierter Geschäftsmodelle. Auch wird derzeit vor allem durch kontinuierliche technologische Neuerungen, ihre vielseitige Integration sowie verbesserte Wirtschaftlichkeit ein neues Konsumentenverhalten gefördert, das in wechselseitiger, positiver Beziehung zu spezialisierten Geschäftsmodellen für dezentrale Energiesysteme steht.



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## Foreword

Over the past decade we have witnessed seismic shifts in the global energy landscape triggered by developments including the most severe economic downturn since the Great Depression, the world's first global agreement of climate change mitigation, dramatic reductions in alternative energy technologies and major geo-political incidents that have illustrated the fragility of global energy security (e.g. Fukushima, Russian gas crisis). These developments have placed mounting pressure upon incumbent energy companies, negatively impacting upon the profitability of their centralised, fossil-fuel, volume oriented business model. In parallel a host of novel business models have emerged to take advantage of this fast changing environment, aimed at satisfying our energy needs in an environmentally, socially *and* economically sustainable fashion. Whilst it is difficult to say whether we are witnessing the beginning of an 'energy revolution' these changes raise interesting questions about whether the incumbent models will remain dominant in the future or whether a new order of energy business models will emerge.

In this context this thesis makes a valuable contribution to the extant literature by examining the types of innovative decentralised energy business models that have emerged, taking Germany and its Energiewende as a case study. By employing a co-evolutionary framework it examines the relationship these business models share with their wider socio-technical environment such as institutions, technologies, consumers and incumbent energy companies. Three key messages emerge from this thesis.

The first is that we are seeing not just one but a host of new decentralised energy business models emerging that are both characteristically distinct from incumbent centralised model

and from one other. These demonstrate a number of unique strengths and weaknesses but if compared to traditional business models they offer many advantages in relation to capturing added value from intermittent renewable energies for both suppliers and consumers.

The second is that their emergence is the product of a co-evolutionary relationship where wider changes to the energy landscape have resulted in a more supportive selection environment for these models (e.g. renewable energy technology innovation, institutional support for climate change) but also that the adoption of these models has in turn shaped this landscape (e.g. changes to consumer expectations and behaviours). This positive feedback cycle could serve to 'lock-in' these new business models and potentially 'lock-out' the incumbent models.

The third is that the incumbent centralised energy companies have not yet overhauled their centralised, fossil fuel, volume-based supply model, incorporating only piecemeal aspects of alternative renewable or efficiency based decentralised models. This raises important questions about whether the utility companies will indeed survive in this fast changing selection environment that increasingly champions a low-carbon, energy efficient and socially responsible energy supply.

In summary I welcome the valuable contribution this thesis makes to a burgeoning literature of energy business model innovation and sustainability transitions, seeking to tackle difficult questions about the relative roles of novel and incumbent energy business models as part of a transition to a radically different energy system.

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*London, May 2016*





***“The Stone Age did not end for lack of stone,  
and the Oil Age will end long before the world runs out of oil.”***

Sheikh Zaki Yamani (1973), former Saudi Arabian oil minister.

## 1 Introduction

### Topic

*“Energy has become a core issue for the European Union. However, the EU does not have an exclusive competence in this field”* (Morris and Pehnt 2012: 53).

The European energy policy aims to integrate energy markets as a key of a cost-efficient decarbonisation of its energy supply. Among others, the expansion of transmission capacity in the electricity sector, an on-going coupling of energy markets, the development of a joint regulatory framework as well as the complex adaptation of energy supply systems are playing a crucial role in the European energy transition. With regard to especially national energy systems and markets, an evolution of a co-system can be observed currently. In some European countries an incumbent, centralized electricity system (CES) fuelled with high-carbon intensive energy resources is rapidly replaced by a coevolving distributed electricity system (DES) based on low-carbon intensive energy resources and renewable energy (RE) (Foxon 2011; Burger and Weinmann 2013).

Germany, often named as a pioneering example with its *Energiewende*, is currently undergoing such energy system<sup>1</sup> change, affecting also underlying markets and incumbent business models. But even though Germany is currently taking a leading role with global attention, recent developments are not seen without any doubts (Morris and Pehnt 2012; BMWi 2014b; Rosenkranz 2015). With its radical transition Germany is entering a new complex territory, which is described as challenging, lacking clear structures and best practice. Leprich for instance points out that *“Man würde sich verheben, schon heute einen Masterplan für das Design des Stromsystems über den gesamten*

<sup>1</sup> Even though energy and electricity does not necessarily have the same meaning, the author uses the terms as synonyms. Since the focus of this thesis is on electricity, energy shall be understood accordingly.

*Zeitraum der Transformation präsentieren zu wollen”*<sup>2</sup> (bne 2013: 18). However, Germany’s national developments provide experiences which might help to achieve a cost-efficient decarbonisation pathway for the entire European energy transition and give plenty of impulses for supporting research, from a practical perspective but also from a methodological point of view.

### Problem

Practically, although experts agree to a substantial economic potential and quick development of DES, pioneering literature is still rarely available. For example, coevolving DES-related business models are assumed to play a key role in the continuing transition (Strobel and Frühbauer 2011; Gerbert et al. 2013; Richter 2013a; Richter 2013b; Hannon et al. 2013; Burger and Weinmann 2013; Fox-Penner 2014; Marko 2014; Arriag et al. 2014; Henbest et al. 2015). However, several studies refer to a lack of investigation about DES-related business models and how they can overcome economical, technological, institutional and psychological hurdles (e.g. Burger and Weinmann 2013; Hannon et al. 2013; Arriag et al. 2014). In addition, little is known about business model innovation (BMI) of struggling CES-related incumbent utilities and their competition towards new players in a transforming electricity system. This also includes recent developments (e.g. technologies and markets) which allow a diverse look into the future in order to facilitate the success of new DES-related business models (Richter 2013a; Hannon et al. 2013; Burger and Weinmann 2013).

To account for the complexity and lack of structure, some academic researchers are recently investigating comprehensive approaches in order to frame the overall picture of a transition and to pick out specific elements for deeper analysis. For instance, one stream of econo-

<sup>2</sup> Own translation: One would expect too much to already today elaborate and present a master plan about the design of the electricity system over the whole period of the transition.

mists attempts to transfer Charles Darwin's (1859) three biological principals of evolution (i.e. variation, replication, and selection) to socio-technical systems, which assumingly also undergoes evolutionary cycles (e.g. Foxon 2011; Norgaard 1994). Broadly speaking, they expect that a variation of human shaped systems coevolves and the most competitive in a dynamic environment dominates (selection), locks-in and develops further to an incumbent system (replication) (Hodgson and Knudsen 2004; Hodgson 2005). Termed as 'creative destruction' by Schumpeter (1934), new players are persistently questioning and challenging the incumbent system with incremental and sometimes radical innovation, triggering defence or adaptations strategies (Henderson 1993; Burger and Weinmann 2013).

### **Purpose**

In order to give potential directions within complex transition of energy systems with renewables, Foxon (2011) provides a coevolutionary framework, which is recently used by several researchers to focus and analyse different domains and players in the energy system (e.g. Hall and Foxon 2014; Taylor et al. 2013; Hannon et al. 2013). For instance Hannon et al. (2013) firstly put a business model perspective into the centre of investigation from which they derive promising insights for the energy transition in the United Kingdom (UK).

Consequently, this gives inspiration to shape an own coevolutionary business model framework in this thesis and firstly apply it within Germany's Energiewende. The aim is to structure the complex national electricity transition in order to disclose relevant interactions of DES-related business models with their selection environment (Richter 2013a; Hannon et al. 2013; Burger and Weinmann 2013). This might provide a new perspective for relevant players, particularly for incumbent but also new types of utilities. To conclude, this thesis addresses two questions:

- (1) What type of new utility, representing DES-related business models, does currently challenge the struggling, incumbent utilities, representing the CES-related business model?
- (2) What role does the selection environment for the further development of DES-related business models play?

### **Structure**

In order to understand the need and fundamentals for a new type of business models, this

thesis in a first step (chapter 2) aims to comprehensively describe the relevant background of Germany's electricity system, divided into a centralized and a coevolving distributed one, as well as their underlying electricity markets. Furthermore, the current state of incumbent utilities is uncovered in order to derive implications for DES-related business models. In a second step, chapter 3 describes the thematic relevance and scope of the analytical framework for this thesis in order to shape an own coevolutionary business model framework with a main focus on DES-related business models. In a third step, chapter 4 entirely sheds light on DES-related business models, including its classification, its market presence and its comparison with CES-related business models. Most importantly this part also analyses the wider and dynamic socio-technical environment of DES-related business models based on the own coevolutionary business model framework. Finally, chapter 5 draws a conclusion about the findings and gives implications for further research.

## 2 Background

In order to investigate electricity system-related business models in a coevolutionary framework, it is first necessary to understand CESs and DESs itself. Hence this chapter firstly breaks down its development from a global to a national perspective, shortly describes its historical development, and finally sheds light on its today's constitution with regard to its physical functionality, its classification and unique characteristics respectively, as well as its related energy markets.

### 2.1 The global transition of energy systems

The International Energy Agency central scenario predicts a global growth of energy demand by 37 percent (%) until 2040. The energy use is assumed essentially flat in most parts of Europe, Japan, Korea and North America, but rising consumption is concentrated in the rest of Asia (60% of the global total), Africa, the Middle East and Latin America. In particular China, India, Southeast Asia, the Middle East and sub-Saharan Africa take over as the engines of global energy demand growth. In order to meet the global energy need, the supply mix is predicted to change and will be divided into four almost-equal parts: oil, gas, coal and low-carbon sources by 2040 (IEA 2014). This growing energy demand and its attributive supply mix have significant impact on the environment. To prevent and limit human made global warming and climate change, especially low-carbon sources take an important role within an ongoing, global debate.<sup>3</sup> The recent global energy outlook by Bloomberg New Energy Finance highlights that developed countries are rapidly shifting from traditional CES to more flexible and decentralized ones that are significantly less carbon-intensive. Over the next 25 years a new energy generation mix with new, evolving technologies is going to establish, offering new market opportunities (Henbest et al. 2015).

From different perspectives, Germany is taking in a pioneering role, pursuing a radical change of its energy system. According to a global trend report by World Wide Fund for Nature (WWF) and Lichtblick, Germany is designated as a trigger and pioneer for a global *Energiewende* (i.e. energy transition), even though

<sup>3</sup> A critical trend analysis in the energy sector affecting investments profile on a global stage is not part of this thesis. However, a short overview by WEC (2014) is provided in Table 2 in Appx: A.

no reasons for any stakeholder to lean back exist (Rosenkranz 2015).

According to absolute installed capacity of RE,<sup>4</sup> Figure 1: 5 highlights the top three countries, as well as the global efforts to increase electricity generation from renewables between 2005 and 2014. RE capacity (excluding hydro power<sup>5</sup>) has increased by almost a factor of six worldwide from 116 gigawatt (GW) in 2005 to 658 GW in 2014, even though it only represents 6.2% of global electricity production in 2014<sup>6</sup>. Germany as pioneer has been among the top three countries since the beginning of this development. In a relative term, with regard to electricity production from renewables per capita, Germany is by far taking the leading role among all represented countries, EU-28 and the world from the beginning on. For instance in 2014, on average for each German 1,070 W (W) RE capacity was installed, which is roughly twice as much as in EU-28 (500 W), three times more than in United States (330 W), ten times more than in China (110 W) and twelve times more than in the world (90 W) (Figure 1: 5).

### 2.2 Germany's electricity system

This section sheds light on the development of Germany's electricity system with regard to its historical development, special features and today's constitution. A special focus is on the differentiation of CES and distributed electricity systems (DES). This is necessary in order to better understand the transition of the electricity system and analyse related business models (e.g. Schoettl and Lehmann-Ortega 2011; Richter 2013b).

#### 2.2.1 Historical development

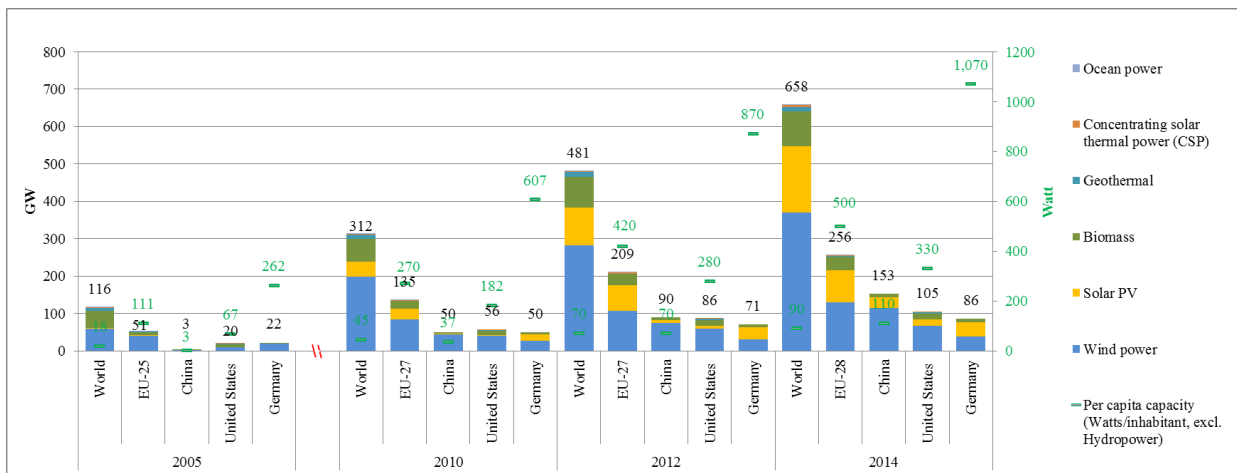
##### 2.2.1.1 Rise of a distributed electricity system

The history of electricity value chain in Germany has begun in the end of the sixties and beginning of the seventies of the 19<sup>th</sup> century as a result of the development of the electric small-scale generator and electric lighting. In 1905

<sup>4</sup> Absolute figures are the most important trigger as lighthouse effect and in terms of economies of scale and learning curves.

<sup>5</sup> Even though hydro power has the largest share among RE capacity worldwide, it is geographically limited to a few countries and therefore difficult to compare. Therefore many studies consider hydro power separately (e.g. REN21 2015)

<sup>6</sup> Global electricity production end of 2014: 77.2% fossils fuel and nuclear, 16.6% hydropower and 6.2% other renewables (wind 3.1%, bio power 1.8%, solar photovoltaic (PV) 0.9%, rest 0.4%) (REN21 2015).



**Figure 1: Global renewable electricity capacity, top three countries, EU and world (2005, 2010, 2012 and 2014).** Source: Own figure, based on data from Global Status Reports by REN21 (2006-2015), PRB (2005) and PRB (2010).

already 1,175 power plants were put into operation exclusively in urban areas because of limited distribution and transmission capabilities of direct current (Fischer 1992). With the introduction of alternating current, so called power stations also extensively supplied rural areas with electricity, covering lightning, electrical trams, industry and households. Commonly in private ownership, in the beginning of 19<sup>th</sup> century a municipal- and public share ownership finally become wide spread. Since then, the integrated grid and electricity utilities strongly expanded, accounting with 10,000 distributed companies its maximum in 1936 (Müller 2001).

### 2.2.1.2 Centralization of the electricity system

The high concentration of competitors and fragmented grid structures often made the business unprofitable and led to shutdowns and consolidations (Fischer 1992). As a consequence, the first energy act 'Energiewirtschaftsgesetz' (EnWG) was announced in 1935 and the government started to regulate the energy sector. One of the leading premises was the reduction of economically harmful effects of competition. The energy sector was seen as very sensitive business, since electricity cannot easily be stored and bound to the grid. Its transportation requires special and unique transmission and distribution systems and additionally electricity supply and demand need to be balanced at any time. Being afraid of the destabilizing experiences with competition, electricity supply became vertically integrated and concentrated with oligopolistic and monopolistic structures, driven by the logic of economies of scale. The ownership structure

was strongly characterized by public share, particularly by federal states. The electricity market adhered to the Energiewirtschaftsgesetz, Germany's Energy Industry Act (EnWG) for more than 60 years until 1998 when the law was amended for the first time (Bartel 2011; Schneidewind and Scheck 2012; Gerbert et al. 2013).

### 2.2.1.3 Liberalization of the electricity system

Inspired from the technical innovation within the telecommunication market and its successful implementation of competition, the energy market also started to liberalize with the amendment of the EnWG in 1998. Both industries fundamentally relied on a sensitive grid infrastructure, so that experiences were seen as transferable. This development was strongly driven by the legislative power of the European Commission (EC), which pushed forward a European Single Market for energy. The main purpose was the implementation of the single market directive for electricity until 2011, mainly comprising a gradual market deregulation, non-discriminatory grid access and unbundling (i.e. legal separation of generation and grid) (Bartel 2011; Gerbert et al. 2013).

### 2.2.1.4 The Energiewende – the national commitment

Apart from the legislative purpose of the EC, also the German government has committed to ambitious national goals, highlighted as the 'Energiewende'<sup>7</sup>, e.g. to fight climate change,

<sup>7</sup> The Energiewende movement resulted from the anti-nuclear movement in the 1970. The term 'Energiewende' goes back to the 1980's and a publication of the German

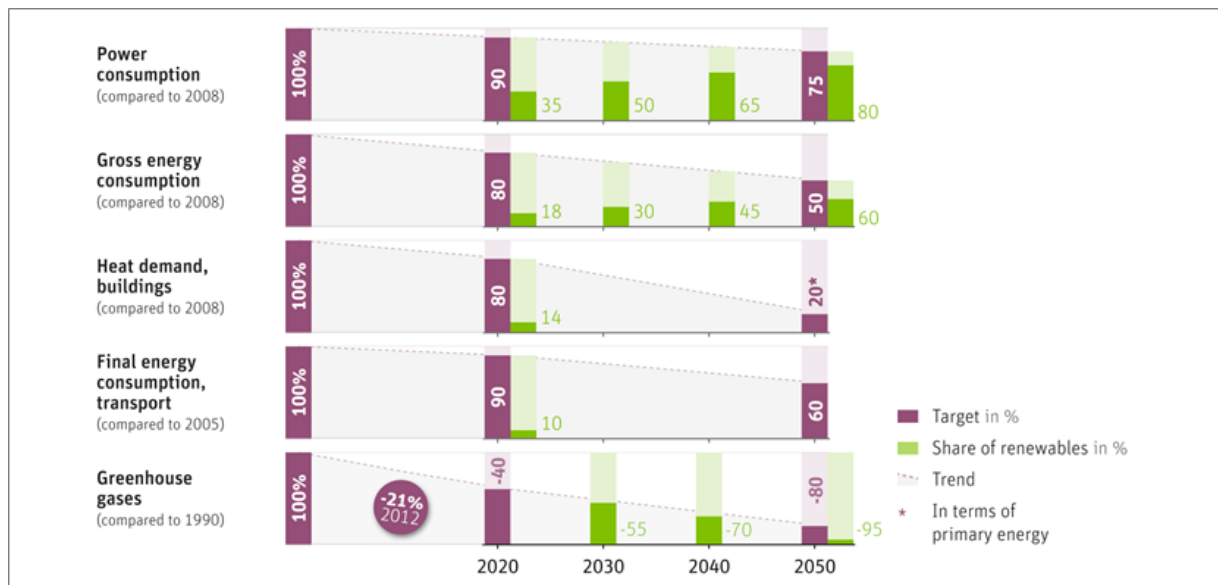


Figure 2: Long-term energy and climate targets set by the German government in 2010. Source: Morris and Pehnt (2012: 11).

reduce energy imports, stimulate technology innovation and the green economy, reduce and eliminate the risk of nuclear power, ensure energy security, and strengthen local economies and provide social justice (Morris and Pehnt 2012). The major target in long-term is to become both carbon- and nuclear-free (Morris and Pehnt 2012; Burger and Weinmann 2013). Regulated and supported in Germany's Renewable Energies Act 'Erneuerbare-Energien-Gesetz' (EEG) (e.g. through feed-in tariff (FiT)), fossil and nuclear based generation in national energy system is planned to be increasingly replaced with intermittent RE and low-carbon resources (e.g. solar PV, wind, biomass). Figure 2: 6 represents the importance of an increasing share of renewables (see green bars) in order to achieve the comprehensive long-term energy and climate targets until 2050 set by the German government in 2010. The aim is not only to reduce power consumption, gross energy consumption, heat demand for buildings, and final energy consumption for transport, as well as greenhouse gases (GHG), but also a strong electrification of the energy sector with renewables, including also heating and transportation which is traditionally separated and powered by fossil fuels (Morris and Pehnt 2012; SRU 2013; BMWi 2014b).

These long-term reductions targets, as well as integration of intermitting RE confronts the energy system, and particularly the electricity system not only with complex technological,

but also with various, interrelated institutional, societal, market and business challenges (BMWi 2014b).

### 2.2.2 Today's electricity system

With regard to the electricity system, both the liberalization as well as the Energiewende with its introduction of RE generation facilitates a move back to a distributed value chain approach. Since the beginning of the 21<sup>st</sup> century, the concentrated formed electricity system is somewhat turning back to its historical, distributed origin in the mid-19<sup>th</sup> century, but with entirely new features, technologies and dimensions. Consequently, as illustrated in Figure 3: 7, the today's electricity system in Germany can be distinguished into the traditional CES (see left to right) and a coevolving DES (see top to down).

Both attach a different value to certain electricity system-related domains and electricity markets, and are strongly characterized by its used generation, network and control technologies. In order to understand and differentiate both electricity systems, it is on the one hand fundamental to link CES- and DES-related business models accordingly and on the other hand to also derive interrelations with subsystems of the coevolutionary framework, which will be introduced in chapter 3. Therefore, the following sections give an overview about the characteristics and distinction between CESs and DESs, its practical dissemination, as well as an introduction into the three underlying electricity markets, linking business models to electricity systems.

Oeko-Institut (Krause et al. 1980) which points out scenarios for growth and wealth without oil and nuclear power.

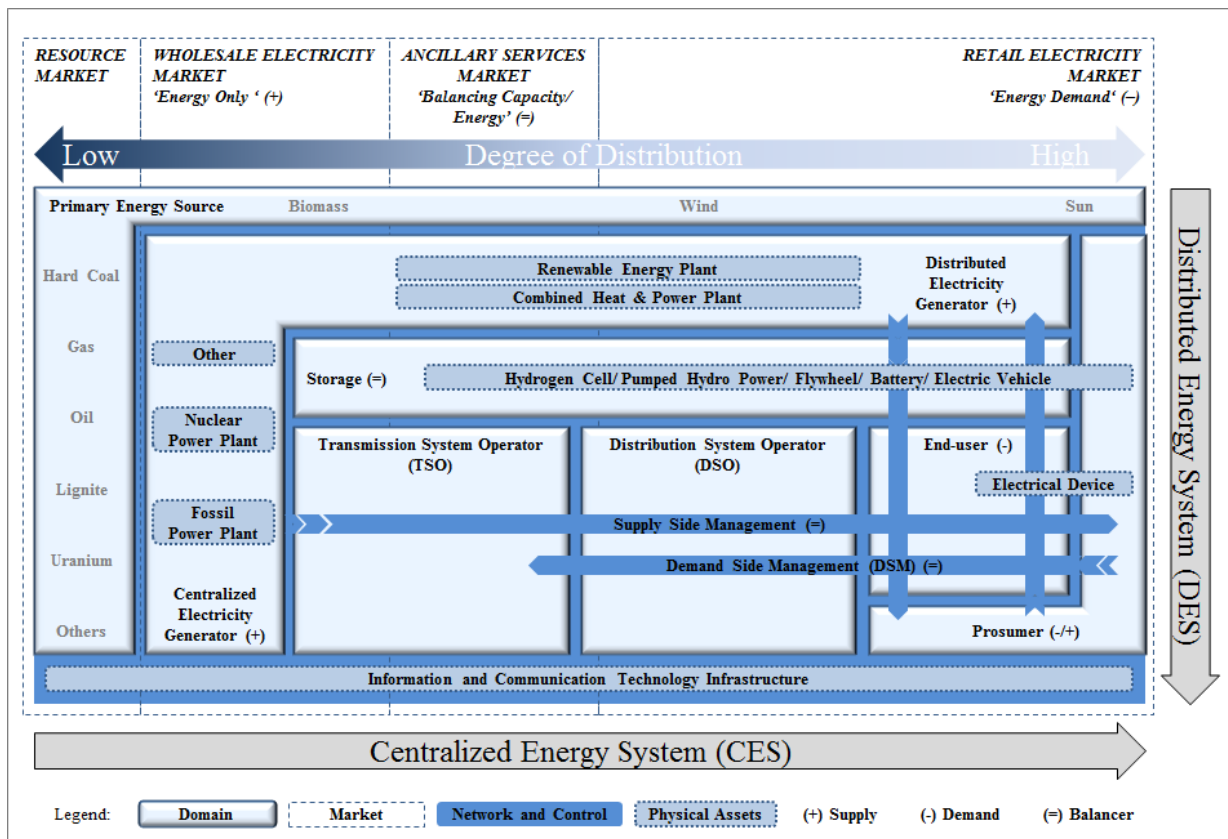


Figure 3: The German electricity system at a glance. Source: Own figure.

### 2.2.2.1 CES

As illustrated in Figure 3: 7 (see left to right), the CES traditionally consists of five energy domains: primary energy source (e.g. lignite), generation (e.g. fossil power plants), transmission, distribution and end-user. There are 300 electricity producers each with more than 100 megawatt (MW) capacity in Germany, dominated by four vertically integrated power utilities<sup>8</sup>, namely Rheinisch-Westfälisches Elektrizitätswerk AG (RWE), E.ON, Vattenfall and EnBW (BIG4)<sup>9</sup>. They share the majority of the electricity market and use mainly fossil and nuclear energy sources to centrally generate bulk electricity which is traded at wholesale markets. In 2014 through a regulated, oligopolistic transmission system (e.g. high voltage, long-distance grid) with four operators (i.e. 50Hertz, Amprion, TenneT, TransnetBW) and a regulated, competitive distribution system (e.g.

low and middle voltage, short- and medium distance grid of power lines and substations) with 884 operators, electricity is transported and finally retailed by 1,117 suppliers to their contracted end-users (i.e. load consumers) (Ibrahim and Ilinca 2013; SRU 2013; Konstantin 2013; BMWi 2014a; Bundesnetzagentur and Bundeskartellamt 2014; Verivox 2015). Suppliers can either act as vertically integrated utilities and sell own generated electricity through own distribution networks or purchase electricity volumes in the wholesale market in combination with necessary transport services (Knieps and Brunekreeft 2003; Bundesnetzagentur and Bundeskartellamt 2014). End-users are distinguished into household, commercial and industrial customers according to voltage, annual consumption, annual peak load and annual utilization time (Bundesnetzagentur and Bundeskartellamt 2014).

During the last decade the CES is radically pressured through the impact of DES with renewables (see top to down in Figure 3: 7). For example the recent global energy outlook by Bloomberg New Energy Finance<sup>10</sup> highlights

<sup>8</sup> Definition: "An electric utility is an electric power company (often a public utility) that engages in the generation, transmission, and distribution of electricity for sale generally in a regulated market (...). Electric utilities include investor owned, publicly owned, cooperatives, and nationalized entities. They may be engaged in all or only some aspects of the industry" (SKM 2015).

<sup>9</sup> Hereafter RWE, E.ON, Vattenfall and EnBW will be termed as the BIG4 ('Big Four').

<sup>10</sup> Bloomberg New Energy Finance provides unique analysis, tools and data for decision makers driving change in the energy system.

that developed countries are rapidly shifting from traditional CES to more flexible and decentralized ones (Henbest et al. 2015). The ongoing shift from a CES towards a DES also termed as 'deconstruction and fragmentation' is mainly impelled by re-regulation, new business models, increasing competition and a strong pressure on return on investment (Gerbert et al. 2013).

### 2.2.2.2 DES

The growing availability of small-scale generation technologies such as renewables and combined heat and power units shorten the transportation distance between production and consumption. This consequently increases the degree of distribution within electricity systems, labelled as DES. Fossil-based primary energy source in the first domain of electricity systems loses importance, as the primary RE sources such as solar radiation, wind and under certain restriction also biomass are infinite and physically available almost everywhere to almost zero marginal cost. Through evolving technologies, RE sources can be harvested more and more efficiently everywhere. Consequently, producers and consumers of electricity move closer together and even become one single entity, called prosumers<sup>11</sup> who entirely or in parts do not rely on centralized generation, transmission, distribution and electricity markets as in a CES (Bremdal 2011; Shandurkova et al. 2012; Orecchini and Naso 2012; Gerbert et al. 2013; Clinton and Whisnant 2014).

This development is accompanied and supported by a new, sixth domain within the value chain, i.e. energy storage. Whereas fossil-based energy sources theoretically incorporate storage characteristics by nature (e.g. coal can be burned when electricity is needed), intermittent RE source such as wind and PV are dependent on weather conditions and daytimes. For example, electricity from solar PV needs to be stored temporarily during daily sunshine hours to guarantee electricity supply also during the night and overcast days.

Depending on its attributes and benefits, different promising energy storage systems (e.g. battery, pumped hydro power, flywheels) are installed and used at different domains of the

value chain (e.g. directly at the power plant, in support of the transmission and distribution system, and on the end-user side) (Makansi and Abboud 2002). Currently, batteries are among the most promising artificial electricity storage systems because of their relative efficiency and technical applicability for small-scale DEG based on renewables (Shandurkova et al. 2012; Guerrero-Lemus and Martinez-Duart 2013). Energy storage allows to better balance fluctuation of electricity production and consumption, from a technical as well as an economical point of view (Makansi and Abboud 2002). However, intermittency of renewables remains a key challenge where the development of storage technology lags behind (WEC 2014).

Together with the integration of new evolving network and control infrastructure (i.e. information and communication technology (ICT)) (highlighted as blue background in Figure 3: 7), all six domains (i.e. primary energy source, generation, transmission, distribution, energy storage and end-user) create a more responsive market, in particular enabling a smart, remote and bidirectional monitoring, control and communication along the entire value chain, also termed as smart grid. Firstly in time, a purely unidirectional and supply side management driven electricity system is increasingly complemented by the technological opportunity to actively interact with end-users, termed as demand side management (DSM) (Makansi and Abboud 2002; Ibrahim and Ilinca 2013; SRU 2013).

Pérez-Arriaga summarizes the attributes of a DES in his definition as follows: "A *Distributed Energy System* [...] is a system combining one or more distributed energy resources (DERs), including distributed generation, distributed storage, and/or demand response, with information and communication technologies (ICTs) to enable a business model that provides valued services to energy end users or upstream electricity market actors" (2014: 18).

### 2.2.2.3 Comparison of CESs and DESs

The differentiation of CES and DES is mainly determined by the characteristics of its electricity generation, as well as its network and control system, discussed as follows. Furthermore, to give a first indication about the increasing degree of distribution within the electricity system this section shows its progress based on the technologies used in the national electricity generation mix, as well as associated ownership structures.

<sup>11</sup> The concept of a 'Prosumer' is firstly termed in Toffler's (1980) book, the Third Wave (Tapscott and Williams 2006). Because of its relevance today, Don Tapscott's (1996) book 'The Digital Economy' reintroduced the term 'prosumption', describing "how the gap between producers and consumers is blurring" (Tapscott and Williams 2006: 125), based on new technologies (e.g. smart grid technologies and small-scale DEG) (Shandurkova et al. 2012).



**Characteristics of electricity generation**

According to Rawson “distributed generation is electricity production that is on-site or close to the load centre” (2004: 5) which implies that concentrated generation is far away from the user. Nevertheless, Orecchini and Naso point out that “both refer to the size and the localization of a plant (large conversion plants far from users, or small-sized plants close to users), but neither the size nor the distance from users indicate any values of sharp distinction between distributed and concentrated production” (2012: 297-298).

Therefore, Orecchini and Naso (2012) highlight a different degree of distribution of generation. For example PV plants range from directly installed plants at one end-user’s roof-top, up to ground-mounted PV plants that supply entire groups of residential, commercial or industrial end-users. Moreover, the authors particularly aim for a global energy efficiency point of view where the distance between generation and end-users also includes losses for transport.

Orecchini and Naso (2012) define two types of DEG:

- The first is seen “as the production through plants that use primary resource locally available as a resource”

(Orecchini and Naso 2012: 298), implying that the overall efficiency increases with the ‘degree of distribution’. The closer generation and consumption are localized, the higher is the degree of distribution and the better is the overall efficiency. This definition exemplarily includes solar PV plants and wind power plants (Orecchini and Naso 2012).

- The second type evaluates the ‘degree of optimal distribution’ and rather applies to resources such as biomass. It is defined as “the production through plants that use as a resource an energy vector made available to the end user and for whose transportation energy was spent” (Orecchini and Naso 2012: 298). This type of DEG creates transport losses at the generation and end-user side and therefore overall efficiency increases by finding the optimal trade-off between both. For instance biomass has a low energy density (in weight and volume) and transport energy losses during energy production are relatively energy intensive. To keep acceptable values (10-20%) for these transport losses, the distance between the primary source

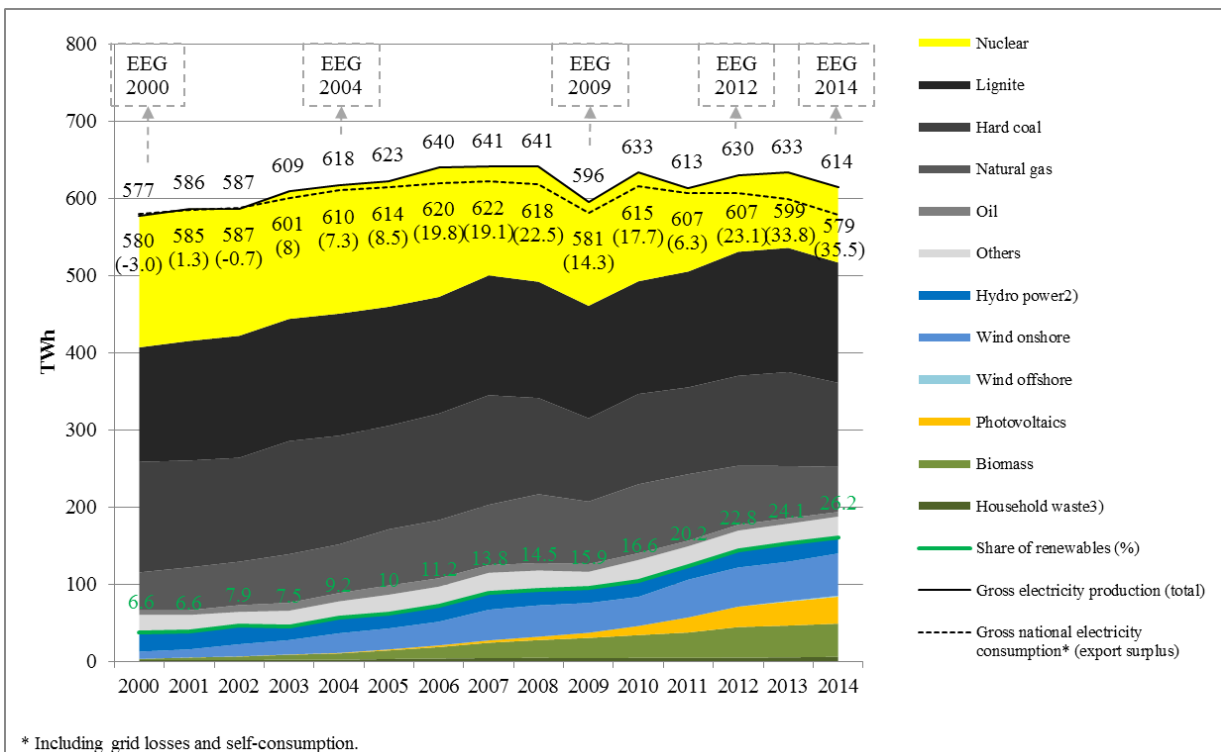


Figure 4: Germany’s gross electricity production mix and consumption (2000-2014). Source: Own figure, based on data from AGEB (2015).

and generation unit should be limited to 100-150 kilometres. This context does not mean centralizing production, but rather to distribute transport losses near the resource and not near users (Orecchini and Naso 2012).

**National electricity generation mix**

With regard to characteristics of electricity generation, the national electricity generation mix provides a first indication about the progress of a transforming electricity system. In addition, first conclusions about the degree of distribution of the electricity system, its size, as well as general trends can be drawn.

Figure 4: 9 shows generation technologies used and their electricity output in terawatt hour (TWh) in relation to total gross electricity production and consumption in Germany between 2000 and 2014.

The trend reflects indications about the interaction of technological developments, business strategies and regulations, as well as changing consumer and citizen behaviour (Schneidewind und Scheck 2012). The graph strongly emphasizes the ongoing pressure of DESs with renewables (e.g. wind, PV and biomass) on CESs with fossil fuels (e.g. nuclear, lignite and

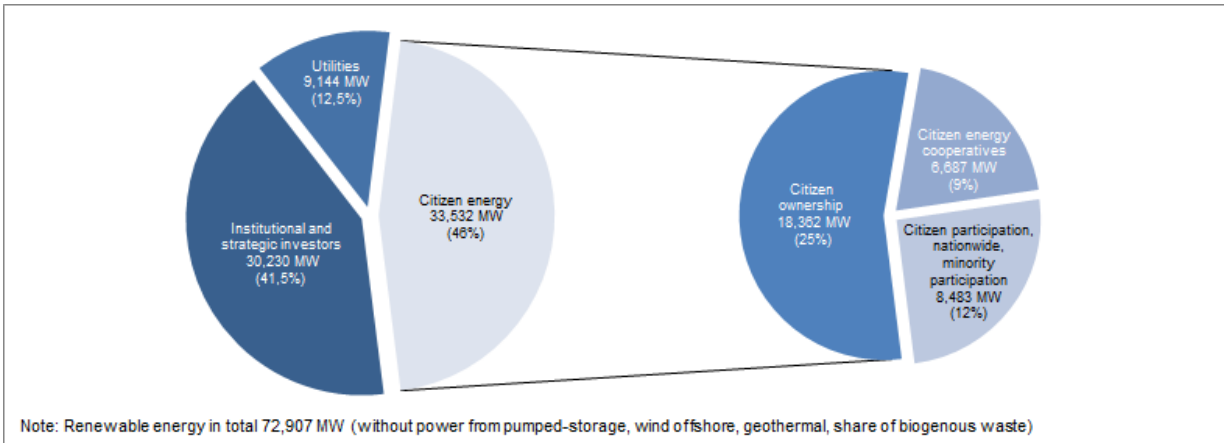
to 579 TWh, reaching a similar level as in 2000 (580 TWh).

Secondly, since the turn of the millennium, the energy mix is significantly transforming as a consequence of market liberalization as well as the governmentally induced Energiewende. Produced electricity from RE sources rapidly increased from only 6.6% in 2000 to a total share of 26.2% in 2014, mainly driven by wind onshore, PV and biomass installation and the shrinkage of nuclear, hard coal and natural gas electricity generation.

Thirdly, the electricity exchange balance<sup>12</sup> indicates an increasing export surplus with Germany's neighbour countries since 2003, from 8 TWh in 2003 up to 35.5 TWh in 2014. This is caused by falling gross electricity consumption with a simultaneous growth of electricity production, induced by the share of RE growing faster than nuclear and fossil fuel generation is declining.

**Ownership structure**

Germany's citizen plays a leading role within the Energiewende and DESs. DEG with renewables also enables a new ownership structure DESs compared to the CES. The availability of DEG technology increasingly transforms



**Figure 5: Installed RE capacity by ownership groups in 2012. Source: Own figure, based on trend:research and LU (2013).**

hard coal).

Firstly, the graph illustrates a stagnating gross electricity production slightly above the six-hundred-level (average of 614 TWh between 2002 and 2014) during the last decade with a slight peak load of 641 TWh in 2007. During the same period the gross national electricity consumption also experienced an arch-shaped development with a slight increase up to 622 TWh in 2007 which was then going down

traditional private, residential and industrial consumers into prosumers who partially or even entirely self-consume own electricity (Gerbert et al. 2013). For example Germany operates 1,600 conventional power plants with ≥10 MW nominal capacity, almost exclusively

<sup>12</sup> The electricity exchange balance indicates either the difference between gross electricity production and gross national electricity consumption and/ or the difference between electricity imports and exports.

owned by some big investors such as utilities (Bundesnetzagentur 2015a).

This number of conventional power plants is small, in comparison to for instance 24,867 wind power stations by the end of 2014 (BWE 2014) and more than 1.4 M PV power plants by June 2015 (Wirth 2015). In 2012, citizen ownership, citizen energy cooperatives and citizen participation held the majority share of 46% of the total installed RE capacity in Germany, more than institutional and strategic investors (41.5%) and almost four times as much as all utilities with 12.5% (Figure 5: 10). The BIG4 accumulate even less than 1%.

### Network and control system

With regard to the whole system, the traditional electricity system merged over decades and is characterized by large plants, centralized control and optimal management at a regional level. This led to the present CES based on an essentially unidirectional structured and designed network, i.e. electricity flows from production hubs to passive end-users from higher voltage transmission to lower voltage distribution grids. The CES focuses on robust supply side management rather than on a flexible DSM (Orecchini and Naso 2012; Richter 2013b). ICT infrastructure can improve the reliability of the electricity supply, reduce peak load problems, increase the efficiency of transmission and distribution facilities and existing power plants, and reduce and defer required investment respectively, for both CES and DES (Makansi and Abboud 2002; Ibrahim and Ilinca 2013; SRU 2013). However, from a quantitative viewpoint the centralized approach is limitedly suitable for a bidirectional system in which DEG has a particular relevance. For example Germany operates 1,600 conventional power plants with  $\geq 10$  MW nominal capacity (Bundesnetzagentur 2015a) compared to for instance 24,867 wind power stations by end of 2014 (BWE 2014) and more than 1.4 Mio PV power plants by June 2015 (Wirth 2015). A massive penetration of DEG units would strongly challenge the unidirectional network, and highly degrades the quality of the grid service, operation and protection. DES uses smart grid technology by exploiting the advantages of ICT to combine and connect DEG units (Orecchini and Naso 2012) and complement the traditional paradigm 'supply follows consumption' with a 'consumption follows supply' practice, based on intermitting RE (Schleicher-Tappeser 2012; EFZN 2013). Kiesling summarizes as follows: "*Decentralized coordination is good, and is preferable to centralized control*

*because it harnesses the dispersed knowledge of many market participants, it honors differences in individual preferences, and it enables discovery of individual preference and cost differences, in consumer willingness to pay and producer willingness to accept. Decentralized coordination leads to more robust and resilient economic efficiency in the face of change and has more adaptive capacity over time than a system that relies on centralized control"* (2009: 12).

As a consequence the system responsibility of traditionally big utilities is increasingly distributed among a growing number of market players so that interactions, interfaces and dependencies become considerably more complex (Gerbert et al. 2013). This can also be observed with regard to the three electricity submarkets attached with different value to CESs and DESs (cf. Figure 3: 7). Therefore, it is important to understand how they work and develop recently in order to derive economic value of CES- and DES-related business models.

### 2.2.3 Three electricity submarkets

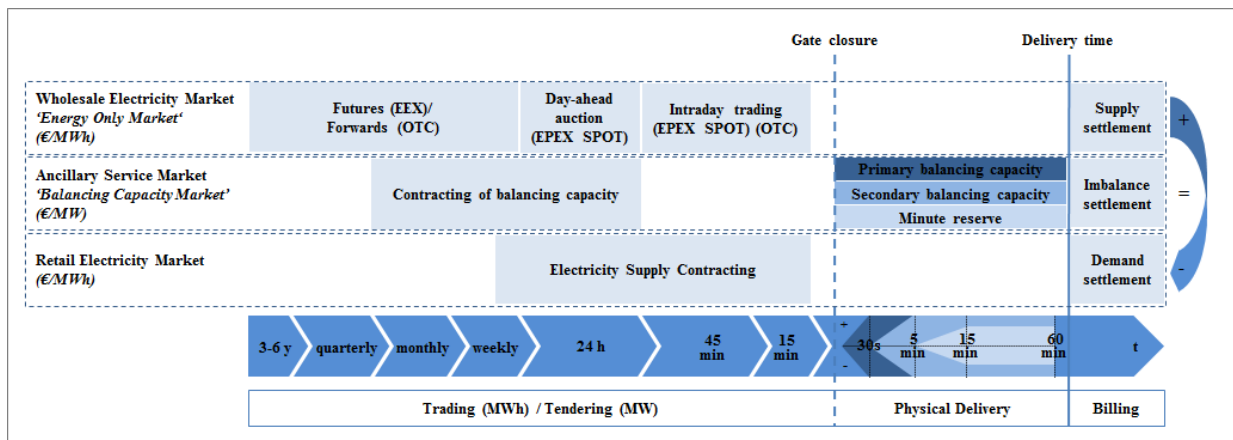
Electricity systems, as well as each profit oriented business model, are linked to three electricity submarkets (cf. Figure 3: 7), two commercial (i.e. wholesale and retail market) and a physical equilibrium market (i.e. ancillary services market). An own illustration about its role and function in terms of time is provided in Figure 6: 12 and explained as follows. In addition, this section also gives practical market insights in order to underline its importance for CES- and DES-related business models.

#### 2.2.3.1 Wholesale market

##### Function

The wholesale market is with regard to its commercial volume the most fundamental submarket in the electricity value chain. Defined as 'energy-only market', bulk electricity volumes such as megawatt hour (MWh) from centralized and distributed sources are traded by different market participants to meet the end-user demand on the retail market. Whereas utilities rather trade centralized generated electricity, either TSOs or direct marketers are responsible to feed-in RE (in accordance with EEG) on the market place.

Two product markets with different time horizons are available:



**Figure 6: Three electricity markets with products and time horizon. Source: Own figure, based on BMWi (2014b) and Next Kraftwerke (2015a).**

- Futures/ forwards<sup>13</sup> (long-term) markets trade physical delivery options between one week and three years, and financial delivery options up to six years in advance.
- Spot (short-term) markets are divided into day-ahead auctions (i.e. previous day of delivery) and intraday trade (i.e. between 3 p.m. of previous day and 45 minutes (on energy exchanges) and 15 minutes ('over-the-counter')<sup>14</sup> before delivery).

Both product markets are traded either over-the-counter (OTC) or via energy exchanges. Whereas OTC transactions are organized bilaterally, mainly via broker platforms, energy exchanges provide a central and liquid platform, giving important price signals along the entire value chain. The two most important energy exchanges for the (not only) German market are the European Energy Exchange (EEX) in Leipzig and the European Power Exchange (EPEX SPOT) in Paris (SRU 2013; Bundesnetzagentur and Bundeskartellamt 2014; BMWi 2014b). With regard to volumes, OTC transactions are many times larger than accumulated trade on both energy exchanges. For instances in 2013, OTC transactions (5,900 TWh) (Bundesnetzagentur and Bundeskartellamt 2014) were 5.7 fold as much as both energy exchanges (1,026 TWh<sup>15</sup>) together.

<sup>13</sup> 'Forwards' refer to 'over-the-counter' (OTC). 'Futures' refer to energy exchanges.

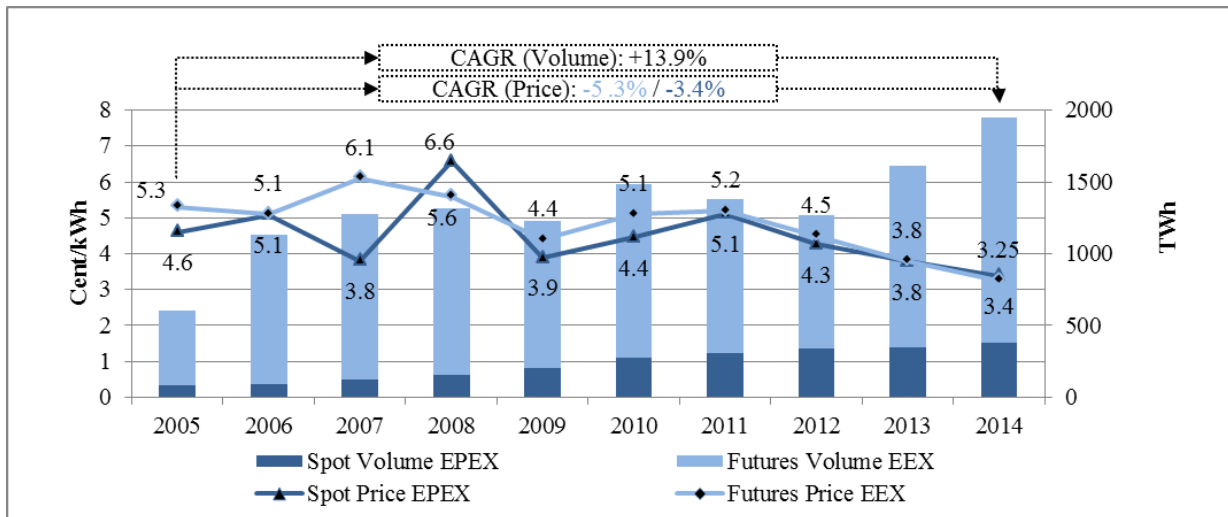
<sup>14</sup> In case of unforeseeable power cuts at power plants.

<sup>15</sup> Accumulated volume of futures (1,264 TWh) and spot market (345 TWh) minus EEX OTC-clearing (582.6 TWh) in 2013, based on EEX (2014b), and EEX and EPEX SPOT (2014).

The pricing is determined by the merit order principle. Depending on the type of power plant, electricity producers offer prices for specific quantities of power, which are ranked by their respective marginal costs in ascending price order. Simultaneously, power consumers give indications about their price sensitivity for specific quantities in descending order. The point of intersection of the most expensive price shows the energy exchange price of the entire quantity traded, so that substantial profit margins are realized by the most cost-efficient suppliers. The almost zero marginal costs attribute gives legal priority to the feed-in of RE such as PV and wind power, and consequently forces out conventional power sources with higher marginal cost, weakens wholesale prices and reduces margins of conventional power producers, called the merit-order effect (Wirth 2015) (cf. Figure 25 in Appx: E).

### Insights in recent developments

On the one hand, the total exchange volume increased from 603 up to 1,952 TWh (compounded annual growth rate (CAGR): +13.9%) between 2005 and 2014, with an average proportion of 83% futures and 17% spot volumes (Figure 7: 13). As an efficient possibility of integrating RE in the short-term into the market, especially flexible volumes traded on the EPEX SPOT intraday markets increased tenfold over the last five years (EEX and EPEX SPOT 2014). On the other hand, with regard to the CAGR between 2005 and 2014, the exchange spot market price dropped by 3.4% and the price for futures even by 5.3% each year, down to slightly above EUR cent 3 per kilowatt hour (kWh) each. Reasons are seen in an increased competition and improved utilization of production capacity and grid infrastructure through liberalization and ongoing coupling of the Eu-



**Figure 7: Development of prices and volumes on spot and future market (2005-2014).** Source: Own figure, based on EEX and EPEX SPOT (2014), EEX (2014a), EEX (2014b) and Statista (2015).

ropean electricity market. Those in combination with a flat demand in Europe and installation of new RE capacity led to increasing overcapacities especially in Germany since 2003 (e.g. export surplus of 35.5 TWh in 2014). As a consequence, the technical inflexibility of nuclear and most fossil fuel power plants to ramp-down their production easily, especially on sunny and windy days with high RE production and low electricity consumption (e.g. weekends), intensifies overproduction and falling wholesale prices, even at negative levels. Eventually, this normalizes in a mid-term with the phase out of 12.1 GW nuclear power capacity, representing around 100 TWh energy production in Germany by 2022 (BMW 2014b).

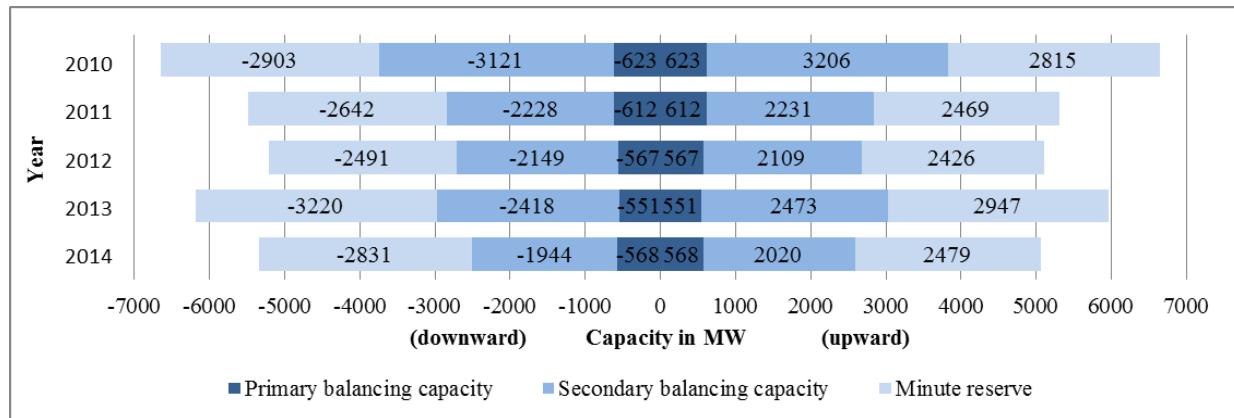
### 2.2.3.2 Ancillary service market

#### Function

The ancillary service market is for physical system stability for short-term and real time response. This is why it is also described as a short-term capacity market (Pilgram 2013). Because of the physical nature of electricity systems this market is of systemic relevance. Despite a comprehensive balancing forecast between electricity supply and demand on the wholesale market, the physical equilibrium between generation and consumption cannot necessarily be guaranteed in real time. Deviations especially occur from unforeseen, intermittent events such as changing weather conditions (e.g. relevant for wind and PV), power plant failures or a short-term variation of consumption patterns. Therefore, transmission system operators (TSOs) calculate, competitively tender and procure three types of balancing capacity (not energy) with different

(de-)activation and modification speed and directions (i.e. upward/ downwards) to guarantee physical equilibrium between generation and consumption (BMW 2014b; Amprion 2015):

- (1) Primary balancing capacity must be available within 30 seconds and last for five minutes until secondary balancing capacity takes over. For this many controllable power plants retain some percentages of power capacity as reserve. TSOs automatically control the quantity and direction of capacity on a permanent basis.
- (2) Secondary balancing capacity synchronously starts with primary balancing capacity to be available within five minutes for at least 15 minutes until the minute reserve takes over. Controllable power plants such as pumped-storage power and gas power plants are activated. TSOs automatically control the quantity and direction of capacity on a permanent base.
- (3) Minute reserve (tertiary balancing capacity) starts in case of a predictable, longer lasting use of secondary balancing capacity and must be available within 15 minutes for 60 minutes. Minute reserves guarantee an emergency backup in case of power plant failures to either support or replace secondary balancing capacity. TSOs manually instruct their contracted suppliers about the control of quantity and direction of capacity by telephone (Amprion 2015).



**Figure 8: Average volume of contracted operational reserves (2010-2014).** Source: Own figure, based on IAEW and E-Bridge (2014), Bundesnetzagentur and Bundeskartellamt (2012-2014) and Bundesnetzagentur (2011).

Whereas primary and secondary balancing capacity is publicly tendered on a weekly base, minute reserve is handled on a work daily basis. Only prequalified suppliers are allowed to participate in public tenders and provide balancing capacity.

Since 2013 not only electricity generators can participate in the market for balancing capacity but also electricity consumers through interruptible loads and DSM (e.g. heat pumps, electric vehicles or industrial consumers) regulated in the 'Verordnung über Vereinbarungen zu abschaltbaren Lasten'. Contracted providers of all types of balancing capacity are remunerated in one or two ways. On the one hand they get paid to reserve a certain quantity of capacity ('standby remuneration' or 'capacity price'), and on the other hand they get compensated for the ex-post energy volume actually used ('energy price')<sup>16</sup>. Both prices are strongly fluctuating but are generally profitable for generators since they are usually above the exchange electricity price. Cost for balancing capacity is paid by consumers through grid charges and balancing energy by balancing responsible parties through the system of balancing groups and imbalance settlement (Bundesnetzagentur and Bundeskartellamt 2014; Next Kraftwerke 2015a).

### Insights in recent developments

The market for ancillary services, in particular for balancing capacities shows a quite stable development. This market is operated by the four TSOs and regulated by the Federal Network Agency. In order to secure system stability for the German electricity markets, generators must guarantee both upward and down-

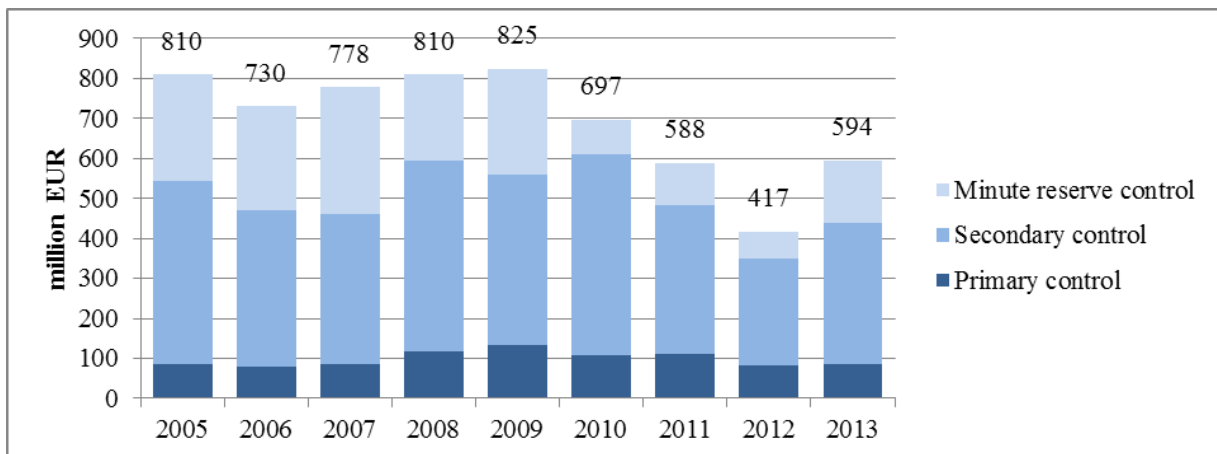
ward balancing capacity at any time (Next Kraftwerke 2015a). For instance, in 2014 the four TSOs totally contracted operational capacity reserves of 5,067 MW upward and 5,343 MW downward in Germany (Figure 8: 14).

Whereas primary balancing capacity takes the minor share, secondary capacity and especially minute reserves take the main share for balancing volumes. However, even though the proportional remuneration is the most attractive, also the requirements are the highest. Whereas only 16 suppliers were prequalified for primary capacity, there were 29 for secondary capacity and even 42 for minute reserve in June 2015 (Regelleistung 2015). The main share of balancing energy is provided by large, centralized utilities. This is currently changing especially with regard to secondary and minute reserve. It is widely believed that especially the aggregation and pooling of small-scale DEG will be of more importance in the future (e.g. Oberzig 2014; Next Kraftwerke 2015a).

An indicator for the revenue potential of related business models are indirectly represented by costs for ancillary services, which are passed on and embedded in the retail price. With regard to total net costs for ancillary services (Figure 9: 15), in particular for primary, secondary and minute reserve control, a decrease in recent years can be observed. Whereas before 2010 often more than Euro (EUR) 800 million (Mio) for control services were procured (e.g. in 2005, 2008, 2009), the cost dropped down to less than EUR 700 Mio in 2010 and even to EUR 417 Mio in 2012.

Nevertheless, Götz et al. (2014) emphasize insufficient incentives in the system of balancing groups and imbalance settlement in the

<sup>16</sup> This excludes primary balancing capacity which is solely compensated with a capacity price.



**Figure 9: Net costs of ancillary services of German TSOs (2005-2013).** Source: Own figure, based on data from Bundesnetzagentur and Bundeskartellamt (2012-2014) and Bundesnetzagentur (2006-2011).

wholesale market and estimate that only 30-50% of balance responsible parties actively manage their balancing group on the intraday market. With the integration of more intermittent RE such behaviour jeopardizes the system reliability. In unforeseeable peak times the disproportional use of balancing capacity raises the electricity price, or even worse a bottleneck of balancing capacity reserves destabilizes the system (Götz et al. 2014; BMWi 2014b). Therefore many experts see a major challenge for utilities to find new ways of balancing the system, both over time and geographically (Burger and Weinmann 2013).

However, a study by German Energy Agency (dena) about ancillary services in 2030 predicts that the changing generation mix with intermittent renewables will significantly pressure the system stability under today's market conditions (dena 2014b). All three capacity types are either expected to increase their volumes (i.e. both upward and downward), to require new innovative technologies, to shorten their tender frequency, to change their pricing mechanism or to change their prequalification requirements (dena 2014b). For example capacity for secondary balancing and minute reserve is expected to increase with the growing share of renewables (Agora Energiewende 2014).

### 2.2.3.3 Retail market

#### Function

The retail market is a pure point of sales where household, commercial and industry customers select their electricity supplier depending on their grid territory and electricity source (e.g. RE). As a consequence of the liberalization process of European electricity markets, retail markets have begun to become competitive. In

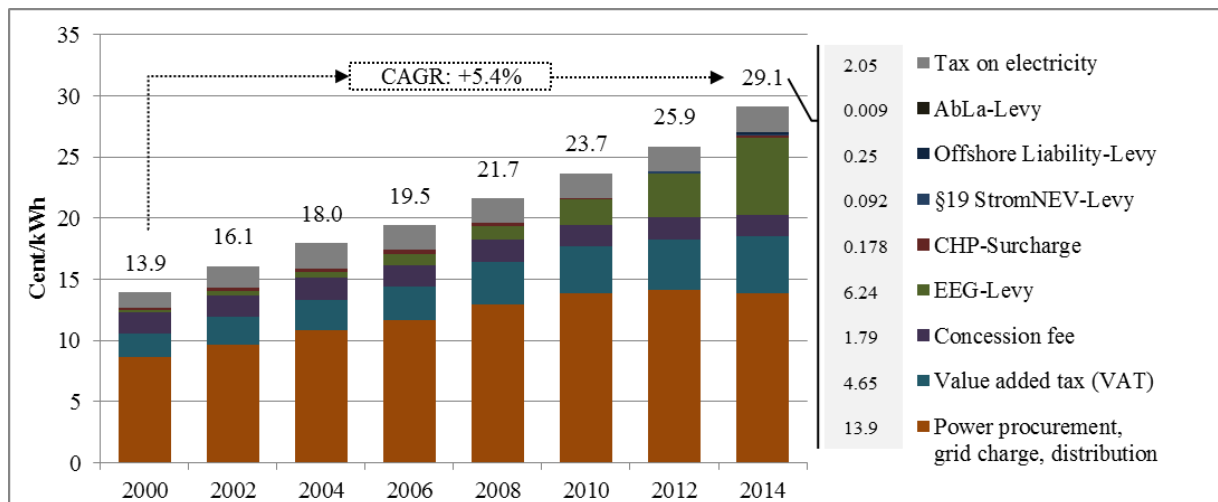
Germany every final consumer can freely choose its electricity provider for his or her needs. Usually utilities and/or suppliers bind their customers with full supply contracts<sup>17</sup> with a fixed electricity price per kWh (Burger and Weinmann 2013; Bundesnetzagentur and Bundeskartellamt 2014).

The average prices can be categorized into three main elements: power procurement, distribution and margin (25% in 2014), regulated grid charges (23% in 2014), and tax, fees and levy (52% in 2014) (BDEW 2014). Moreover, the average electricity price strongly differs between customer types. For instance in 2014, industrial customers paid EUR cent 15 per kWh (excluding Value added tax (VAT)), commercial customers EUR cent 22 per kWh (excluding VAT) and household customers between EUR cent 28-31 per kWh (including VAT) (Bundesnetzagentur and Bundeskartellamt 2014).

#### Insights in recent developments

The retail market is characterized by a high degree of competition and even though the market records a relatively constant number of competitors, customers increasingly switch between them (BDEW 2014). In 2013, end-users could select between 103 suppliers per grid territory in average. Furthermore, the market gives information about the price end-users need to pay in a transitioning system. Even though the price for electricity on wholesale markets steadily decreased over the last decade (cf. Figure 7: 13), the average retail price for household and industry customers contrarily increased with a CAGR of approximately 3%

<sup>17</sup> Electricity is delivered on the doorstep as an all-inclusive package.



**Figure 10: Average household electricity price development (3.5 MWh per year) (2000-2014). Source: Own figure, based on data from BDEW (2014).**

between 1998 and 2014 (Figure 10: 16, Figure 27 in Appx: F).

Between 2000 and 2014 the price for an average three-person's household with 3,500 kWh per year consumption constantly increased from EUR cent 13.9 per kWh up to EUR cent 29.1 per kWh (CAGR +5.4%) (Figure 10: 16). This was mainly impelled by a surge in power procurement, grid charges and distribution, as well as the EEG-Levy of recent years. Furthermore, new price components became effective, among others the load-management-levy ('AbLa-Levy' of 'AbLa-Verordnung'<sup>18</sup>) in 2012, an important enabler for new business models, as later discussed. In Europe, Germany shows with almost EUR cent 30 per kWh the second highest household electricity price, slightly after Denmark and 60% above the EU-28 average with EUR cent 18.17 per kWh in 2013 (cf. Figure 26 in Appx: F). However, the main price differential is caused by tax, fees and levies which is three times higher than the EU-28 average (Bundesnetzagentur and Bundeskartellamt 2014).

Even though the industry is charged with more or less half of the household price, a relatively similar development of the average industry electricity price can be observed (cf. Figure 27 in Appx: F). Compared to Europe, Germany shows with EUR cent 16.7 per kWh a high industry electricity price in 2013, 34.4% above the EU-28 average (cf. Figure 27 and Figure 28, in Appx: F and G).

<sup>18</sup> For more detailed information, please see Netztransparenz (2015).

### 2.3 Germany's incumbent utilities

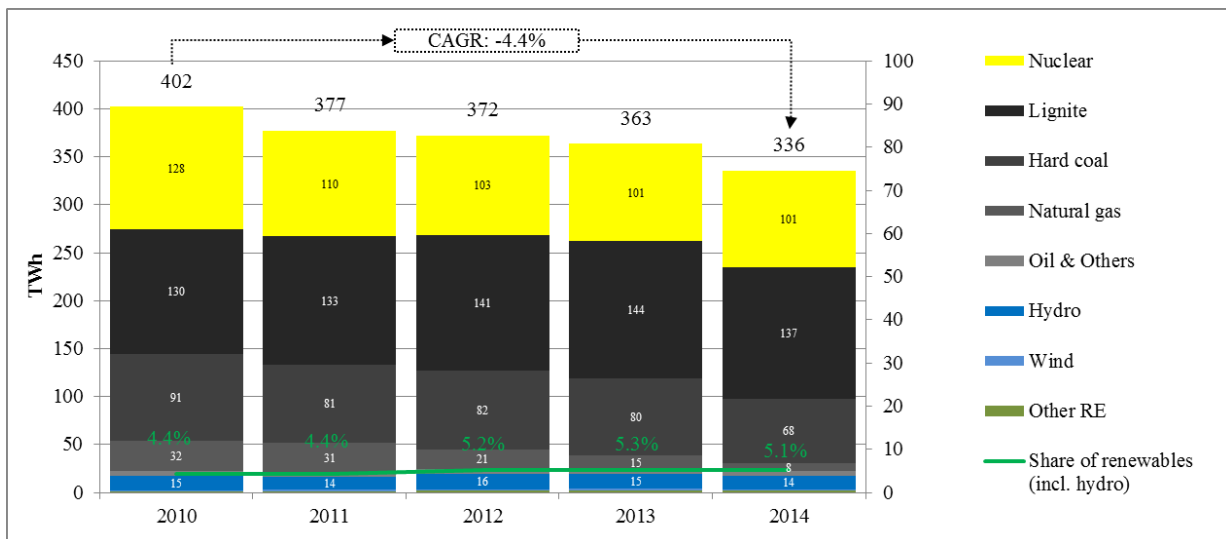
Two dominant types of incumbent utilities can be distinguished within the German electricity system, differentiating according to their level of vertical integration and strategic focus. First, the vertically integrated super utilities collectively summarized as the BIG4, almost purely focusing on the CES. Second, the (regional) integrated distribution and supply utility, also known as municipal utility, with strong local presence and activities also in small-scale power production or tolling from multi-party generation facilities (Schwinkendorf 2009; Starace 2009).

In order to understand their today's market presence and their related business model success, the following two subsections give insights about both.

#### 2.3.1 The BIG4 vertically integrated utilities

Germany's net electricity production is dominated by four oligopolistic, vertical integrated utilities, already introduced as the BIG4, covering all domains of the electricity system (i.e. primary energy source, generation, storage, transmission, distribution and sales to end-user) and operate in all electricity submarkets. All four have profited from a stable CES-related business model, characterized by a high degree of integration along the value chain and supply of bulk generation of electricity at low cost through economies of scale (Nimmons and Taylor 2008; Richter 2013a; Hannon et al. 2013; SRU 2013). Since the market liberalization and the induced Energiewende, their ag-





**Figure 11: Accumulated attributable electricity generation of the BIG4 in Germany (2010-2014).** Source: Own figure and analysis, based on annual reports of E.ON (2011-2012; 2013b; 2014b; 2015), EnBW (2011-2015), RWE (2011-2013; 2014b; 2015e) and Vattenfall (2011-2015).

gregated market share in Germany<sup>19</sup> with regard to total generation capacity (85% in 2007, 77% in 2010 and 68% in 2013) and total produced electricity (88% in 2007, 84% in 2010 and 74% in 2013) is continuously decreasing. Their attributive generated electricity even decreased by 16.4% from 2010 to 2014, having a CAGR of -4.4% respectively (Figure 11: 17). The BIG4 mainly cut down their generation mix from nuclear, hard coal and natural gas sources and kept the other sources (i.e. lignite, hydro and wind) at a nearly constant, absolute level. This marginally increased the share of renewables from 4.4% (2010) to 5.1% (2014), although RE without hydro energy counted less than 1% in 2014. For example the CEO of RWE, Peter Terium acknowledges: “We have to adjust to the fact that, in the longer term, earning capacity in conventional electricity generation will be markedly below what we’ve seen in recent years” (Interview in De Clercq 2013).

Nevertheless, the BIG4 still hold the majority share with their dominant CES-related business model, albeit their ownership of DEG assets is almost negligible (cf. Figure 5: 10). The combination of an induced phase out of nuclear power, a stagnating national electricity consumption, overcapacity through feed-in of EEG electricity (cf. Figure 4: 9) and low wholesale prices (cf. Figure 7: 13), led to shrinking profit margins of conventional power producers (see merit-order effect in section 2.2.3.1). This

tremendously affects their incumbent, CES-related business model success.

Even though the accumulated sales volume of the BIG4 in Germany between 2010 and 2014 went up slightly from EUR 74,552 Mio to EUR 82,648 Mio (+6%), the proportional adjusted EBITDA (absolute) decreased from 15.9% (EUR 11,863 Mio) down to 10.8% (EUR 8,934 Mio). Also the sales share of renewables maintained relatively stable at a low level between 1.4% in 2010 and 1.6% in 2014 (Figure 12: 18).

The declines in operative profits during the last five years also limited the total investment activity in Germany, which strongly decreased from EUR 6,948 Mio to EUR 3,436 Mio (CAGR of -16.1%). However, investments in renewables between 2010 and 2014 slightly increased from EUR 3,299 Mio up to EUR 3,451 Mio (CAGR of 1.1%), so that the relative share of total investments almost doubled from 15.3% to 28.7% (Figure 13: 18).

However, interviews by Richter (2013a; 2013b) indicate that the utilities’ activities in the field of DES with renewables are still in a preparatory stage, so that investments into appropriate infrastructure are practically limited to research and development and pilot projects. Via different media channels each of the BIG4 publicly announce intention to expand their RE involvement, focusing both CESs and DESs. For instance RWE’s homepage states a strategic focus on wind energy expansion and appropriate investment partnership (CES-related), and cooperation with municipal authorities and es-

<sup>19</sup> Excluding generators with less than 10 MW nominal capacities, for instance EEG subsidized renewable energy system such as roof-mounted system PV.

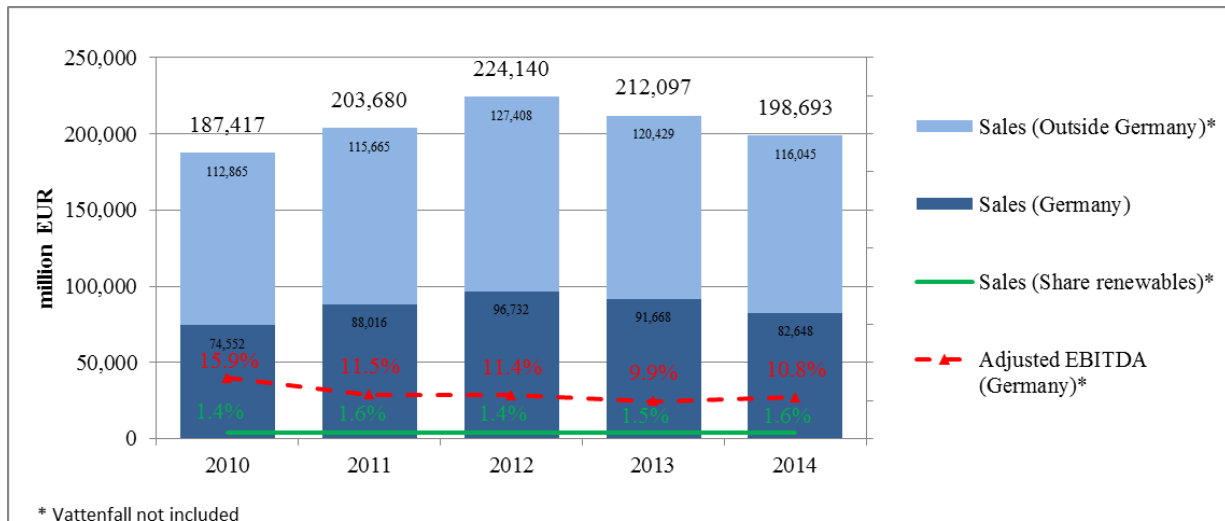


Figure 12: Accumulated investment development of the BIG4 (2010-2014). Source: Own figure and analysis, based on annual reports of E.ON (2011-2012; 2013b; 2014b; 2015), EnBW (2011-2015), RWE (2011-2013; 2014b; 2015e) and Vattenfall (2011-2015).

established suppliers to gain a greater foothold in the market for distributed energy. Furthermore, they explicitly seek for DES-related business models for residential and corporate customers, who already produce their own electricity (RWE 2015a). Nevertheless, several expert interviews confirm that appropriate product and service portfolios exist, but are not actively pursued in practice (Richter 2013a).

### 2.3.2 Municipal utilities

Apart from the BIG4, Germany has also about 800-1,000 municipal utilities ('Stadtwerke') of different size and characteristics (Burger and Weinmann 2013; VKU 2014). Some have several thousands of employees, others are small and medium sized enterprises. Some are in 100% public ownership, but many have private minority holdings. Furthermore, they can be

distinguished according to their level of vertical integration within the value chain, operating in either one or more domains. In 2014, municipal utilities supplied 46% of Germany's household customers with electricity, produced 12% of Germany's electricity and even 43% of combined heat and power and owned and operated 60% of all distribution medium- and low-voltage grids (which is of significant importance for the integration of RE) (Gerbert et al. 2013; VKU 2014). In contrast to the BIG4, municipal utilities started to moderately extend their business practice towards renewables and grew their share of RE production from 7.6% in 2009, 8.7% in 2011 to 11.4% in 2012. Furthermore, even though the total investment in generation capacity decreased during the last years, in the meanwhile almost half of it goes into renewables (VKU 2011; VKU 2013). Apart from energy

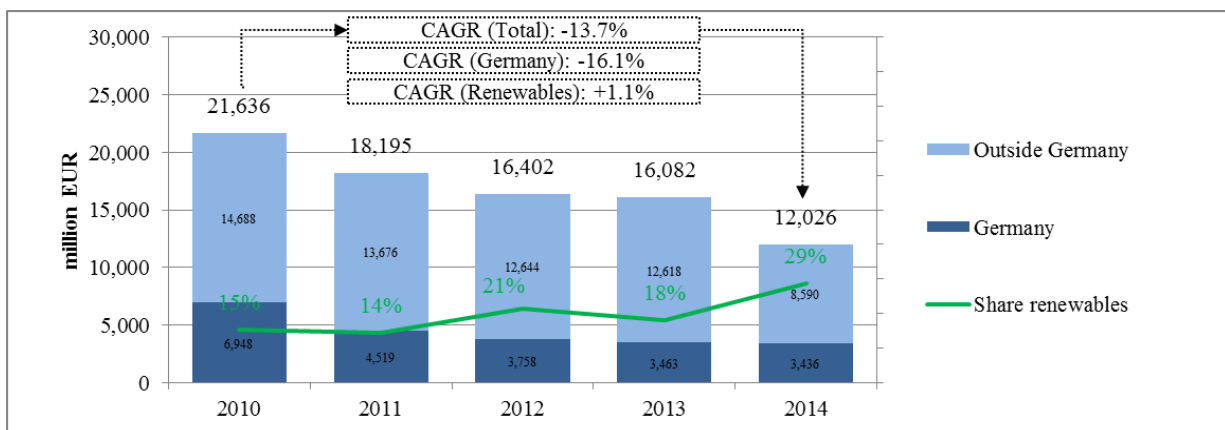


Figure 13: Accumulated sales and adjusted EBITDA of the BIG4 (2010-2014). Source: Own figure and analysis, based on annual reports of E.ON (2011-2012; 2013b; 2014b; 2015), EnBW (2011-2015), RWE (2011-2013; 2014b; 2015e) and Vattenfall (2011-2015).

supply, they are often also involved in other community services such as waste, water supply, and public transport. In addition their geographic and cultural proximity to their customers allows a better relationship management compared to the (inter-)nationally operating BIG4 (Burger and Weinmann 2013). In contrast to the BIG4, the distributive nature of municipal utilities is seen as more promising for the distributive character of the Energiewende (Leprich 2012).

### 2.3.3 Paradigm shift: A new green service utility?

Incumbent utilities have realized the evolution of a parallel, distributed supply structure which is continuously growing. Interviews with E.ON, EnBW and some municipal utilities independently claim the age of decentralization in the energy sector (Burger and Weinmann 2013). The rapidly growing self-sufficiency of traditional end-users through distributed PV, combined heat and power, wind and storage technologies endangers the CES by making conventional power plants (i.e. merit-order effect) uneconomical. Also the economic viability of the solidary transmission and distribution system can only be guaranteed, if all consumers pay a basic charge, corresponding to the actual grid service fee. The more prosumers unplug from the grid, the less pay a fee and the more expensive the fee becomes for the rest (Adam et al. 2012). A municipal utility notes: *"We are lucky that the output of the installations of private producers is often far higher than the electricity they consume themselves, even if they are able to store parts of it. That is why they have to transmit some of it via the grid"* (Interview in Burger and Weinmann 2013: 101-102), and thus they need to pay the service charge. Nevertheless, the chairmen of a municipal utility for instance comments: *"Decentralization cannot be stopped"* (Interview in Burger and Weinmann 2013: 186). Another municipal utility points out that *"distributed electricity generation will become more important. Either we enter this market, or others will do"* (Interview in Richter 2013a: 1232).

For this paradigm shift, Starace (2009) exemplary introduces and describes an innovative, specialized utility, referred to as new green service utility. This new entrant is evolving based on *"small-scale green energy production (from PV to small wind power and fuel cells), the trading of green energy, and the multitude of new green energy services (energy efficiency, small-scale integrated energy solutions for SME businesses and families) create open*

*spaces that the existing utilities are not fast and/or credible enough to occupy"* (Starace 2009: 160).

However, less is known about the DES-related new green service utilities, as comprehensive market data does not exist yet. This gives an initial starting point for the next two chapters. In the following chapter 3 a framework of analysis is elaborated in order to shape an own coevolutionary business model framework, which is subsequently applied with focus on DES-related business models of new green service utilities in chapter 4.

### 3 Framework of analysis

The previous chapter presents not only insights into the design, the setting and radical change of the electricity system, but with its interrelated dimensions, markets and players, also gives an indication about its complexity. At the current stage, this complexity creates a high level of uncertainty, which on the one hand particularly challenges and even overextends incumbent utilities and their CES-related business models, but on the other hand also gives impetus for new DES-related business models. Based on the coevolutionary theory, the challenge of this thesis is to tackle this complexity and give guidance for further development of business models within the Energiewende. Therefore, in this section the analytical framework for the thesis will be derived, based on the integration of a coevolutionary and business model framework under the assumption of the transition towards a low-carbon energy market. Firstly, the coevolutionary and secondly the business model framework will be elaborated, and thirdly integrated into a combined framework.

#### 3.1 Coevolutionary framework

##### 3.1.1 Thematic classification

Evolutionary approaches strongly contradict the standard neoclassical view of perfect rational agents and (quasi)-equilibrium analysis. Dynamics within evolutionary approaches are rather assumed as bounded rationality in complex systems, innovation in form of 'creative destruction', diversity in systems, path-dependency in system developments and lock-in of incumbent systems (Schumpeter 1942; Nelson and Winter 1982; van den Bergh et al. 2006).

Evolutionary approaches based on Charles Darwin's (1859) three biological principles of evolution (i.e. variation, replication, and selection) represent the attempt to extend these principles to changing socio-technical systems. It is assumed that entities or populations reproduce differently (variation) and environmental pressure leads to the survival of the best adopted copy (selection) which stays stable over a certain amount of time or generation (retention). Termed as 'Universal or Generalized Darwinism' (Hodgson and Knudsen 2004), the social-scientists apply these principles to other evolving systems, including human, cultural or social evolution (Hodgson 2005). The exploration of different evolutionary approaches have recently been discussed in a special

issue of 'Ecological Economics' (i.e. Kallis and Norgaard 2010; Hodgson 2010; Manner and Gowdy 2010). All approaches are strongly rooted in the basic, multiple system framework worked out by Norgaard (1981; 1994) who incorporated the coevolution of environment, knowledge, organization, technologies and values.

##### 3.1.2 Relevance in the context with the Energiewende

The challenge of this thesis is to investigate coevolving DES-related business models in Germany's complex energy transition (the Energiewende), in order to give guidance for future development. For this, not only the relevance of the coevolutionary framework needs to be highlighted, but also the prerequisite of its application need to be examined.

Firstly, with regard to its relevance, Foxon's (2011) coevolutionary framework is described as a structured and suitable tool in order to handle coevolutionary complexity, focusing most important dimensions. For example, the author argues that "*the value of such a framework is that it focuses attention on the most relevant analytical categories, whilst avoiding trying to be 'a theory of everything'*" (Foxon 2011: 2261). The framework among others addresses three key research and policy challenges that are related to a transition towards a low-carbon economy (Foxon 2011), happening with the Energiewende in Germany and addressed within this thesis:

- (1) Inform about the implementation of energy and climate policies to promote innovation and take-up of low-carbon technologies through detailed empirical analyses.
- (2) Develop a framework for analysing interrelations between social and technological dimensions within potential transition scenarios to a low-carbon energy system.
- (3) Support in further development and specification of more formal, multi-level evolutionary economic models through pass on findings (Foxon 2011).

Secondly, with regard to prerequisites, Murmann points out that "*not everything that looks like co-evolution is really co-evolution*" (2003: 23) and therefore a mutual relationship needs to be cross-checked. Murmann defines the prerequisites for coevolution as follows: "[T]wo evolving populations co-evolve if and only if

they both have a significant causal impact on each other's ability to persist" (2003: 22). According to Foxon (2011) this causality can be shown within this thesis in two ways:

- (1) By either pointing out the impact of a modification of selection criteria, e.g. a new incentive structure such as FiT being able to push new technologies such as DEG, or
- (2) By pointing out the modification of replicative capacity of individual entities, e.g. a company realigns its business strategy and rather invests in technological innovation than in existing technologies. This is discussed later under BMI in section 3.2.3.

### 3.1.3 Scope and focus of the framework

Based on an intensive literature review, Foxon (2011) refines the coevolutionary approach and combines insights from socio-technical transition approaches to better analyse the multi-level energy transition towards a sustainable, low-carbon system, which Germany defines as the Energiewende. He emphasizes the coevolution between five heterogeneous key subsystems, namely ecosystems, technologies, institutions, business strategies and user practice,

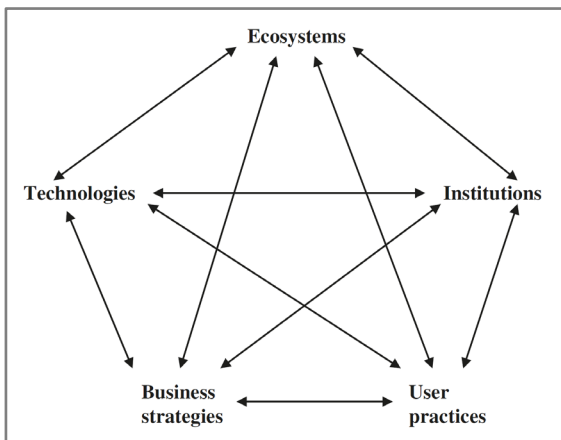


Figure 14: Coevolutionary framework. Source: Foxon (2011: 2262).

as illustrated in Figure 14: 21 and explained as follows.

#### Ecosystems

Ecosystems are defined as systems of “*natural flows and interactions that maintain and enhance living systems*” (Foxon 2011: 2262). This perspective describes the interactions of human techno-economic systems with natural ecosystems, taking into account a local, regional and global view. Of special interest is

the global perspective, probably seeing the ozone layer as the most considered single ecosystem in the transition from high carbon (e.g. fossils) to low-carbon energy systems (e.g. wind, solar, hydro and biomass). Nevertheless, also the impact of low-carbon energy systems on local ecosystems is recommended to be considered.

#### Technologies

The physical technological system is defined according to Beinhocker as a system of “*methods and designs for transforming matter, energy and information from one state to another in pursuit of a goal or goals*” (2006: 244). The evolution of technologies is assumed to be constrained by human decision rules, so that radical innovations are often firstly applied and matured in niches, where favourable attributes are particularly beneficial, from which it becomes widely spread.

#### Institutions

An institutional system is broadly defined as “*[formal] ways of structuring human interactions*” (Foxon 2011: 2262). Here, the author follows the institutional economics tradition of North who defines institutions as “*the rules of the game in a society*” (1990: 3). Such rules can be seen as formalized structures, including for example regulatory frameworks, property rights and standard forms of business organization. Informal rules or constraints are summarized under the next concept of user practices.

#### User practices

User practices are defined as “*routinized, culturally embedded patterns of behavior relating to fulfilling human needs and wants*” (Foxon 2011: 2263) of individuals or small groups of people. Even though the concept is derived from sociological theories, Foxon (2011) frames it with an evolutionary term, analysing the changing patterns of practitioners and competing practices from an evolutionary view. Ropke (2009) suggests that investigating the sustainable consumption pattern reveals domestic practices with systems of provision, supply chains and production, which in particular allows to draw conclusions about the coevolution of technologies, institutions and business strategies (Foxon 2011).

#### Business strategies

Business strategies are defined as “*the means and processes by which firms organize their activities so as to fulfill their socio-economic*

purposes” (Foxon 2011: 2262). Foxon (2011) especially emphasizes the profit-orientation of commercial firms which is bounded by social factors, such as their reputation. Hence, the definition also comprises social oriented enterprises, which deliver useful goods and services and are less focused on profit or financial return.

Each of the five categories is of equal importance and considered as a coevolving subsystem, meaning that each evolves through causal interaction, partially out of its own dynamics (i.e. endogenous) and partially influenced by (and influences) dynamics of other subsystems (i.e. exogenous). Because of this interdependence, many researchers investigate the coevolution of different levels of social organization (McKelvey 1997).

Furthermore, none of the subsystems allow predictions too far into the future, because of fundamental uncertainties. Evolutionary processes between the systems are path-dependent which can lead to sensitivities to particular historical events. As a consequence, long-term effects can be difficult to predict.

### 3.1.4 Limitations of coevolutionary framework for this thesis

Even though a coevolutionary framework helps to structure and overview complex transition process, its application is not without limitation. For instance, Kallis and Norgaard are concerned by the complexity a coevolutionary approach attempts to deal with, as follows: “*Complexity explodes as co-evolution within hierarchical systems (i.e. among interacting hierarchical levels) combines with co-evolution between different biological and social hierarchical systems*” (2010: 696). Consequently the complexity within and between socio-economic systems makes the coevolutionary analysis very challenging. For instance, studies emphasize the difficulties to determine the geographic range of coevolutionary interaction, especially in a globalized economy (e.g. Balaguer and Marinova 2006; Kallis and Norgaard 2010; Turner 2012; Coenen et al. 2012; Quitzow 2013). Even though the underlying thesis is primarily limited to Germany, global interrelation cannot be excluded and will be considered according to remarkable interdependencies. However, this analysis remains mainly limited with regard to its geographic range, and does not claim to be comprehensive on a global perspective.

In addition, Murmann (2013) indicates that even though much work underlines the importance of coevolution, little work explains its precise mechanisms and how co-evolutionary mechanisms impact the change of the three Darwinian process principles (i.e. variation, selection, and retention). A better understanding of different causal levers is needed to potentially shape coevolutionary environments (Murmann 2013). As the scope of this thesis is limited, it does not try to render more precisely the three principles.

Moreover, Rammel et al. (2007) mention a lack of empirical studies about coevolution within ecological economics in relation to organization theory or industrial organization. However, this argument is going to be outdated with regard to several recent publications (e.g. Gual and Norgaard 2010; Turner 2012; Hannon et al. 2013; Quitzow 2013; Taylor et al. 2013). Furthermore, the framework is already applied in the UK energy transition and even focusing on business models (e.g. Taylor et al. 2013; Hannon et al. 2013), which gives inspiration for an application on Germany’s transition.

## 3.2 Business model framework

As this thesis seeks a major focus on coevolving DES-related business models (or the new green service utility respectively, mentioned in section 2.3.) within the Energiewende, the next section elaborates a more detailed view on a business model framework. Because less is known about DES-related business models, a structured approach might finally help to analyse their evolution in a combined framework, which will be derived hereafter in section 3.3.

### 3.2.1 Thematic classification

Business modelling is a relatively new strategic management tool, that emerged from the analysis of internet companies in the mid-1990s (Gassmann et al. 2013; Zott et al. 2011) and is used as templates to conceptualize an enterprise’s organizational and financial structure (Chesbrough and Rosenbloom 2002). It essentially defines how a firm provides value to the customer in a way that makes him willing to pay for offerings in a profitable manner (Teece 2010). One of the most prominent business model concepts among researchers and practitioners (e.g. Zott et al. 2011; Hannon et al. 2013; Richter 2013a; Trapp 2014) is the Canvas business model framework. It is provided by Osterwalder and Pigneur and “*describes the rationale of how an organization creates, delivers, and captures value*” (2010: 14).

However, apart from a business model as a vehicle for innovation to commercialize innovative ideas or technologies, a comprehensive literature review by Trapp (2014) reveals that a business model itself can be a subject of innovation when it is transformed and renewed according to its dynamic environment, termed as BMI (Mitchell and Coles 2003; Chesbrough 2010; Teece 2010; Zott et al. 2011).

The relevance of the Canvas business model as a static, as well as BMI as a dynamic component for the framework of this thesis, is described in the following sections.

### 3.2.2 Relevance of the Canvas business model and BMI for this thesis

#### Canvas business model

The Canvas business model allows the structured analysis and comparison of organizational designs. It especially helps to design generic business templates (e.g. DES-related business models) which can be used to adopt or adjust management practices ex-ante (Wüstenhagen and Boehnke 2008; Baden-Fuller and Morgan 2010; Teece 2010; Zott et al. 2011; Richter 2013a; Richter 2013b). The framework allows a consistent measurability over time and across firms based on pre-defined categories (Trapp 2014). For this thesis, it will help to highlight and differentiate CES- and DES-related business models, and additionally enables a more comprehensive view beyond a utility's boundaries by analysing also the interaction with customers and key partners. Because of its recorded appliance in many studies, especially also in the field of energy transition (e.g. Hannon et al. 2013; Richter 2013a; Richter 2013b),

the Canvas business model has proved to be a suitable method also for the framework of this thesis. Furthermore, the study by Hannon et al. (2013) also gives guidance on how to integrate the Canvas business model into the coevolutionary framework.

#### BMI

BMI is considered for this thesis, since an increasing consensus evolves that it positively impacts business performance (Giesen et al. 2007; Zott et al. 2011; Amit and Zott 2012). For instance, a global study by IBM revealed that out of 765 interviewed corporate and public-sector leaders, financially outperforming enterprises focus twice as much on BMI compared to underperforming enterprises (Giesen et al. 2007). In this context, three success driving types of BMI were identified, namely industry model innovation (innovations in industry supply chain), revenue model innovation (innovations by reconfiguring offerings and/or introducing new pricing), and enterprise model innovation (innovate the structure of the enterprise and the role it plays in new or existing value chains) (Giesen et al. 2007; Clinton and Whisnant 2014).

This is why Trapp (2014) recommends to not solely classify business models statically according to their attributes, but also to highlight its internal transformation with regard to dynamic environments and other business models.

### 3.2.3 Scope and focus of the Canvas business model and BMI

#### Canvas business model

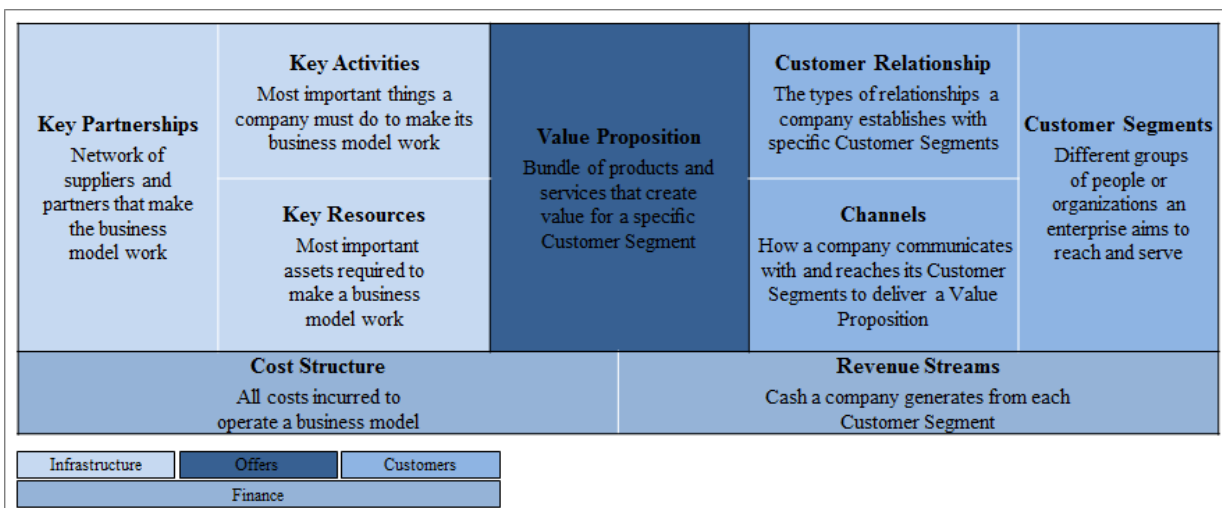


Figure 15: The 9 building blocks of the Canvas business model. Source: Own figure, adapted from Osterwalder and Pigneur (2010).

The Canvas business model framework represents “a shared language for describing, visualizing, assessing, and changing business models” (Osterwalder and Pigneur 2010: 12). It defines four main business areas (i.e. customers, offers, infrastructure, and financial viability) and proposes nine elementary building blocks for analysis: customer segments, value proposition, channels, customer relationships, revenue streams, key resources, key activities, key partnerships, and cost structure. Figure 15: 23 illustrates the building blocks and briefly describes their purposes.

**BMI**

BMI is defined as “the process for the integration of a value enhancing, new-to-the-firm business model, comprising a new value proposition and value constellation – here: without involving M&A” (Trapp 2014: 38). Derived from

incentives to stay and transact within the activity system, e.g. Nespresso machine with coffee capsules);

- (3) Complementarity (i.e. value-enhancing effects through interdependencies among business model activities, e.g. eBay facilitates its retail business with online payment business PayPal);
- (4) Efficiency (i.e. operational cost savings through the inter-connections of the activity system).

In addition, Chesbrough remarks that BMI is “not a matter of superior foresight ex ante – rather, it requires significant trial and error, and quite a bit of adaptation ex post” (2010: 356). Furthermore, BMI can hinder its own acceleration, e.g. when the adoption of a new business practice is strongly competed by the existing

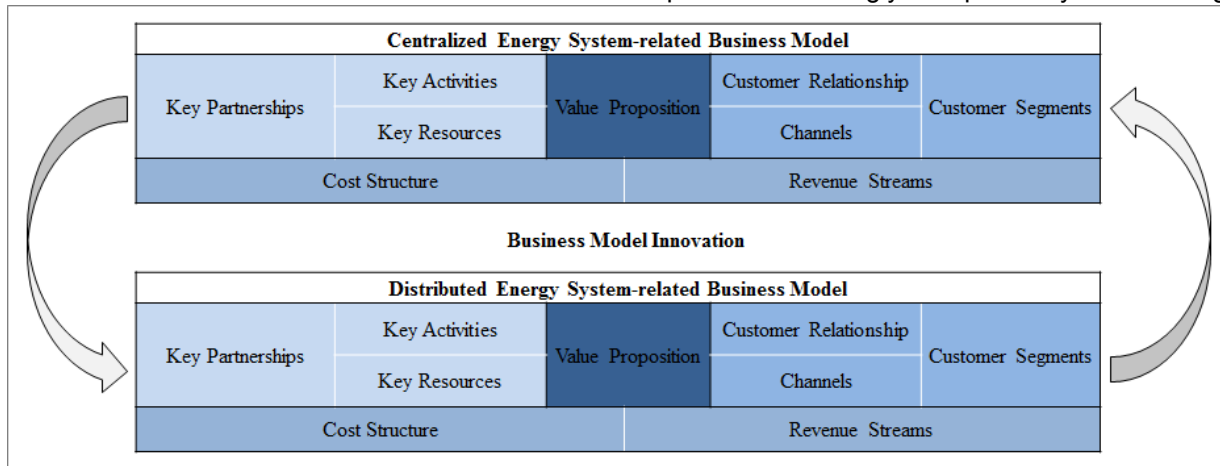


Figure 16: Canvas business model and BMI. Source: Own figure.

the nine building blocks of the Canvas business model (Figure 15: 23), the innovation process can be understood as an interaction between at least two business models concepts. Illustrated in Figure 16: 24, each building block of a CES-related business model is somehow linked to the dynamics of one or more building block(s) of a DES-related business model. It is important to note that successful BMI does not necessarily occur in every building block at the same time.

Generally, the internal innovation process is influenced by four key aspects originating from Amit and Zott (2012) and described as follows:

- (1) Novelty (i.e. degree of BMI in the activity system, e.g. incremental versus radical innovation);
- (2) Lock-in (i.e. degree of participant ‘dependency’ through switching costs or

business model. The organizational challenge is to “perform well in their current business (and business model), while at the same time undertaking the experiments necessary to nurture a new model” (Chesbrough 2010: 361).

**3.2.4 Limitations of the business model concept for this thesis**

Criticism about business model concepts in general mainly arises from its novelty and hence anticipated immaturity and its wide divergence of attributes among publications. In addition, many concepts remain theoretically underdeveloped and sometimes overloaded which makes empirical testing often challenging (Zott et al. 2011). Teece states that “like other interdisciplinary topics, business models are frequently mentioned but rarely analyzed: therefore, they are often poorly understood” (2010: 192), which already led to commercial



failure of promising technologies. Furthermore, a business model is limited due to its static reflection of a single point in time which does not incorporate the dynamics and determinants over time (Osterwalder et al. 2005; Mason and Spring 2011). Such limitations also need to be considered for this thesis, especially with regard to the interpretation and generalizability of the results. However, the Canvas business model is already used in numerous energy transition-related studies (e.g. Hannon et al. 2013; Richter 2013a; Richter 2013b). Furthermore, the collection of primary data goes beyond the scope of this thesis, and only a widespread use of this business model concept in related studies makes relevant secondary data available.

### 3.3 Combined coevolutionary business model framework

Shaping business models strongly relies on internal factors (e.g. organization, business strategy and technology) but also on its external environment (e.g. competition, legal, social, technological change and changes in customer demand) (Osterwalder and Pigneur 2010). As this thesis focuses on business models in a wider socio-technical system, also the external environment will be integrated as follows in a combined framework, termed as coevolutionary business model framework.

#### 3.3.1 Integration of the business model into the coevolutionary framework

Adapted from Foxon's (2011) framework, Hannon et al. (2013) investigate the coevolutionary relationship between the incumbent and a novel business model in the UK energy system. For this purpose, they integrate their business model framework into the coevolutionary framework. Following the integration of Hannon et al. (2013), the business strategy dimension (cf. Figure 14: 21) is firstly replaced with the business model notation, which usually contains the execution of a business strategy (Osterwalder and Pigneur 2010). Then, the business model dimension is moved into the centre of analysis. Hereon, the nine Canvas business model building blocks framework from Osterwalder and Pigneur's (2010) are applied to both business models of investigation (i.e. CES-related and DES-related business model) (cf. Figure 16: 24). This aims at a more comprehensive and structural reflection on coevolutionary interaction with regard to BMI between the two distinct business models and their four wider, dynamic socio-technical systems. Finally, an illustration of the own integrated and combined coevolutionary business model framework is provided in Figure 17: 25. This framework can be used in order to better understand how relevant changes in the other four socio-technology subsystems reciprocally influence the coevolution of the two business models and vice versa (Hannon et al. 2013; Foxon 2011).

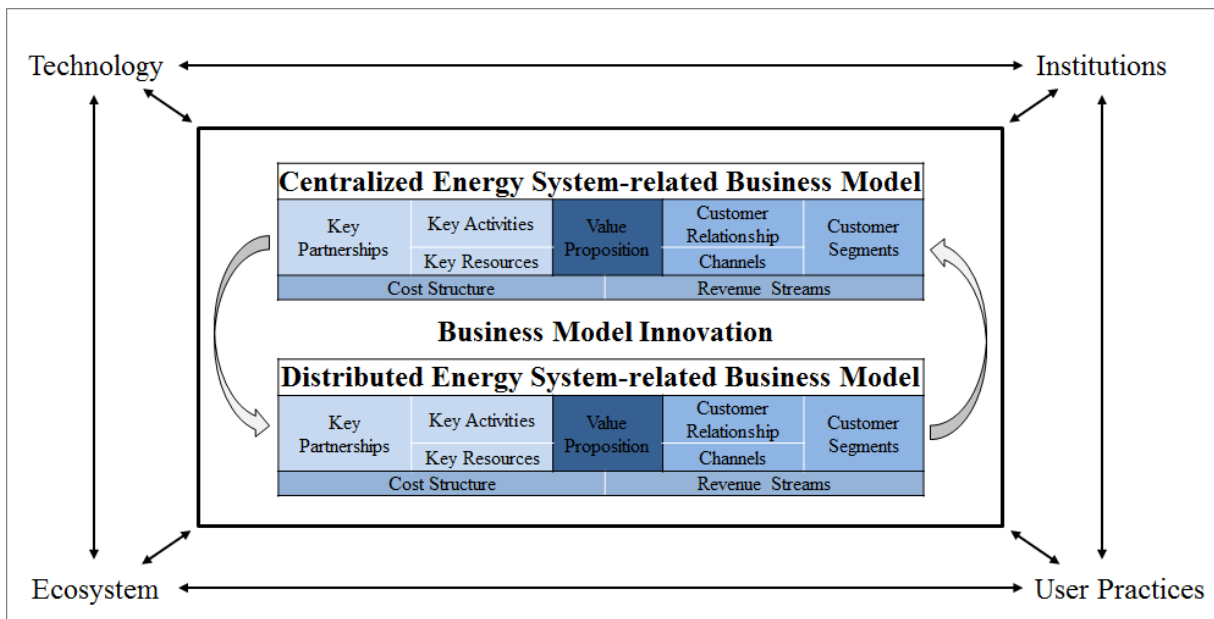


Figure 17: Coevolutionary business model framework. Source: Own figure, adapted from Osterwalder and Pigneur (2010), Foxon (2011) and Hannon et al. (2013).

### 3.3.2 Information and data source

Applying the depicted coevolutionary business model framework within Germany's Energiewende requires certain information and data base. Therefore, this paper follows a multiple source approach based solely on secondary data, as one type of research proposed by Saunders et al. (2009) and already proved in practice (e.g. Buber et al. 2013). This includes area- and time series based sources such as country reports, governmental and scholarly publications, books, academic journals as well as industry statistics and reports. In order to increase the reliability of this study, a variety of different sources is used (Saunders et al. 2009).

In particular, secondary survey data is used from relevant studies focusing on the coevolutionary framework, the Canvas business model and BMI within the transitioning energy systems, led by Hannon et al. (2013), Richter (2013b), Richter (2013a) and Burger and Weinmann (2013). In order to give an overview about the interviewees used by relevant studies, a list is provided accordingly in Table 3 and Table 4 in Appx: D. Furthermore, during an extensive literature review, new players could be identified and considered accordingly.

### 3.3.3 Overall limitations for this thesis

This thesis is faced with methodological limitations, already discussed above for each element of the coevolutionary business model framework as well as practical limitations through the nature of Energiewende, which is too complex to be investigated comprehensively, especially within a Master thesis. Therefore, the aim of this study is to apply the coevolutionary business model framework as a structural approach, to pick out relevant elements for DES-related business models. Furthermore, there are too many new and different players with specific features shaping DES-related business models during the transition (e.g. 800-1,000 municipal utilities). Therefore, active players are rather generically described in form of different business modules, which does not take into account all special features. Furthermore, due to time and resource constraints this coevolutionary analysis is limited to the impact of the framework dimensions on DES-related business models and does not consider the other way round. Even though highlighted when explicitly considered in the literature, the same limitation applies to the mutual influence among the dimension which cannot be comprehensively analysed.

In addition, even though progress within the Energiewende is documented in various ways, only obvious and major developments are investigated. However, this does not mean that the thesis claim to be all-inclusive with regard to all important aspects of the radical transition.

In addition, change is often influenced in a global perspective, but the focus of this paper attempts to remain on Germany. This is important to mention, because Germany's electricity systems is for example increasingly coupled with its neighbouring countries and also technological advancements take place on a global stage. Thus the cross-border as well as international perspective is only selectively considered when underlined in the secondary sources.

## 4 DES-related business models in the coevolutionary framework

The analysis of the transition of Germany's recent electricity system (chapter 2) highlighted a radical coevolution of DESs next to an incumbent CES. Those insights form the rationale to apply the coevolutionary business model framework, elaborated in the previous chapter 3, in order to investigate important factors that influence the coevolution of DES related business. The focus is on factors which help to explain the heterogeneity of the DES-related business model population (variation), its level of adoption (selection) and reasons why they will possibly persist in Germany's Energiewende (retention).

Firstly, section 4.1 elaborates a great variation of DES-related business models in theory and practice, from which some are already establishing and providing practical insights. Then, section 4.2, compares CES- and DES-related business models according to the nine building blocks of Canvas business model in order to better understand their different characteristics, indicating space for innovation. Finally, section 4.3 analyses the interactions of evolving DES-related business models with the various dimensions of the coevolutionary framework, including the impact of ecosystems, institutions, technologies, user practices, as well as BMI with the incumbent CES-related business model.

### 4.1 Coevolution of DES-related business models

In order to derive generic major modules of business models, section 4.1.1 overviews a variation of potential DES-related business model elements, considered in theory and practice. Furthermore, based on publicly available information, section 4.1.2 picks out active players and new green service utility in order to give insights into a new market for DES-related business models.

#### 4.1.1 Classification of DES-related business models

##### Focus on service and operation as a package of offerings, excluding construction

Gerbert et al. (2013) illustrate the variation of DES-related business model offerings currently arising, comprising the construction, services and operation, for example in order to improve demand flexibility, optimize distributed network

operations with prosumers or facilitate DEG (Figure 18: 28).

However, this overview does not claim to be comprehensive and even if, a detailed analysis on every single activity along the value chain would exaggerate the extent of this thesis. Furthermore, coevolving business models are of more complex nature, often comprising a package of offerings (Marko 2014). In addition, as defined previously in section 2.3.3, this thesis explicitly focuses on new green service utilities. This utility provides small-scale green energy production, trading and services, and covers attractive market niches incumbents that are not fast and/or credible enough to occupy. Therefore, this thesis seeks a type of utility which is probably less active in the construction, but rather in the service and operation column of Figure 18: 28.

##### Focus on end-user with own DEG (prosumer)

Here, Richter (2013a) gives a first starting point by addressing a number of recent studies (e.g. Frantzis et al. 2008; Nimmons and Taylor 2008; Schoettl and Lehmann-Ortega 2011) from which he derived two generic business models for RE, each with an own underlying business logic. Both are distinguished by their degree of distribution of RE generation according to the underlying definition by Orecchini and Naso (2012), mentioned in chapter 2.2.2.3. The first is explicitly CES-related, termed as utility-side RE business model and the second is rather DES-related, termed as customer-side RE business model. Whereas the first refers to the incumbent CES-related business practice where conventional, fossil-fired power plants are only replaced with large-scale renewables assets, the latter DES-related is seen as a stronger "*potential pillar of the future energy landscape and associated with substantial environment benefits*" (Richter 2013a: 1229), especially when achieving the highest degree of distribution based on prosumers with 100% energy self-sufficiency (Shandurkova et al. 2012; Richter 2013a; Gerbert et al. 2013).

##### Focus on small-scale DEG led by PV and related technologies and energy services

Moreover, DES-related business models fundamentally focus on small-scale DEG and related technologies and energy services (Strobel and Frühbauer 2011; Richter 2013b; Gerbert et al. 2013; Marko 2014). New DEG installations comprise wind, PV and biomass power plants, currently representing the three biggest shares in Germany's renewable pro-

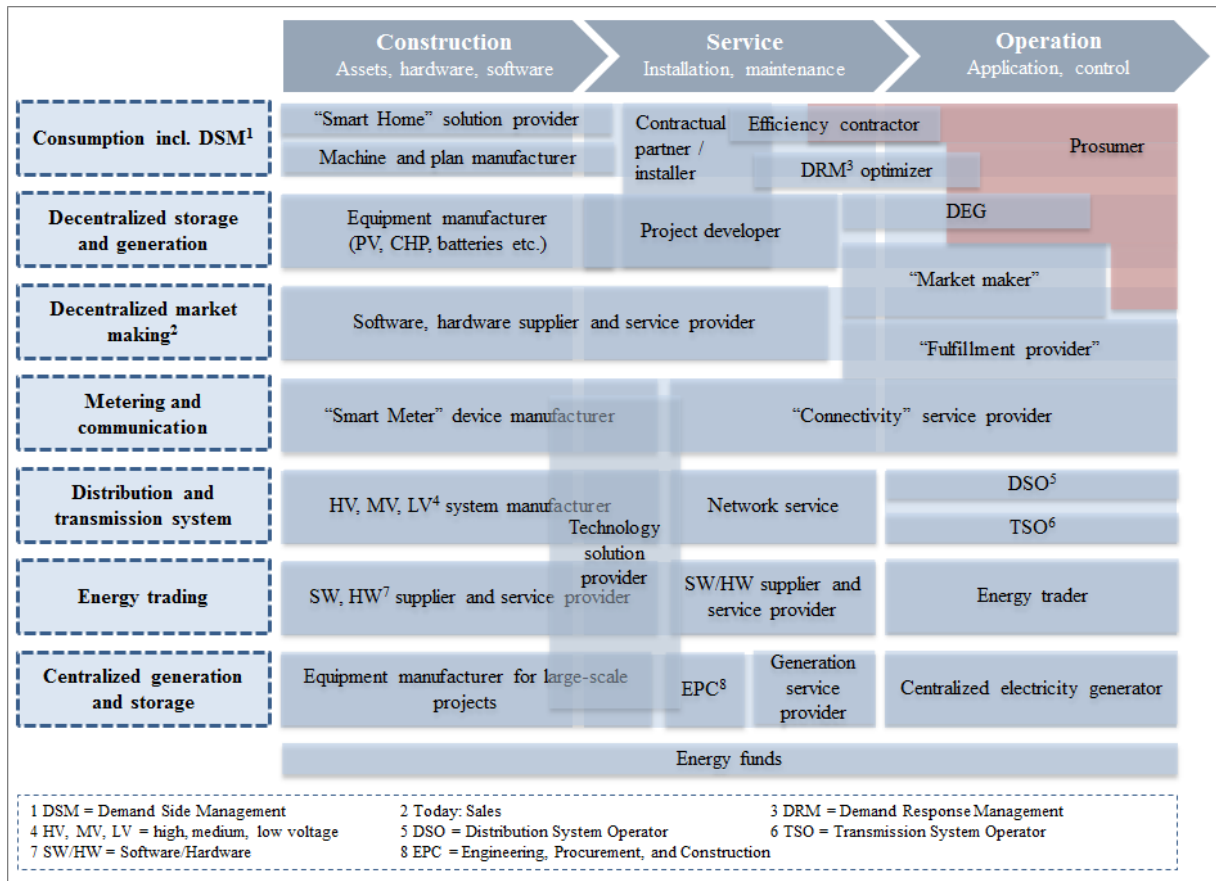


Figure 18: Variation of DES-related business models. Source: Own figure translation, based on Gerbert et al. (2013).

duction mix (cf. Figure 4: 9), but also other small-scale generation technologies such as micro-wind turbines, and micro-combined heat and power (micro-CHP) systems with a capacity range between a few kW and about 1 MW close to the point of consumption (Orecchini and Naso 2012; Richter 2013a). However, among different DEG technologies, PV takes a leading role in the current academic debate (Schleicher-Tappeser 2012; Richter 2013b), which is also highlighted in a recent global energy outlook by Bloomberg New Energy Finance, where small-scale PV is projected to dominate both, additional and installed capacity in the Organisation for Economic Co-operation and Development (OECD) countries over the next 25 years (Henbest et al. 2015).

**Focus on flexibility, optimization, integration, remote grid operation and services**

Furthermore, the overall increase of RE within the share of electricity production over the next decades (cf. Figure 20: 40) is going to require a huge flexibility from the electricity system in order to balance the strong, weather-dependent intermittency of PV and wind

(Starace 2009; Droste-Franke et al. 2012; SRU 2013; BMWi 2014b). DES-related business models need to give impetus to meet required flexibility, based on the implementation of ICT infrastructure and related smart grid application, which allows distributed load management and feed-in management within network operations such as 'Pooling/ Aggregation' (BMWi 2014a; Arriag et al. 2014; dena 2014c). Already today more than 98% of the PV capacity in Germany is connected to the low voltage distribution grid (Wirth 2015), highlighting the importance of the distribution system for RE integration (Gerbert et al. 2013; VKU 2014). Reversely, the integration of intermittent renewables underlines a significant challenge to balance the overall electricity system, as well as optimize DEG output locally (e.g. improve energy self-sufficiency) with storage technologies such as batteries and DSM (Rundel et al. 2013; Gerbert et al. 2013; EFZN 2013; Guerrero-Lemus and Martinez-Duart 2013; Richter 2013b; Agora Energiewende 2014; Hittinger et al. 2015).

Finally, based on the above insights and requirements, and with regard to the relevant

dimensions of the electricity system, three generic modules as strategic options to enter DES-related business models for a new green service utility can be derived, as well as are proposed (e.g. Richter 2013b; Arriag et al. 2014; Hannon et al. 2013; Strobel and Frühbauer 2011; Fox-Penner 2014):

### **(1) Distributed Supply Side Manager (Module 1)**

Module 1 is generically termed as ‘Distributed Supply Side Manager’. It comprises products and services related to the supply side of the DES, including for instance the installation, maintenance and operation of DEG and related physical assets (e.g. PV, wind, and network and control appliances) and related consulting services. The value of this module is to facilitate the quantitative expansion of DEG, with either mature or new technology, but also qualitative integration or optimization, e.g. standardization of processes, the aggregation and remote control of many DEGs and the complementary integration of further modules (Richter 2013b).

### **(2) Distributed Demand Side Manager (Module 2)**

Module 2 is generically termed as ‘Distributed Demand Side Manager’. It comprises energy efficiency products and services on the demand side of the DES. Richter (2013b) uses different types of energy efficiency measure which in the United States of America (USA) are commonly defined as DSM. DSM comprises “*all activities or programs undertaken by Load-Serving Entity or its customers to influence the amount and timing of electricity use*” (NERC 2015: 29). It can be distinguished by its time horizon into energy efficiency (permanent, long-term focus) and demand response (temporary, short-term focus).

- (1) On the one hand, energy efficiency represents “*permanent changes to electricity use through replacement with more efficient end-use devices or more effective operation of existing devices. Generally it results in reduced consumption across all hours rather than event-driven targeted load reductions*” (NERC 2014: 6). Energy efficiency provides permanent load reduction through various upgrade measures, for example adoption of efficient technologies (e.g. low energy lighting, new engines, and ice storage air conditioning), energy saving targets including audits, monitoring and verifi-

cation technologies (e.g. especially smart metering infrastructure and energy service platforms), rebates or sanctifying price differentials and investment incentives.

- (2) Demand response on the other hand stands for “*changes in electric use by demand-side resources from their normal consumption patterns in response to changes in the price of electricity, or to incentive payments designed to induce lower electricity use at times of high wholesale market prices or when system reliability is jeopardized*” (NERC 2014: 4). Demand response is used as a flexible load management tool (e.g. load control, shifting, shaping, and curtailment) that helps to temporarily adjust consumption during peak hours and power bottlenecks.

In general, energy efficiency and demand response are complementary measures, influencing and determining each other, especially with regard to smart metering infrastructure and energy service platforms. For instance Richter (2013b) and Fox-Penner (2014) specifically mention automatic interaction of load management systems according to flexible electricity tariffs. Whereas Strobel and Frühbauer (2011) summarize these characteristics as ‘Energy Efficiency Provider’ or ‘Provider for Smart-Home-Infrastructure’, Marko (2014) includes it within his ‘Complete Service Package’ business model, and Fox-Penner (2014) terms this as ‘Smart Integrator’ or ‘Energy Service Utility’, depending on ownership structures and level of market regulation.

Module 2 is seen as an extension and complement to module 1. In comparison to the DEG market, complex demand management systems are at an earlier stage of development (Richter 2013b; EFZN 2013).

### **(3) Distributed Storage Side Manager (Module 3)**

Module 3 is generically termed as ‘Distributed Storage Side Manager’. It comprises products and services related to electricity storage on the storage side of the DES. Especially with regard to the increasing share of weather-dependent, intermittent DEG with renewables, electricity storage can significantly improve the energy usability (Strobel and Frühbauer 2011; Gerbert et al. 2013; EFZN 2013; Rundel et al. 2013; SRU 2013; Agora Energiewende 2014; Hittinger et al. 2015). Consequently, it highly

depends on and complements the expansion of module 1. The distributed storage manager mainly focuses on a battery and thermal storage system, as well as the integration of electric vehicles (Strobel and Frühbauer 2011; Burger and Weinmann 2013; Gerbert et al. 2013; Richter 2013b). In this context, Strobel and Frühbauer (2011) for instance discuss the potential of storage as a service close to consumption, such as ‘Electricity Banks’ where electricity can be stored locally off-grid when cheaply produced and consumed when needed.

As the economics of suitable storage equipment is still high, module 3 appears the most promising when leveraged in combination with related value propositions of module 1 and 2 (He et al. 2011; Grünwald et al. 2012; Richter 2013b; WEC 2014).

#### 4.1.2 Emergence of DES-related business models in practice

The following section elaborates on active players and new green service utility in order to provide insights into a new market for DES-related business models.

##### 4.1.2.1 Distributed Supply Side Manager

As long as flexible supply and demand cannot be technically balanced and stored locally, small-scale DEG feed-in electricity excesses into distribution and transmission networks. This strongly stresses grid operators who need to physically balance the system (cf. section 2.2.3.2) (e.g. frequency and voltage regulation) but do not have direct control over DEG units. One of the most discussed business model value propositions in theory and practice, especially among utilities, is the market-based approach of a ‘Virtual Power Plant’ (VPP) (E.ON 2013a; Burger and Weinmann 2013; Arriag et al. 2014; Machina Research 2014; RWE 2015b; VDI Wissensforum 2015).

A VPP can be understood as *“an artificial layer placed between the system operator and the DG [distributed generation] user. It is formed out of individual DG units, and co-ordinates the actions of the units as a whole (where this is technologically possible), rather than leaving units to govern themselves individually”* (Newman and Mutale 2010: 308). As a special type of microgrid *“a virtual power plant is a link-up of small, distributed power stations, like wind farms, combined heat and power units, photovoltaic systems, small hydropower plants and biogas units, but also of loads that can be switched off, in order to form an integrated*

*network. The plants are controlled from one central control room”* (RWE 2015b).

Many companies<sup>20</sup> start to establish VPP-related business models, for instance to participate in ancillary service and wholesale markets and absorb uncertainty and forecasting inaccuracy of intermittent RE generation (EFZN 2013; Next Kraftwerke 2015a; CLENS 2015), especially in rural areas (Burger and Weinmann 2013; BMWi 2014a).

An important starting point for VPPs is seen in the amendment of the EEG in 2012 for subsidized RE. It opened up a new marketing channel, termed as ‘market bonus scheme’, which gives a market premium for direct selling of excess electricity on electricity markets. Whereas before TSOs balanced the uncontrollable feed-in of RE, end-users (prosumers) afterwards benefit when upgrading and transferring the management to a utility with VPP. For example Siemens promptly realized two VPPs, based on its decentralized energy management system (DEMS). One is operated within Munich by the municipal utility Stadtwerke München, bundling six CHPs, five hydro power plants and one wind power unit with a total capacity of 20 MW (Siemens 2012a). The other one is operated by RWE with a similar capacity of 20 MW from biomass, biogas-CHP, PV, wind power and hydro power plants (Siemens 2012b; RWE 2015d) which is already extended to 1,000 MW in 2013 (RWE 2014a), five times more than projected for 2015 (RWE 2015d). Also Vattenfall, EnBW and E.ON are aware of the future role of VPP-related business models and undergoing related business activities. One utility states that VPPs play a major role for the Energiewende, in particular as a provider of upward capacity in the market for balancing services. The concept will expand with the extension of intermittent RE generation and an increasing level of distribution (E.ON 2013a).

Apart from incumbent utilities, there are also new green service utilities, operating solely a DES-related business models with VPPs. For instance since 2009 one of the biggest direct seller of EEG subsidized electricity Energy2market GmbH (e2m)<sup>21</sup> runs a VPP with own ICT infrastructure and related trading activities

<sup>20</sup> For instance: Clean Energy Sourcing AG, Next Kraftwerke GmbH, Balancepower GmbH, energy & meteo systems GmbH, VPP Energy, Energy2market GmbH, Statkraft, Lichtblick, Stadtwerke München and the BIG4 (Source: Based on own research).

<sup>21</sup> E2m operates 2,000 decentralized units with 3,400 MW capacity in 2014 (Oberzig 2014).

on wholesale markets. Since 2012 e2m is prequalified supplier for secondary balancing capacity and since 2013 even for primary balancing capacity from decentralized generation units in all four German grid zones (Oberzig 2014). Furthermore, it is currently a prequalified supplier for minute reserves (Regelleistung 2015). In 2013 e2m generated EUR 708 Mio with 56 employees (CLENS 2014).

In 2009 also the Next Kraftwerke GmbH was founded, a company which is entirely positioning as VPP provider. Today it employs 91 people, generates EUR 100.6 Mio (2013) and operates 2,418 generation units with an accumulated capacity of 1,471 MW in its VPP (Next Kraftwerke 2015a). Next Kraftwerke is prequalified for secondary balancing capacity and minute reserves (Regelleistung 2015).

The growing importance of VPPs can also be observed on their improving functionality. VPPs are deployed for more than three decades, albeit in Germany, Scandinavia, and North America a new concept emerge with regard to changing energy markets and system technologies. *“This new generation of VPP aims to manage an interconnected market of energy devices through the intelligent application of abstracted software tools and systems. The new generation of VPPs optimizes the system as a whole before managing individual and discrete parts”* (Machina Research 2014: 2). So this new type not only includes the supply side perspective but also the demand side and energy storage side of the DES (Machina Research 2014).

With an increasing production share with intermittent RE, DSM and storage will play an increasingly important role to guarantee flexibility when the electricity system is stressed, for instance through weather condition (SRU 2013; BMWi 2014a).

#### 4.1.2.2 Distributed Demand Side Manager

The activation of flexible consumption in the electricity system, so called DSM, is seen as a key measure to handle the growing replacement process of conventional power plants with intermittent RE production (EFZN 2013; Burger and Weinmann 2013; Biegel et al. 2014; BMWi 2014a). Here also the concept of VPPs is used to aggregate flexible loads on the demand side. In recent times ICT infrastructure and technology significantly reduced the complexity and response times of aggregated control of distributed load centres and hence allows the commercial participation with downward bal-

ancing energy and capacity on spot and balancing service markets (EFZN 2013).

The BMWi (2014a) supported field tests during the research project E-Energy and found out that flexible electricity tariffs in combination with monitoring systems for consumption motivate certain customer types to shift up to 10% of their loads (i.e. demand response). Stronger financial incentives even increase load shifting behaviour. The related cost savings during the field tests ranged between some euros and EUR 100 per year and EUR 60 in average for residential and commercial customers with expandable potential. The load shifting potential often increases with the consumption volume of the customer. That is why the potential for large load centres such as commercial and industrial consumers is seen as promising (BMWi 2014a), while residential customers with a shifting potential of only 5% are rather seen fairly limited for demand response (Burger and Weinmann 2013). This is because *“[I]ights are switched on when it is dark – and not when a lot of electricity is available because it is windy or the sun is shining. The oven in the kitchen is used when one wants to cook at midday or in the evening, but not at midnight because the electricity is cheaper then”* (Interview in Burger and Weinmann 2013: 117). For example Biegel et al. (2014) calculated a minimum flexible load capacity under today market conditions necessary to economically participate on spot or balancing service markets, which is hardly to achieve for an average household customer. But the study also predicts that upcoming market changes will strongly facilitate DSM even for end-users with very low flexible consumption capacities (Biegel et al. 2014).

As of today, German TSOs only allow industrial users to provide demand response for balancing services. Small user aggregation does not fulfil the current strict, but questionable prequalification requirements for balancing markets, which still undermines their potential as a flexibility resource (Koliou et al. 2014).

Furthermore, DSM-related monitoring systems revealed a permanent saving potential of 10% for household and even 20% for commercial customers (i.e. energy efficiency) (BMWi 2014a).

A comprehensive study of Buber et al. (2013) captured a great potential for DSM, as well as a high interest and willingness of energy intensive industry participants. The study revealed 450 MW demand response capacity of energy intensive industries in Southern Germany

which could be released for one hour during peak load events. Based on this data, the current technical potential throughout Germany is projected to be 1,705 MW (Buber et al. 2013). According to FfE (2010) the estimate of the technical potential is with about 2,500 MW even higher (cf. Figure 30 in Appx: H). In Southern Germany 300-400 MW capacity were already used for peak load shedding and 76 MW traded on the market for balancing services. This demand response capacity is seen as less cost intensive compared to conventional peak load power plants (Buber et al. 2013).

In Germany, new green service utility with DES-related demand side management business models are currently starting to be establish. For instance Entelios, founded in 2010<sup>22</sup>, tries to leverage the current potential for demand response in Germany. As a demand response service provider, the company is prequalified for secondary balancing capacity (Regelleistung 2015) and aggregates and controls loads from commercial and industrial customers which are traded on spot and balancing capacity markets (Flamm 2014). Entelios manages around 100 clients, e.g. paper mills, treatment plants, public buildings, silicon plants or breweries with an accumulated capacity of 650 MW, similar to a medium-sized coal power plant (Schultz 2014). For example since 2010 the Paulaner brewery in Munich provides 1 MW demand response capacity to Entelios by temporarily taking off refrigeration units from the grid during electricity bottlenecks. During an event Paulaner and Entelios share the service fee paid by TSOs for balancing support to the grid (EnerNOC 2015).

Other aggregators for demand response services in Germany are Balancepower GmbH, Clean Energy Sourcing AG and Next Kraftwerke GmbH (Regelleistung 2015). Furthermore, one of the biggest pilot projects for DSM is currently executed in Bavaria and managed by dena to promote DSM in all domains and layers of the German energy system (dena 2014a).

Nevertheless, aggregated demand response as a viable market resource is still in its beginning, but provides a promising business strategy to balance volatility in a DES (Koliou et al. 2014).

<sup>22</sup> In 2014 Entelios was acquired by EnerNOC, one of the world leading demand response service providers.

#### 4.1.2.3 Distributed Storage Side Manager

The Distributed Storage Side Manager is a business model module which could also serve as a flexibility option to balance the grid and to generate profits from price differentials. The underlying logic is to purchase and store electricity during off-peak periods when prices are low and sell it to the grid responsible during peak periods when prices are high. The price would theoretically reflect the current physical system stability which is strongly influenced by intermitting renewables. Revenues come from arbitrages between off-peak and peak load in the electricity system (Taylor et al. 2013; Rundel et al. 2013). The bidirectional transformation process (i.e. charge and discharge) of electricity into a storable form through electricity storage technologies can provide multiple services within all domains of the electricity system. A major value proposition of electricity storage with battery systems lies in the quick response time and high transformation efficiency (Guerrero-Lemus and Martinez-Duart 2013). This allows for example frequency and voltage regulation and makes batteries suitable even for primary balance capacity (WEMAG 2014; Agora Energiewende 2014), which is currently not possible for DSM providers (Regelleistung 2015). Furthermore, end-users of distributed, small-scale generation from renewables can increase their energy self-sufficiency by improving asset utilization. This helps to achieve energy autarky and save electricity cost by avoiding expensive retail electricity prices. In addition, electricity storage is also attractive for arbitrages on spot markets (He et al. 2011; Droste-Franke et al. 2012; Taylor et al. 2013; Rundel et al. 2013; Burger and Weinmann 2013).

In practice, profitable business models based on distributed battery storage technologies are at a beginning stage, because costs for batteries are still too high for large-scale application. That is why Strobel and Frühbauer (2011) projected commercial business models such as Electricity Banks by 2020. Nevertheless, a first public research project of battery banks with PV and CHP units already started in the end of 2014. 14 households and four commercial customers are able to check online their daily account balance of electricity supply and demand. The battery bank has a capacity of 100 kilowatt (kW) with an output of 116 kWh and is located in the district of its customers in Mannheim. The subsidized research project is administrated by MVV Energie AG, a larger utility, based on system solution from ads-tec



GmbH, an industrial IT-solution provider (adstec 2014).

However, today liberalized electricity markets already offer business opportunities for entrepreneurs to experiment and roll-out business models without subsidies (Burger and Weinmann 2013; Gerbert et al. 2013). First companies attempt to figure out commercially viable business models and establish innovative financing ways to overcome high investment costs. For example Yunicos, a system integrator for renewables, provides a software management solution for battery storage which helps to amortize investments cost through the participation on balancing markets. Together with the municipal utility WEMAG, the company established the largest commercial battery unit in Germany in Schwerin, a region with an 80% penetration rate out of renewables. With a capacity of 5 MW and an output of 5 MWh, WEMAG is prequalified for primary balancing capacity (WEMAG 2014; Regelleistung 2015). With regard to the volume of primary balancing service market of about 600 MW (cf. Figure 8: 14), 120 times more similar sized stationary batteries could be commercially operated in Germany. Similar stationary batteries are already under construction in different cities, for example in Feldheim (10 MWh) and in Aachen (5 MWh) (Kempkens 2014).

Another BMI is followed by Lichtblick, which plans to coordinate a pool of storage units through its own VPP, called 'SchwarmBatterie'. The established green service utility extends its VPP solution together with PV-storage system providers as SMA, Tesla, Sonnenbatterie and Varta Storage (Lichtblick 2015), and pools end-users of these systems with attractive price models (Sonnenbatterie 2015). Other providers pursue similar business strategies, for instance Fenecon and Ampard (Ampard 2015) and the Deutsche Energieversorgung, a 2009 founded company with 35 employees (2013) and annual revenues of EUR 12 Mio (2012), which pools 3,500 PV-storage units for the balancing service market (Sterner et al. 2015).

Furthermore, Lichtblick successfully interfaced the grid with a pool of 20 electric vehicles in a pilot project in Berlin (Schulte 2014). Electric vehicles could be an economically attractive option for customers with own PV installations when charged with cheaper, own produced electricity. Nevertheless electric vehicles are not expected to be a key element in grid stabilization (balancing services), as their technical configuration and expansion make slow progress (Burger and Weinmann 2013). For ex-

ample Daimler estimates that *"even a million electric vehicles would only account for 1 percent of the demand for electricity. That will hardly provide a robust backup for the public grid"* (Interview in Burger and Weinmann 2013: 142). Germany has 18,948 electric vehicles in 2015, which is expected to increase up to between 50,000-300,000 in 'lower' scenario, 400,000-700,000 in 'central' scenario, or 1-1.4 Mio in 'upper' scenario by 2020 (Plötz et al. 2013).

Deutsche Bank Research estimates the German market for stationary electricity storage units will be around 40 TWh in 2040 with a potential investments volume of around EUR 30 billion (bn) by 2030 (Auer and Keil 2012). Especially optimized PV-storage systems for energy self-sufficiency and autarky enter the market and form a substantial business volume (Agora Energiewende 2014).

Nevertheless necessary flexibility of the future grid can be provided by different options (e.g. flexible power plants, DSM) which compete with storage technologies. Therefore, the role of storage solutions is hard to predict (Agora Energiewende 2014). Stationary storage devices are already economically viable in isolated areas with grid bottleneck. In addition, attractive business opportunities arise when electricity storage is linked to fluctuating wholesale and ancillary service markets and/ or cross functional industries such as automotive with electric vehicles. The benefits of more comprehensive, multi-functional business models are for example proposed in a study by He et al. (2011) who optimize revenues by combining the variety of possible electricity storage application. Companies with special capabilities for system integration obtain useful value propositions for evolving DES-related business models.

#### 4.2 Comparison of CES- and DES-related business models

Based on a variety of different studies (e.g. Nimmons and Taylor 2008; Hannon et al. 2013; Gerbert et al. 2013; Richter 2013a; Richter 2013b; Burger and Weinmann 2013; Arriag et al. 2014; Marko 2014; Sterner et al. 2015) this section draws a comparison between CES- and DES-related business models based on the building blocks of the Canvas business model. This section especially helps to better understand differences between both types of business models. The detailed overview is given in Table 1: 35 at the end of the section which is summarized in the following.

On the one hand, the typical integrated utility's value proposition comprises a reliable, mass production and delivery of electricity as commodity for a fixed price per kWh. Customers are flexible in their supplier choice but are not involved in any other domain of the CES. Economies of scale and optimization of large-scale power plant production and transport shall guarantee competitive retail prices. On the other hand DES-related utilities are rather fragmented and specialized to single domains. Their value proposition offered by decentralized generation differs fundamentally from the CES. As they do not own DEG units, they provide customer value through customized solutions and energy related services. The customer becomes an energy partner. DES-related business models focus on the integration of distributed system components and optimize an isolated or even the entire system.

In contrast to CES-related utilities, a DES-related business model guarantees and increases electricity price stability, profits, self-sufficiency, autarky, a green lifestyle and reduces costs and production losses of its customers. It helps to better match the customer's consumption with its own produced electricity. For this, DES-related business models bundle small-scale system components, optimize decentralized structure and support access to wholesale and ancillary services markets, as well as cross-sector markets. This disburdens inefficiencies in central grids, which saves and defer investments for grid renewal and extension.

Whereas DES-related utilities strongly interact with their customers through smart ICT infrastructure and build up local knowledge, the incumbent vertically integrated utility shows no need for customer interference, as it does not go beyond the meter for DSM activities. The more energy self-sufficient and distributed prosumers become, the more they are targeted by DES-related business models. This comprises residential, private, small- and medium businesses, as well as agricultural customers with local PV, wind or biomass production. Furthermore, DSM measures can also be aggregated with all types of customers without own energy production.

Whereas customers within DES are rather characterized as heterogeneous and active, the incumbent CES customers are regarded as homogeneous and passive, without interest in energy self-sufficient or DSM activities. On the

one hand, those secondly mentioned customers are interfaced through marketing channels to issue all around short-term power purchase agreements. On the other hand DES-related companies rather actively and continuously communicate with its customers to ensure long-term relationships, first via traditional channels to acquire customers and second via online management systems to manage and optimize mutual benefits.

Whereas a CES comprises a peak-load oriented, small number of capital intensive, large power units, and transmission and distribution system as key resources, a DES requires a large number of small power units which are optimized locally to provide a high degree of energy self-sufficiency based on a smart ICT infrastructure. For this on the one hand, CES-related players need to partner with financial institutions and investors, electrical power generation companies, transmission and distribution system operators (TSOs and DSOs). DES-related companies on the other hand need to partner with end-users (prosumer), manufacturers and installers of RE systems, storage units, electric vehicles and ICT systems.

Whereas the CES-related revenue is mainly driven by the maximization of sales volumes, profits in DES-related business models are decoupled from sales volumes, but generated through continuous system integration and optimization based on energy efficiency, information transparency and aggregated participation on increasingly volatile wholesale and ancillary service markets. This causes high transaction costs compared to CES-related business models, because processes are difficult to standardize and well trained staff for customers' trainings is needed. Furthermore, higher operational expenditures to operate and maintain ICT infrastructure is needed. In contrast, utilities in a CES focus on economies of scale from large projects and project portfolios to optimize their sales volume. Since power purchase agreements fixes retail prices, additional profits will be generated through trading schemes and cost reductions within the own value chain. Cost drivers are seen in high total cost of ownership, including operational and asset capital expenditures (often tied up long term) and the cost for acquisition or usage of premises and land. Furthermore, whereas primary resources (fossil fuel) for conventional power plants produce marginal cost, RE such as wind and PV is available for almost zero marginal costs.

**Table 1: Comparison of CES- and DES-related business models. Source: Own table, based on Nimmons and Taylor (2008); Hannon et al. (2013); Gerbert et al. (2013); Richter (2013a); Richter (2013b); Burger and Weinmann (2013); Arriag et al. (2014); Marko (2014) and Sterner et al. (2015).**

	<b>CES-related business models</b>	<b>DES-related business models</b>
Customer Value Proposition	<ul style="list-style-type: none"> <li>• Fulfil energy needs at low cost (economies of scale and optimization of the large-scale power plant portfolio, efficient transportation and distribution)</li> <li>• Reliable, bulk generation of electricity</li> <li>• Maximize the sales volumes of kWh to final customers</li> <li>• Electricity as commodity (price per unit without qualitative differentiation)</li> <li>• Short-term contracts mean flexibility for customer</li> <li>• e.g. few behavioural stipulations</li> <li>• Financial strength</li> <li>• Supply side driven</li> </ul>	<ul style="list-style-type: none"> <li>• Integration and bundling of geographically atomized energy producers into a complex, interconnected network</li> <li>• Local knowledge and customers proximity</li> <li>• Customize energy related solutions &amp; services</li> <li>• Strong interference with customer 'beyond the meter' e.g. DSM</li> <li>• Stabilize prices</li> <li>• Optimize and guarantee self-sufficiency, autarky and profits</li> <li>• Information transparency &amp; trust</li> <li>• Enable green lifestyle</li> <li>• Demand side driven</li> </ul>
Target Customer	<ul style="list-style-type: none"> <li>• Residential, commercial, industrial and agricultural</li> <li>• Homogeneous, passive groups of customers</li> </ul>	<ul style="list-style-type: none"> <li>• Residential, private, small-and medium business, agricultural customers and prosumer</li> <li>• Heterogeneous active customers</li> </ul>
Customer Channels	<ul style="list-style-type: none"> <li>• Online, TV, telephone, postal &amp; door-to-door marketing, purchasing, metering, billing &amp; customer feedback</li> <li>• Energy supplied unidirectional via a national transmission &amp; distribution network (i.e. B2B)</li> <li>• Support via customer service call centre, metering &amp; billing etc.</li> </ul>	<ul style="list-style-type: none"> <li>• Online, energy association, postal &amp; door-to-door marketing</li> <li>• Energy supplied bidirectional via a national transmission &amp; distribution network in interaction with demand side</li> <li>• Smart grid, network control centre via ICT infrastructure and interface management</li> </ul>
Customer Relationship	<ul style="list-style-type: none"> <li>• Impersonal &amp; standardized</li> <li>• Short-term power purchase agreements on B2B-level (e.g. TSOs, DSOs and suppliers) rather than a relationship with the end-customer</li> <li>• Little interference with customer as they do not go 'beyond the meter'</li> <li>• Customer responsible for managing most conversion processes (e.g. gas to heat via boiler)</li> </ul>	<ul style="list-style-type: none"> <li>• Customer is involved in energy generation by hosting the DES</li> <li>• Sharing benefits/ profits with the utility</li> <li>• Strong interference with customer 'behind the meter' e.g. DSM</li> <li>• Proximity to customers</li> <li>• Long-term customer relationship</li> </ul>
Key Activities	<ul style="list-style-type: none"> <li>• Typically integrated utilities engage in primary energy</li> </ul>	<ul style="list-style-type: none"> <li>• Fragmented utilities are specialized in certain domains</li> </ul>

	<b>CES-related business models</b>	<b>DES-related business models</b>
	<p>sourcing, generation, distribution and supply (some transmission)</p> <ul style="list-style-type: none"> <li>• Key activity is asset management and operation</li> <li>• Generation – finance, design, build, operate and maintain large-scale, centralized energy generation &amp; distribution infrastructure</li> <li>• Distribution – own and operate to link transmission and generation with supply</li> <li>• Supply – electricity trading and metering &amp; billing of energy supply</li> <li>• Rarely go ‘beyond the meter’</li> <li>• Some installation &amp; maintenance of small-scale conversion and control technologies (e.g. central heating)</li> </ul>	<ul style="list-style-type: none"> <li>• Key activity is asset integration and optimization</li> <li>• Generation – consulting, build, maintain, financing support, information</li> <li>• Distribution – own and operate to link transmission and generation with supply</li> <li>• Supply – enable access to ancillary service and wholesale markets for (automated) electricity trading, as well as cross-sector markets (e.g. electric vehicle)</li> <li>• Demand – make customers more flexible and provide information</li> <li>• Electricity system – integrate and manage distributed supply, storage and demand (e.g. VPP) through remote monitoring and control (i.e. smart appliances)</li> </ul>
Key Resources	<ul style="list-style-type: none"> <li>• Small number of large-scale centralized generation assets, transmission &amp; distribution technologies</li> <li>• Financial and technical resources to develop large-scale, centralized generation and distribution infrastructure</li> <li>• Customer facing services i.e. nationwide metering, billing and customer service network</li> <li>• Fossil fuels (e.g. gas, coal)</li> </ul>	<ul style="list-style-type: none"> <li>• Large number of small-scale assets (e.g. PV, wind, biomass, CHP, stationary battery, electric vehicles and load centres)</li> <li>• Technical resources to develop ICT infrastructure (i.e. smart grid)</li> </ul>
Key Partnerships	<ul style="list-style-type: none"> <li>• Financial institutions &amp; investors</li> <li>• Electrical power generation companies</li> <li>• TSOs &amp; DSOs</li> </ul>	<ul style="list-style-type: none"> <li>• Energy producing customers/prosumers</li> <li>• Manufacturers and installers of RE systems, storage units, electric vehicles and ICT systems</li> </ul>
Revenue Streams	<ul style="list-style-type: none"> <li>• Sale of units of delivered energy (price per metered unit)</li> <li>• Trading of surplus electricity on the market</li> <li>• Revenues through feed-in of electricity</li> <li>• Economies of scale from large projects and project portfolios</li> </ul>	<ul style="list-style-type: none"> <li>• Decouple sales volume from revenues</li> <li>• Low-carbon financial incentives (e.g. renewables obligation certificates)</li> <li>• Revenue from direct use, feed-in and/or from services</li> <li>• Arbitrage revenues through participation in dynamic pricing at wholesale and ancillary service</li> </ul>

	<b>CES-related business models</b>	<b>DES-related business models</b>
		markets with generation units and load shifting and shedding (i.e. DSM) <ul style="list-style-type: none"> <li>• Onetime revenue from consulting service (e.g. energy efficiency)</li> </ul>
Cost Streams	<ul style="list-style-type: none"> <li>• High total cost of ownership (e.g. generation assets, operations &amp; maintenance)</li> <li>• Premises &amp; land acquisition</li> <li>• Marginal cost through primary resources, e.g. gas, oil, coal</li> <li>• Marketing and communication</li> <li>• Infrastructure for metering &amp; billing</li> <li>• Finance or investment repayments</li> <li>• Technical, financial and legal consultancy</li> <li>• Staff</li> </ul>	<ul style="list-style-type: none"> <li>• High transaction costs (e.g. lack of standardization)</li> <li>• Operational expenditures (e.g. operations &amp; maintenance of ICT infrastructure)</li> <li>• Trade-off between transport cost and production efficiency (e.g. offshore wind park with high transport cost but high efficiency vs. roof-top PV with no transport cost but lower efficiency)</li> <li>• Staff</li> </ul>

### 4.3 Interactions within the coevolutionary business model framework

This section analyses the impact of ecosystems, technologies, institutions, and user practice as well as BMI between CES-related business models and DES-related business models, as defined in the coevolutionary business model framework.

#### 4.3.1 Ecosystems and DES-related business models

Similarly to the UK, the ecosystem rather influences the wider electricity system and is largely mediated through the other systems, particularly by institutions and its regulatory impact (Hannon et al. 2013), by user practice, considering the Energiewende movement resulted from the anti-nuclear movement in the 1970, as well as by business models, for instance described as “*positive societal and environmental impacts of the firm on society by ensuring long-term health and wellbeing of stakeholders (including society and the environment)*” (Bocken et al. 2014: 51).

Especially business models “*as a vehicle to coordinate technological and social innovations with system-level sustainability*” (Bocken et al. 2014: 423) can form an important link to bring together sustainability targets (e.g. reduce energy and emissions), society and economic value (Bocken et al. 2014). Baden-Fuller and

Haefliger conclude that “*for managers, the ecosystems perspective holds the promise of opening up the wider entrepreneurial and collaborative space that a new technology affords – and provides room for novel business models to succeed*” (2013: 424).

The major requirement on the ecosystem dimension is best reflected by climate change. The significant impact of human made emissions of GHG on climate change is generally established by the Intergovernmental Panel on Climate Change. Global carbon dioxide (CO<sub>2</sub>) emissions have increased by 40% since pre-industrial times, primarily from fossil fuel emissions. The average of all four scenarios predicts that the global mean surface temperature increases by 1.0 to 3.7°C (mean) above the average for 1850-1900 in 2100. In order to prevent dramatic effects on our ecosystem, one of the global key challenges of our century is to urgently restrict global warming to 2°C by 2100 through a significant reduction of GHG emission (IPCC 2013).

Germany framed the ecosystem dimension in various ways into the Energiewende concept (Rosenkranz 2015), whereof one aims to reduce its GHG emission by reducing and replacing GHG emitting fossil fuel based electricity generation on the supply side and reducing the overall electricity consumption through energy efficiency measures on the demand side (cf.

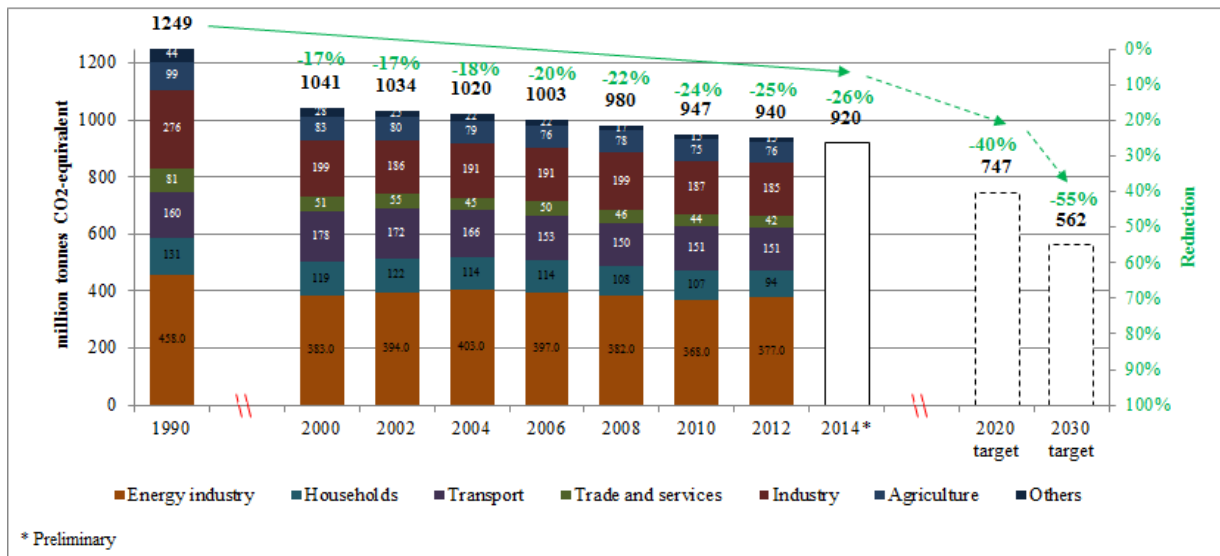


Figure 19: GHG emission by sector between 1990 and 2014 and governmental targets. Source: Own figure, based on data from Agora Energiewende (2015).

Figure 2: 6). The development of GHG emissions (Figure 19: 38) already shows a slight, constant downwards trend by 26% in 2014 compared to 1990 which the government committed to further reduce by 40% by 2020, 55% by 2030 and 80-95% by 2050. With regard to its share, the transition of the electricity system (as part of the energy system) is essential, as the energy industry is the major CO<sub>2</sub>-emitter (378 Mio ton (t) CO<sub>2</sub>-equivalent in 2013) (Agora Energiewende 2015), although it states the second lowest, relative reduction track record among all industries in Germany since 1990 (Figure 19: 38). However, replacing energy generation with renewables significantly contributes to GHG emission reduction. According to the Federal Environment Agency, 715 gram (g) CO<sub>2</sub>-equivalent per kWh is attributed to PV, between 750-780 g to wind, and even 800 g to biomass. In 2012, renewables in total were attributed to avoid 145 Mio t CO<sub>2</sub>-equivalents, whereof about 101 Mio t were linked to the electricity system, 38 Mio t to heating and 5 Mio t to fuel (Memmler et al. 2013).

However, even though a positive impact of the ecosystem on DES-related business models and vice versa can be assumed, it is currently hard to measure how ecosystems exactly influence its acceleration. Finally, the increasing awareness about environmental impact might push business model expansion (REN21 2015).

#### 4.3.2 Institutions and DES-related business models

Even in liberalized markets an exclusion of regulatory authorities such as governments from the sector is practically impossible, especially with regard to negative externalities such as climate change and supply security (Burger and Weinmann 2013). Therefore, the development of the German Energiewende, from which also BMI derives, was strongly driven by governmental support. In particular, the energy market design and business models strongly depend on investment support and governmental regulation. So far, this does not only create advantages, but also creates huge uncertainty among market players. Nevertheless, further significant adjustment within the electricity system will come for sure, and its elaboration is continuously hard to predict. The role of the government ranges between a passive political framework and an active control of system relevant actors (Gerbert et al. 2013).

For example, the Federal Ministry for Economic Affairs and Energy of Germany recently published its Green Paper which publicly discusses a broad range of possible regulatory adjustment measures in electricity markets and systems in the near future. Those measures definitely impact incumbent CES-related business models and either strengthen the need for BMI or open up possibilities for new DES-related business models. The Green Paper addresses an integrated approach, including DEG, storage, DSM and VPP. For instance, new price mechanisms are presented (e.g. demand response) which might replace or substitute FITs

as installation incentive (BMW 2014b). However, apart from adaptations in the near future some important measures have already been developed, which gives momentum to DES-related business model.

### **Market access**

For example, recent regulatory measures enable the access of distributed supply and demand sources to new markets such as ancillary services. For example in 2011, the Federal Network Agency reduced the minimum supply capacity, shortened the tendering periods for balancing capacity and enabled pooling of distributed resources for primary and secondary balancing capacity as well as minute reserve. The aim is to promote new market participants and market access of new technologies such as DSM systems, electricity storage, flexible small-scale generators (Bundesnetzagentur and Bundeskartellamt 2014). However, barriers are still too high and need further regulatory improvement (Connect Energy Economics 2015). In general, regulatory instruments should optimize network flows, increase consumer price elasticity, and avoid unnecessary investments into local grid reinforcement (Burger and Weinmann 2013; dena 2014c).

### **Smart grid**

Governments also need to stimulate private investments for certain technologies, for example in order to modernize electricity system towards more flexibility. Relevant also for DES-related business models is for instance smart grid technology. The governmental interest is high, as smart grid investments are complementary to already deployed DEG, enabling an efficient local balancing of demand and supply. This maintains local or overall system stability and saves huge investments into grid reinforcement, which in turn releases tax expenditures for redistribution (Burger and Weinmann 2013; dena 2014c; Connect Energy Economics 2015). Therefore, public funding currently stimulates 90% of private investments in smart grid projects in Europe, whereof more than half of the total smart grid funding comes from France, the UK, Germany and Spain. Forty nine percent of the total budget of all 459 smart grid projects come from private capital, 18% from national, 22% from the EC, 9% from regulatory funding and 2% funding is unclassified (Covrig et al. 2014).

### **Smart meter**

However, a comprehensive roll-out of smart meters, an important two-way communication

device within smart grid infrastructure, has not started yet in Germany and is expected not earlier than the beginning of 2016. For this, a comprehensive study by dena (2014c) analyses in two roll-out scenarios the speed, functional benefits and cost for smart meter systems until 2030 (cf. Figure 32 and Figure 33 in Appx: I and J). The 'baseline scenario' assumes (and criticizes) a continuity of current regulatory framework and represents an analyst based recommendation. Whereas both scenarios enable distributed load management, only the 'roll-out plus scenario' also allows feed-in management of DEG units by 2030. In 2030 in Germany around 12.5 Mio smart meter systems on the end-user side (i.e. 69% household and 31% commercial customers) will be rolled-out. This covers 100% of the commercial customer and 21% of the household potential for load shifting by 2030, and consequently reduces 8% investment cost into grid reinforcement. As the baseline scenario is not expected to leverage requirements for sufficient grid services through feed-in management, the potential of DES-related business models will be rather inhibited. Instead of a smart integration and control management through for example VPPs, more investments into grid reinforcement would be needed, which lower the commercial attractiveness of a DES-related business model. Only in the roll-out plus scenario, around 1.3 Mio DEGs will be equipped with smart meter systems by 2020, covering 69% of the market. By 2030, smart meter system installations double to around 2.6 Mio, then covering 100% of potentially controllable DEGs. This is estimated to reduce 30% investment cost into grid reinforcement (dena 2014c).

However, several barriers for smart grid roll-out need to be overcome in order to also accelerate DES-related business models and markets. For example, costs for smart meter systems often exceed the expected benefits for most residential consumers, as their annual demand is below 10,000 kWh, a bottom-line for a reasonable load-shifting potential (Burger and Weinmann 2013). Even though dena (2014c) expects an annual cost reduction for smart meter systems of 1.5% until 2030, the cost burden for customer will still be high. Moreover, cost and benefits are distributed unequally among market players. For example, third parties such as utilities and grid operators take an information advantage that primarily serves their coordination requirements which minimizes operational expenditures (Müller et al. 2010; dena 2014c), or there is a public benefit

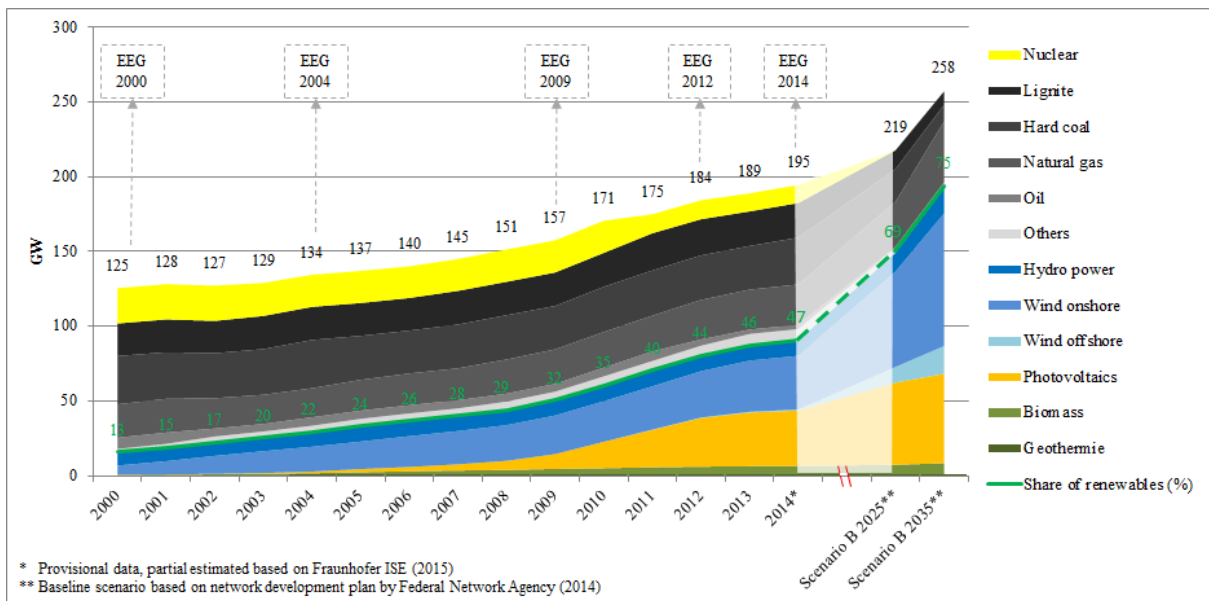


Figure 20: Germany's electricity capacity mix (2000-2014) with scenarios (2025, 2035). Source: Own figure, based on data from BMWi (2015), Bundesnetzagentur (2014) and Mayer et al. (2015).

through energy security and decarbonisation effects (Hall and Foxon 2014). The value of demand response as a business model could balance the unequal cost distribution by shifting revenue streams towards the responsible of the smart meter investment (Hall and Foxon 2014). In addition, smart grid will generate a huge amount of data for utilities and consumers which need to be processed. Appropriate capabilities will be a challenge and at the same time a value proposition in the transforming electricity system (Burger and Weinmann 2013).

#### 4.3.2.1 Distributed Supply Side Manager Investment support

The most important governmental intervention is seen in the introduction of the EEG in 2000 (e.g. FiT). Even though it was modified several times until today (i.e. especially the most recent amendment in Germany in end of 2014 is seen very critical), the EEG is worldwide recognized as the most successful tool to promote RE (REN21 2013; WEC 2014). The EEG represents a regulatory framework and also provides investment support to achieve national goals. Worldwide 71 countries and 28 states/ provinces enacted some form of FiT policy as of early 2013, a rapid spread out compared to 2005 (cf. Figure 37 in Appx: L), led by developing countries with regard to a number of FiTs in place (REN21 2013).

The German FiTs provide a fixed tariff above the retail rate of electricity which incentivized investments in renewables. Although some

stakeholders note that Germans have overpaid not only financially (e.g. high electricity prices with EEG-levy (cf. Figure 10: 16, Figure 27 in Appx: F) but also with regards to energy security and system reliability, the FiTs efficiently accelerate technological advancements and cost, especially of PV (cf. Figure 38 in Appx: M) (WEC 2014). However, recently FiTs have strongly weakened, since they are continuously adjusted towards decreasing RE system prices. The most recently reduced German FiTs from the end of 2014 make profit oriented, private solar PV investments less attractive. This thwarts the previously quick expansion of renewables in the years before. Theoretically, it also slows down the development of DES-related business models which relied on FiT support.

#### Regulatory support

Germany and some other European countries recently made significant amendments, unfavourable for the common practice of citizen ownership. For example, the German Federal Ministry for Economic Affairs and Energy starts to significantly limit RE expansion with a target corridor<sup>23</sup> and is going to switch from FiT to a public tendering scheme by 2017, testing the scheme already on new ground-mounted PV in 2015. International experiences have shown that usually rather big investors dominate this policy scheme (Schleicher-Tappeser 2012; Grau 2014; Schumacher 2014; Degenhart and

<sup>23</sup> PV and Wind Onshore: each 2.4-2.6 GW per year; Wind Offshore: 6.5 GW by 2020, 15 GW by 2030.



Nestle 2014; Klessmann 2014), rather stopping an increasing degree of distribution of ownership structures. However, even though governmental actions cannot be planned in detail for the entire energy transition in advance, for example the final decision in 2011 to phase out of nuclear power by 2022<sup>24</sup>, the decision in 2007 to stop subsidies for hard coal mining in Germany by 2018 because of a complete lack of competitiveness (Huy et al. 2013), as well as a strong expansion and penetration of renewables will continue as part of the corridor for expansion defined in the EEG. For this, Figure 20: 40 illustrates not only the development but also includes the baseline scenario<sup>25</sup> generation mix for 2025 and 2035 based on the network development plan by the Bundesnetzagentur (2014) (cf. Figure 24 in Appx: E). The expected key focus will be on wind onshore and PV generation capacity, and partly offshore wind and biomass capacity. Non-renewables (i.e. fossil-fired power plants) will increasingly be forced out and form the minority share within the generation capacity mix.

#### **4.3.2.2 Distributed Demand Side Manager Investment support**

First investment (and regulatory support) for new concepts such as DSM came into force in 2012, termed as load-management-levy (§18 AbLaV), which opened up space for new DES-related business models as demand side managers respectively (EFZN 2013).

#### **Regulatory support**

However, with regard to the load-management-levy (§18 AbLaV) further adaption is needed especially for distributed, small-scale participation (i.e. current minimum capacity is very high with 50 MW) through pooling with VPPs (EFZN 2013). According to a municipal utility “*politicians are not yet fully aware of [VPPs]*” (Interview in Burger and Weinmann 2013: 104). The demand response service provider Entelios also criticized the insufficient exploitation of demand response potentials in Germany. He explains that there is no bottleneck of interested commercial and industrial demand response participants, but only regulatory hurdles from an ancient electricity system which only focus-

es the supply side (Flamm 2014; Connect Energy Economics 2015).

#### **4.3.2.3 Distributed Storage Side Manager Investment support**

Since 2013 also the national development bank ‘Kreditanstalt für Wiederaufbau’ (KfW) started a public funding program to strongly expand distributed battery storage in Germany. Until the end of 2014 about 8,300 storage units (55-83% of total installation in Germany) were stimulated, often combined in a PV-storage system, which need to be increasingly capable to provide grid services, a prerequisite for a business model of a distributed storage manager (Sternier et al. 2015). Therefore, also the regulatory framework for storage application needs to open up new and strengthen incumbent markets, standardize interfaces, enable remote control possibilities and better promote appropriate cost allocation with the electricity system to further facilitate private storage investments (EFZN 2013; Sternier et al. 2015).

However, the development of DES and related business models are path-dependent. Whereas regulatory authorities give a first, important investment impulse for the development of DEG technologies, economics – rather than policy – will increasingly drive further deployment (cf. Figure 23: 45 in upcoming section 4.3.3.1; Oberzig 2014; Henbest et al. 2015). The strong investment support within the last decade initiated a boost in technology innovation and competition, so that on the one hand a new global market for single RE products and services evolve, and on the other hand system-oriented, integrative and cross-technological business models arise. This can lead to competitive DEG technologies (e.g. wind and solar PV) discussed as follows.

#### **4.3.3 Technologies and DES-related business models**

According to Baden-Fuller and Haefliger (2013) business models are fundamentally linked with technological innovation, even though business model design can be separable from technology evolution. The authors argue that business models mediate the link between technology and firm performance. In this context business model decision to developing the right technology strongly relies on openness (i.e. permeability of the company boundaries with their stakeholders) in connection with user engagement (Baden-Fuller and Haefliger 2013). This finding strongly supports the development of DES-related business models where openness and

<sup>24</sup> As a consequence of the critical nuclear incident in Fukushima in Japan in 2011 (BMW 2014b).

<sup>25</sup> The comprehensive base scenario incorporates governmental climate, RE generation and energy efficiency goals as well as market analyses, and forms the basis for the current network development plan by the Bundesnetzagentur (2014).

proximity to end-users is part of the customer value proposition.

Various studies also point out the disruptiveness of technologies, describing technology characteristics which are still rarely spread in established markets (Provance et al. 2011; Richter 2013a). In his literature review Richter (2013a) for example concludes that disruptive technologies change the market design in the medium- and long-term and replace value proposition of the incumbent business models, which are rather unable to commercialize the disruptive technologies, lacking the capabilities of BMI (Richter 2013a). Technologies such as distributed PV, wind power, ICT systems, and storage solutions have the potential to fundamentally change the electricity system in the years ahead (Schleicher-Tappeser 2012). And even though the current market has essentially proved a successful design for the Energiewende, the future development is expected to be challenging. A radical shift in large technical electricity systems occurs less frequently than in other industries. Components of electricity systems, their standards, institutions, and routines are technically highly interdependent and also create path-dependency in the overall system configuration, in particular in grid based energy services (Burger and Weinmann 2013: 9). This makes mid- and long-term industry developments in general difficult to predict (Gerbert et al. 2013; BMWi 2014b).

The most promising technologies for DES-related business model domains will be further investigated in the following.

#### 4.3.3.1 Distributed energy generation technologies

##### Theoretical and technical potential (global)<sup>26</sup>

It is estimated that modern renewables (wind, solar, biomass and geothermal power) only provide 1.3% of the current world energy consumption (not only electricity) (REN21 2015). However, the theoretical potential of energy production with renewables on earth is much higher (i.e. geothermal 100,000, solar 10,000, and others about 10 times higher) than world energy consumption. Even the technical potential, which is only 0.0052% of the theoretical potential, is 20 times higher than needed. Among all direct renewables, energy from solar and geothermal sources has the highest technical and theoretical potential. The technical potential per year of indirect solar power such

as wind (8.49%), hydro (0.66%) and biomass (3.66%) is about half of solar direct technical potential (20.89%) or about one fifth of geothermal power (66.3%). The theoretical potential of direct solar power is 2.71% and geothermal power 97.28% among all renewables sources (Table 5 in Appx: H). Therefore, renewable implementation mainly depends on technological capacity and costs, not on availability (Orecchini and Naso 2012).

##### Competitiveness of RE and conventional power plants

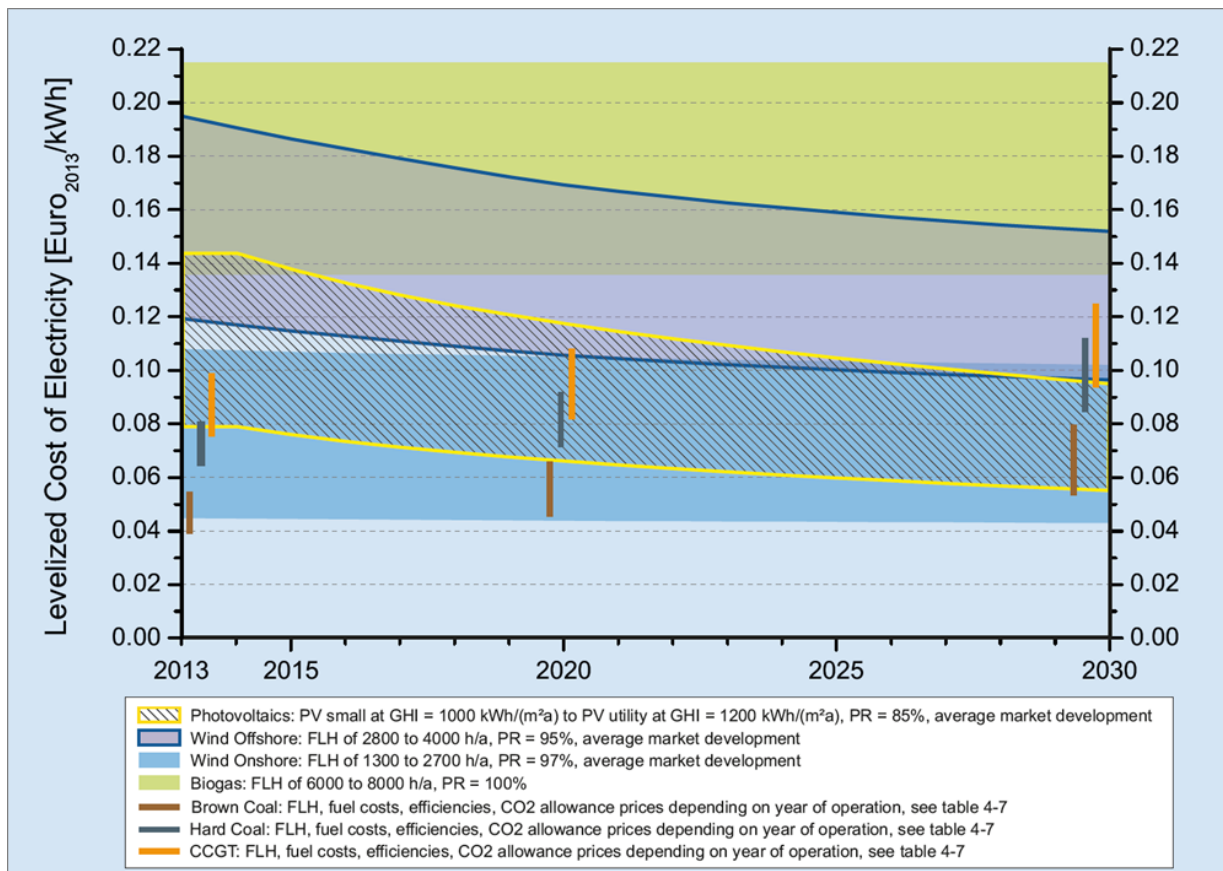
DEG technologies need to reach a degree of maturity from which market demand is driving the technology choice of firms entering this industry (Provance et al. 2011). Therefore, the attractiveness of a DEG technology for DES-related business models strongly depends on three key competitiveness indicators, discussed as follows:

- (1) Its today's competitiveness among generation technologies,
- (2) Its competitiveness compared to the established electricity system, and
- (3) Its evolution mainly driven by their penetration rate based on performance improvements (i.e. learning curves) and price drops through industrial mass production of niche technologies (i.e. economy of scales) (Naam 2011, Schleicher-Tappeser 2012, Burger and Weinmann 2013; Kost et al. 2013; Wirth 2015).

Firstly, a comparable benchmark in EUR per kWh among relevant generation technologies is mapped in Figure 21: 43, which shows the actual and future development of levelized cost of electricity (LCOE)<sup>27</sup> in Germany until 2030 (Kost et al. 2013). Each graph varies within single technologies and among different technologies based on different physical conditions

<sup>27</sup> "The LCOE methodology is an abstraction from reality and is used as a benchmarking or ranking tool to assess the cost-effectiveness of different energy generation technologies. The abstraction is made to remove biases between the technologies. The method considers the lifetime generated energy and costs to estimate a price per unit energy generated. The method usually does not include risks and different actual financing methods available for the different technologies. For example, a FiT takes away the price risk for RE targets by guaranteeing the price to be paid for energy generated by the source, but does not necessarily take away the financing risk for the technology, which is still a hurdle. Rather all technologies should be given the same economic analysis, with the only difference being the actual costs, energy produced and lifetime" (Branker et al. 2011: 4471).

<sup>26</sup> For a more detailed classification of the concept of potential please see Figure 29 in Appx: G.



**Figure 21: Learning curve based predictions of LCOE for RE technologies and conventional power plants in Germany by 2030. Source: Kost et al. (2013: 3).**

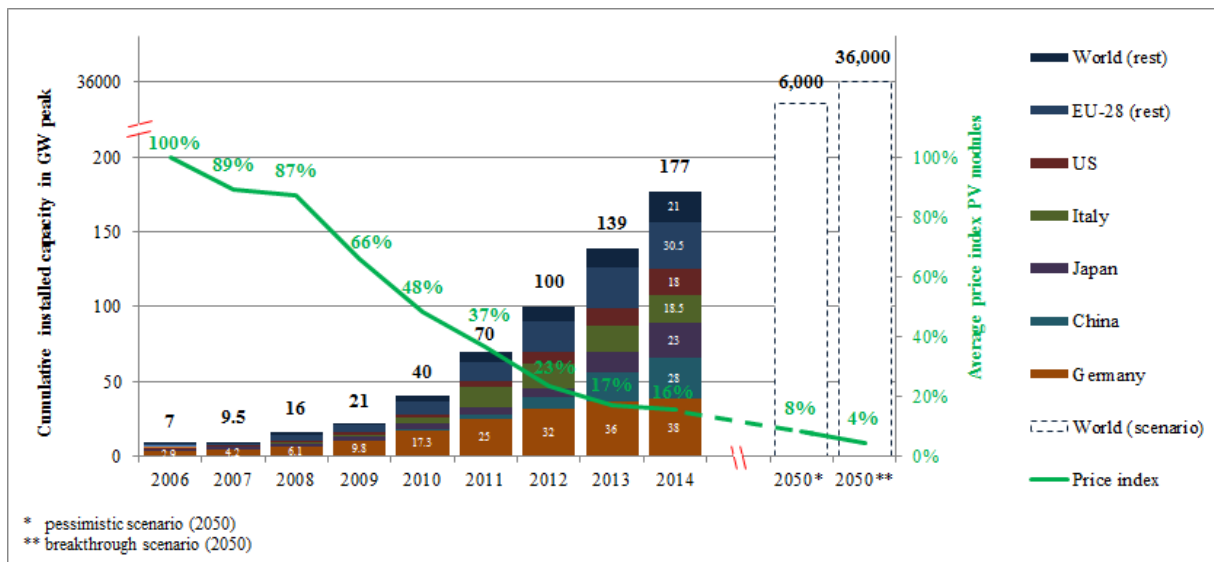
(e.g. weather, radiation, temperature, size). For example in 2013 the LCOE for large- and small-scale PV ranges between EUR 0.08 and EUR 0.14 per kWh, which can be price competitive with almost all other technologies except for lignite under favourable conditions. By 2030, PV is expected to be one of the three most cost competitive technologies (i.e. wind onshore, PV and coal) under favourable conditions. Nevertheless, under favourable conditions wind onshore already today demonstrates the second most and by 2020 the most cost competitive technology available, after new centralized and CO<sub>2</sub>-emitting coal power plants.

Secondly, the attractiveness of new generation technologies does not only rely on today's LCOE, but also on its related cost competitiveness according to the established grid, termed as grid parity<sup>28</sup>. In this context, Richter (2013b)

<sup>28</sup> "The term 'grid parity' is meant to describe the point in time, at which a developing technology will produce electricity for the same cost to ratepayers as traditional technologies. That is, when the new technology can produce electricity [i.e. LCOE] for the same cost as the electricity available on a utility's transmission and distribution 'grid'" (REA 2015).

highlights a general debate about economical attractiveness of generation technology, which either already results with grid parity or only with a LCOE much lower than the retail price, because costs for grids, storage and taxes would also have to be included.

Thirdly, when discussing different DEGs, its future potential through economies of scale and learning curve effects needs to be considered. Even though several generation types play a major role within future energy mix, wind and PV as complementing technologies reveal the most promising future among generation technologies. Whereas, wind already today shows a competitive LCOE, PV with regard to its price-learning curve and degree of distribution indicates a stronger consideration for DES-related business models (e.g. Schleicher-Tappeser 2012; Richter 2013b; Figure 21: 43). Even though "several problems must be overcome for its widespread use, including technical and economic ones, linked to the low energy density, and to its discontinuity (night/day alternation, seasons cycle, variation in weather conditions)" (Orecchini and Naso 2012: 30), today "PV cells are the most disrupt-



**Figure 22: Globally installed, cumulative PV capacity and PV module price development (2006-2014) with two scenarios (2050).** Source: Own figure, based on data from Global Status Reports by REN21 (2010-2015), EuPD Research (2013), photovoltaik (2015), SolarServer (2015), Mayer et al. (2015) and own calculations.

ive energy technology as they allow consumers of all sizes to produce power by themselves" (Schleicher-Tappeser 2012: 64). Smart DES-related business models, such as the Distributed Supply Side Manager can help to solve such problems.

Therefore, PV is worth to be discussed more in detail first, before the economic potential of different wind technologies are described more broadly afterwards.

### Competiveness of PV

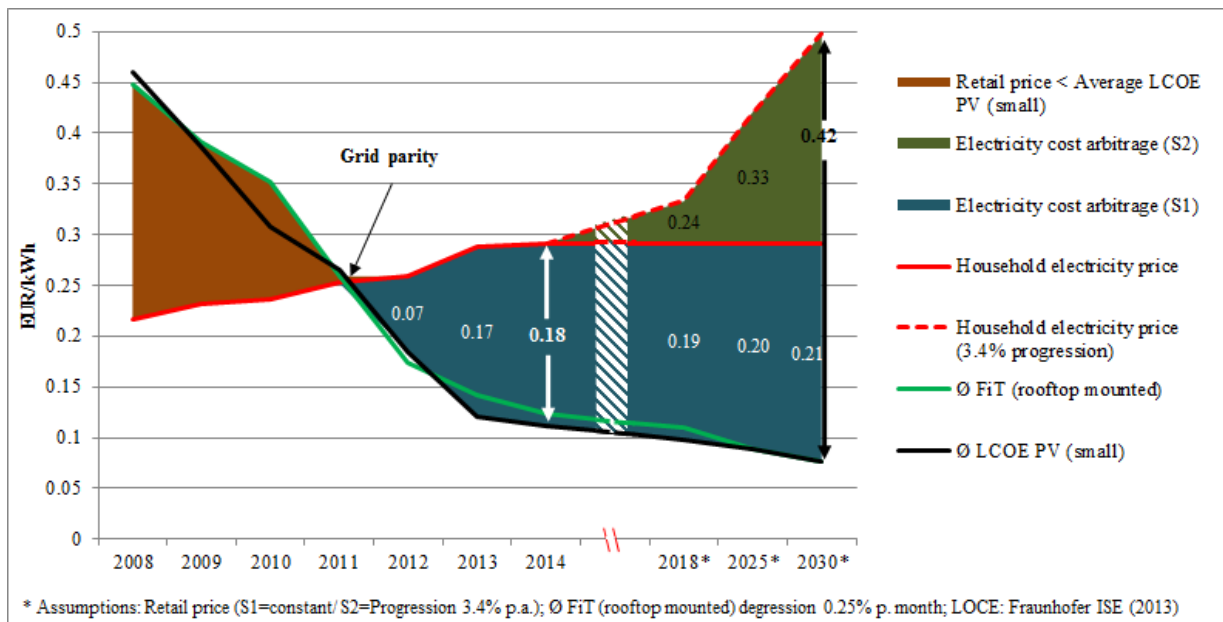
PV module prices account for about half of the total investment costs of a PV plant. When comparing the global accumulated PV capacity from 2006 to 2014 in relation to its price index based on 2006, its average historical PV price development indicates a constant decrease. Shown in Figure 22: 44, between 2006 and 2014 around 177 GW cumulative PV capacities were installed globally, which caused an average price drop of PV modules by 84% accordingly. With around 22%, the largest share of installed PV capacity (38 GW) is attributed to Germany.

For modules the price development even follows a constant price-learning curve, meaning that doubling the whole installed capacity decreases the module price by a constant percentage. The general trend for more than 30 years indicates a 20% price reduction when doubling the accumulated capacity installation (cf. Table 5 in Appx: H), which is expected to continue. Module prices dropped from almost

Unites States Dollar (USD) 30 per W in 1980 down to less than USD 1 per W in 2012 (Naam 2011, Wirth 2015). Naam (2011) predicts that if this PV price-learning curve continuously applies for the next 4-6 years (which is extremely likely), PV will be as price competitive as coal, and if this development continuous for the next 15 years (which is scientifically and technically possible), PV will be half the price of coal. Also Mayer et al. (2015) expects that power generation from large-scale solar PV plants will be cheaper than any other conventional production technology in large parts of Europe and many regions of the world. In different scenarios ('pessimistic' and 'breakthrough') Mayer et al. (2015) expects a global cumulative capacity installation between 6,000 and 36,000 GW and module price drop to EUR 0.14-0.36 per W by 2050 compared to EUR 3.91 per W in 2006 (equals an average price index between 4-8%) (Figure 22: 44).

The price drop for PV technology is expected to drive a global surge of USD 3.7 trillion in solar investments by 2040, both small- and utility-scale installations. Furthermore, with regard to the degree of distribution of DEG, small-scale PV is expected to dominate installations, with USD 2.2 trillion (Henbest et al. 2015).

The impact of price-learning effects are already reflected in today's LCOE for PV and wind, which already achieved grid parity in several regions and became economically competitive with conventional electricity systems (Branker



**Figure 23: Economics of PV self-sufficiency versus FiT (2008-2014) with scenarios (2018, 2025, 2030).** Source: Own figure, based on data from EuPD Research (2011), Bundesnetzagentur (2015b), Kost et al. (2013), BDEW (2014) and own calculations and estimations.

et al. 2011). A comparison between LCOE of PV and real cost of electricity<sup>29</sup> supports this trend for many regions around the world. For example Deutsche Bank (2015)'s solar outlook predicts that 80% of the global market will achieve grid parity by 2017, caused by rising grid based electricity prices on the one hand and a continuous drop in PV module costs (e.g. -40% over the next four to five years) on the other hand (cf. Figure 31 in Appx: I). Derivation between LCOE and cost of electricity all around the world will strongly facilitate electricity arbitrages and accelerate BMI on a global level (Deutsche Bank 2015), especially for PV on rooftops (Henbest et al. 2015).

This already applies to Germany since 2011, where even LCOE for small-scale PV firstly matched the retail price and achieved grid parity. Since then, the price between own produced PV electricity and the retail price is continuously spreading, which makes a cost arbitrage through electricity self-sufficiency increasingly attractive (Figure 23: 45).

For example in 2014, a resident with own PV electricity generation could theoretically save EUR 0.18 per kWh through local self-sufficiency. As the FiT and LCOE for PV is expected to decrease further, and the retail price is going to be constant in scenario 1 (S1) or will increase further with its CAGR (1998-

2014) of 3.4% in scenario (S2), the electricity cost arbitrage could go up to EUR 0.21 (S1) or even EUR 0.42 per kWh (S2) for electricity self-sufficiency by 2030. Consequently, adequate revenue streams for business models of a distributed supply manager for small-scale PV reveal good chances to accelerate under current market conditions.

However, although grid parity for households has been reached in Germany already in 2011, the mismatch of sunshine hours and local electricity consumption makes the use of more than 35% of rooftop PV electricity production difficult without supplementary investments (e.g. storage) (Schleicher-Tappeser 2012) or changing consumption patterns (e.g. DSM). Current calculation for commercial PV (not residential) even assumes a local consumption rate of at least 80% for suitable investments (Fuhs 2014) which is even more difficult to achieve with an investment focus on just one generation technology. An integrated DES with complementary generation technologies, storage and flexible consumption pattern is needed. For example due to climate conditions in Germany, wind and PV negatively correlate and therefore complement each other well, especially with regard to seasonal and day-night electricity fluctuations (Wirth 2015). This is why wind power shall be introduced briefly as follows, in order to give a more overall picture and to understand its future role within the electricity system.

<sup>29</sup> Cost of electricity also depends on the marginal cost of electricity generated by the given power plant and market-based or regulatory measures (Branker et al. 2011).

## Competiveness of wind

With regard to different levels of distribution and characteristics, three different types of turbines need to be discussed: wind onshore, wind offshore and small wind turbines in urban settings.

Wind onshore is the most mature and competitive technology, not only among wind power technologies, but also among all generation technologies (cf. Figure 21: 43). Furthermore, the total wind onshore production potential in Germany (2,898 TWh) (capacity potential 1,188 GW) (Lütkehus and Salecker 2013) is enough to meet Germany's gross national electricity consumption five times in 2014 (579 TWh) (cf. Figure 4: 9). Moreover, even with regard to the degree of production distribution within Germany (North 1,378 TWh (48%), Central 728 TWh (25%), South 791 TWh (27%)) each part of almost the same size could produce more than sufficient electricity to entirely meet Germany's gross national electricity consumption (Lütkehus and Salecker 2013).

In 2014, in Germany 35.9 GW (cf. Figure 4: 9) of wind onshore capacity were already installed with a production of 54.7 TWh – the biggest share among renewables (cf. Figure 20: 40). The capacity is planned to be almost doubled to 63.8 GW until 2025 according to Scenario B of the most recent network development plan of the four German TSOs (cf. Figure 20: 40). The capacity share within the generation mix will almost double from 18% in 2014 to 29% in 2025, which will be twice the amount of lignite (6%) and hard coal (10%) together and slightly more than PV (25%). Under favourable conditions new wind onshore installations are expected to be the cheapest generation technology with regard to LCOE already in 2020 (cf. Figure 21: 43), even though its learning-curve associated cost benefits are marginal.

Wind offshore is going to develop within the next ten years, planned to expand its share within Germany's electricity mix from 0.3% in 2014 to 5% in 2025 (cf. Figure 20: 40). But even though there is a learning-curve, associated cost benefit potential predicted within the next 10 years, wind onshore, PV, lignite and hard coal under favourable conditions will remain economically more attractive (cf. Figure 21: 43). Furthermore, the degree of distribution stays limited to coastal areas and a transport of electricity will be required. Therefore, wind offshore remains strongly limited for DES and related business models.

Small wind turbines for an urban setting are small-scale generation units with 100 kW or less capacity, either as rooftop or ground mounted installation, making them attractive in urban and rural areas, and allows the highest degree of distribution among wind turbine types (Gsänger and Pitteloud 2015). As wind power generation disproportionately depends on wind speed, its LCOE strongly differs on local conditions and during the course of time. For example, in Berlin an average LCOE of EUR 0.20 per kWh is roughly imaginable.<sup>30</sup> In addition, in a typical location near buildings, turbulent wind can outperform energy production of recent technologies with surplus of 20-40%. The potential in Germany is seen for customers who desire a high degree of self-sufficiency, similar to the small-scale PV (Quiet Revolution 2011, in: Burger and Weinmann 2013). However, the market for small wind turbines is still in its infancy stage (global small wind capacity account for 755 MW in end of 2013). Most recently the world market grew by 8% from 806,000 units in 2012 to a cumulative total of at least 870,000 units end of 2013. However, most of the installations in 2013 are distributed to China (625,000 units), USA (157,500 units) and UK (24,000), even though Germany (14,500 units) already ranked fourth with a surge of 45% compared to 2011 (10,000 units in 2011) (Gsänger and Pitteloud 2015).

To conclude, small wind industry is still under development and without any doubt economies of scale are needed in order to reduce relatively high cost in the future. For this, institutional support is required (e.g. appropriate legal frameworks and support schemes) (Gsänger and Pitteloud 2015).

Apart from wind power, Schleicher-Tappeser (2012) in general expects that many technologies for DEG can become more energy-efficient and more environmentally friendly than large, central-station type power plants. Aggregated in VPPs, small-scale generation units with renewables and flexible prosumers will be able to match any gradual change in utility loads very well (Schleicher-Tappeser 2012). Hence, the requirements of demand technologies are discussed as follows.

<sup>30</sup> For instance in 2012, the LCOE of a small turbine almost halves from EUR 0.38 per kWh with wind speed of 4 meter per second to EUR 0.20 per kWh with wind speed of 5 meter per second. A wind speed of 6 meter per second even triples the electricity output (Klein-Windkraftanlagen 2012). In Berlin for example the most frequent wind speed is 4 meter per second (SSU 1995), corresponding to EUR 0.20 per kWh.

#### 4.3.3.2 Distributed energy demand technologies

DES and its related business models strongly depend on ICT, which has significantly progressed over the past decade, often termed as digital revolution. The convergence of digital and energy revolution is furthermore described as 'Third Industrial Revolution' (Rifkin 2011). A new layer of ICT enables a smart grid infrastructure which instantaneously integrates distributed agents and electricity system components of autonomous DES of all sizes in an increasingly efficient way (Burger and Weinmann 2013). For instance, system benefits of DSM measures are expected to strongly improve with increasing share of RE in the electricity mix (Connect Energy Economics 2015).

Consequently, investments in smart grid infrastructure are a key enabler for DES with intermitting wind and PV electricity generation as a fundament, especially to open up flexible consumers and related business models (Burger and Weinmann 2013; Hall and Foxon 2014) referred to as distributed demand side manager. Global smart grid investment reached USD 14.9 bn in 2013 (BNEF 2014) which is expected to grow to USD 25.2 bn in 2018 (BNEF 2013). In Europe investment reached EUR 3.15 bn in 2014 (Covrig et al. 2014), mainly driven by new national and international policies and government incentives to achieve energy conservation and emission control, also to meet national climate goals (Shandurkova et al. 2012). Out of 578 smart grid project implementation sites in 33 European countries, Germany operates the majority share with 77 (13.3%) (Covrig et al. 2014).

##### Smart meter

In particular smart meter systems, directly connected to DEG or distributed load units, are fundamental for DES-related business model to access markets, as they allow bidirectional monitoring, communication and controllability between supply and demand. This bidirectional interaction is for instance required to perform contracted balancing services to the grid (e.g. feed-in management of DEG and/or load management) (cf. section 2.2.3). A comprehensive roll-out strongly relies on institutional support as described previously (cf. section 4.3.2). Based on the network development plan of TSOs (cf. Figure 20: 40), the roll-out is estimated to EUR 4 bn (1%) of the total investment need by 2030 to implement the plan. In contrast, attributed investments into the TSO, DSO and grid maintenance is going to amount

EUR 115 bn (cf. Figure 36, in Appx: K) (Gerbert et al. 2013). Considering the potential of dena's (2014c) roll-out plus scenario for 2030, 30% investment cost into grid reinforcement can be reduced through aggregated supply side and demand side management of DEG with renewables. This gives momentum to DES-related business models.

#### 4.3.3.3 Distributed energy storage technologies

The economics of electricity storage devices becomes increasingly more attractive, following an evolutionary process which could impact the whole DES soon (Shandurkova et al. 2012). A variety of competing storage technologies are already or will be technically feasible in the near future with some of them more or less suitable for distributed DESs (Burger and Weinmann 2013).

##### Electricity storage with batteries

Battery technology is among the most promising distributed storage option, as it is a short-term storage with discharge duration between minutes and hours, which is technically very complementary to the intermittency of PV and wind generation (Sterner et al. 2015). Its development and investments is strongly driven by the expansion of the DEG share with renewables and reduction of conventional sources, which increases the fluctuation of prices on electricity markets. The larger related price differentials on wholesale, ancillary service and retail markets become, the more attractive electricity storage will be. Consequently, the expansion of distributed storage follows the expansion of DEG (Agora Energiewende 2014; Wirth 2015; Sterner et al. 2015).

However, a study by Adamek et al. (2012) estimates that our electricity system is able to handle up to 40% RE in the production mix without electricity storage systems, even if research and development, as well as pilot and demonstration projects are recommended. With regard to long-term targets for the Energiewende (cf. Figure 2: 6) and predictions in the network development plan of TSOs (cf. Figure 20: 40), 40% RE in the production mix will be achieved not earlier than 2025. This indicates that the business model of a distributed storage side manager is going to become interesting within the upcoming years. Investments into storage in order to implement the network development plan of TSOs is estimated with EUR 3 bn (1%) of the total investment needs by 2030, which, however, does not in-

clude private investments (cf. Figure 36, in Appx: K) (Gerbert et al. 2013).

Private investments might be rather driven by economics of the battery sector, underwent extensive developments within the last five years, strongly driven by the global electric vehicle progress with lithium ion (li-ion) battery technology (Sterner et al. 2015). Since 2010 li-ion battery technologies are following a constant price-learning curve, similar to PV modules (cf. Figure 22: 44), amounting to a price drop of 21.6% when its global capacity is doubled (cf. Figure 34 in Appx: J), which is expected to continue over the next decade (Liebreich 2015). According to recent analyses, the high price per kWh is projected to fall from around EUR 320 today to EUR 180 by 2020, and to EUR 100 by 2025 (cf. Figure 35 in Appx: K) (Hummel et al. 2014; Straubel 2015).

### PV-storage systems

According to a recent study by Agora Energiewende (2013) a scenario with wide spread distributed PV-storage systems is currently not economically desirable, as long as prices does not drop by 80%.

In 2014 the LCOE for PV-battery storage system for partial self-sufficiency in Germany is estimated between EUR 0.29 and EUR 0.51 per kWh under different assumptions<sup>31</sup> (IE 2014). However, this indicates that a competitive system price with li-ion battery and PV is already available under favourable condition, so that a substantial market for PV-home storage systems is currently emerging. Nevertheless, the future profitability strongly depends on regulatory measures and the development of tariff structures (Agora Energiewende 2014; Sterner et al. 2015). However, additional revenues could be achieved through commercial optimization of a distributed storage manager, who is aggregator and accessor to further markets (e.g. wholesale and ancillary service markets).

In Germany around 10,000 PV-battery storage units are installed with a cumulated capacity of 30-40 MWh (each 3-4 kWh in average) (Agora Energiewende 2014). The German Solar Association even estimates 15,000 installed home battery storage units in Germany at the end of 2014 (Sterner et al. 2015). Furthermore, the first seven months of 2015 show an increasing number of subsidized solar PV-storage installations by 35% in a year in Germany, facilitated

<sup>31</sup> I.e. different real system prices, KfW-funding program 275 and electricity price development (2-4% per year).

by falling prices and the desire for energy independence (Ali-Oettinger 2015). The market development is predicted to be dynamic and will take place in parallel to electric vehicle in medium-term. A particular strong impulse is expected from 2030, when huge amounts of PV installations run out of FiT. 700,000 PV-battery storage units with capacity of 4 kWh each are conceivable by 2030. This represents an accumulated capacity of 600 MW by 2020 and 3.4 GW by 2030, including upgrades of already installed EEG expiring PV modules (Agora Energiewende 2014).

### 4.3.4 User practices and DES-related business models

Burger and Weinmann emphasize that “*decentralized generation emotionalizes consumers by giving them the opportunity to become agents of change and to contribute to a better living environment*” (2013: 186). A DES gives individuals and communities an additional dimension of freedom by having the choice of own (carbon-free) production. This new dimension is termed as empowerment<sup>32</sup>, a trigger which leads to much higher penetration rates of DEG than a mere cost-benefit analysis would suggest. In this context, the World Bank more concretely identifies four key elements that characterize and strengthen empowerment: access to information, inclusion and participation, local organizational capacity and accountability (Burger and Weinmann 2013). All those key elements can be seen as value propositions within DES-related business models.

This strongly reflects the emerging energy prosumer, a consumer that among others attributes also produces energy. The entity can be more than an individual, representing a household, an office, a community or similar. In modern electricity systems, the prosumer is a new and active participant that can be characterized by DEG technologies, energy storage equipment, smart meters and other ICT, which also enables DSM. Based on a desire for energy independence, an affinity for technology and energy, environmental concerns, as well as the image of the utility (Fischer 2003; Leenheer et al. 2011), a prosumer can be (no must) an economically motivated entity that:

<sup>32</sup> “*Empowerment is a multi-dimensional social process that helps people gain control over their own lives. It is a process that fosters power (that is, the capacity to implement) in people, for use in their own lives, their communities, and in their society, by acting on issues that they define as important*” (Page and Czuba 1999).



- (1) *“Consumes, produces, and stores energy in general*
- (2) *Optimizes his economics but also technological and environmental decisions regarding his energy utilization*
- (3) *Becomes actively involved in the value creating effort of an energy service”* (Shandurkova et al. 2012: 35)

Research regarding the prosumer's role in transforming electricity markets is still in its infancy but promising with regard to the rise of DES and with regard to new institutional or market incentive structures for energy investments (e.g. subsidies, FiT, load arbitrages) (Bremdal 2011; Shandurkova et al. 2012). Especially with regard to ownership structures of DEG (cf. Figure 5: 10), Germany states a leading role of its citizens and communities in the Energiewende and exemplarily underlines the evolving prosumer concept. Citizens form cooperatives to drive the energy transition. Between 2001 and 2013, its number increased from 66 to 888, with a steep upward movement started in 2008 (Morris and Pehnt (2012) (cf. Figure 39 in Appx: N).

The ongoing development of smart grid technologies allows better access to information and facilitates the integration of energy prosumers. Consequently, a rising number of new and active participants democratize the electricity system and affect the future grid design (Shandurkova et al. 2012). As an answer to prosumption and DES also global technology and software vendors such as Siemens or Schneider Electric extend and adapt their offerings. For example Siemens (2015) provides a software-based management system for VPP in corporation with RWE. Schneider Electric (2015) even created a prosumer business segment, called 'Prosumer Microgrid Solutions'.

Consequently, DES-related business models can leverage opportunities by helping to economically optimize energy self-sufficiency and autarky with eco-friendly distributed technologies. Based on single technological achievements and their systematic combination in complementary relation to the environment, distributed supply, demand and storage side manager should optimize economics under mutual benefits.

For example Weniger et al. (2012) analyse the optimal component size of a combined system with PV and battery with regard to the degree of energy self-sufficiency and energy autarky

under economic and environmental constraints. They conclude that large-scale PV generators will play an increasingly smaller relevance in the future, when absolute yield is the crucial factor. Their simulation reveals a cost-optimal system configuration, aiming to generate cost arbitrage benefits through self-sufficiency superior to decreasing FiT revenues (cf. Figure 23: 45). PV systems are expected to shrink to small-scale units and small-scale batteries will not only be profitable but also the most economical solution. The smaller the PV-battery system is, the higher the economically optimal degree of self-sufficiency will be (Weniger et al. 2012).

Weniger et al. (2012) show (cf. Figure 40 and Figure 41 in Appx: N and O) that an average household (4,700 kWh per year) with a 5 kW peak small-scale PV system can reach 30% energy autarky and 30% self-sufficiency without battery. If this household adds a 2 kWh battery unit, it could increase its energy autarky to more than 40% and self-sufficiency to 50%. If it even doubles the battery unit up to 4 kWh, energy autarky would go up to more than 50% and energy self-sufficiency to 60%. If the household further enlarges the battery systems, energy autarky and energy self-sufficiency would only slightly and disproportionately increase, as the battery storage units do not discharge sufficiently during night, so that a certain amount of capacity will not be available during the next day. Furthermore, a higher autarky goal than 80% is economically not viable under optimal cost constraints, as expensive batteries would be disproportionately needed (Weniger et al. 2012).

However, apart from economic aspects, which definitely push forward prosumer behaviour and facilitate DES-related business models, consumers need to accept and buy also new products such as new ICT and energy technologies to even optimize load management and possible profits in the near future: *“Smart meters or electric vehicles are prime examples that new technologies are available but that they may not be adopted unless regulatory incentives are introduced”* (Burger and Weinmann 2013: 12-13). It is still not clear how such regulatory incentives would need to look like.

#### **4.3.5 BMI between CES- and DES-related business models**

CES- and DES-related business models strongly compete with each other. On the one hand, the first mentioned mainly drives its revenues by increasing fixed retail price, decreas-

ing generation cost through large-scale applications and increasing their number of customer contracts as well as increasing their electricity consumption. On the other hand, DES-related business models are of more complex nature, by integrating and optimizing distributed small-scale, intermittent RE generation, DSM and storage into one system. Revenues increase with the mutual benefits between the company and its customer, because profits from system optimization will be shared accordingly. Technically, it would be possible to replace the CES with a DES, however the economics still need to be elaborated or further developed. But already today DEG with renewables increasingly reduces the operating hours of conventional, centralized power plants and threatens their economics (Burger and Weinmann 2013). However, one of Richter's "key finding is that utilities do not perceive distributed PV as a threat to their current business models nor do they see it as a potential market for them" (2013b: 456). They perceive renewables as a new centralized generation technology, which will solely substitute centralized assets in a CES, but not accelerate DESs (Richter 2013a). Such retention is also perceived as a consequence of the capital-intensive nature of the CES business. Utilities have bound huge investments in the ownership of existing power plant infrastructure with long maturities and hence resist new business practices with substituting and cannibalizing generation technologies with renewables. Therefore, they rather hinder new competitors to capture the market (Wüstenhagen and Boehnke 2008).

Furthermore, utilities lack a sufficient economic benefit from a RE business model, beyond a pure transmission and distribution of electricity (Richter 2013a). Whereas a fossil-based generation system continuously generates marginal cost which could be attached and sold with a premium, the business with wind and PV is possible with almost zero marginal cost.

Apart from the over-supply through DEG, DES-related business models will redefine the role of struggling incumbent utilities business models (unidirectional) by strengthening the power of consumers and prosumers (bidirectional). Consequently, this is going to weaken the bargaining position of the CES-related business model (Marko 2014).

The distributed demand side manager helps to reduce and shift peak load times, which additionally reduces the demand for peak load power plants, another revenue source of the incumbent CES-related business model. Espe-

cially permanent energy efficiency is generally expected to become a separate major business model for utilities, because it cannibalizes the incumbent electricity volume-oriented revenue model (Burger and Weinmann 2013; Gerbert et al. 2013; Richter 2013b; Fox-Penner 2014).

As a consequence, incumbent utilities attempt to look for new business models, being pressured by an upcoming number of prosumers and PV installation. For instance, the BIG4 utilities in Germany are strongly affected. As a consequence, E.ON recently announced the most radical, new strategic course, deciding the split of its non-renewable generation assets and the strict focus on a business model exclusively with renewables (E.ON 2014a). Also "RWE wants to move away from simply being a developer and owner of concentrated power plants and instead use its expertise to help manage and integrate renewables into the grid" (Lacey 2013) and attempts to implement a 'prosumer business model' (RWE 2015c). Nevertheless, Frantzis et al. remark that "the organizational structure of today's utilities does not facilitate the adoption of the new business models" (2008: 80). For example Sosna et al. (2010) refer to limited mental models and 'bounded rationality' of incumbent managers, hindering to exploit radical BMI under uncertainty and unpredictability of fast-evolving markets, especially as long as common business practice generate revenues.

For example CES-related managers rather apply the traditional economies of scale perspective to the DES and neglect potentially different other value propositions (Richter 2013a; WEC 2014). For example the traditional LOCE of small-scale generators is higher than of large-scale application, but an evolving bidirectional customer and prosumer interaction leverages new value streams (e.g. risk allocation through distribution of intermittent renewables) and cost benefits (e.g. deferred investment into grid reinforcement of 30% (Frantzis et al. 2008; dena 2014c), CES vs. DES electricity price arbitrage (cf. Figure 23: 45) or DSM benefits). In times of growing retail electricity prices, Richter (2013a) for instance highlights a value proposition of a Dutch energy provider, which guarantees stable prices for a long-term period. Customers are equipped with own DEG units (i.e. roof-top PV) sponsored by the energy provider and pay a fixed tariff, similar to the current retail price for grey electricity over the next 20 years. Additional electricity demand is further covered by the CES.

Nevertheless, incumbent utilities, especially the BIG4, are slowly starting to realize benefits out of DES-related business models (Burger and Weinmann 2013). From an investment perspective, they have already lost significant ownership share in the DEG market (cf. Figure 5: 10), incapable for BMI towards a DES (Richter 2013a). In particular citizens and energy cooperatives (46.6%), but also institutional and strategic investors (41.5%) (trend:research and LU 2013) are owning Germany's RE generation capacity and increasingly taking over control in the electricity system, strongly driven by a snowball effect idealism.

## 5 Conclusion

This thesis develops and applies an own analytical framework to pick out specific elements of a complex transition in the energy sector, namely the coevolutionary BMI through DESs within Germany's Energiewende. For this, a comprehensive background highlights not only the complex functionality, but especially the far-reaching changes of Germany's electricity system, which substantially impact the incumbent CES-related business models' success.

However, answering research question (1) the analysis also shows new opportunities for coevolutionary BMI with regard to new DES-related business models, following three main challenges: (1) the intermittency of RE and its attributed need for system flexibility, (2) an increasing degree of (optimal) distribution of RE generation and its (remote, collective) controllability, as well as (3) the externalization of ownership structures of DEG by citizens (prosumers) and its need for energy services. In alignment with relevant domains of the DES, three generic modules of DES-related business models for new green service utilities can be derived from theory and practice: the Distributed Supply, Demand and Storage Side Manager. In comparison to CES-related business models, they most importantly distinguish with regard to their strong customer interaction and proximity, their high degree of specialization and their revenue model based on mutual benefits through optimization services rather than on sales volume extension.

Answering research question (2), bearing in mind recent and emerging developments, and the interactions within the coevolutionary business model framework, evidence from this Master thesis suggests that the three modules of DES-related business models are already or increasingly become attractive within its selection environment. With regard to the five subsystems, firstly path-dependency among them can be shown: concerned about harmful impacts of climate change and the risks of nuclear power such as the nuclear incident in Fukushima (ecosystem), the German government introduced the Energiewende (institutions) to successfully give momentum to the expansion of RE (technologies). This attracts and enables citizens (e.g. prosumers) to produce own electricity (new user practice). Finally, based on innovative DEG, storage and ICT technologies, promising opportunities for new DES-related business models evolve. Secondly, among the five subsystems, the mutual interaction of

technologies and user practice with DES-related business model is uncovered as most important for its momentum at the current stage. Whereas wind already achieved a high level of maturity with sufficient technical and economic potential in Germany, PV revealed very promising economy of scale and learning curve effects as well as suitability for DES-related business models in the near future. Their competitiveness is additionally strengthened by rising primary energy prices for conventional power generation.

Furthermore, given the high retail electricity price for households, energy autarky and self-sufficiency under favourable conditions already are, and continuously become economically attractive without FiT support. This incentivizes a new user practice, termed as prosumption, where own produced and consumed energy creates substantial cost benefits (i.e. arbitrage). Even though electricity storage with batteries is seen as a useful complement to RE generation, a potential large-scale deployment is rather attractive in a medium-term. However, the application of DSM services with smart grid technologies unveils economic potential (e.g. reduce 30% investment cost into grid reinforcement, among others, based on customer's permanent (10-20%) and flexible (5-10%) load management saving potentials which is already being exploited by new green service utilities (e.g. Entelios and Next-Kraftwerke)).

However, the institutional subsystem can be seen as an accelerator and inhibitor for all three modules of DES-related business models. Although governmental support in form of incentive structures (e.g. FiT) was especially impelling to mature RE technologies in the past, currently of more importance are regulative interventions to potentially leverage the deployment of complementary technologies (e.g. smart meter roll-out in order to fulfil requirements for VPPs, DSM and storage application) and to access ancillary service, wholesale and retail electricity markets.

The fourth ecosystem perspective unveils no direct interaction with DES-related business models, although it is assumed to importantly influence the other subsystems. However, as long as no direct economic benefits can be incorporated into a business model (e.g. efficient emission trading schemes) its direct influence is difficult to prove.

Finally, BMI between CES- and DES-related business models reveals different viewpoints. Even though incumbent utilities are recently

struggling with their CES-related business model, they show no serious innovation towards DES, seeing no competitive advantage with DES-related business models. One key barrier is seen in their two contradicting revenue models, strongly competing with each other. Whereas DES-related business models help to optimize profits and reduce costs (i.e. reduce consumption), the CES-related business model benefits from sales volume extension (i.e. increase consumption). Furthermore, incumbents rather put emphasis on large-scale application and leverage benefits from economies of scale instead of benefiting from a high degree of distribution of small-scale DEG with less costs for electricity transmission and distribution.

### **Future research**

Several methodical and practical limitations are underlined for this study (cf. section 3.3.3), providing starting points for future research. To begin with, this thesis firstly applies an own shaped coevolutionary business model framework to Germany's Energiewende with a special focus on DES-related business models.

From a methodological point of view, both elements of the combined framework (i.e. coevolutionary and business model framework) are still in its research infancy, so that only future applications support further development through pass on findings. Therefore, this thesis provides several initial results, but highly recommends further primary data collection in order to empirically test uncovered findings as well as highlight unknown interdependencies.

From a practical point of view, even though this thesis attempts to handle coevolutionary complexity within the Energiewende, some questions for further research are left open. For example, although many players with DES-related business models can be unveiled, less detailed empirical data is available in order to enrich information about generic modules of DES-related business models. Furthermore, this thesis focuses mainly on impulses of sub-systems on DES-related business models, but does not analyse the mutual interaction of sub-systems. Finally, this study mainly concentrates on a national perspective, even though a strong European and even global interrelation are worth to take a look into.

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## Appendix

**Table 2: Critical trends in the energy sector affecting investment profile. Source: WEC (2014: 74-75).**

Sector	Political & regulatory	Technology	Economic	Market
<b>Oil</b>	<ul style="list-style-type: none"> <li>• Policy pressures to reduce GHG emissions and environmental impact.</li> <li>• Evolving and uncertain regulatory frameworks.</li> <li>• Exploration in countries with weaker regulatory frameworks.</li> <li>• Risk of stranded assets under international carbon frameworks.</li> </ul>	<ul style="list-style-type: none"> <li>• End of 'Easy Oil' with increased technical complexity and growing scale of projects (for example, deep water, Arctic or remote unconventional).</li> <li>• Declining production from existing oil fields.</li> <li>• Challenges in finding new conventional oil reserves worldwide.</li> </ul>	<ul style="list-style-type: none"> <li>• Investments have become more risky and projects are costlier (USD 5 bn and more).</li> <li>• Cost of capital is rising, for example, costs of capital for US oil and gas companies, are 33% higher in 2013 compared to 2003.</li> <li>• National Oil Companies (NOC) investment in new upstream and downstream assets to attain size, industrial scope, and technical expertise to manage rising risks.</li> <li>• Some institutional investors divesting from fossil fuels.</li> </ul>	<ul style="list-style-type: none"> <li>• Oil price fluctuations.</li> <li>• CO2 price fluctuations.</li> <li>• NOC expansion into international markets due to depletion of local resources.</li> </ul>
<b>Gas</b>	<ul style="list-style-type: none"> <li>• Policy pressures to reduce GHG emissions and environmental impact.</li> <li>• Public concerns regarding unconventional gas exploration.</li> <li>• Pressures to increase gas exploration to improve economic security.</li> <li>• Policy discussion around accelerating energy-water-food nexus.</li> <li>• In many countries, existing regulatory frameworks do not yet address unconventional gas development in-</li> </ul>	<ul style="list-style-type: none"> <li>• Uncertainty around use of new technologies (for example, use of chemicals in hydraulic fracking, assessment and evaluation of fractures, liquefaction and handling etc.).</li> </ul>	<ul style="list-style-type: none"> <li>• Producers may face depletion effects with rising costs.</li> <li>• A large number of major LNG projects in the pipeline may create over-supply in some gas markets and depress prices.</li> <li>• High capital cost of LNG infrastructure.</li> </ul>	<ul style="list-style-type: none"> <li>• Project economics might alter over the next 10-15 years based on likely changes in global supply and demand for gas, and technological advances in drilling.</li> <li>• Shale gas discoveries push down the price of gas.</li> <li>• Market integration (integration with LNG, pipeline transport, gas balancing etc.).</li> </ul>

Sector	Political & regulatory	Technology	Economic	Market
	sufficient detail and slow development.			
<b>Coal</b>	<ul style="list-style-type: none"> <li>• Policy pressures to reduce GHG emissions and environmental footprint may have significant impacts on longer-term prospects.</li> <li>• Environmental regulation drive retirement of coal generation capacity (e.g. 60 GW reduction of coal generation capacity by 2020 in US).</li> <li>• Without carbon capture, utilization and storage (CCUS) risk of stranded assets under international carbon frameworks.</li> </ul>	<ul style="list-style-type: none"> <li>• The expedited development and large-scale deployment of clean coal power generation technologies, in particular CCUS, maybe necessary under a meaningful post-2015 climate agreement.</li> </ul>	<ul style="list-style-type: none"> <li>• Producers may face depletion effects with rising costs.</li> <li>• Proposed legislation by the US to reduce GHG emissions from coal plants may affect the financing and construction of coal-fired plants in developing countries through multi-lateral development banks.</li> <li>• CCUS will be an added cost and will require investments in major pipeline and other infrastructure.</li> </ul>	<ul style="list-style-type: none"> <li>• Demand for coal will continue to grow in booming Asian countries up to 2050 (for example, China and India).</li> <li>• Coal is a cheaper option than gas for generating electricity in many regions.</li> <li>• Shale gas development in the US has dislocated coal into other markets, for example, Europe.</li> <li>• Increased competition from renewables due to policy priority on grid in some countries.</li> </ul>
<b>Nuclear</b>	<ul style="list-style-type: none"> <li>• Social acceptability challenges and several countries are exiting nuclear.</li> <li>• Limited view of future growth.</li> <li>• Uncertainty in license extensions (33 US reactors have licenses expiring by end of 2030).</li> <li>• Added compliance post Fukushima.</li> <li>• Uncertainty of carbon credit schemes structure which could benefit nuclear power.</li> </ul>	<ul style="list-style-type: none"> <li>• High growth locations for nuclear energy lack expertise.</li> <li>• Health and safety, reliability and environmental considerations.</li> <li>• High costs of decommissioning.</li> <li>• Low operational flexibility.</li> </ul>	<ul style="list-style-type: none"> <li>• Ageing fleet of nuclear reactors with higher costs for maintenance and operation.</li> <li>• Capital intensity and cost greater than conventional plants.</li> <li>• Rising operating expenses and relatively low electricity prices are increasing compression of profit margin for many plants.</li> </ul>	<ul style="list-style-type: none"> <li>• Lower cost alternatives are becoming more attractive, e.g. natural gas price drops of 11% US and 15% Europe by 2040.</li> </ul>
<b>Renewables</b>	<ul style="list-style-type: none"> <li>• Political views can impact investment risk perception.</li> <li>• Uncertain regulatory and policy structure.</li> <li>• Subsidies in many countries increase</li> </ul>	<ul style="list-style-type: none"> <li>• Rapidly evolving technology outside comfort zone of many investors.</li> <li>• Risk of obsolescence due to technology developments.</li> </ul>	<ul style="list-style-type: none"> <li>• Lack of credit history.</li> <li>• Concerns over viability of scaling new technology and supply chain.</li> <li>• Cost and competitiveness remain</li> </ul>	<ul style="list-style-type: none"> <li>• Can face difficulty achieving competitive prices given small-scale.</li> </ul>



Sector	Political & regulatory	Technology	Economic	Market
	<p>regulatory risk as schemes can be redesigned or cancelled.</p>	<ul style="list-style-type: none"> <li>• Intermittency remains a key concern and the development of storage technology lags behind.</li> <li>• Need for new transmission and distribution lines that often are not publicly accepted.</li> </ul>	<p>major issue in many places.</p>	
<p><b>Power (electricity generation)</b></p>	<ul style="list-style-type: none"> <li>• Pressures to transition to lower carbon generation mix.</li> <li>• Incentives for renewables.</li> <li>• Increasing number and ambition of RE targets.</li> </ul>	<ul style="list-style-type: none"> <li>• Increase in DEG (could represent 2% of generation in US by 2016 and 290 GW of Europe capacity by 2030).</li> </ul>	<ul style="list-style-type: none"> <li>• Rising costs to operate, maintain, decarbonize ageing infrastructure.</li> <li>• Long-term electricity prices may be settling at lower level and profits of utilities may continue to decrease.</li> </ul>	<ul style="list-style-type: none"> <li>• Slow growth in electricity demand in OECD countries (1% per year in last decade); demand rising rapidly in developing nations.</li> <li>• Fuel cost fluctuations driving high competition in parts of market.</li> <li>• Emerging competitors (for example, IT companies or home improvement providers), in energy management and supply.</li> </ul>

**Table 3: List of firms of the interviewees. Source: Burger and Weinmann (2013: 3).**

	Incumbents	Municipal utilities	New entrants
Energy	<i>Energy and gas utilities</i>	<i>Integrated utilities</i>	<i>Micro turbines</i>
	E.ON		Greenenvironment
	GASAG		
	<i>Regional grid operators</i>		<i>Virtual power plants</i>
	EnBW Regional		LichtBlick
	ODR		
	<i>Manufacturers</i>	SWK	<i>Island solutions and storage</i>
	Siemens	SWU	Younicos
	Viessmann		
	<i>Smart meters</i>		<i>Building efficiency</i>
Itron		co2online	
<i>Electric vehicles</i>		<i>Energy performance</i>	
Daimler		<i>contracting</i>	
		Argentus Energie	
	<i>Micro cogeneration</i>	<i>Bioenergy villages</i>	
Non-energy	VW	Jühnde	

**Table 4: List of interviewed German utilities. Source: Richter (2013a: 459).**

List of interviewed German utilities.

Category (revenues in m€)	Interviewed utilities	Revenues (in m€)
1. Multinational utilities (>€10,000m)	E.ON AG	79,974
	RWE AG	47,741
	Vattenfall AB	20,036
	EnBW Energie Baden-Württemberg AG	15,564
2. Regional utilities (€10,000m–€1,000m)	EWE AG	5798
	Stadtwerke München GmbH	4900
	Stadtwerke Düsseldorf AG	1918
	Mainova AG	1611
3. Large local utilities (€999m–€100m)	Stadtwerke Karlsruhe GmbH	997
	HEAG Südthessische Energie AG	603
	Stadtwerke Aachen AG	419
	Elektrizitätswerke Mittelbaden GmbH	202
	Stadtwerke Tübingen GmbH	155
4. Small local utilities (<€100m)	Stadtwerke Uelzen GmbH	100
	GWS Stadtwerke Hameln GmbH	82
	Technische Werke Schussental GmbH	70
	Stadtwerke Munster-Bispingen GmbH	26
	Hamburg Energie GmbH	n.a.

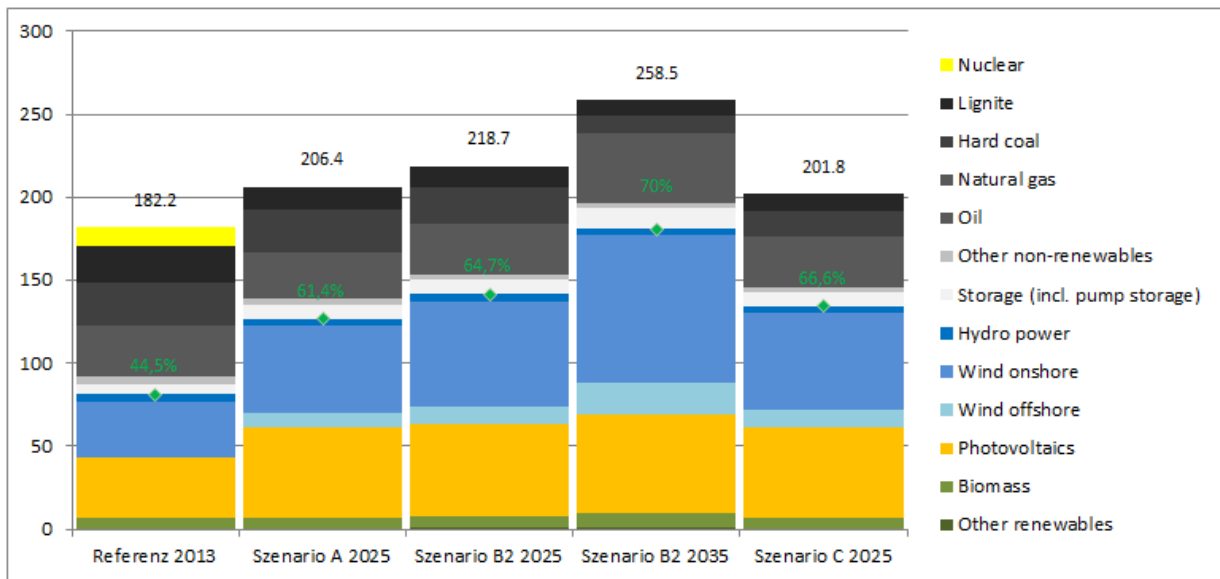


Figure 24: Frame of scenarios for installed capacity in Germany 2025/2035. Source: Own figure, based on data from Bundesnetzagentur (2014).

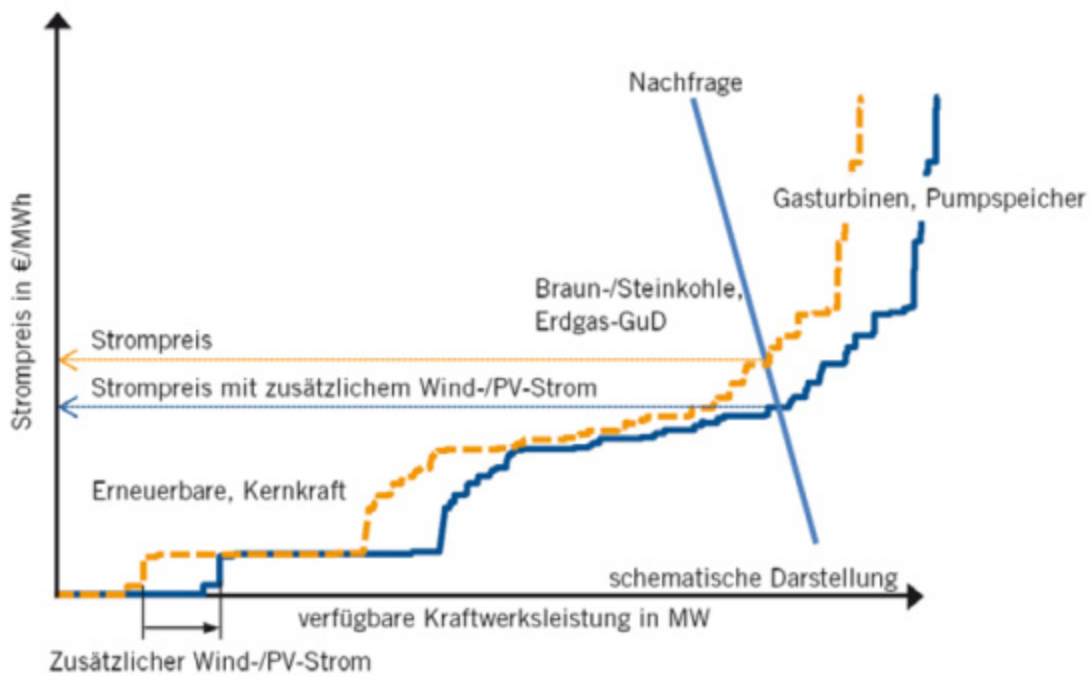
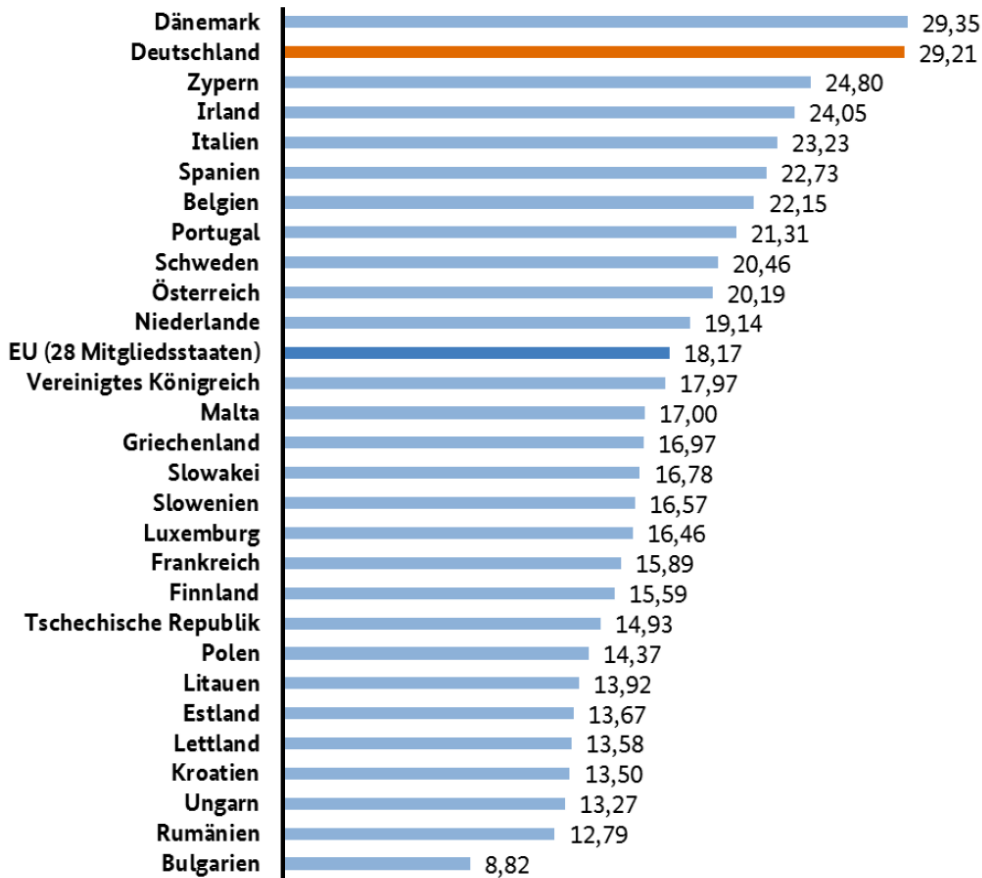


Figure 25: Influence of RE on pricing on the energy exchange for 2008. Source: Wirth (2015: 11).

**Vergleich der durchschnittlichen europäischen Strompreise (Gesamtpreis) für private Haushalte (Verbrauch zwischen 2.500 kWh und 5.000 kWh) im 2. Halbjahr 2013 auf Gesamtpreisebene**  
in ct/kWh



Quelle: Eurostat

Figure 26: Comparison of average household electricity prices in Europe in 2013. Source: BDEW (2014: 181).

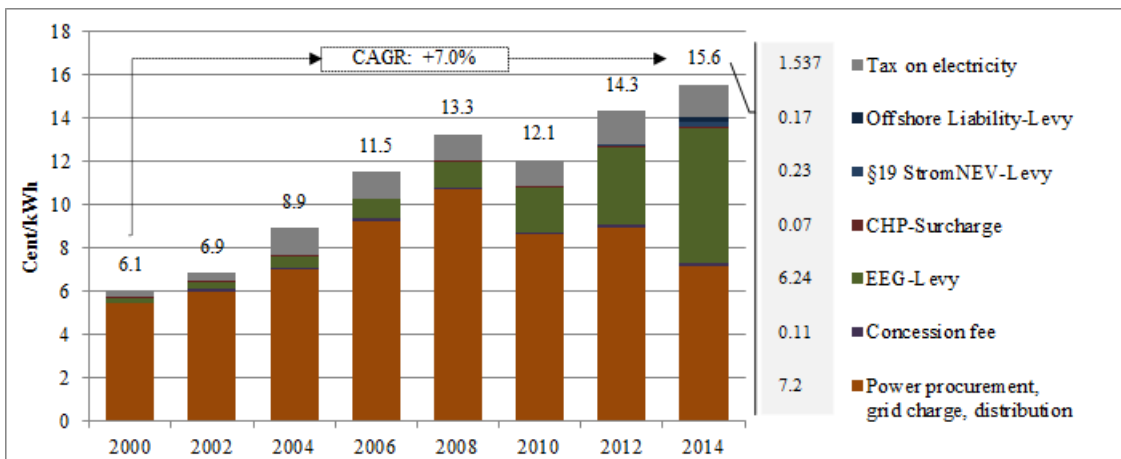
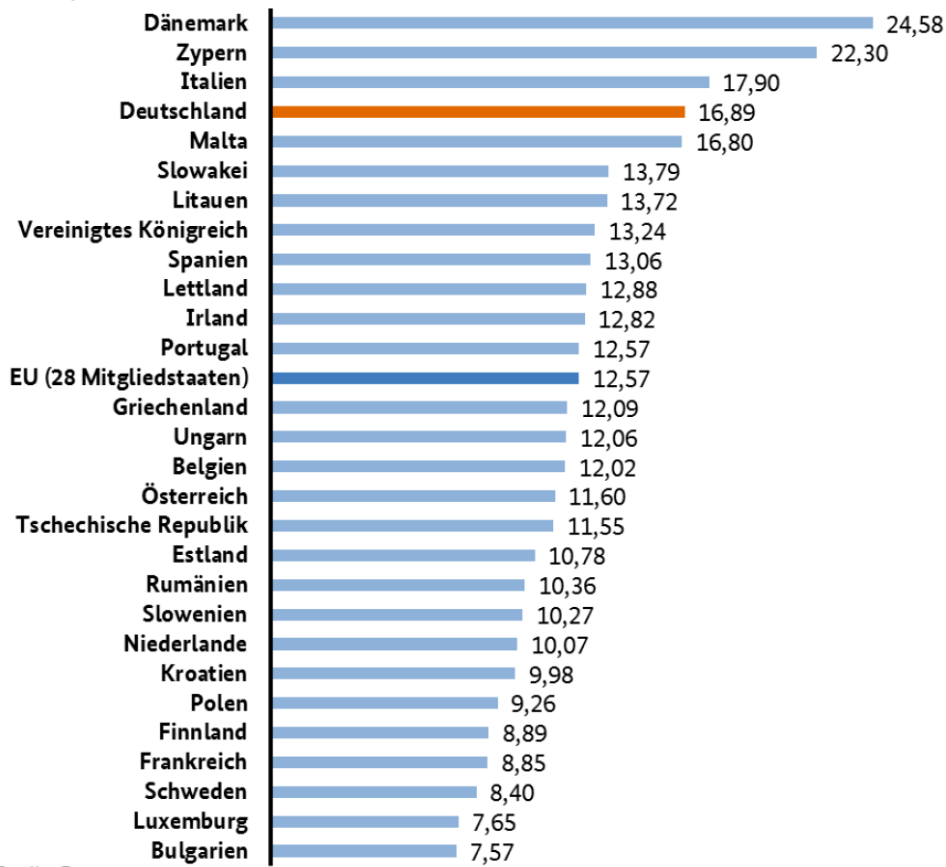


Figure 27: Average industry (more than 20 GWh per year) electricity price development from 2000-2014. Source: Own figure, based on data of BDEW (2014).

**Vergleich der durchschnittlichen europäischen Strompreise  
(Gesamtpreis) für Industrieabnehmer (Verbrauch zwischen 2.000 MWh  
und 20.000 MWh) im 2. Halbjahr 2013**  
in ct/kWh



Quelle: Eurostat

Figure 28: Comparison of average industry electricity price in Europe in 2013. Source: BDEW (2014: 186).

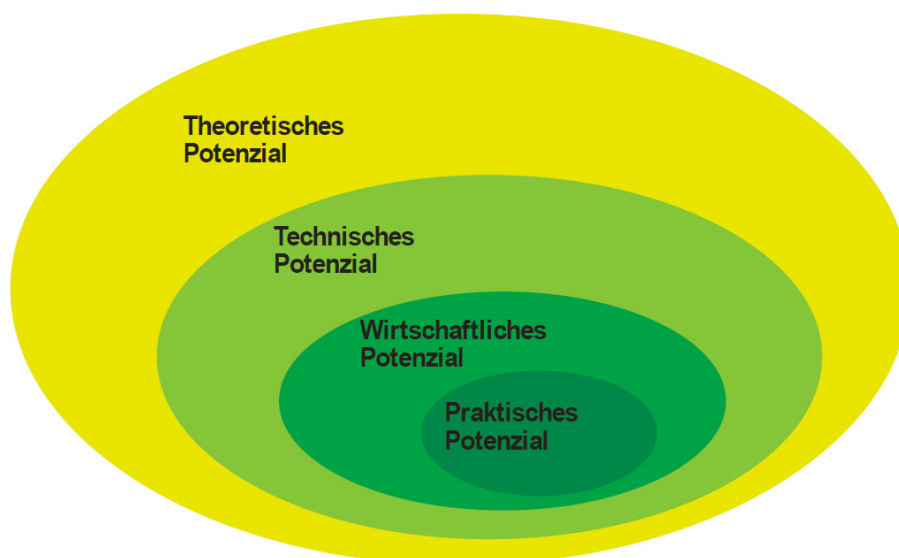


Figure 29: The concept of potential. Source: FfE (2010: 10).

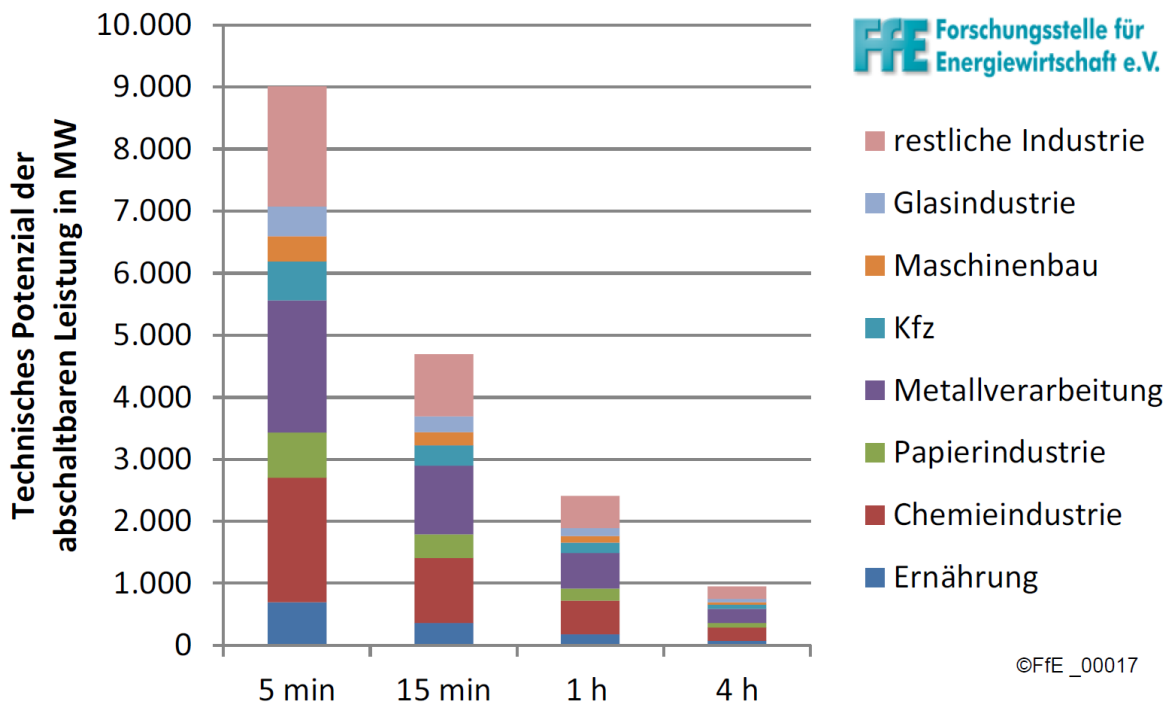


Figure 30: Technical potential of industrial load management depending according to switch-off time. Source: FfE (2010: 15).

Table 5: Summary of the RE source potential in energy joule per year. Source: Orecchini and Naso (2012: 62).

Resource	Current	Share (%)	Technical Potential	Share (%)	Theoretical potential	Share (%)
Biomass	48.3	79.3103	276	3.6600	2,900	0.0002
Hydro	10.0	16.4204	50	0.6630	147	0.0001
Solar power	0.2	0.3284	1,575	20.8858	3,900,000	2.7100
Wind power	0.3	0.4926	640	8.4869	6,000	0.0042
Geothermal power	2.1	3.4483	5,000	66.3042	140,000,000	97.2837
Total	60.9	100.0000	7,541	100.0000	143,909,047	100.0000

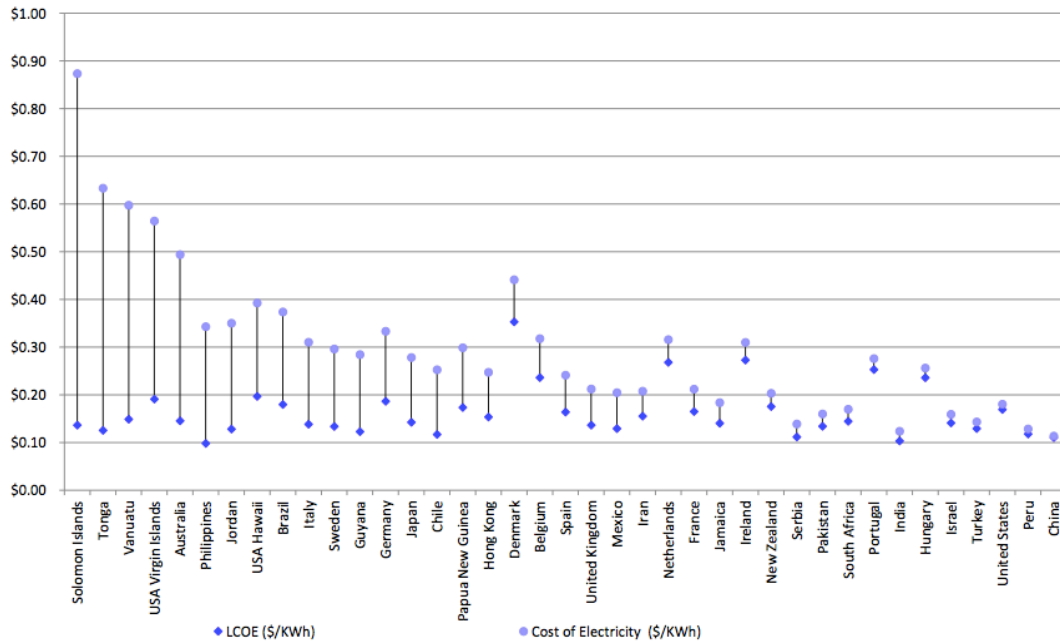


Figure 31: Countries with regions of PV grid parity in 2017 (estimation). Source: Deutsche Bank (2015).

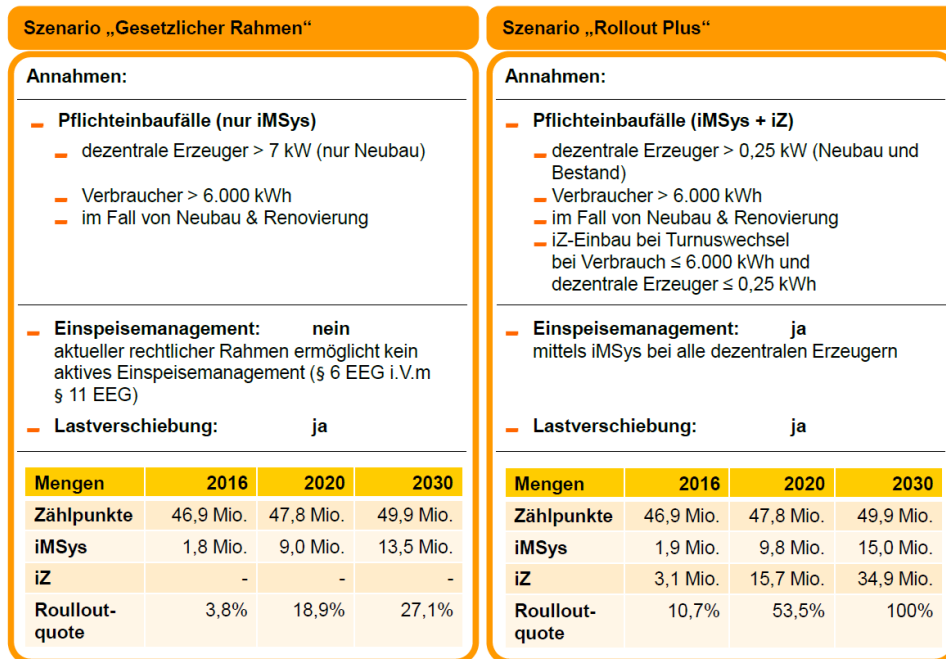


Figure 32: Global assumptions of the two scenarios of the dena smart meter study (Germany-wide consideration). Source: dena (2014c: 12).

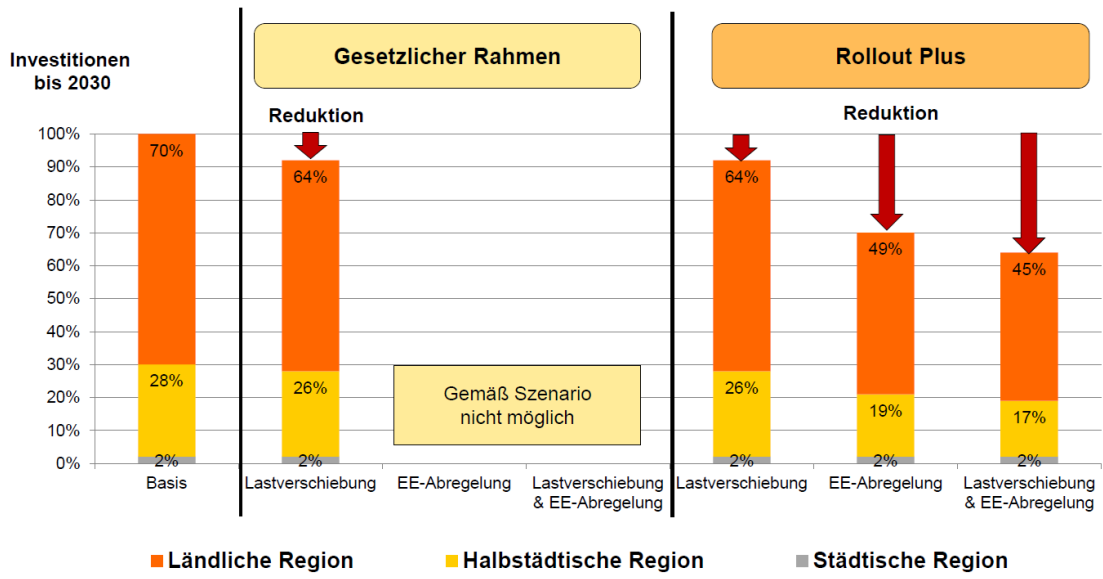


Figure 33: Benefits of grid balancing through feed-in management and DSM. Source: dena (2014c: 22).

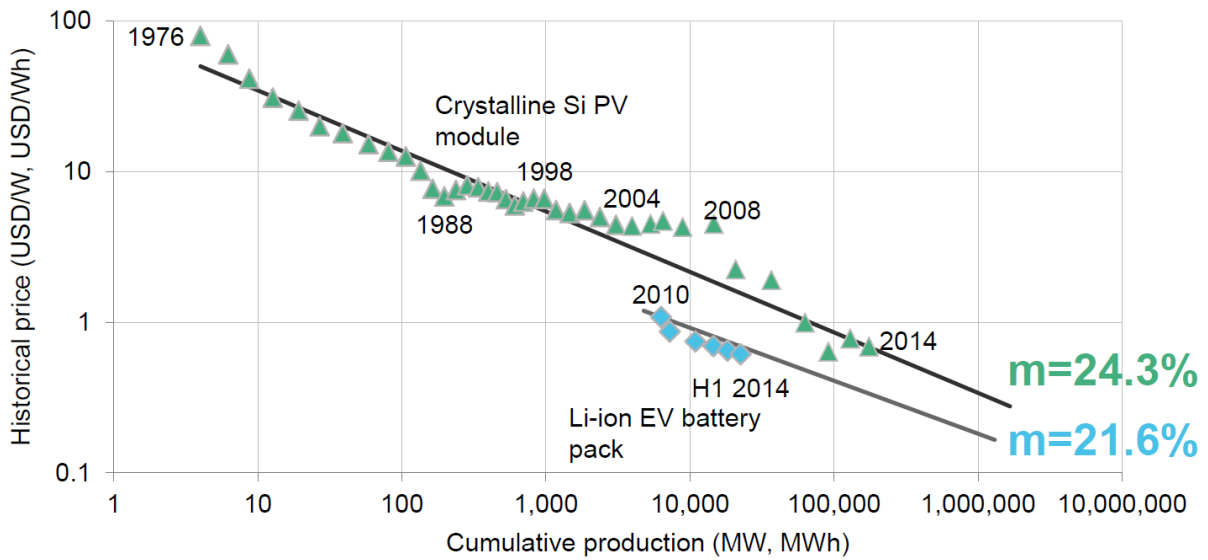


Figure 34: Experience curves for PV and li-ion battery (electric vehicle). Source: Liebreich (2015: 13).



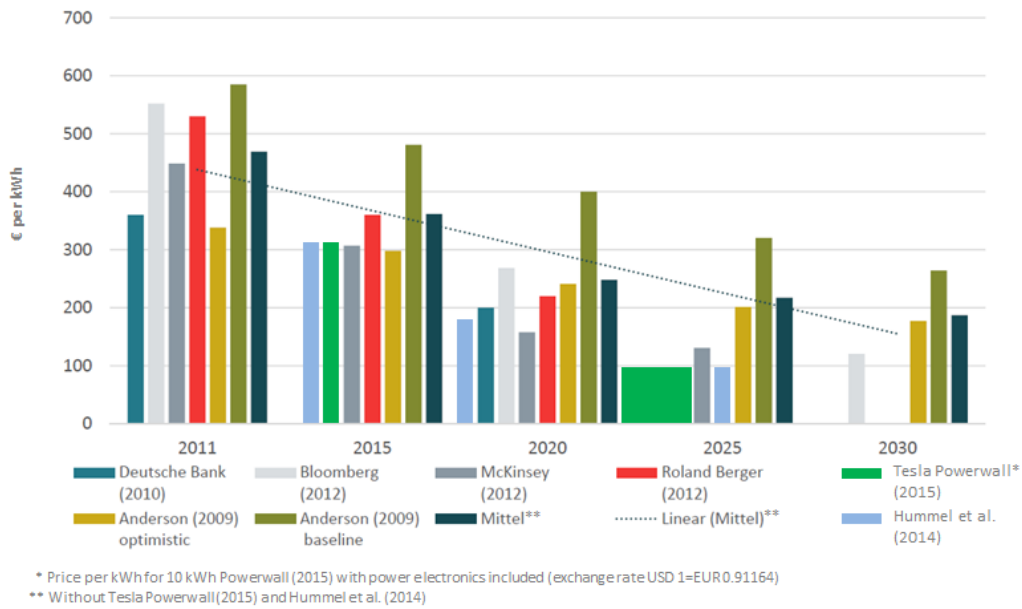


Figure 35: Price forecast for li-Ion-Batteries 2011-2030 by different studies. Source: Adapted from Werner (2014: 9) with data from Hummel et al. (2014) and Straubel (2015).

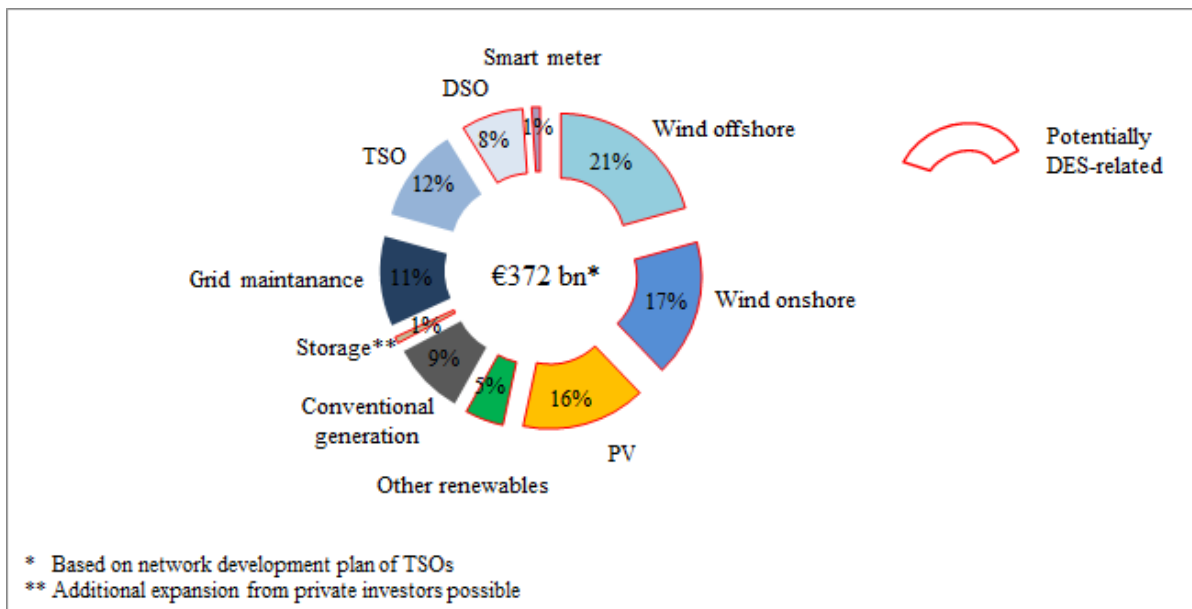


Figure 36: Cumulative investments in Germany's electricity sector until 2030. Source: Own figure, based on Gerbert et al. (2013).

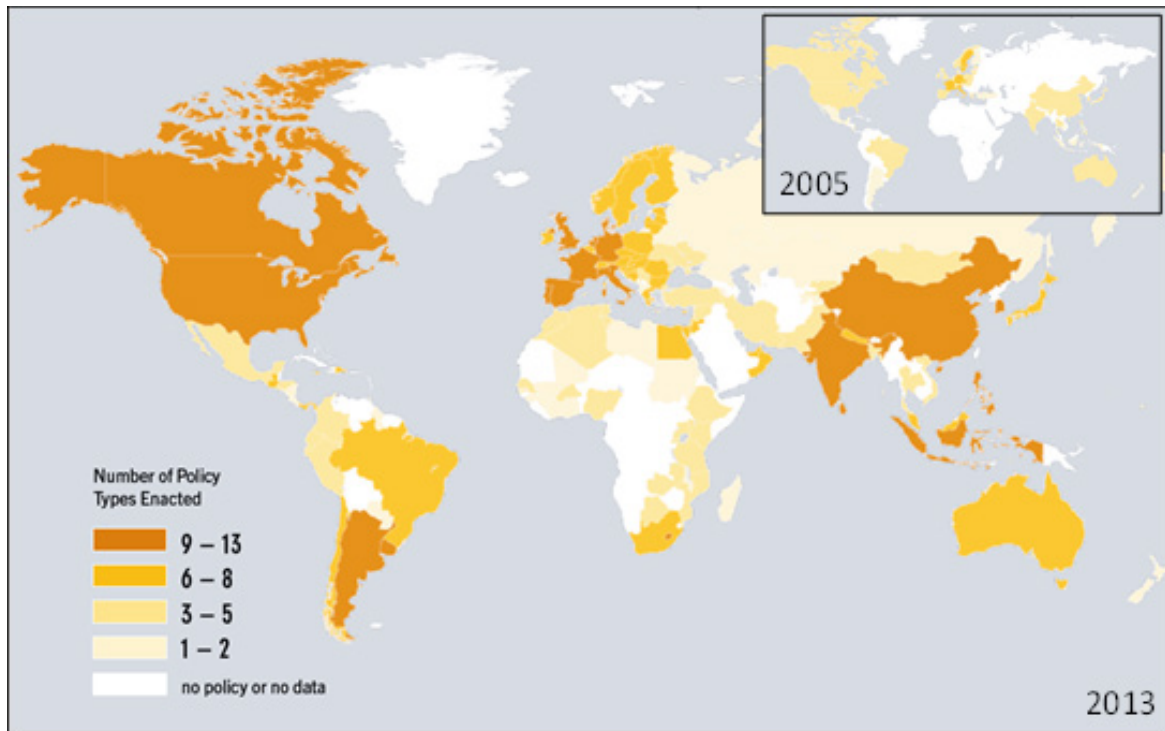
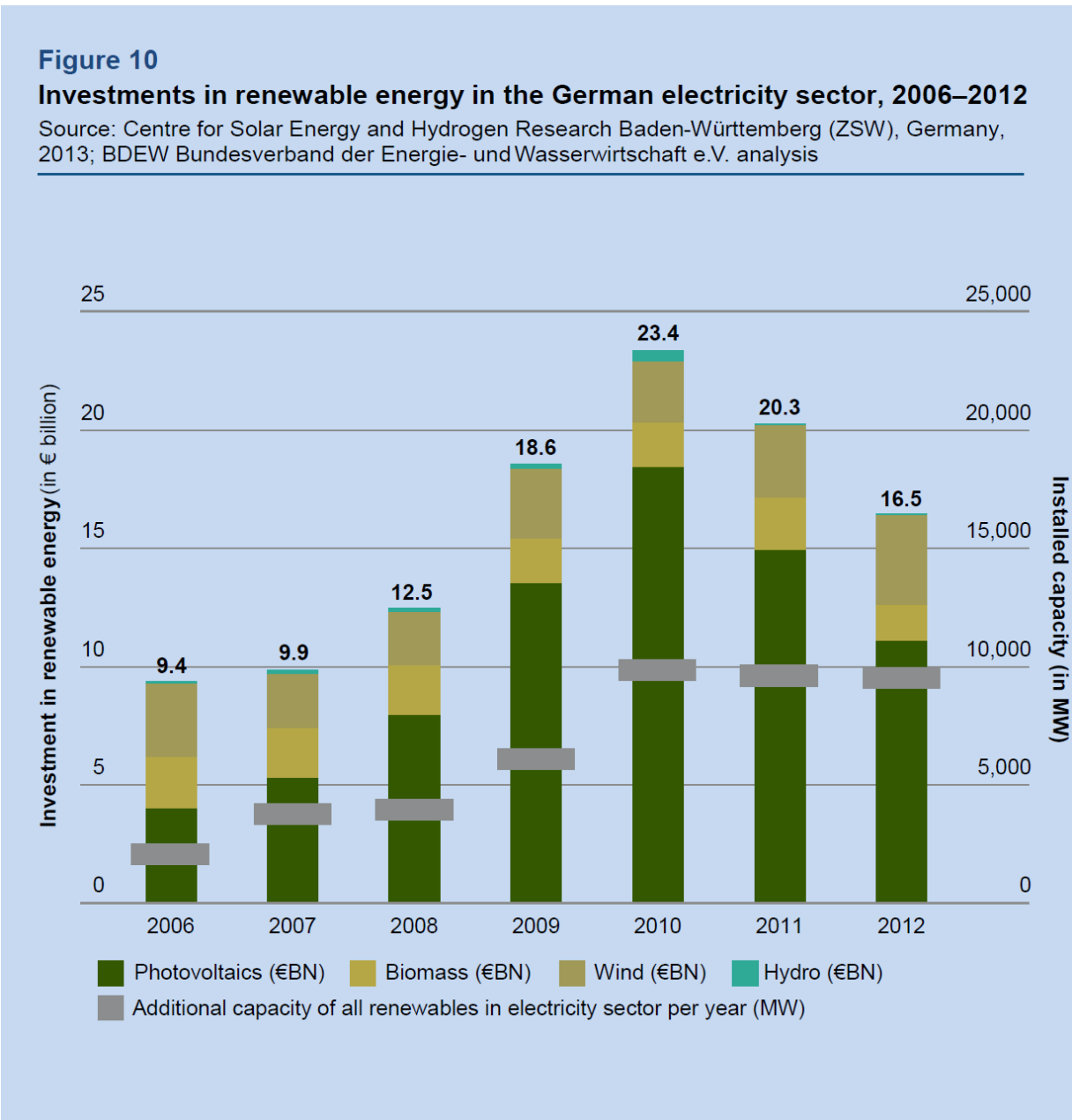


Figure 37: Countries with RE policies (2005 and early 2013). Source: Adapted from REN21 (2013: 79).



**Figure 38: Investments in RE in the German electricity sector (2006-2012). Source: WEC (2014: 42).**

Note: From a mere investment perspective, while absolute investment in RE generation has decreased in recent years, the actual added installed capacity remains mostly the same since 2010.

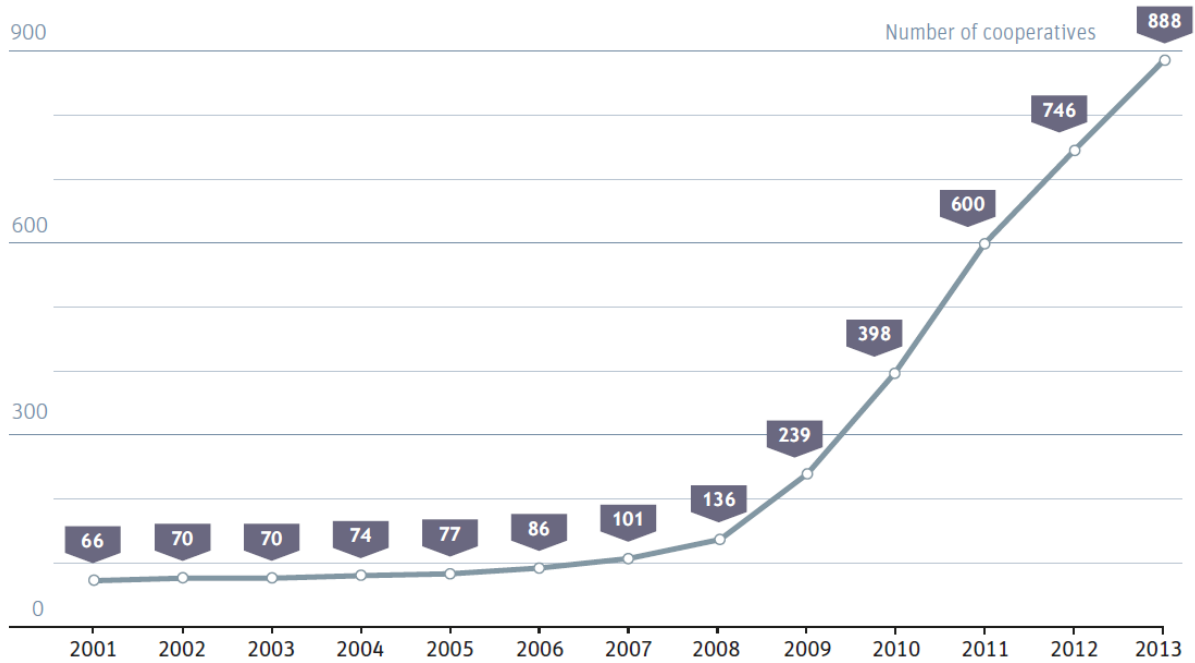


Figure 39: Number of energy cooperatives in Germany (2001–2013). Source: Morris and Pehnt (2012: 9).

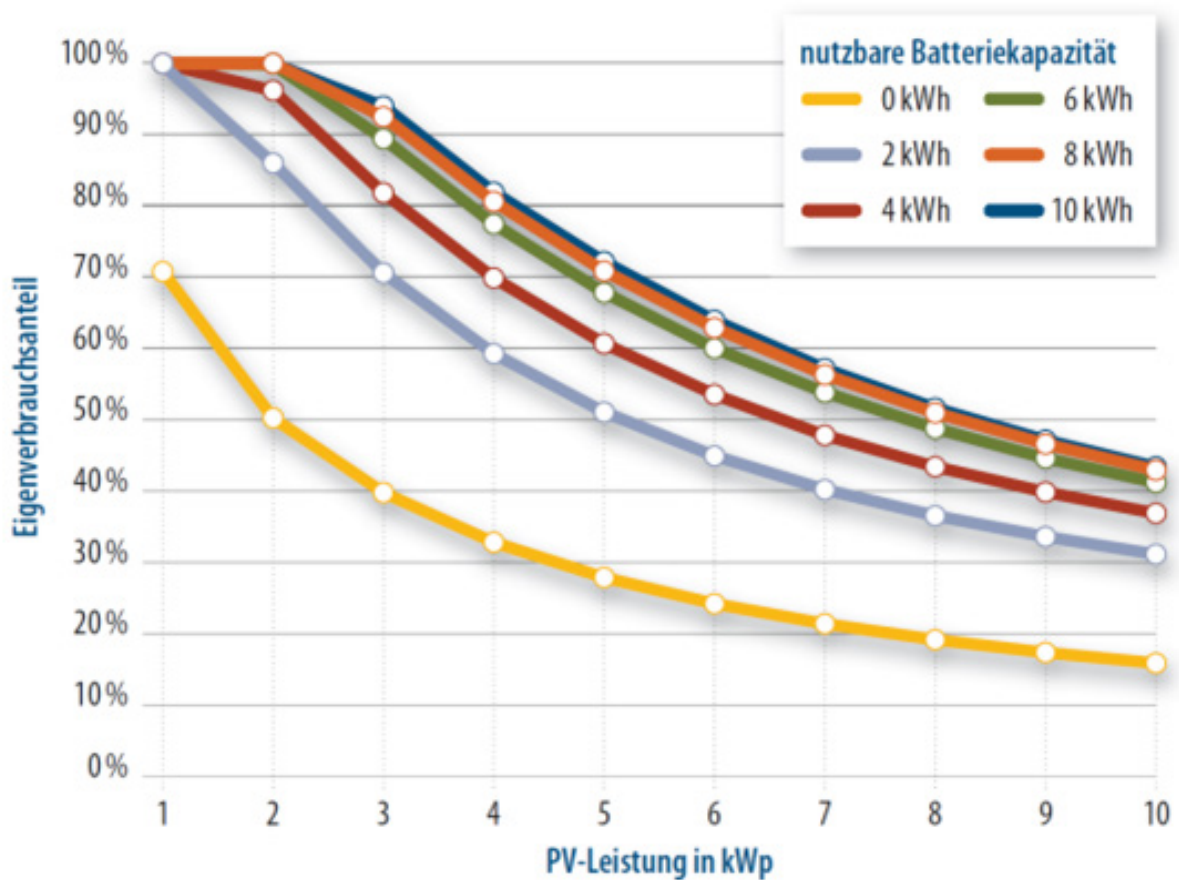


Figure 40: Self-consumption share in relation to battery capacity and PV output for a power consumption of 4,700 kWh per year. Source: Weniger et al. (2012: 52).

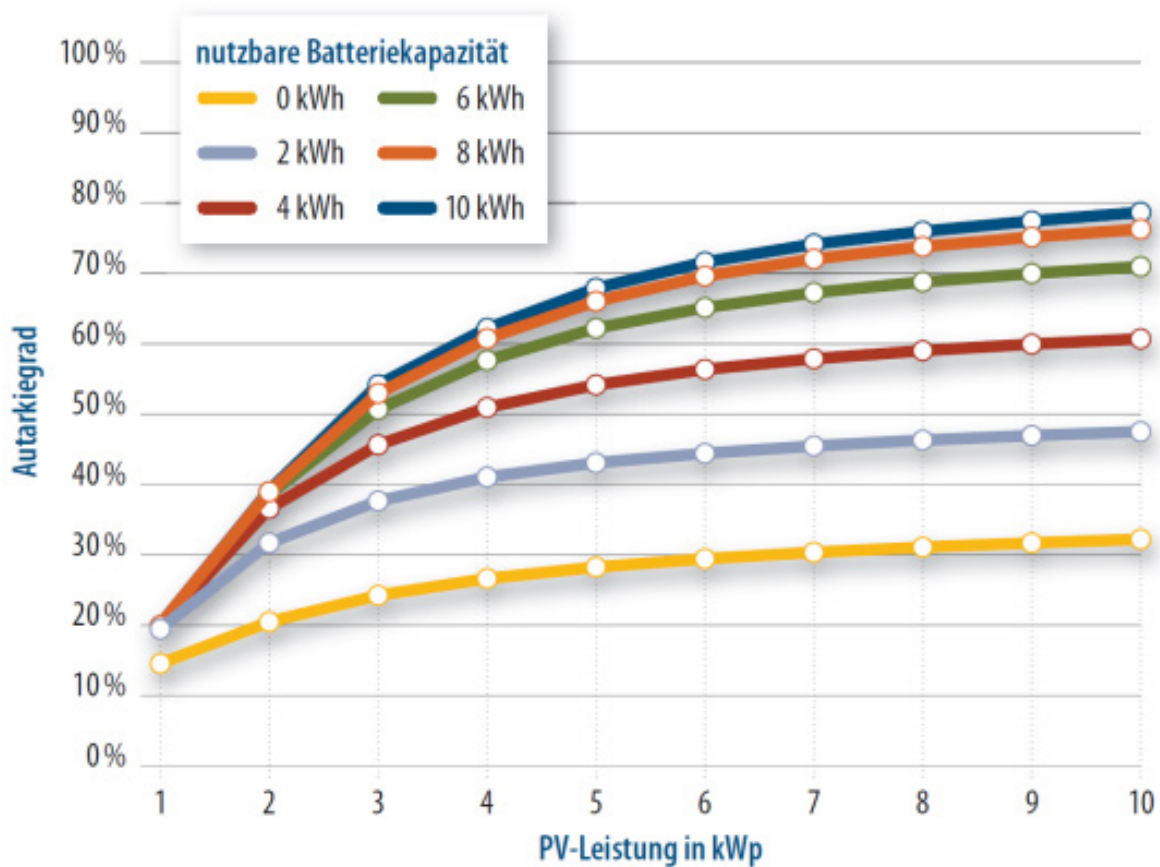


Figure 41: Degree of autarky in relation to battery capacity and PV output for a power consumption of 4,700 kWh per year. Source: Weniger et al. (2012: 54).

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**Abbreviations**

°C	Degree Celsius
§	Paragraph
%	Percent
AbLaV	Verordnung über Vereinbarungen zu abschaltbaren Lasten
Appx	Appendix
B2B	Business-to-business
BMI	Business Model Innovation
Bn	Billion
CAGR	Compounded annual growth rate
CES	Centralized electricity system
Cf.	Conferre (“compare”)
CHP	Combined heat and power
CO <sub>2</sub>	Carbon dioxide
DEG	Distributed electricity generation
Dena	Deutsche Energie-Agentur (“German Energy Agency”)
DER	Distributed energy resources
DES	Distributed electricity system
DSM	Demand side management
DSO	Distribution system operator
EC	European Commission
Et al.	Et alii (masculine), et aliae (feminine) or et alia (neuter) (“and others”)
Etc.	Et cetera (“and the rest”)
EEG	Erneuerbare-Energien-Gesetz (Germany’s “Renewable Energies Act”)
EEX	European Energy Exchange
E.g.	Exempli gratia (“for example”)
EnWG	Energiewirtschaftsgesetz (Germany’s “Energy Industry Act”)
EPEX SPOT	European Power Exchange
EU	European Union
EU-28	28 member countries of the European Union: Austria, Belgium, Bulgaria, Croatia, Cyprus, Czech Republic, Denmark, Estonia, Finland, France, Germany, Greece, Hungary, Ireland, Italy, Latvia, Lithuania, Luxembourg, Malta, the Netherlands, Poland, Portugal, Romania, Slovakia, Slovenia, Spain, Sweden, United Kingdom
EUR	Euro
FiT	Feed-in tariff
GHG	Greenhouse gases
GW	Gigawatt
GWh	Gigawatt hour
G	Gram

ICT	Information and communication technology
I.e.	Id est (“that is to say”)
KfW	Kreditanstalt für Wiederaufbau (Germany’s “national development bank”)
KW	Kilowatt
KWh	Kilowatt hour
LCOE	Levelized cost of electricity
Li-ion	Lithium ion
M&A	Mergers and acquisition
Mio	Million
MW	Megawatt
MWh	Megawatt hour
OECD	Organisation for Economic Co-operation and Development
OTC	Over-the-counter
Pp.	Pages
P.m.	Post meridiem (“after noon”)
PV	Photovoltaic
RE	Renewable energy
RWE	Rheinisch-Westfälisches Elektrizitätswerk AG
SME	Small or medium enterprise
TSO	Transmission system operator
TWh	Terawatt hour
T	Ton
UK	United Kingdom
USA	United States of America
USD	United States Dollar
VAT	Value added tax
Vol.	Volume
W	Watt
WWF	World Wide Fund for Nature