

PATHWAYS project

Exploring transition pathways to sustainable, low carbon societies
Grant Agreement number 603942

Deliverable D2.2: ‘Analysis of stability and tensions in incumbent socio-technical regimes’

Country report 1: Regime analysis of the German electricity system

Karoline S. Rogge, Nele Friedrichsen and Barbara Schlomann

Fraunhofer ISI, Karlsruhe, Germany

May 28, 2015

Preface

This report is produced in the context of work package 2 ('Dynamics of transition pathways') of the FP-7 funded PATHWAYS project ('Exploring transition pathways to sustainable, low carbon societies'). More precisely, this report provides the German country study of the electricity regime for deliverable 2.2 ('Analysis of stability and tensions in incumbent socio-technical regimes'). The UK counterpart can be found in sub-report 2 and includes additional information on the multi-level perspective (MLP) as the analytical framework which underlies this analysis.

The analysis in this report is based on a research template developed by Frank Geels and colleagues at the University of Manchester and shared between the different contributors to WP2 to enable a comparative analysis of the findings for different countries (UK, Netherlands, Sweden, Portugal, Germany) and empirical domains (electricity, heat, mobility, agro-food and land-use).

We are grateful for stimulating discussions and useful feedback by PATHWAYS researchers at our project meeting in Leipzig and beyond, and would particularly like to thank Frank Geels and Benjamin Pfluger for their constructive comments on earlier versions of this report. Finally, we gratefully acknowledge excellent research assistance by Jonas Lehmann and editorial support by Gillian Bowman-Köhler.

Executive Summary

This report provides an analysis of the degrees of stability and tension in the incumbent German electricity regime, and constitutes a key step in the analysis of the transition dynamics within the German electricity system using the multi-level perspective (MLP). As such, this report complements the earlier analysis of green niche innovations in electricity supply and demand in Germany (see deliverable 2.1, sub-report 1).

The analysis here will shed light on two aspects: first, the main external landscape developments relevant for the German electricity regime which could potentially create pressure on the regime, and second, the development of the German electricity regime, which, if destabilized, could create windows of opportunity for a wider diffusion of green niche innovations, such as wind, PV or smart metering.

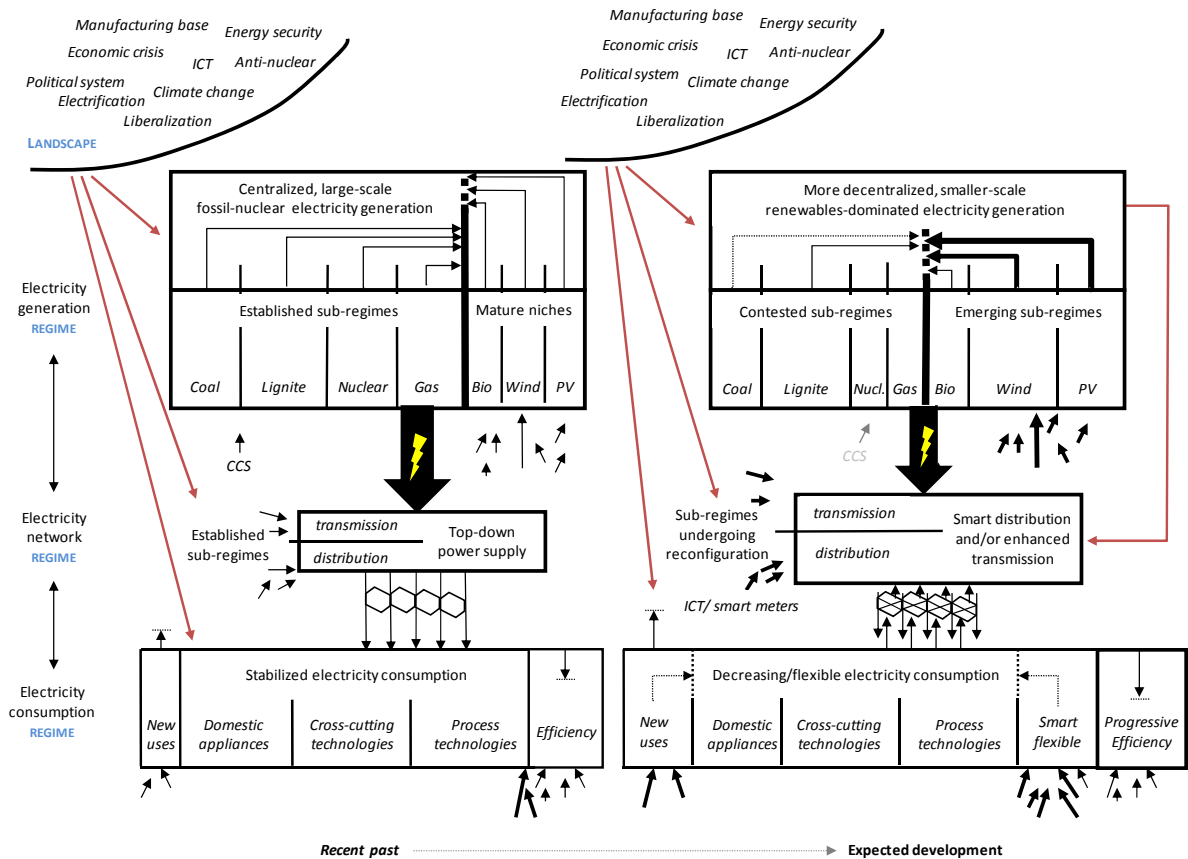
Regarding the first aspect, we find that many of the exogenous landscape developments put pressure on the existing regime and thus destabilize it, although some factors also contribute to stabilizing the electricity regime.

- Perhaps the most influential landscape factor has been Germany's *strong anti-nuclear movement*. There was a very strong public reaction to two nuclear accidents abroad, the first one at Chernobyl in the Ukraine in 1986 and the second at Fukushima in Japan in 2011. This ultimately led to a cross-party agreement to phase out nuclear power in Germany by 2022, thus bringing the country back on track with the initial phase-out negotiated by the government of Social Democrats and Greens under Gerhard Schroeder in 2000.
- The global issue of *climate change* has been on the political agenda since 1989 (Helmut Kohl) and has increased in importance since then. This is evidenced by the European CO₂ price signal introduced through the EU emissions trading system in 2005, the pivotal role played by the "climate chancellor" Angela Merkel in adopting the EU's 20-20-20 energy and climate targets for 2020, and Germany's ambitious climate targets for 2050. However, attention to climate change at the top level of government has declined since 2008 and particularly since the failure of Copenhagen in 2009, although there have been some recent signs of a revival given the increases in CO₂ emissions and the lurking gap in target achievement.
- The *liberalization* of the electricity market and the unbundling of utilities driven by EU regulation broke up the oligopoly market structures in Germany and led to a restructuring of the industry, resulting in four big, internationally more active electricity suppliers and four big transmission system operators.
- The *German proportional voting system* that allows small parties (with a share over 5%) to send the corresponding number of representatives to parliament made it possible for the Green Party to enter the national parliament in 1983, thereby giving a parliamentary voice to "Green" concerns (about the climate, nuclear accidents, nature conservation). When the Greens became part of a coalition government with the Social Democrats (1998-2005), they were able to use their influence to introduce the

Renewable Energy Act (EEG) in 2000 and defend it in 2004, despite strong opposition from regime stakeholders. With hindsight, the introduction of the EEG can be interpreted as the most influential policy change as it sowed the seeds for and functioned as a catalyst for the German *Energiewende*.

- As an *engineering and manufacturing nation* and export champion, Germany plays a driving role in developing renewable energy technologies, such as solar PV or wind, and the German government is harnessing this innovativeness through its High-Tech Strategy and its recognition that environmental policy can function as industrial policy, creating green growth, jobs and income.
- The *financial and economic crisis* brought about a fairly moderate and relatively temporary decline of industrial electricity demand in 2009, but in the longer term it has led to a fairly strong decline in electricity spot market prices and thereby to lower profit margins for electricity generation.
- There are also wider *environmental sustainability concerns* such as nature conservation and the protection of biodiversity, which lead to public resistance to CCS, scepticism about shale gas, or debates about corridors for new transmission lines.
- The industrial structure in Germany with several *energy-intensive branches* calls for reliable supply and low electricity prices in order to safeguard its international competitiveness and safeguard jobs and income at home.
- *Energy security* concerns, particularly regarding the dependence on Russian gas, cast a favourable light on lignite as a domestically available energy source (but also benefit renewable energies).
- The *electrification of mobility and heat* is expected to increase electricity demand in the coming decades. This will supplement the expected rising demand from IT equipment (laptops, mobile phones, tablets), thereby providing good growth prospects for electricity suppliers.
- *Green ICT (smart technologies)*, which is favoured by German policy and European Directives (Ecodesign and Labelling, Energy Star), could influence regime development, especially in the longer term, but has already had an impact. However, the potential use of smart meters, which are strongly driven by EU regulation, may be limited due to high data protection standards.

Regarding the second aspect – regime developments – we distinguish three interrelated sub-systems: electricity generation, electricity transmission and electricity use, as depicted in the figure below. For these three sub-systems, the analysis focuses on the regime level and splits this into different sub-regimes. For the electricity generation regime, we discuss sub-regime developments for coal and lignite, nuclear, and gas-fired electricity generation. For electricity grids, we differentiate between transmission and distribution networks. For electricity demand, we highlight developments in domestic appliances, cross-cutting and process technologies in industry and services, and new uses. The interplay and expected regime changes are summarized in the following graph:



The analysis of developments within the German electricity system has highlighted that the interconnected regimes of electricity generation, transmission and consumption are experiencing significant landscape pressures (anti-nuclear movement, climate change, energy security, liberalization) and knock-on effects from the resulting growth of increasingly mature niches and interactions between the three regimes.

The resulting change is most advanced in the electricity generation regime, in which the mature niches of wind, PV and bioenergy have expanded so radically that at least PV and wind are on the brink of becoming new sub-regimes that are driving the regime in the direction of much more decentralized and smaller scale electricity generation based on renewable energies. This transformation of the generation regime creates pressures on the transmission regime, which has started to adjust to the new circumstances of more fluctuating, at times bi-directional electricity flows. Even the quite stable electricity consumption regime, which so far has experienced mainly incremental changes, is coming under increasing pressure to make the changes needed for the overall success of the low-carbon transformation of the German electricity system, both in terms of radical cuts in electricity demand (despite additional uses, such as e-mobility) and increasing the flexibility of use. In the following, for each of the regimes, we summarize our conclusions on the most important stabilizing and destabilizing developments.

Electricity generation regime

Over the period from 1990 until today the German electricity generation system has witnessed major landscape pressures – most importantly a strong anti-nuclear movement paired with concerns about climate change. Additional tensions have resulted from the increasing impacts of the emerging niches of wind, solar PV and bioenergy, which have expanded significantly and can now start to be viewed as new sub-regimes (see table below). The sheer size, different ownership structure and characteristics of these emerging green sub-regimes have meant fundamental changes along many dimensions of the German electricity regime. This regime is now transforming from one characterized by centralized, large-scale electricity generation dominated by large utilities to a much more decentralized, and smaller scale electricity generation regime based on renewable energies, with the ownership of generation capacities spread across a multitude of new entrants, including a high share of citizens, farmers and cooperatives. In addition, the established business models of the incumbent utilities are eroding. Indeed, while the large incumbents have undergone multiple changes in beliefs and are now investing in large-scale renewable energies, their long-term survival is still at stake because of their lack of business model capabilities to harness the chances and opportunities from the ongoing energy transition. In 2012 and 2013, however, the decarbonisation of the electricity generation system experienced a setback due to rising shares of lignite and hard coal in the generation mix – despite declining capacities. There have also been recent changes in the key policy instrument supporting the expansion of renewable energies, the EEG, which indicate a change in policy favouring larger investors. This is partly due to pressures to advance the market integration of renewables, and partly due to political concerns about the ever-increasing EEG surcharge, which is largely borne by private electricity consumers because of the exemptions for energy-intensive industries. Hence, while nuclear phase-out and the transition towards renewable energies are not being questioned, there are ongoing disputes about what the future regime will look like (e.g. regarding the degree of decentralization) and who the winners and losers will be.

GENER- ATION	Lock-in, stabilizing forces	Cracks, tensions, problems
External landscape pressures	WEAK <ul style="list-style-type: none"> - Further electrification of society (heat, mobility, ICT) potentially leading to increased electricity demand - Maintaining competitiveness of energy-intensive industries 	STRONG <ul style="list-style-type: none"> - Very strong anti-nuclear movement - Climate change and nature conservation taken very seriously - Federal political system with proportional voting (enabling Green Party in government coalitions and initiatives at national, federal and local levels) - Liberalization and unbundling of electricity markets - Engineering and manufacturing nation benefitting economically from the

		<p>development and sale of renewable energy technologies</p> <ul style="list-style-type: none"> - Financial and economic crisis reducing electricity demand and electricity prices - Geo-political tensions with Russia (gas) and security of supply concerns
Utilities	<p>MODERATE</p> <ul style="list-style-type: none"> - Sunk investments in power plants, and commitment to existing technologies and resources (particularly lignite as domestic resource) - Business model and internal knowledge focuses on centralized, large-scale power generation - Attempts to socialize burden from second nuclear phase-out (court cases) - Especially in the early years, hardened fronts between utilities and renewable energies (losing market shares to new entrants) - Critical regime players for reliable electricity production, job creation, generation of public income due to still big, albeit shrinking, market shares - Beginning involvement in larger-scale renewables (e.g. offshore wind) 	<p>STRONG</p> <ul style="list-style-type: none"> - Acknowledgement of climate change and policy target of decarbonisation of electricity system by 2050, but struggling with identifying aligned strategy - Growing realisation of the misalignment between old business model (large-scale fossil-nuclear) and new market realities due to increasing shares of intermittent, decentralized renewable electricity and phase-out of nuclear (similarly pending for coal due to unavailability of CCS and politically stable long-term climate targets) - Financial difficulties, reduction in staff, restructuring in an attempt to survive the energy transition - Loss of influence in policy circles (compared to very close links between policy-makers and the “big 4” utilities (E.ON, RWE, Vattenfall, EnBW) in the past)
Consumers	<p>MODERATE</p> <ul style="list-style-type: none"> - Electricity consumption is an essential part of private and professional life and is taken for granted - Only limited switching of customers between electricity providers thereby reducing retail price competition and the pressure to pass on spot market electricity price reductions of renewables - Marketing efforts of retailers to sell existing hydropower as “green electricity” (greenwashing) successful to 	<p>MODERATE</p> <ul style="list-style-type: none"> - Several green electricity tariffs exist, but demand for these is lower than the current share of renewable electricity generation (15 vs. 25%) - Attempts to reduce electricity demand by switching off lights, using energy saving light bulbs or LEDS, and reading energy labels when buying appliances (see consumption regime)

	<p>some extent</p> <ul style="list-style-type: none"> - Consumers are paying for renewables through EEG surcharge, leading to complaints about rising electricity bills and concerns about distributional fairness 	
Policy-makers	<p>MODERATE</p> <ul style="list-style-type: none"> - Strong support of new entrants and private investors in the past, but in recent years, increased attention to cost and management considerations favouring larger investors (having surpassed 25% of electricity generated from renewable energies, debates about rising EEG surcharge and pressure from the EU) - Economics ministry for a long time on the side of large incumbents and blocking transition to decentralized renewables, but with counterpart of environment ministry, which was in charge of renewables and promoted new entrants - Explicit niche protection of offshore wind as large-scale renewable energy technology promoting industrial development of economically deprived coastal regions and accommodating big utilities (since 2002, but recent reduction of 2020/30 targets in 2014) - Regional governments of coal- and lignite-rich federal states block destabilization policies phasing out coal (e.g. NRW) 	<p>STRONG</p> <ul style="list-style-type: none"> - Climate policy has introduced a new environmental policy style with targets supported by economic instruments (eco-tax, EU ETS), but political attention to climate change has ebbed since 2009 (lack of leadership in fixing low CO2 price in EU ETS, high priority to costs and competitiveness). Renewed momentum during the run-up to influential 2015 COP in Paris - German government has focused the most climate change attention on electricity generation, with strong policies supporting the expansion of renewable energies (EEG) and reconfirmed phase-out of nuclear (cross-party support in 2010 after Fukushima) - The energy transition is a political flagship project with front-page coverage - missing policy targets would damage the reputation of leading politicians such as the Economic Minister Gabriel (Vice Chancellor, responsible for energy transition) - Recent shift of energy expertise from environment ministry to economics ministry signals greater political attention to the energy transition's success and cost minimization, but could also undermine the focus on decentralized, citizen-investor-driven transition - Difficult search for safe site for future storage of nuclear waste
Public debate and opinion	<p>WEAK</p> <ul style="list-style-type: none"> - Debates about rising electricity prices and distributional unfairness caused by exemption rules for energy-intensive industry, but energy transition as such not questioned 	<p>STRONG</p> <ul style="list-style-type: none"> - Open and engaged debates about how to achieve a radical transformation of the energy system at all governance levels (including city initiatives), and central media coverage

	<ul style="list-style-type: none"> - Local concerns about loss of jobs in coal regions, but research has shown positive net employment effect from transition to electricity generation based on renewable energies 	<ul style="list-style-type: none"> - High public acceptance of transition to electricity system based on decentralized renewable energies linked to strong anti-nuclear movement, negative image of large utilities, large share of private investors benefitting from feed-in tariffs (e.g. rooftop PV) and job creation effect of renewables - Strong opposition to storing CO₂ underground and to shale gas, increasing resistance to coal-fired power plants
Pressure from social movements, NGOs, scientists	<p>WEAK</p> <ul style="list-style-type: none"> - Some neoclassical economists continue to argue for emissions trading as a least-cost solution, i.e. suggest abandoning the EEG, but despite high visibility, they have lost much of their influence in public and particularly policy debates 	<p>STRONG</p> <ul style="list-style-type: none"> - Most NGOs advocate radical, decentralized renewable electricity technologies that deviate from the existing regime, and are important voices in public debates - Growth of environmental think-tanks and scientists with strong modelling capacities, who are actively advising policy-makers, industry and NGOs, highlighting cost-effective ways of achieving decarbonisation and renewables targets without nuclear - Highlighting high costs of nuclear and feasibility of electricity system based on PV and wind
Overall assessment	<p>WEAK</p> <p>The electricity regime is undergoing radical changes which at this point seem irreversible, implying that the main future sub-regimes will be PV and wind with some flexible back-up (gas, biomass), but there is an ongoing dispute about the final regime dimensions. Resistance from regime actors is focused on reducing losses, buying time and identifying new business models to ensure survival in the new regime</p>	<p>STRONG</p> <p>There are major and most likely irreversible tensions and cracks in the electricity generation regime. The climate change problem and anti-nuclear movement has led to significant institutional changes, e.g. ambitious GHG reduction, RES expansion and nuclear phase-out targets and specific policies. The resulting structural changes in infrastructure (renewable energy makes up 50% of generation capacity, with a negligible share owned by large incumbents) with their reduction of electricity market prices and thus decreased profitability of existing conventional plants are forcing large incumbents to rethink their beliefs and strategies</p>

Stability and tensions in the German electricity generation regime

Electricity consumption and end-use regime

The consumption side of the electricity regime is evolving incrementally through the interplay of several dynamics which may have a reverse effect on the development of electricity consumption. Changes in the range and absolute number of electrical products and to production and employment in the industrial and service sectors have the predominant effect of increasing electricity consumption. These factors dampen the rise of electricity consumption only during periods of economic recession. Another growth-stimulating effect is the still ongoing trend to greater automation and widespread diffusion of new electrically powered applications and technologies (as e.g. information and communication technologies, electric vehicles and electric heat pumps). On the other hand, energy efficiency innovations have helped to suppress increases in electricity consumption. These manifested themselves in manufacturers' efforts to increase the energy efficiency of electric household appliances and cross-cutting technologies (e.g. electric motors, lighting, ICT) and the increasing market penetration of such technologies. This development was stimulated to a large extent by the EU's and national governments' policy measures. However, it is often unclear how behavioural and organisational changes impact the purchase and use of electric appliances and products in private households and companies. They can have a decreasing effect on electricity consumption, often stimulated by informational and advice programmes, but the opposite is also possible, e.g. through rebound effects.

These patterns can be understood in the context of competing landscape pressures (see table below). On the one hand, concerns about climate change and energy security as well as the favourable side-effects of energy efficiency have exerted pressure on the consumption regime, generating the drive towards greater energy efficiency. On the other hand, the trend towards greater electrification of households and companies is an important stabilizing force on the regime. The following table summarizes the countervailing pressures exerted by the different actors in the electricity consumption regime.

CONSUMPTION	Lock-in, stabilizing forces	Cracks, tensions, problems
External landscape pressures	MODERATE <ul style="list-style-type: none">- Future trend towards greater electrification in all end-use sectors (ICT, electric mobility, heat pumps)	STRONG <ul style="list-style-type: none">- Favourable economic side-effects of energy efficiency on economic growth, employment, competitiveness of the economy and others (the so-called "multiple benefits" of energy efficiency; IEA 2014) are a strong argument to address more efficient use of electricity- Climate change and energy security also place pressure on regime to address electricity consumption levels

Industry	<p>STRONG</p> <ul style="list-style-type: none"> - For retailers and wholesalers, the energy efficiency of appliances and products sold is not at the top of their agenda - Producers of electricity-using products try to prevent progressive energy efficiency standards which would favour smaller appliances by lobbying activities - Weak control of compliance with the regulations for electricity-related products (minimum energy efficiency standards, labelling) concerning both retailers and producers in Germany limits these groups' actions on energy efficiency issues - Exemptions from several taxes and surcharges on the electricity price for large industrial electricity consumers lower their incentive to invest in energy efficiency - Electricity utilities (especially the "big 4") tend to be rather conservative and reluctant to develop new business models for energy services 	<p>MODERATE</p> <ul style="list-style-type: none"> - German producers have a strong market position in the field of high-quality electrical household appliances and electrical cross-cutting technologies for industry and commerce; these products are usually also highly efficient - A relatively new association of the German energy efficiency industry (DENEFF) has become a stronger voice of German energy efficiency businesses
Consumers	<p>MODERATE</p> <ul style="list-style-type: none"> - Tendency to purchase larger and more appliances in the field of consumer electronics (e.g. large TV screens) and information technologies in private households and parts of the service sector (retail trade, hotels and restaurants) - Negative public reaction to energy efficiency standards for some goods, e.g. vacuum cleaners or shower heads, stabilize existing regime dynamics 	<p>MODERATE</p> <ul style="list-style-type: none"> - High electricity prices in Germany, especially for private households and small companies, favour investments in energy-efficient products and – though less pronounced – promote electricity-saving behaviour - Consumer groups and energy agencies at the national, regional and local levels campaign for the purchase of energy-efficient-products and behavioural changes with regard to electricity consumption
Policy-makers	<p>STRONG</p> <ul style="list-style-type: none"> - No support for progressive energy efficiency standards favouring smaller electrical products 	<p>MODERATE / STRONG</p> <ul style="list-style-type: none"> - Ambitious targets set for energy efficiency (also including a reduction target for electricity) in the Energy Concept of 2010 and implementing the

	<ul style="list-style-type: none"> - Sufficiency aspects about the level of energy demand are widely neglected when designing policy measures 	<p>policies from the new National Energy Efficiency Strategy of December 2014 mean that energy efficiency is becoming more and more established as the 2nd pillar of the Energiewende (alongside the expansion of renewable energies)</p>
Public debate and opinion	<p>MODERATE</p> <ul style="list-style-type: none"> - High data protection standards limit the spread of smart metering, smart appliances and smart homes, which otherwise could help to reduce electricity consumption. 	<p>WEAK</p> <ul style="list-style-type: none"> - Debates about the very high electricity prices in Germany for private households and small businesses, but these are mainly directed at the generation sub-regime, rather than at consumption and appliance use
Pressure from social movements, NGOs, scientists	<p>WEAK</p> <ul style="list-style-type: none"> - Some scientists (but not the majority) argue that specific policies addressing electricity efficiency and consumption at the level of end-uses are not necessary or even counter-productive if a well-functioning emissions trading system exists - In general, energy efficiency suffers from a relatively weak lobby, as it has fewer beneficiaries than, for example, investments in renewable energy 	<p>WEAK</p> <ul style="list-style-type: none"> - Other scientists and NGOs criticise that rebound effects and sufficiency issues are not taken into account enough by the policy-makers
Overall assessment	<p>MODERATE / STRONG</p> <p>The future trend towards greater electrification in some fields (ICT, electric mobility, heat pumps) and some rebound effects (e.g. in lighting) may counteract the efforts to reduce electricity consumption.</p> <p>There are some important actors for whom energy efficiency is not a top priority (esp. electricity utilities, retailers and wholesale trade); this may undermine the efforts to increase efficiency and reduce electricity demand.</p>	<p>MODERATE</p> <p>There is a relatively broad consensus of all affected groups on the benefits of energy /electricity efficiency and the political target of reducing electricity consumption.</p>

Stability and tensions in the German electricity consumption regime

Electricity network regime

Over the period from 1998 until 2015, the German electricity networks have been experiencing major challenges to the traditional operating strategies of the power system. Major drivers were developments in the generation structure with the emerging niches of wind, solar PV and bioenergy as well as the nuclear phase-out driven by the anti-nuclear movement. Another major factor at landscape level was the push for liberalization and unbundling of the electricity sector initiated and pursued by the EU from 1996 to 2009 with three waves of liberalization directives.

Changes in generation structure have challenged and are still challenging the system physically and require network expansions. However, since network expansion is not keeping pace with the changes, is plagued by acceptance issues and might not always be the most efficient solution, adaptations in network operation and management are also required. To some extent, this is taking place already with network operators engaging in redispatch and generation management. However, so far, this is mainly being managed centrally via the network operators and (nearly) limited to emergency situations. A wider use of flexibility options is being discussed, but the framework to implement this is still missing. This shifts the focus to the flexible management of generation and supply, optimization via smart grids using intelligent control and metering as well as storage solutions. It may therefore push the niche development of smart metering. Overall, the system is moving from centralized, top-down management towards a more decentralized, interactive system, but so far this is mainly happening on a physical level. This represents a challenge for the networks, some of which are approaching their limits already, but which cope mainly using existing measures. In the future, roles, responsibilities and regulations will have to be modified to be able to adapt operations to these changes. At the same time, transmission networks are also being enhanced by innovative technologies and it is not yet clear what the network regime of the future will look like and how it will combine smarter distribution and expanded and enhanced transmission (probably also long-distance, high-voltage transmission to connect with other countries).

The network business as a centrally regulated activity is relatively stable per se, but is undergoing reconfiguration. Changes to regulation have been made to adapt it to the investment needs and quality demands which enable further changes in the future.

NETWORK	Lock-in, stabilizing forces	Cracks, tensions, problems
External landscape pressures	MODERATE <ul style="list-style-type: none">- EU directives on network regulation, network tariffs as well as international technical agreements	HIGH <ul style="list-style-type: none">- Increase of DG, (fluctuating) renewable generation, phase-out of nuclear and perhaps also coal/lignite within generation regime puts pressure on network with increasing congestion and need for redispatch- Development of ICT and information

		society -> new technological possibility such as smart grids may foster flexible integration of demand-side and generation-side resources into network management
Industry	<p>MODERATE</p> <ul style="list-style-type: none"> - Investments in grid infrastructure, long-lived assets - Incumbent companies rooted in old model of centralized power generation and transport of power “top-down” - Problems of refinancing, insufficient interest in investments plus time lag in recognition of investments in regulation have since changed. Similarly, problems of refinancing innovative technologies (in particular operational advances) are now being at least partially addressed in the regulation 	<p>MODERATE</p> <ul style="list-style-type: none"> - Some assets, particularly in distribution networks, are at the end of their lifetime and have to be renewed in any case, which may be a good moment to switch to more advanced network management/intelligent components, i.e. combining network renewal with upgrades - Unbundling formerly integrated incumbents (generation and network) makes network companies more focused on solely network operation and cost-efficiency. Incentives for innovation and quality are set separately via regulation to contain cost-efficiency incentives. - Operational model for networks is changing forced by DG and RES -> reverse power flows -> network operators are under pressure to change and changes in the regulatory framework have been necessary (partially realized already) - New actors promoting the use of flexibility since they see a business model in it
Consumers	<p>MODERATE</p> <ul style="list-style-type: none"> - Recent concerns about rising network tariffs and spatial inequality - Whether or not potential new roles of consumers (e.g. with DSM) will actually have a large impact on the systems remains to be seen 	<p>MODERATE</p> <ul style="list-style-type: none"> - Rising network tariffs partially caused by renewables plus locational inequality - Problem of self-generation and concerns about solidarity in cost sharing of the network (focus of debate is PV and household consumers, industrial self-generation not such a big issue) - Network tariffs and exemptions for industrial consumers are a big issue. More contribution from privileged consumers to relieve network desired and may be required for privileges to be granted in future
Policy-	HIGH	HIGH

makers	<ul style="list-style-type: none"> - regulatory system - technical aspects and (international) guidelines (e.g. within the network of European Transmission System Operators ENTSO-E) limit or slow down the options for radical change - grid operators are not allowed to be active on the supply side due to unbundling of the sector; this limits their options to assume new roles, for example, by operation flexibility measures (this obligation derives from EU regulations) - regulatory incentives can help to steer network development, but the Federal regulator seems to be conservative and relatively slow in adapting the framework for network development and recognizing expenditure for innovative activities. However, recent changes mean that some pure R&D activities are now recognized. So far, regulation does not clearly target a low carbon power system. - Strong opposition of state/local politicians to the construction of new transmission lines 	<ul style="list-style-type: none"> - The focus on expanding renewable generation also puts networks in the limelight since they are needed to integrate the renewable power. Several laws to speed up network expansion have been passed. Even though their effectiveness remains to be seen, this seems to be a big step in the right direction. - Attention only paid to transmission networks to start with but now increasingly to distribution networks as well. - Research programmes and financial support for RD&D in smart grids, networks for the future and innovative network technologies with the aim to drive diffusion and practical experiences with new technologies and operational concepts featuring greater flexibility.
Public debate and opinion	<p>HIGH</p> <ul style="list-style-type: none"> - New transmission lines face massive acceptance problems - Some NGOs argue that the new transmission lines are more useful for lignite power plants than for renewables 	<p>HIGH</p> <ul style="list-style-type: none"> - Plan N as a project to reconcile different positions and find a way forward
Pressure from social movements, NGOs, scientists	<p>MODERATE</p> <ul style="list-style-type: none"> - Local resistance/ citizen initiatives (at local level) against network expansion/ construction - Environmentalists (collision of birds with overhead lines) 	<p>HIGH</p> <ul style="list-style-type: none"> - Scientists claim that more flexibility and more advanced flexible pricing are needed to reduce network congestion and restrict expansion - Inequality with respect to network tariffs and exemptions for energy-intensive industry

Overall assessment	<p>MODERATE</p> <p>A long-lived assets structure and regulation stabilize the existing regime. Regulation changes (such as targeted investment incentives to spur certain developments) can theoretically be realized more easily, but seem to be slow and are not likely to result in radical changes but only gradual adaptations of the regulatory framework.</p>	<p>HIGH</p> <p>Renewable integration and increase in decentralized generation require adaptations to the network management and structure. This has already led to some changes being made to the regulatory framework that allow and encourage network operators to make such adaptations. The changes also improve the incentives for network expansion, increase acceptance and streamline administrative processes. There is a strong consensus that network expansion is needed at the transmission level as well as the expansion and greater intelligence of distribution networks. Further changes are targeted with adaptations in the regulatory framework and network access conditions and could trigger the reconfiguration of the network regime.</p>
--------------------	---	--

Stability and tensions in the German electricity network regime

Contents

1	Introduction.....	18
2	Overview of development of climate and energy policy strategy	19
3	Overall system trends and longitudinal developments	22
3.1	Longitudinal fuel developments in electricity generation	22
3.2	Longitudinal developments in electricity consumption and user practices	25
3.3	Longitudinal developments in electricity transmission and distribution	28
3.4	Environmental performance (CO ₂ -emissions).....	32
4	External landscape developments	35
5	Developments in electricity generation regime	37
5.1	Developments of the main tangible system elements	37
5.2	Main social groups and intangible regime elements.....	44
6	Developments in consumption and end-use regime	55
6.1	Developments of the main tangible system elements	55
6.2	Main social groups and intangible regime elements.....	61
6.2.1	General overview of intangible regime elements	61
6.2.2	Main social groups and actors within the consumption and end-use regime	64
7	Developments in electricity network regime	72
7.1	Developments of the main tangible system elements	73
7.2	Main social groups and intangible regime elements.....	76
8	Conclusions about stability and tensions	81
8.1	Electricity generation regime	83
8.2	Electricity consumption and end-use regime	87
8.3	Electricity network regime.....	90
	Publication bibliography	94

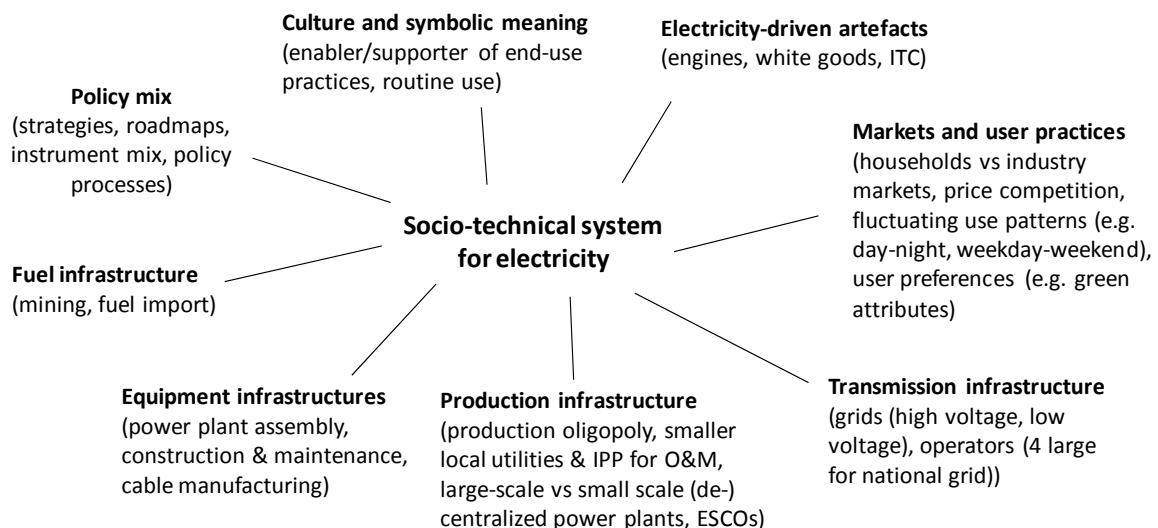
1 Introduction

This report provides an analysis of the degrees of stability and tension in the incumbent German electricity regime, and constitutes a key step in the analysis of the transition dynamics within the German electricity system using the multi-level perspective (MLP). As such, this report complements the earlier analysis of green niche innovations in electricity supply and demand in Germany (see deliverable 2.1, sub-report 1).

The analysis here will shed light on two aspects: first, the main external landscape developments relevant for the German electricity regime which could potentially create pressure on the regime, and second, the development of the German electricity regime, which, if destabilized, could create windows of opportunity for a wider diffusion of green niche innovations, such as wind, PV or smart metering. Methodologically, we synthesize main patterns and trends based on the analysis of multiple data sources, including official statistics, government reports, academic and grey literature.

The socio-technical system for electricity is an integrated system which instantaneously balances supply and demand of electricity – with storage, export and demand-side management acting as limited buffers. It is build upon infrastructure for producing the fuels and equipment needed to produce and transmit electricity to various users, including industry, households and services with their artefacts, markets and user practises (see Figure 1). In addition, this system is governed by a rich policy mix shaping the electricity market, regulating investments in grids, limiting carbon emissions, or promoting the increase of energy efficiency.

Figure 1: Elements of socio-technical system for electricity



Source: Own illustration building on Geels 2005

In this report we distinguish three interrelated sub-systems: electricity generation, electricity transmission and electricity use, as depicted in Figure 1. For these three sub-systems, the analysis focuses on the regime level and splits this into different sub-regimes. For the

electricity generation regime, we discuss sub-regime developments for coal and lignite, nuclear, and gas-fired electricity generation. For electricity grids, we differentiate between transmission and distribution networks. For electricity demand, we highlight developments in domestic appliances, cross-cutting and process technologies in industry and services, and new uses.

Finally, we want to stress that given the multiple uses of electricity as well as the competition for inputs (fuel, land) with other systems it is clear that the electricity system partly overlaps with the other empirical domains studied within the PATHWAYS project, particularly heat and transport, but also land-use and biodiversity.

The remainder of the report is structured as follows: Chapter 2 describes the development of Germany's climate and energy policy strategy, which is followed by a summary of overall system trends and longitudinal developments in chapter 3. In chapter 4 we then identify the main external landscape developments relevant for the German electricity regime. In the main part of the report we describe longitudinal developments in the German electricity generation regime (chapter 5), the electricity demand regime (chapter 6) and the electricity grid regime (chapter 7). Chapter 8 concludes the report by offering conclusions on stability and cracks in all three regimes and their interplay within the German electricity system.

2 Overview of development of climate and energy policy strategy

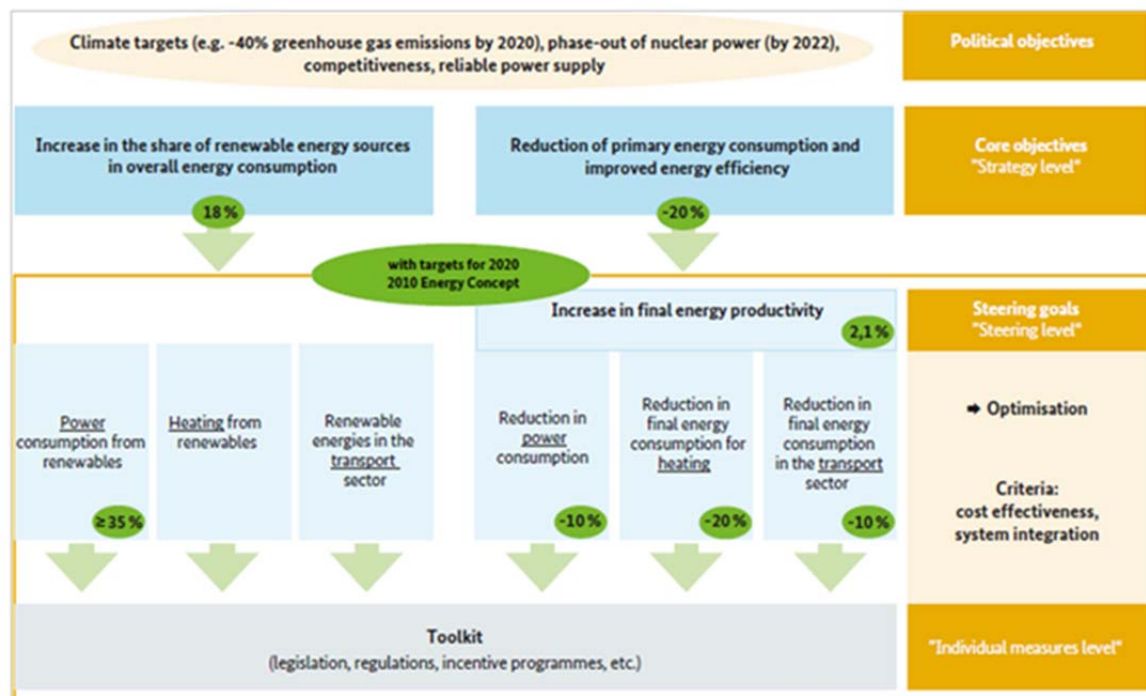
Germany has been one of the frontrunners in climate and renewable policy since the mid-1980s and has a complex policy mix in place (Bruns et al. 2009; Laes et al. 2014)¹. The development of this policy mix was accompanied by a continuous sequence of national strategies and programs which underline a stable political consensus in Germany regarding the importance of energy and climate policy. In 2002, the “National Sustainable Development Strategy” of Germany was first presented at the UN World Summit on Sustainable Development in Johannesburg in 2002. Through a total of three extensive reports, this strategy has been continuously updated over two changes of government, with a recent summary published in the Progress Report adopted by the Federal Cabinet in February 2012 (German Government 2012).

The German government's “Integrated Energy and Climate Programme” (IECP) of August 2007 comprised a package of 29 policy instruments which focused upon increasing the share of renewable energy and combined heat and power (CHP) in the national energy mix as well as improving energy efficiency in buildings and in the transport sector (Fraunhofer ISI et al. 2008). It was aimed at achieving Germany's target of reducing greenhouse gas emissions by 40 % by 2020 compared to 1990.

¹ A detailed overview is provided by the German ministry in a map of laws which includes both strategies and laws, acts, directives, and reports for different energy carriers and also differentiates between European and German elements of the policy mix for the whole energy system BMWi 2014c.

This 2020 perspective was extended to 2050 when in September 2010 Germany adopted its Energy Concept (German Government 2010) outlining its energy policy until 2050. This roadmap foresaw instruments to achieve a decarbonisation of Germany's energy system through the development of renewable energy sources, power grids and energy efficiency. In the original energy concept from 2010, nuclear energy was seen as a bridging technology and a limited extension of the operation live of existing nuclear power plants by about 12 years was foreseen. This was a partial withdrawal of the step by step phase-out of nuclear energy until the beginning of the 2020s, which was implemented by the former government (a red-green Coalition of the former Chancellor Schroeder) in 2002. At the same time the German government ratified its National Renewable Energy Action Plan (NREAP) to the EU specifying targets for the expansion of renewable energies in Germany (BMU 2010).

Figure 2: Target architecture of the German energy strategy



Source: BMWi 2014g, p. 5

Following the Fukushima incident in March 2011, the Merkel government shut down eight nuclear power plants and returned to the much supported permanent nuclear power phase-out (which was a withdrawal from the "anti phase-out" decisions on nuclear energy in the energy concept in September 2010) and took further decisions to fundamentally transform the German energy system: the so-called "Energiewende" (BMWi 2012). Therefore, on June 6, 2011 an energy package was adopted to supplement the targets and instruments of the Energy Concept. For the first time, an official monitoring process was established to evaluate the progress made towards the targets and the current state of implementation. The evaluation results are published in annual reports which are further supplemented every three years by a

strategically oriented progress report, with the first one published in December 2014 (BMWi 2014g). It differentiates between top level political objectives of the Energiewende, which are specified by core objectives representing a strategy level differentiating between renewable energies and energy demand. These strategic objectives are further broken down into steering goals, whereby a target architecture distinguishing various levels was proposed (Figure 2).

Table 1 summarizes the medium- and long-term targets of the Germany Energiewende and how far Germany has come so far in reaching them. According to recent data from the national energy balances for 2014 (AGEB 2015), Germany made considerable progress towards the reduction targets for primary energy and electricity consumption. In 2014, the decrease in primary energy consumption amounted to 9 % and electricity consumption decreased by 6.4 %, both compared to the reference year of the targets, 2008.

Table 1: Status quo and quantitative targets of the German Energiewende

Table 1: Status quo and quantitative Energiewende targets

				2050		
Category	2011	2012	2020	2030	2040	2050
Greenhouse gas emissions						
Greenhouse gas emissions (compared to 1990)	-25.6%	-24.7%	at least -40%	at least -55%	at least -70%	at least -80% to -95%
Renewable energies						
Share in gross electricity consumption	20.4%	23.6%	at least 35%	at least 50% (2025: 40 to 45%)	at least 65% (2035: 55 to 60%)	at least 80%
Share in gross final energy consumption	11.5%	12.4%	18%	30%	45%	60%
Efficiency						
Primary energy consumption (compared to 2008)	-5.4%	-4.3%	-20%	-50%		
Gross electricity consumption (compared to 2008)	-1.8%	-1.9%	-10%	-25%		
Share of electricity generation from combined heat and power plants	17.0%	17.3%	25%			
Final energy productivity	1.7% per annum (2008–2011)	1.1% per annum (2008–2012)	2.1% per annum (2008–2050)			
Buildings						
Primary energy requirement	–	–	–	around -80%		
Heat requirement	–	–	-20%	–		
Rate of modernisation	approx. 1%	approx. 1%	doubling of levels to 2% per annum			
Transport						
Final energy consumption (compared to 2005)	-0.7%	-0.6%	-10%	-40%		
Number of electric vehicles	6.547	10.078	1 million	6 million	–	

Source: BMWi 2014d p.4

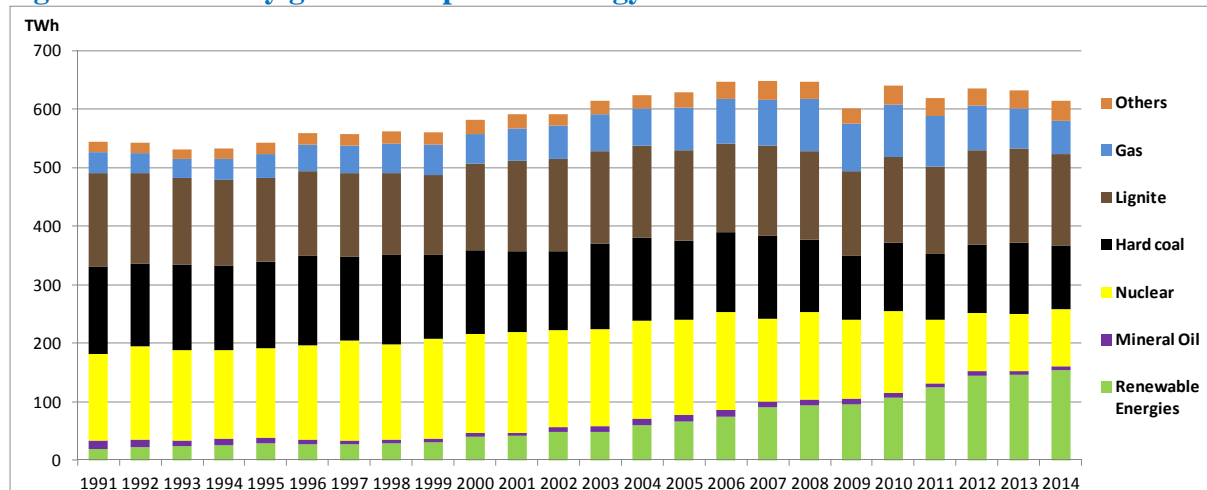
Nevertheless, there is still a gap to the ambitious energy and climate targets for 2020, which has to be filled during the coming years. Therefore, in order to achieve the medium-term targets for 2020, the German Government launched a comprehensive strategy on Energy Efficiency and Climate Protection and adopted the “Climate Action Program 2020” (BMUB 2014) and a National Action Plan on Energy Efficiency (BMWi 2014i) on 3 December 2014. These include a set of further energy and climate policy instruments which need to be implemented in the course of 2015.

3 Overall system trends and longitudinal developments

3.1 Longitudinal fuel developments in electricity generation

In the past, electricity generation in Germany has been dominated by coal, lignite, and nuclear – each making up roughly 30% of generation in 1991 (Figure 3). However, over the past 20 years the electricity mix has become more diversified, while at the same time generating around 74 TWh extra electricity in 2014 compared to 1991 (+13.7%). The perhaps most significant reason for this diversification originates from the electricity generation from renewable energy sources which has expanded significantly and with a share of 25.1% by now closely follows lignite (25.5%) as second most important energy carrier in 2014 (Figure 5). In contrast, electricity generation from coal has declined as well to a share of just below 18% in 2013, while nuclear has even fallen to a share of 15.8% of German electricity generation in 2014.

Figure 3: Electricity generation per technology from 1991 to 2014

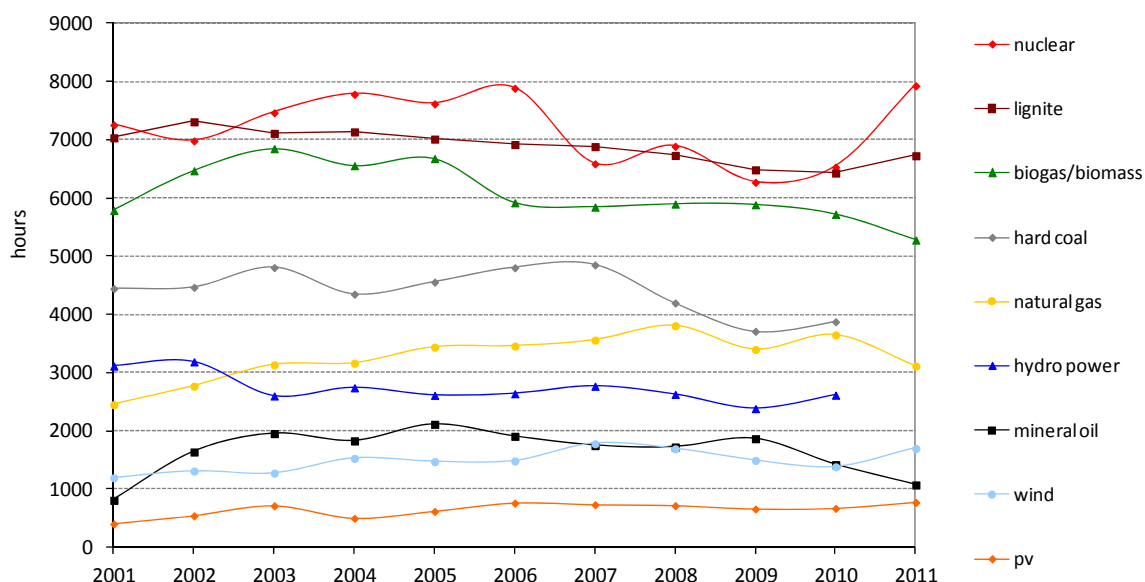


Source: BMWi 2014b

However, in 2010/11 the trend of declining shares lignite and coal fired electricity generation and increasing shares of gas reversed or at least halted, thus representing a critical point for the decarbonization of Germany’s electricity generation mix. At the one hand generation from lignite has started to rise again from 2011 onwards. Reasons for this higher utilization of existing lignite fired power plants (Figure 4) include low CO₂ prices within the EU ETS, much lower fuel prices for lignite and coal compared to gas and higher electricity exports to

neighboring countries. Another factor explaining the experienced recent increase of the share of lignite in German electricity generation may have been the need to quickly substitute for the unplanned shut down of nuclear power plants following Fukushima in 2011. On the other hand, and in contrast to lignite, the share of gas generated electricity has stopped its increase to almost 15% by 2011, and instead has fallen again to a share of roughly 10% in 2014.²

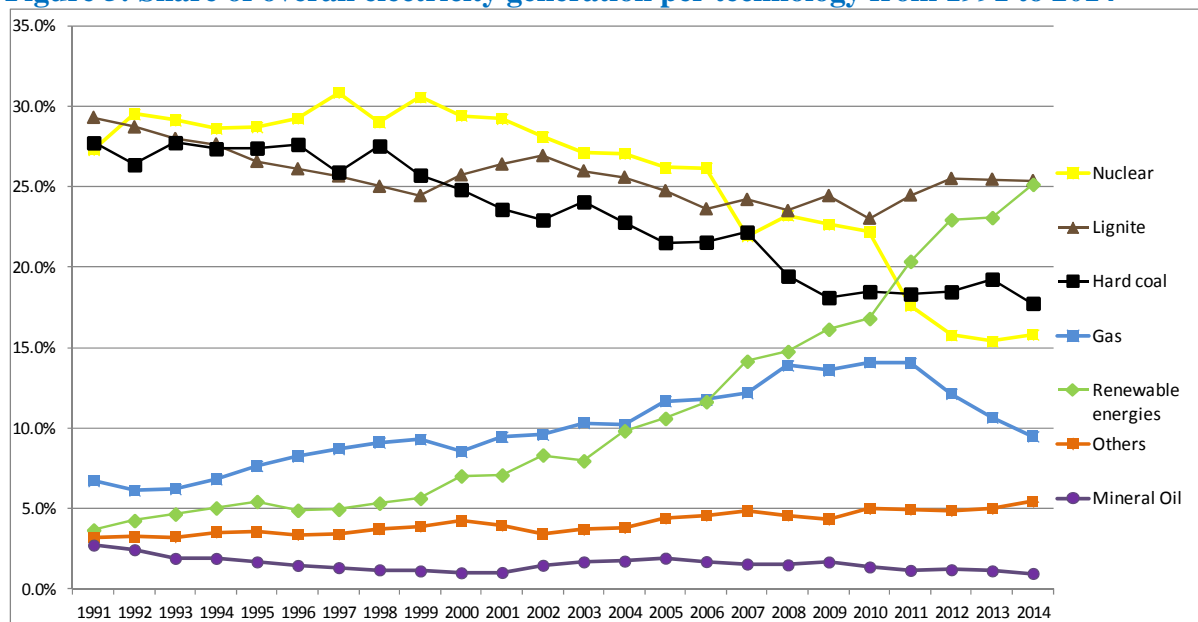
Figure 4: Development of full load hours per technology



Source: Bundesnetzagentur 2012

² In addition, it should be noted that the share of combined heat and power (CHP) in net electricity generation in Germany has steadily risen from 13.5% in 2003 to 17.3% in 2012 BMWi 2014e, Table 7.1. However, it is very likely that the policy target of 25 % will be missed significantly.

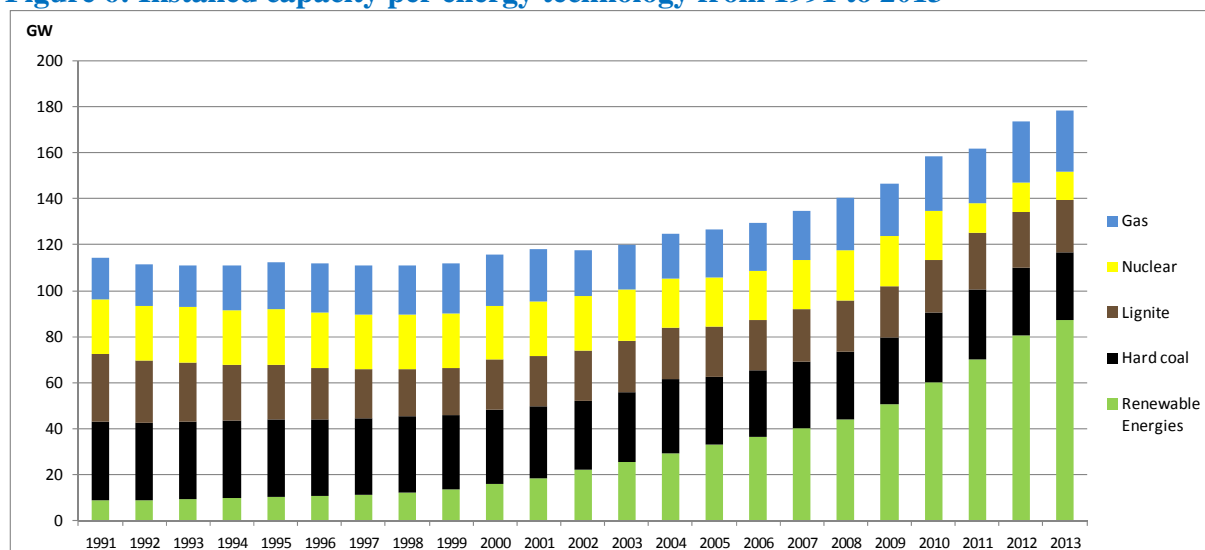
Figure 5: Share of overall electricity generation per technology from 1991 to 2014



Source: BMWi 2014b

However, the picture looks a bit different when looking at generation capacities. For the past 20 years these have significantly increased by 63 GW or +49.8% between 1991 and 2013 (Figure 6).

Figure 6: Installed capacity per energy technology from 1991 to 2013

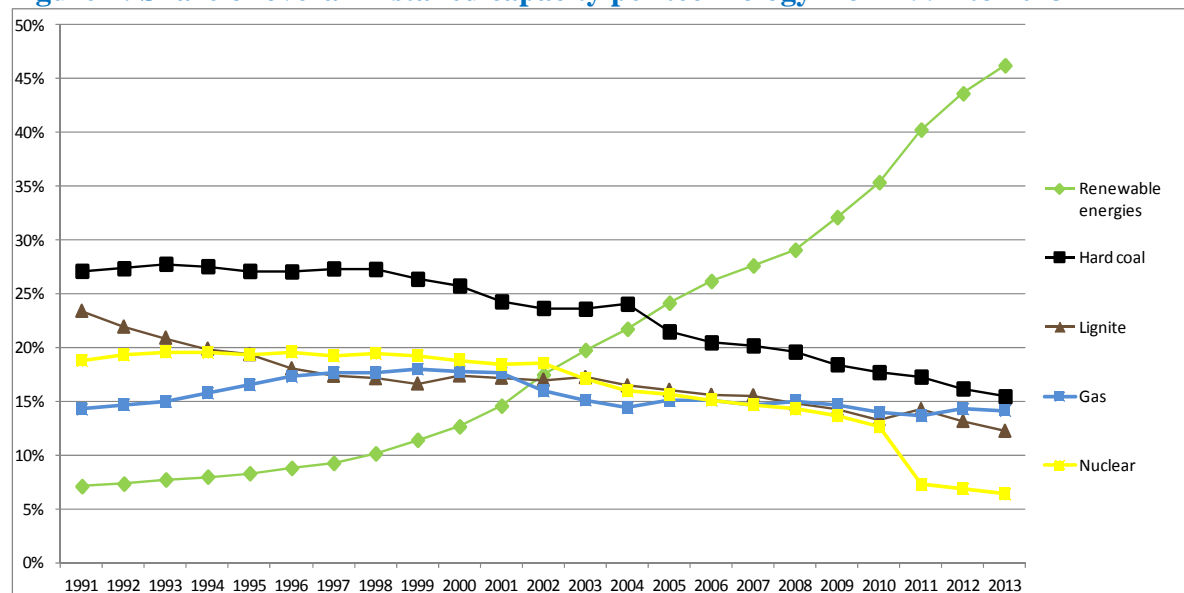


Source: Energiedaten BMWi 2014

This trend was mainly driven by the expansion of renewable energies which since 2005 constitute the largest share of German electricity generation capacities and until 2013 have further grown to a share of almost half of the overall capacities in 2013. In contrast, the share of lignite, coal and nuclear has decreased over time, while gas has by and large kept its

position. As a consequence, by 2013 coal, lignite and gas now each constitute roughly 10-15% of overall German electricity generation capacity, while nuclear capacities are down to a share of only slightly above 5% (Figure 7).

Figure 7: Share of overall installed capacity per technology from 1991 to 2013



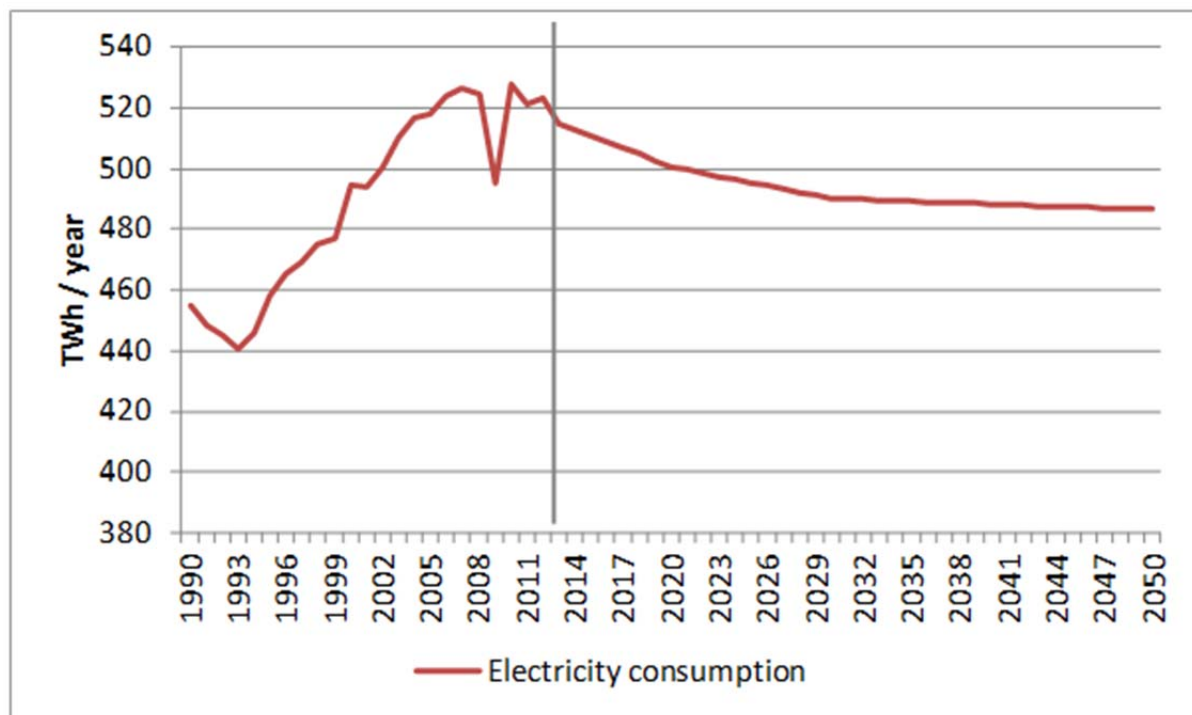
Source: BMWi 2014b

These trends indicate a future electricity generation regime dominated by renewables, and supported by gas. However, the figures also point to difficulties associated with the continued phase-out of lignite (and coal), and ongoing challenges for gas fired electricity generation, which will be explored further in the section 5.

3.2 Longitudinal developments in electricity consumption and user practices

Electricity consumption in Germany has risen by around 13% from 1990 to 2013. However, it has started to stabilize from 2006 onwards, levelling off at around 525 TWh (see Figure 8). Since 2012, a slightly decreasing trend could be observed, which is expected to continue according to the recent reference energy projections for Germany – at least in the medium-term until 2030. In the long-term, a stabilization of electricity consumption at a level of around 485 TWh is projected in a trend scenario (see Figure 8).

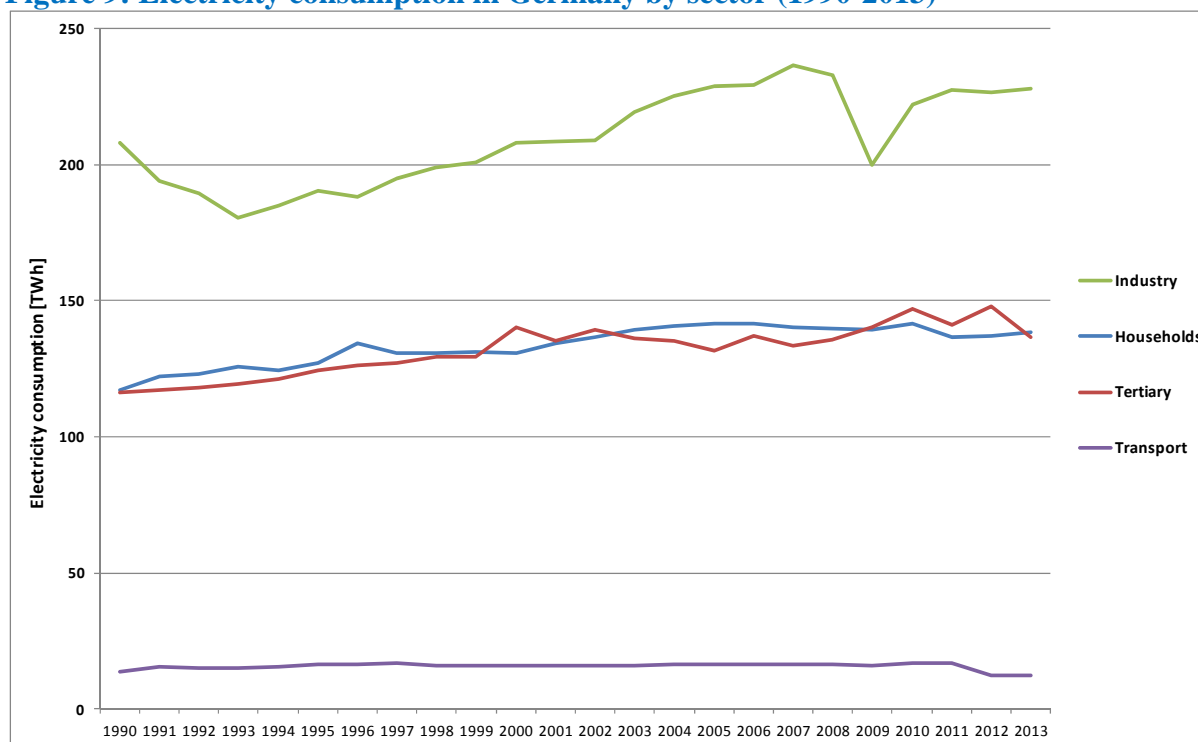
Figure 8: Past and projected net electricity consumption for Germany (1990-2050)



Source: Own combination of data from statistics until 2013 (AGEB 2014) and recent projection by Prognos et al. 2014

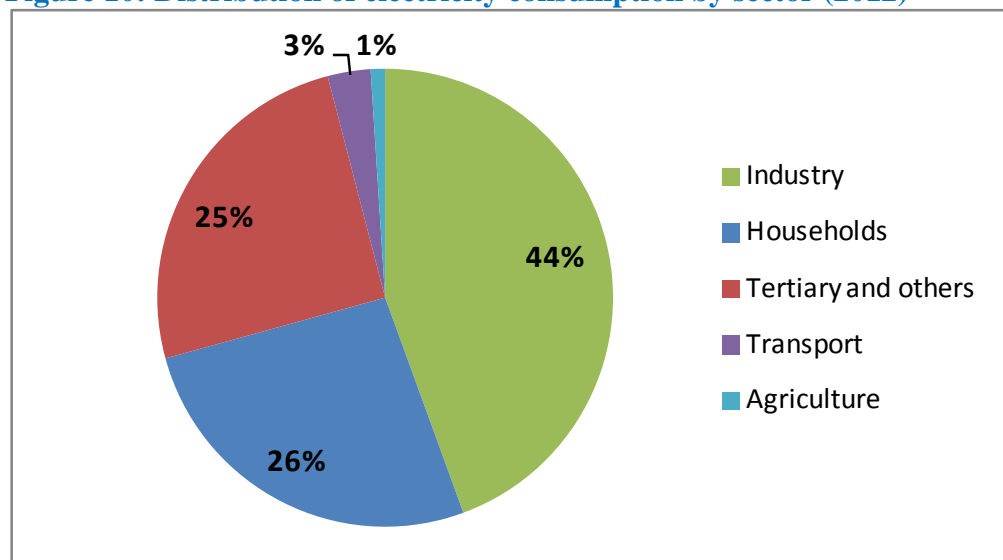
The industrial sector is by far the biggest electricity consumer in Germany and largely contributed to the increasing consumption trend until the mid 2000s (Figure 9). The use of electricity in the household and tertiary sector has risen by around 18% from 1990, but especially the domestic use shows signs of stabilization from 2011 onwards at around 137 TWh. In contrast, electricity consumption by transport has remained at a low level and has even decreased in 2011 and 2012. However, this small share of transport in final electricity consumption of just 3% in 2012 (Figure 10) may increase in future due to a trend to electrification (electric vehicles).

Figure 9: Electricity consumption in Germany by sector (1990-2013)



Source: AGEB 2014

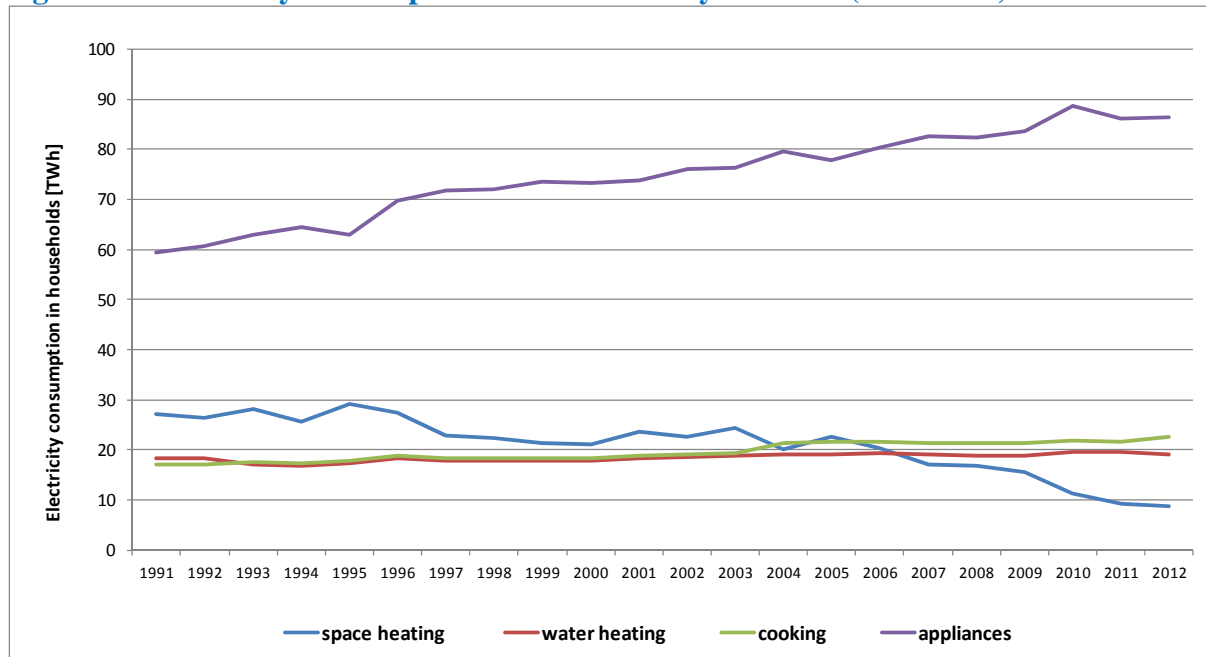
Figure 10: Distribution of electricity consumption by sector (2012)



Source: Fraunhofer ISI 2014 for Odyssee-database (www.odyssee-mure.eu)

As can be seen from Figure 11, the largest growth and biggest share of electricity consumption by households in the past is associated with electrical appliances. On the other hand, electric space heating consumption considerably decreased by almost two thirds during the last two decades and only plays a negligible role in 2012. In contrast, electricity consumption for lighting, water heating and cooking has almost remained constant over the past 20 years, exhibiting very moderate growth trends.

Figure 11: Electricity consumption of households by end-uses (1990-2012)



Source: Fraunhofer ISI 2014 for Odyssee database (www.odyssee-mure.eu)

For the longer-term, in ambitious energy efficiency scenarios electricity use by households is predicted to decrease by almost 20% between 2008 and 2030, with the biggest projected percentage decrease in lighting (-72%), while ICT as third wave of household electrification is assumed to stabilize at 2015 levels (Rohde 2012). In contrast, future electricity use by other sectors may increase, partly because of the electrification of transport (electric vehicles) and heat (e.g. electric heat pumps). As a result of these opposite trends, total electricity consumption may stabilize after 2030 (as projected in Figure 8). Other scenarios even predict a reversal of the decreasing trend after 2030 due to the new electricity uses stemming from electric heat pumps, electric vehicles, power to gas or electrolysis (Fraunhofer ISI, Öko-Institut 2014, p.250). However, the diffusion of these can at least partially be seen as decarbonisation efforts, as the shift to electricity as energy carrier allows the reduction of fossil fuels in other sectors and can lead to a reduction in emissions, if the major share of the electricity is generated from renewable energies.

3.3 Longitudinal developments in electricity transmission and distribution

The national grid is – due to liberalization and unbundling efforts – now owned by four companies which cover four regions of Germany (Figure 12):

- TenneT TSO, a subsidiary of the Dutch transmission network operator TenneT (north-to-south, including grid expansion responsibilities for offshore wind in North Sea),

- 50 Hertz owned jointly by the Belgian transmission system operator Elia and the Australian infrastructure investor IFM (east, including grid expansion responsibilities for offshore wind in Baltic Sea),
- Amprion predominantly owned by investors from the German insurance industry with the utility RWE holding a minority share (west),
- TransnetBW a company of the utility EnBW (south-west).

Figure 12: Balancing areas of the four German TSOs



Lizenz: Creative Commons by-nc-nd/3.0/de/
Bundeszentrale für politische Bildung, 2013, www.bpb.de

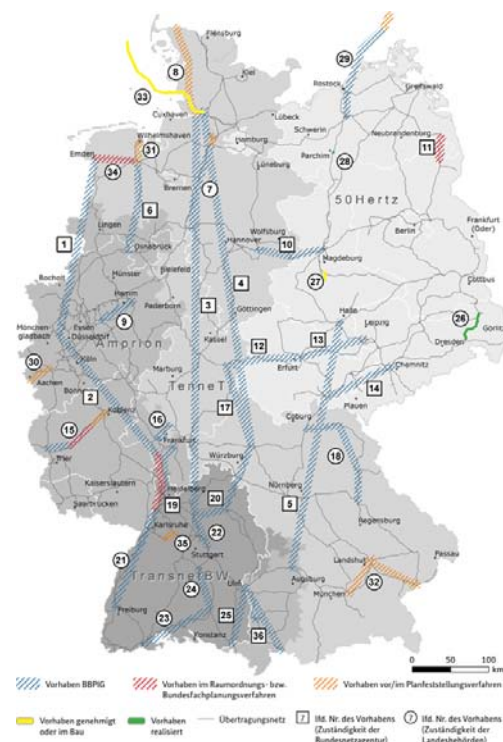
(cc) BY-NC-ND

Source: Figure published under a Creative Commons License. by-nc-nd/3.0/de/ Author: Manuel Berkel for bpb.de

There are also cross-border connections to other countries for electricity imports and exports (AT, CH, CZ, DK, FR, LU, NL, PL, SE) with exports exceeding imports (apart from 2002) significantly, even after the immediate shut-down of 8 nuclear power plants after the Fukushima incident in 2011 (BMWi 2014e, Fig. 8.7); between 2003 and 2013, electricity exports ranged between 52 and 72 TWh/a.

Given the rising share of renewables with their intermittent nature, it is widely agreed that the national grid needs to be significantly expanded, implying a large infrastructure investment need – with key planned activities shown in Figure 13 (according to BBPIG) and Figure 14 (according to EnLAG).

Figure 13: Planned grid expansion activities according to the national needs assessment – the “Bundesbedarfsplan” (BBPIG)



Source: Bundesnetzagentur 2014 - Monitoring of the projects according to the Bundesbedarfsplan (BBPIG)

Figure 14: Planned grid expansion activities according to the “Energieleitungsbaugesetz” (EnLAG)

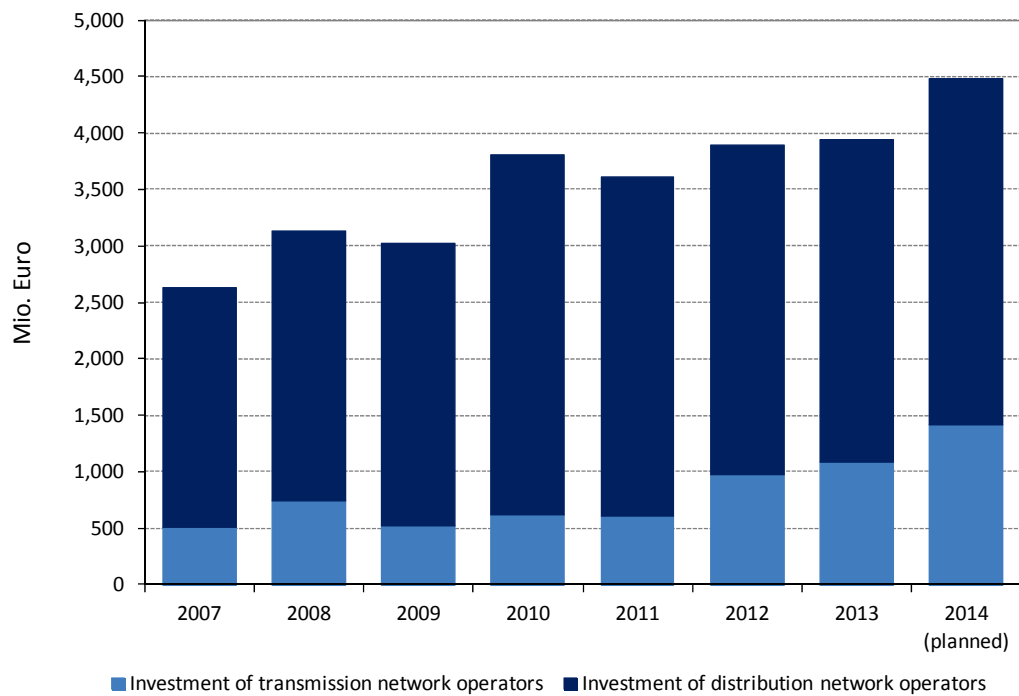


Source: Bundesnetzagentur 2014 - Monitoring of the projects according to the Energieleitungsbaugesetz (ENLAG)

Accordingly, over the past years investments into the expansion of electricity grids have risen (Figure 15). Network expansion is not only necessary in transmission networks. In particular over the recent years it became clear that massive changes are also required in distribution networks that are challenged by the increasing share of decentralized generation and reverse power flows. The absolute investments are higher in distribution network. Distribution grids also makes up the far larger part of circuit length (1.7 mio km distribution vs 35,000 km transmission network).

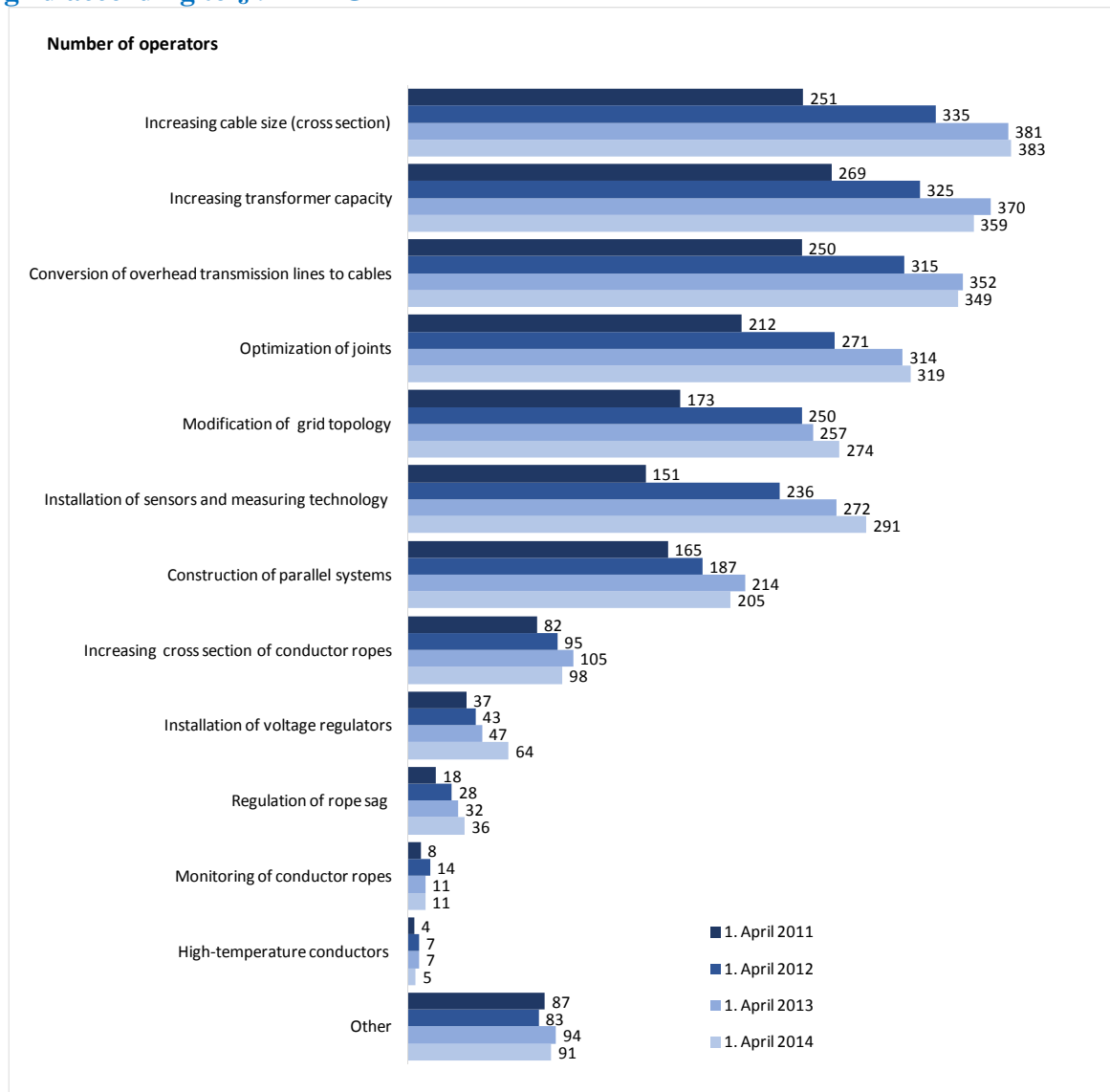
Apart from conventional network expansion also the number of measures to optimize and strengthen the networks has risen strongly since 2011. From 2013 to 2014 expansion of line width has stagnated, while further development is happening with respect to intelligent metering and control as well as restructuring (changes in network topology) as shown in Figure 16.

Figure 15: Network investments of German transmission and distribution network operators from 2007-2014



Source: Bundesnetzagentur, Bundeskartellamt 2014

Figure 16: Number of operators implementing measures to optimize and strengthen the grid according to § 9 I EEG

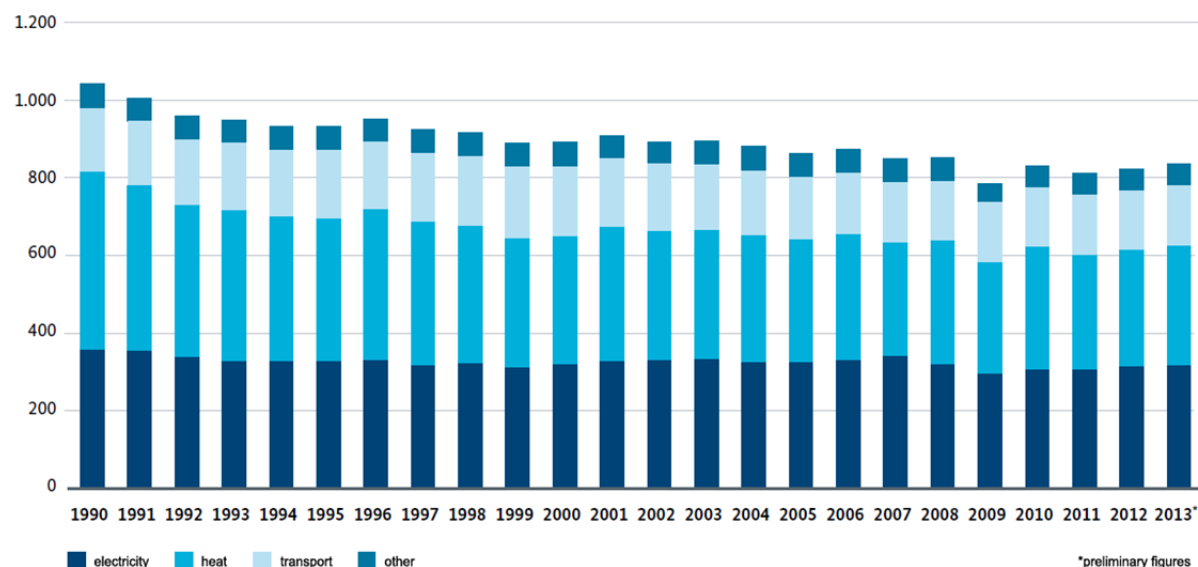


Source: Bundesnetzagentur, Bundeskartellamt 2014 (own translation)

3.4 Environmental performance (CO₂-emissions)

While the annual energy-related CO₂-emissions in Germany have decreased by 24.9% (from 1,042 Mt CO₂ in 1990 to 834 Mt CO₂ in 2013) – a trend which has been mainly driven by the heat domain – electricity-related CO₂-emissions have declined by only 12.8% in the same time period (see Figure 17). In contrast, heat-related CO₂-emissions have declined by almost 50%, while those of transport have gone down by less than 5% from 1990 to 2013. At the same time, the share of electricity-related CO₂-emissions has slightly risen from 34.3% in 1990 to 38% in 2013, while the share of heat-related CO₂-emissions has decreased from 44% to 36.9% and that of transport-related CO₂-emissions increased from 15.6% to 18.5%.

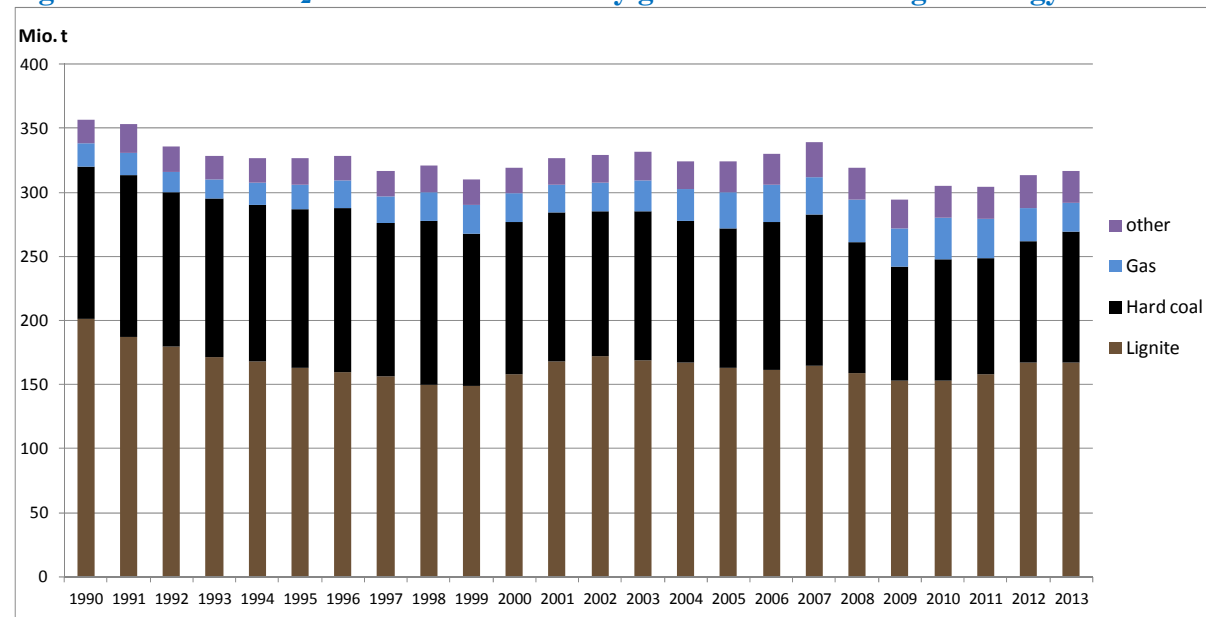
Figure 17: Energy-related CO₂-Emissions according to sectors
in Mio. t CO₂



Source: BMWi 2014h, p.46

CO₂ emissions from electricity generation in Germany have decreased from 353 Mt CO₂/a in 1990 to 294 Mt CO₂/a in 2009 (see Figure 18). However, this general decarbonisation trend has been reverted since 2010 with once again rising CO₂ emissions, reaching 317 MtCO₂/a in 2013, representing an overall reduction between 1990 and 2013 of 12.7% or 40.4Mt CO₂ (BMWi 2014h, p. 46).

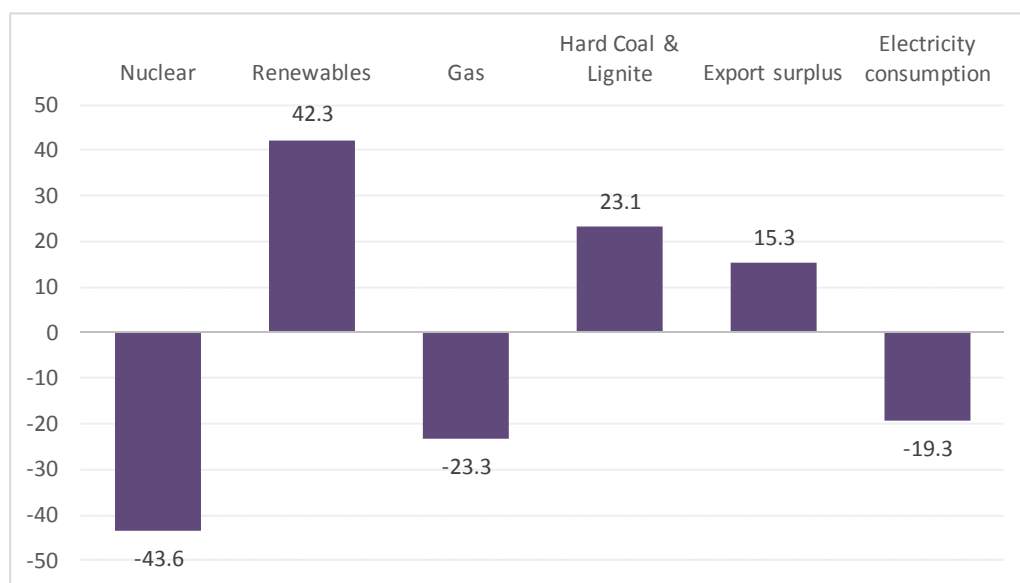
Figure 18: Direct CO₂-emissions of electricity generation according to energy carriers



Source: UBA 2014

This recent increase in CO₂ emissions has been coined the Paradoxon of the Energiewende (Agora Energiewende 2013): while renewables could be said to almost fully substitute for the reduced electricity generation by nuclear power plants, gas has been displaced by lignite and hard coal (Figure 19), owing, among others, to low CO₂ prices and decreased hard coal prices on the world market associated with shale gas developments in the US. This development has resulted in heated political debates about additional policies to close the gap, including a penalty fee for old coal-fired power plants³.

Figure 19: Change in German electricity generation and consumption between 2010 and 2013 (in TWh)

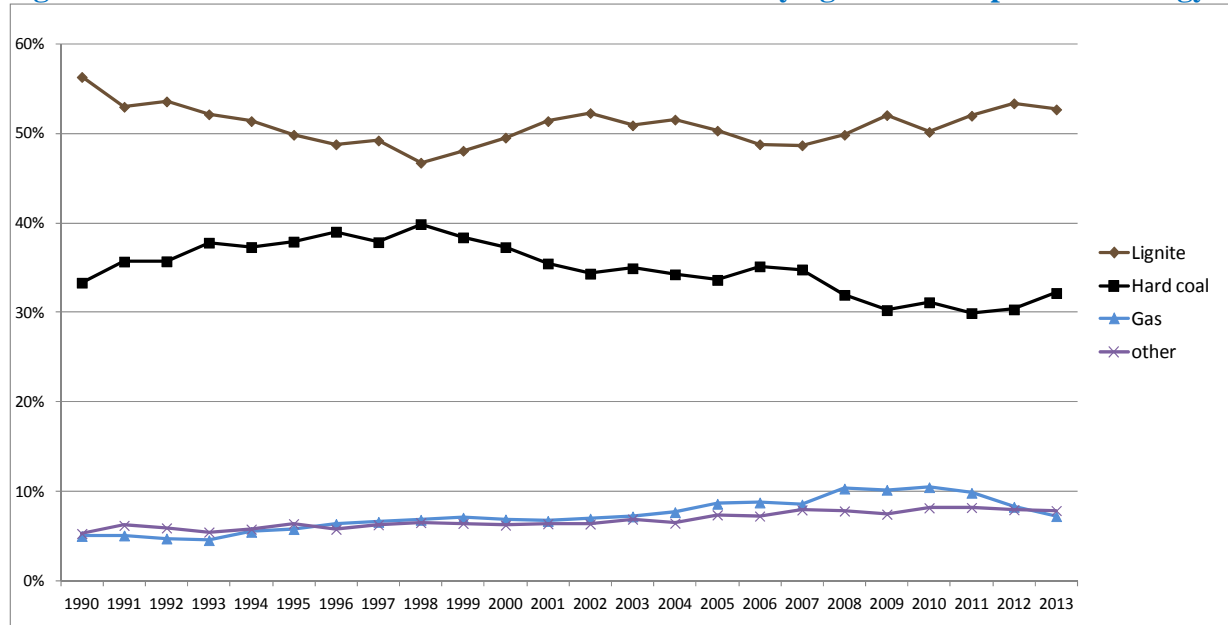


Source: Agora Energiewende 2013, p.9

Half of the electricity-related CO₂-emissions in Germany originate from lignite (see Figure 18 and Figure 20) – which is slightly down from 56.1% in 1990 to 52.7% in 2013, with the lowest share reached in 1998, some ups and downs thereafter, but a rising trend particularly pronounced from 2010 onwards. The second most important source of electricity-related CO₂-emissions is hard coal (with a share of 32.2% in 2013, almost unchanged compared to 33.2% in 1990, although its share was rising up to 40% in 1998 and since then has by and large declined until 2009). In comparison to those two sources of CO₂ emission the share of gas is almost negligible (7.3% in 2013, up from 5% in 1990), while emissions from oil (1.3%), fossil waste (4.1%) and others are below 8% of overall electricity-related CO₂-emissions in 2013 (BMWi 2014h, p. 47).

³ <http://www.spiegel.de/politik/deutschland/kohlekraftwerke-cdu-ministerpraesidenten-kritisieren-klimaabgabe-a-1025961.html>

Figure 20: Share of CO₂-emissions from electricity generation per technology



Source: UBA 2014

4 External landscape developments

The development of the German electricity system over the past 10-20 years has been affected by several exogenous landscape developments. Many of these factors put pressure on the existing regime and thus destabilize it, although some factors also contribute to stabilizing the electricity regime.

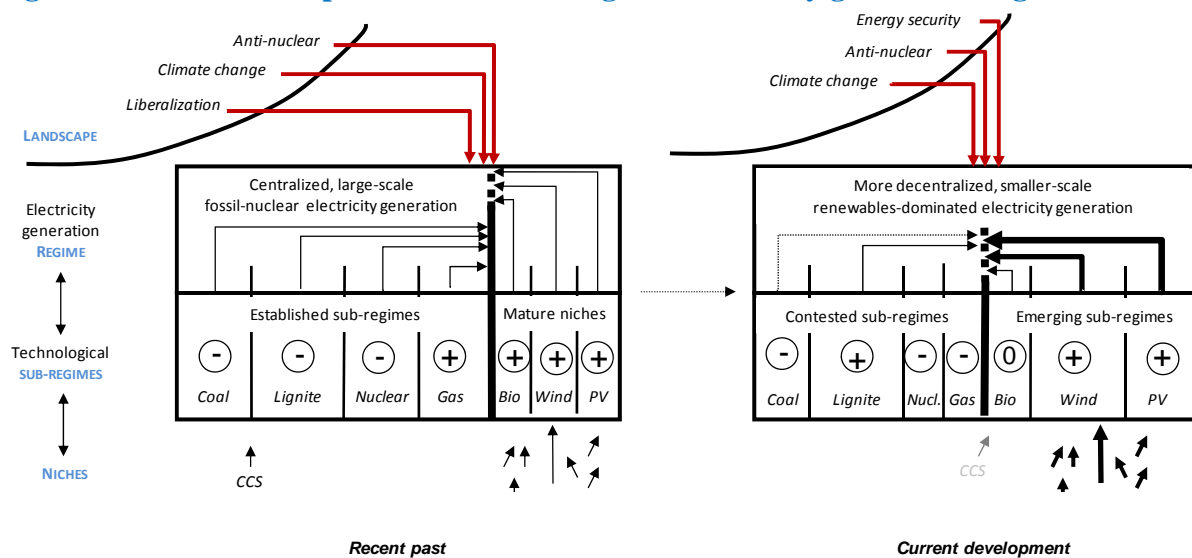
- Perhaps the most influential landscape factor has been Germany's *strong anti-nuclear movement*. There was a very strong public reaction to two nuclear accidents abroad, the first one at Chernobyl in the Ukraine in 1986 and the second at Fukushima in Japan in 2011. This ultimately led to a cross-party agreement to phase out nuclear power in Germany by 2022, thus bringing the country back on track with the initial phase-out negotiated by the government of Social Democrats and Greens under Gerhard Schroeder in 2000 (Morris, Pehnt 2012).
- The global issue of *climate change* has been on the political agenda since 1989 (Helmut Kohl) and has increased in importance since then. This is evidenced by the European CO₂ price signal introduced through the EU emissions trading system in 2005, the pivotal role played by the "climate chancellor" Angela Merkel in adopting the EU's 20-20-20 energy and climate targets for 2020, and Germany's ambitious climate targets for 2050. However, attention to climate change at the top level of government has declined since 2008 and particularly since the failure of Copenhagen in 2009, although there have been some recent signs of a revival given the increases in CO₂ emissions and the lurking gap in target achievement (UBA 2015; Morris, Pehnt 2012).
- The *liberalization* of the electricity market and the unbundling of utilities driven by EU regulation broke up the oligopoly market structures in Germany and led to a restructuring of the industry, resulting in four big, internationally more active

- electricity suppliers and four big transmission system operators (Markard et al. 2004; Markard, Truffer 2006).
- The *German proportional voting system* that allows small parties (with a share over 5%) to send the corresponding number of representatives to parliament made it possible for the Green Party to enter the national parliament in 1983, thereby giving a parliamentary voice to “Green” concerns (about the climate, nuclear accidents, nature conservation). When the Greens became part of a coalition government with the Social Democrats (1998-2005), they were able to use their influence to introduce the Renewable Energy Act (EEG) in 2000 and defend it in 2004, despite strong opposition from regime stakeholders (Jacobsson, Lauber 2006). With hindsight, the introduction of the EEG can be interpreted as the most influential policy change as it sowed the seeds for and functioned as a catalyst for the German Energiewende.
- As an *engineering and manufacturing nation* and export champion, Germany plays a driving role in developing renewable energy technologies, such as solar PV or wind, and the German government is harnessing this innovativeness through its High-Tech Strategy and its recognition that environmental policy can function as industrial policy, creating green growth, jobs and income (Quitow et al. 2014; BMBF 2014; BMWi 2014a).
- The *financial and economic crisis* brought about a fairly moderate and relatively temporary decline of industrial electricity demand in 2009, but in the longer term it has led to a fairly strong decline in electricity spot market prices and thereby to lower profit margins for electricity generation (BMWi 2014h).
- There are also wider *environmental sustainability concerns* such as nature conservation and the protection of biodiversity, which lead to public resistance to CCS, scepticism about shale gas, or debates about corridors for new transmission lines (Duetschke et al. 2014; Heinrich Boell Foundation 2013; Soini et al. 2011).
- The industrial structure in Germany with several *energy-intensive branches* calls for reliable supply and low electricity prices in order to safeguard its international competitiveness and safeguard jobs and income at home (BMWi 2014a).
- *Energy security* concerns, particularly regarding the dependence on Russian gas, cast a favourable light on lignite as a domestically available energy source (but also benefit renewable energies) (German Government 2010).
- The *electrification of mobility and heat* is expected to increase electricity demand in the coming decades. This will supplement the expected rising demand from IT equipment (laptops, mobile phones, tablets), thereby providing good growth prospects for electricity suppliers (Bossmann et al. 2013).
- *Green ICT (smart technologies)*, which is favoured by German policy and European Directives (Ecodesign and Labelling, Energy Star), could influence regime development, especially in the longer term, but has already had an impact so far. However, the potential use of smart meters, which are strongly driven by EU regulation, may be limited due to high data protection standards (BMWi 2015b).

5 Developments in electricity generation regime

We start our analysis of developments in the electricity system by examining key changes in the electricity generation regime (Figure 21). In section 5.1 we first depict developments in the main tangible system elements, differentiating between the sub-regimes lignite, hard coal, nuclear and gas, and then in section 5.2 we describe the main social groups and intangible elements of the electricity supply regime.

Figure 21: Schematic representation of changes in electricity generation regime



Source: Own illustration inspired by Schneider et al. 2010; Rogge, Hoffmann 2010 and Geels 2004

5.1 Developments of the main tangible system elements

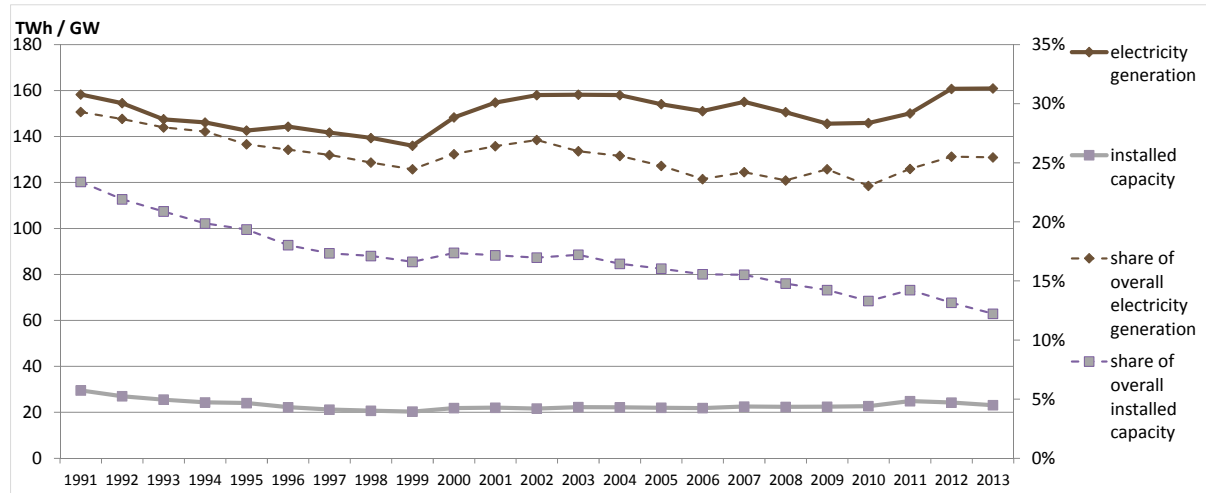
Over the past twenty years the mix of electricity generation technologies in Germany has changed substantially, with reduced capacities and electricity generation by nuclear, hard coal and lignite and increased shares for renewable energies and natural gas. The development of renewable energies was described in detail in deliverable 2.1 of the PATHWAYS project for PV, on- and offshore wind and bioenergy. This report will focus on developments of lignite, hard coal, nuclear and gas, but at times will compare their developments with those occurring in renewable energies. We start by separately discussing changes in generation capacities, actual generation of electricity, and full load hours for lignite, hard coal, nuclear and gas. We then compare knowledge creation and public R&D funding for these sub-regimes.

Lignite

Lignite is the most carbon-intensive energy carrier in the German electricity system. Between 1991 and 2013 its generation capacity has decreased by 21.7%, with its share of German electricity generation capacity even down by 47.7% (given the increase in overall capacity). However, full-load hours of lignite fired power plants have increased by 29.8%, and in

consequence electricity generation increased by 1.6% between 1991 and 2013. Yet, due to the overall increase in electricity generation the lignite's relative share decreased by 13.1% in the same period (Figure 22).

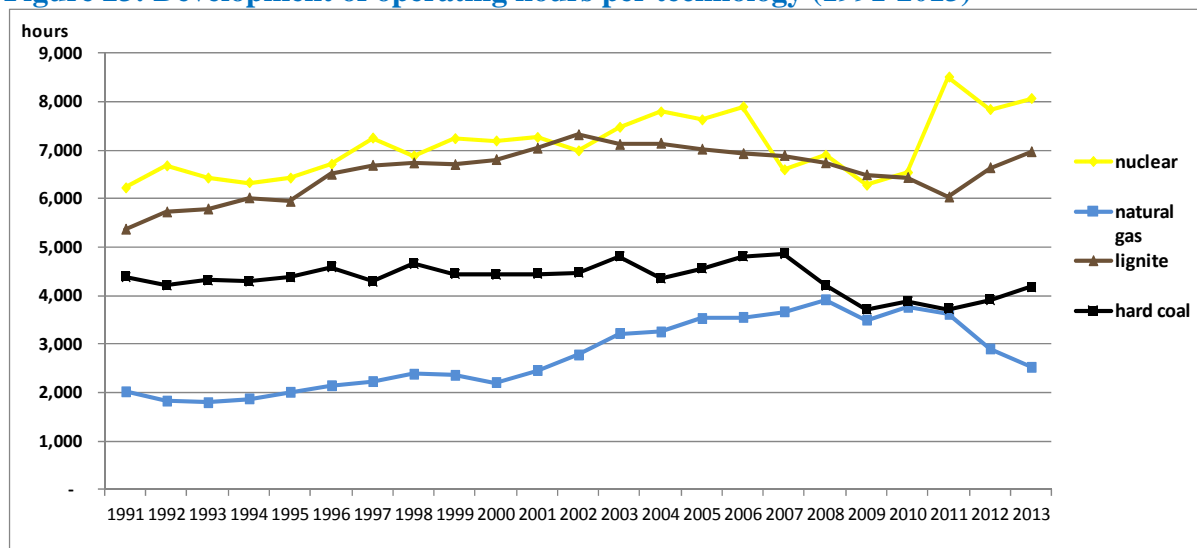
Figure 22: Installed capacity and electricity generation from lignite power plants from 1991 to 2013



Source: Own illustration based on BMWi 2015a

While indicating a slightly declining trend for capacities, it is important to note that electricity generation based on lignite has started to increase since 2011 – with negative implications for CO₂ emissions. That is, by 2013 the share of lignite capacity was down to 12.2% while generation still covered 25.5% of Germany's electricity generation (BMWi 2015a). Reasons for this increase in lignite's full load hours since 2011 are the very low CO₂ prices in the EU ETS (Figure 31) which allowed lignite to fill the sudden gap created by the unexpected moratorium on nuclear plants in 2011. Furthermore, lignite power plants do not shut down or decrease their production in times of high generation from renewables, but rather export power to neighboring countries due to the low generation costs.

Figure 23: Development of operating hours per technology (1991-2013)

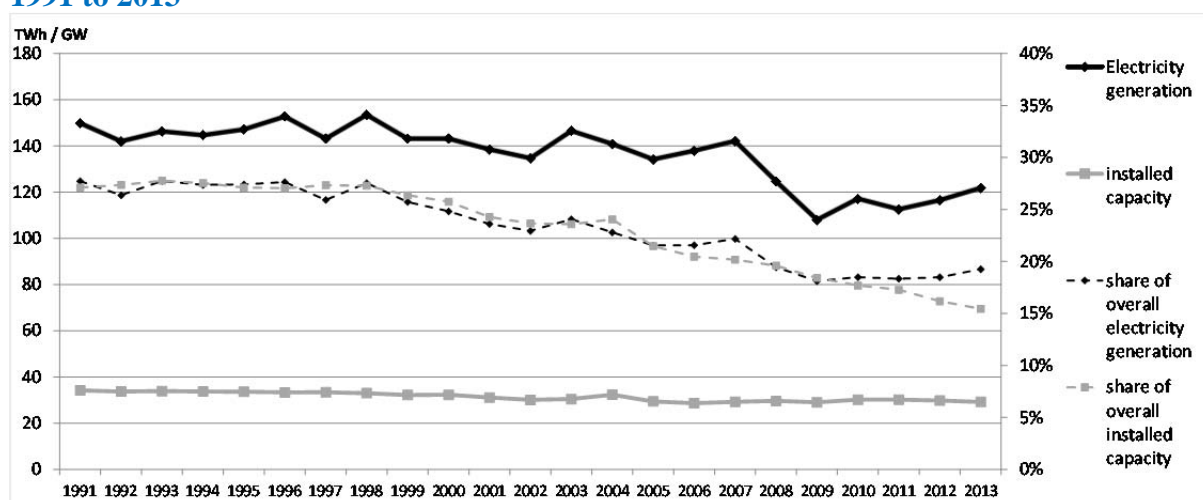


Source: Own calculation based on BMWi 2015a

Hard Coal

Hard coal represents the second most carbon-intensive energy carrier in the German electricity system. Between 1991 and 2013 its generation capacity has decreased by 14.7% and thus not quite as much as for lignite. Yet, given the overall increase in generation capacity the share of hard coal in German electricity generation capacity decreased by 43.0% and thus almost as much as that for lignite.

Figure 24: Installed capacity and electricity generation of hard coal power plants from 1991 to 2013



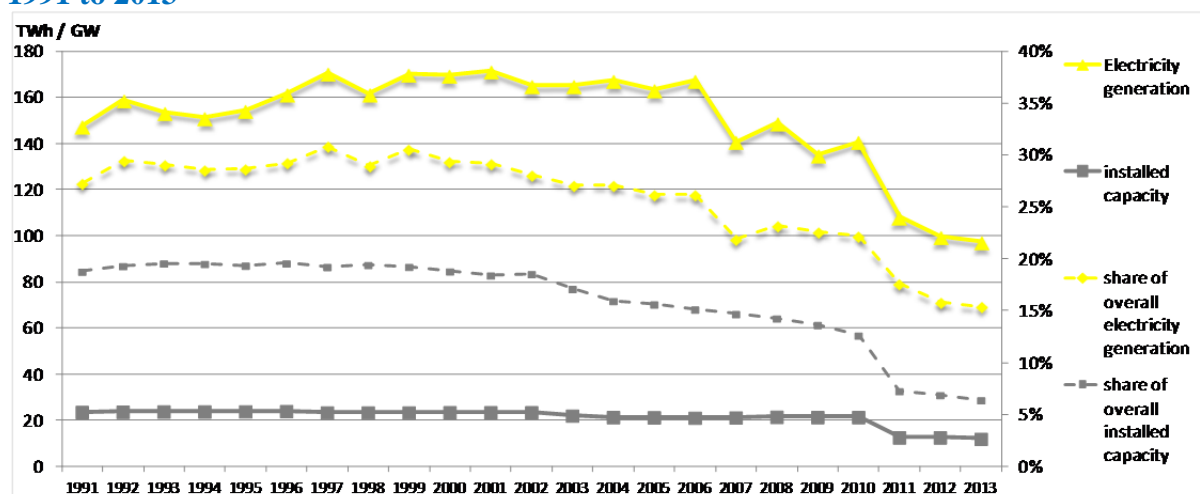
Source: Own illustration based on BMWi 2015a

However, full-load hours of coal fired power plants only decreased by 4.8% between 1991 and 2013, while electricity generation has declined by 18.8% between the same period – and its share of total electricity generation even decreased by 30.5%. Yet, hard coal has experienced a slight revival since 2012, with negative implications for CO₂ emissions. That is, in 2013 the share of hard coal capacity was down to 15.4% while generation still covered 19.3% of Germany's electricity generation (BMWi 2015a).

Nuclear

Germany is committed to phasing out nuclear electricity generation by 2022, following a predetermined step-wise plan agreed in 2011 (see Figure 33). Until 2002 generation capacities have been fairly constant (see Figure 25), and thereafter were scheduled to be taken offline following a gradual phase-out plan negotiated between the Schroeder government and the nuclear industry, which however in 2010 was abandoned by the Merkel government. Yet, following the nuclear accident of Fukushima in 2011 the Merkel government shut down eight plants immediately with further plant closures thereafter. Hence, between 1991 and 2013 nuclear generation capacity decreased by 49.1%, most of which occurring in 2011. When taking into consideration the overall increase in generation capacity in Germany the share of nuclear even decreased by 66% (1991-2013) and is down to 6.4% in 2013.

Figure 25: Installed capacity and electricity generation of nuclear power plants from 1991 to 2013



Source: Own illustration based on BMWi 2015a

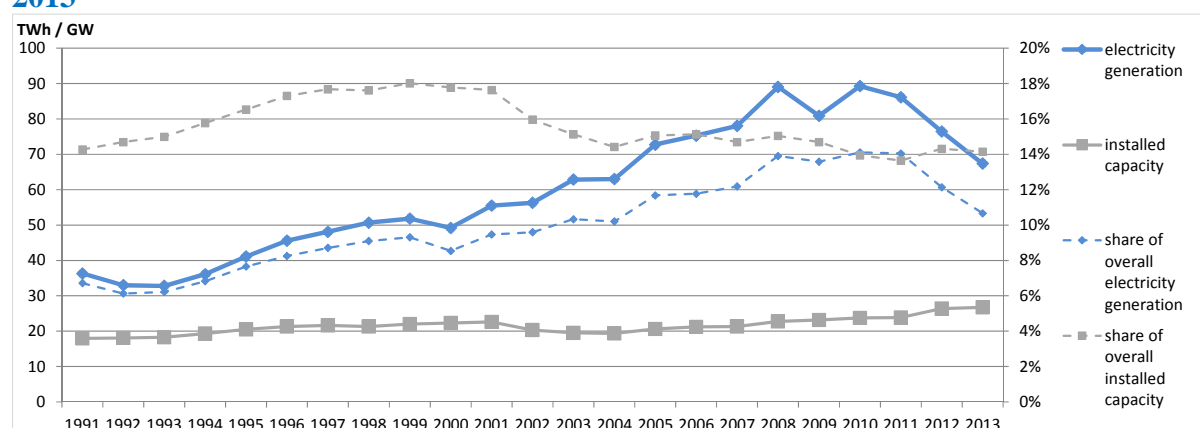
However, the full-load hours of nuclear power plants have increased until 2006, after which they decreased but then jumped up again in 2011 – representing an overall increase by 29.6% between 1991 and 2013. They have reached an all-time high of 8,504 hours in 2011 which only slightly decreased by 2013. Nevertheless, given the massive reduction of generation

capacity in 2011 electricity generation by nuclear has declined by 34% between 1991 and 2013. In the same period, nuclear's share of total electricity generation has even decreased by 43.6%, which is clearly driven by the government's phase out decisions. Consequently, in 2013 the share of nuclear electricity generation was down to 15.4% (BMWi 2015a), with the complete phase-out scheduled for 2022.

Natural gas

In contrast to decreasing generation capacities for lignite, coal and nuclear, gas fired electricity generation capacities have substantially increased (by 48.5%) between 1991 and 2013, with a short intermediary decline in 2002 and 2003. However, due to the increase in overall generation capacity in relative terms the share of gas capacities has remained unchanged over the same time period and reached 14.1% in 2013 – although it had first increased until 2001, after which it started to decrease again (see Figure 26).

Figure 26: Installed capacity and electricity generation of gas power plants from 1991 to 2013



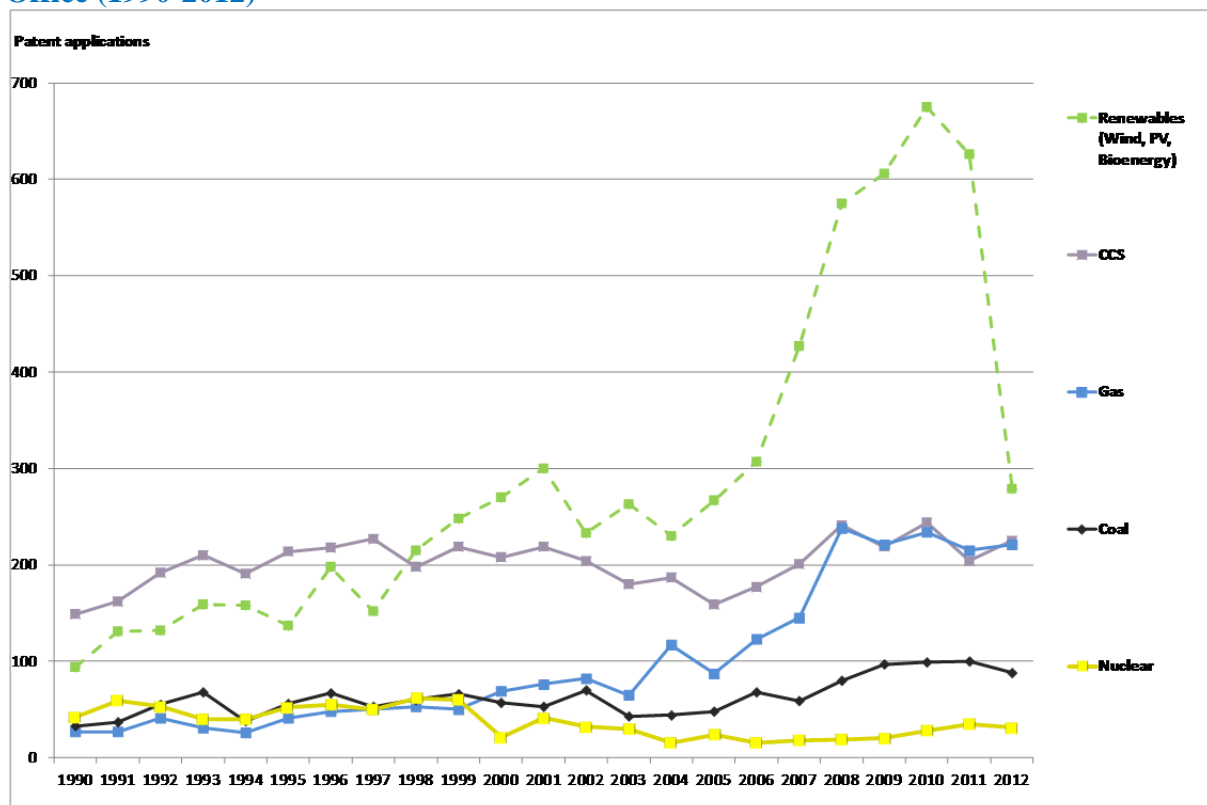
Source: Own illustration based on Energiedaten BMWi 2014, Second Monitoring Report

In addition, full-load hours of gas fired power plants have increased by 48.5% from 1991 until 2008, but then started to decline substantially, reaching 2,521 hours in 2013 which is 25.1% above the 1991 level, but 35.6% below the maximum in 2008. Consequently, electricity generation has experienced a massive increase of 245.4% until 2008, but particularly in 2012 and 2013 it has decreased substantially, resulting in a share of only 11% of overall electricity generation (which, however, is still clearly above the share in 1991). That is, coal and lignite saw a revival in 2012 and 2013 (+14.7 TWh in 2012, 5.5TWh in 2013), largely at the expense of gas (-9.7 TWh in 2012, -9.0 TWh in 2013) (BMWi 2015a). A central problem in this context are the low carbon prices in the EU ETS, which fail to give even new, highly efficient gas power plants a competitive advantage over older, inefficient coal or lignite fired power plants (Figure 31).

Knowledge generation as measured through patent applications

Knowledge generation in the German electricity supply system is another indicator for the regime being significantly challenged by renewable energies, given the massive expansion of knowledge creation particularly for PV and wind from 2004 onwards (Figure 27). In contrast, knowledge creation in the nuclear sub-regime declined since 1981, although patent applications have started to slightly increase again in 2007, albeit at a low level. In contrast, knowledge creation for the gas sub-regime has surged since the introduction of the EU ETS in 2005 and stabilized at a high level from 2008 onwards, despite low-carbon prices. This suggests that innovators believe in the compatibility of the gas sub-regime with the emerging new electricity regime building around a high share of decentralized and intermittent renewable energies. In contrast, patent applications within the coal sub-regime have increased much less, with the biggest increase since 2007 when low CO₂-prices in the EU ETS became apparent. However, if adding the high and relatively stable level of patent applications for Carbon Capture and Storage (CCS), then coal and CCS constitute the highest number of patent applications, only overtaken by renewables in the period from 2007 until 2011.

Figure 27: Development of patent applications at the German Patent and Trade Mark Office (1990-2012)

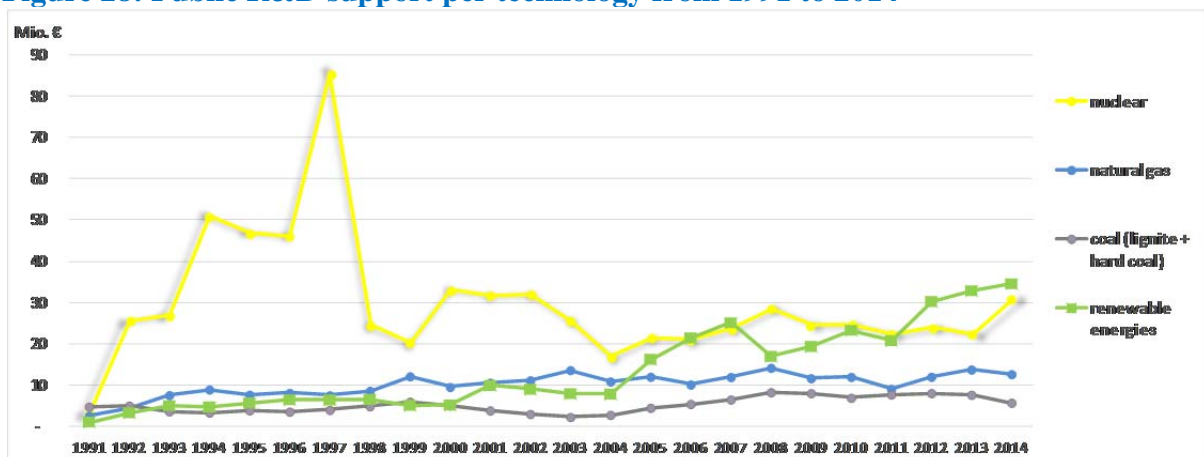


Source: Own compilation based on PATSTAT 2015

Public R&D funding

However, these patterns of knowledge creation do only partly reflect public R&D funding which has also undergone significant changes within the period 1991 and 2013, including an substantial overall increase since 2004 (see Figure 28). When comparing the figures for fossil fuels and nuclear with those for renewables it is evident that the German government in the past 20 years has started to prioritize R&D support for renewable energies, such as PV and wind, but has refrained from downsizing R&D support for fossil fuel based electricity generation. On the contrary, public R&D support for coal has increased, with one key driver being support for CCS. However, CCS knowledge creation already occurred in the period from 1990 till 2005, despite public R&D funding levels being very low back then (reaching their maximum in 2011, after which they significantly decreased again). It is also noteworthy that gas has seen a 20-fold increase public R&D spendings in the past 20 years, indicating the key role past and current governments have foreseen for this technology – which is clearly in line with patenting trends. In contrast, R&D support for nuclear peaked in 1997, and then dropped significantly, but continues to receive higher absolute figures than coal and gas (note that most of this support is labeled under the category decommissioning and dismantling).

Figure 28: Public R&D support per technology from 1991 to 2014

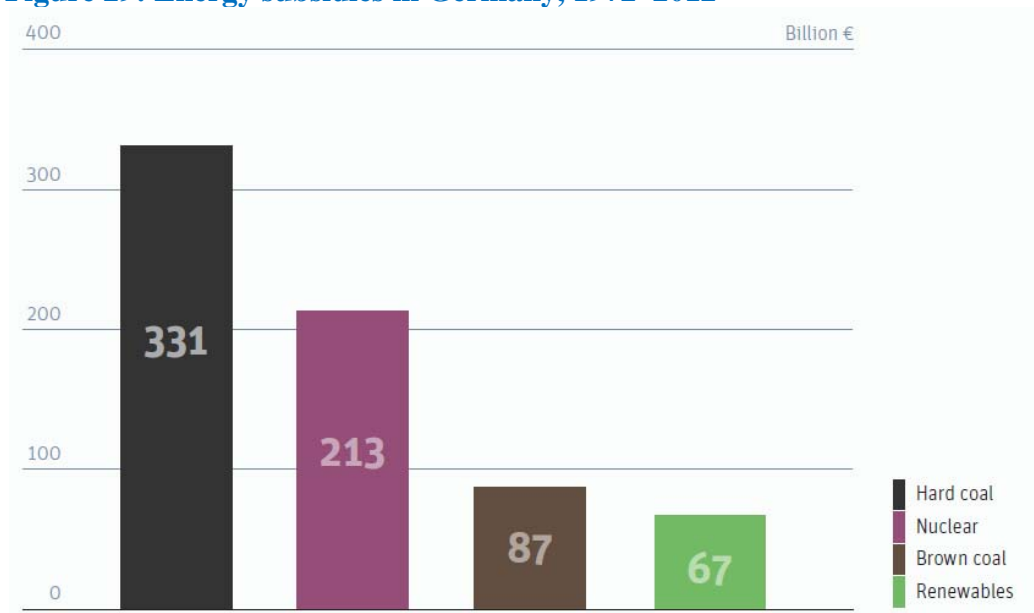


Source: Own compilation based on the EnArgus database

However, when interpreting these figures it is important to keep in mind that in terms of overall public subsidies received renewable energies are still catching up with accumulated subsidies for nuclear and fossil fuels. However, concrete figures vary depending on the scope of calculation. A study by Green Budget Germany calculated that hard coal had received 331 billion € between 1972-2012⁴, nuclear 213 billion, lignite 87 while renewables had been subsidized in the same period by 67 billion € (see Figure 29). As of 2013, coal is still receiving 2.5 billion Euros of state support, which represents a significantly reduced support level compared to 2000 when coal subsidies amounted to 4.45 billion Euros in 2000 (Geels et al 2015).

⁴ Subsidies for hard coal have risen from 0.4 billion Euros in 1975 to more than 4 billion Euro in the early 1990s. However, German mining of hard coal is being phased out, with the number of mines down from 146 in 1960 to 12 in 2000 (Jacobsson, Lauber 2006).

Figure 29: Energy subsidies in Germany, 1972–2012

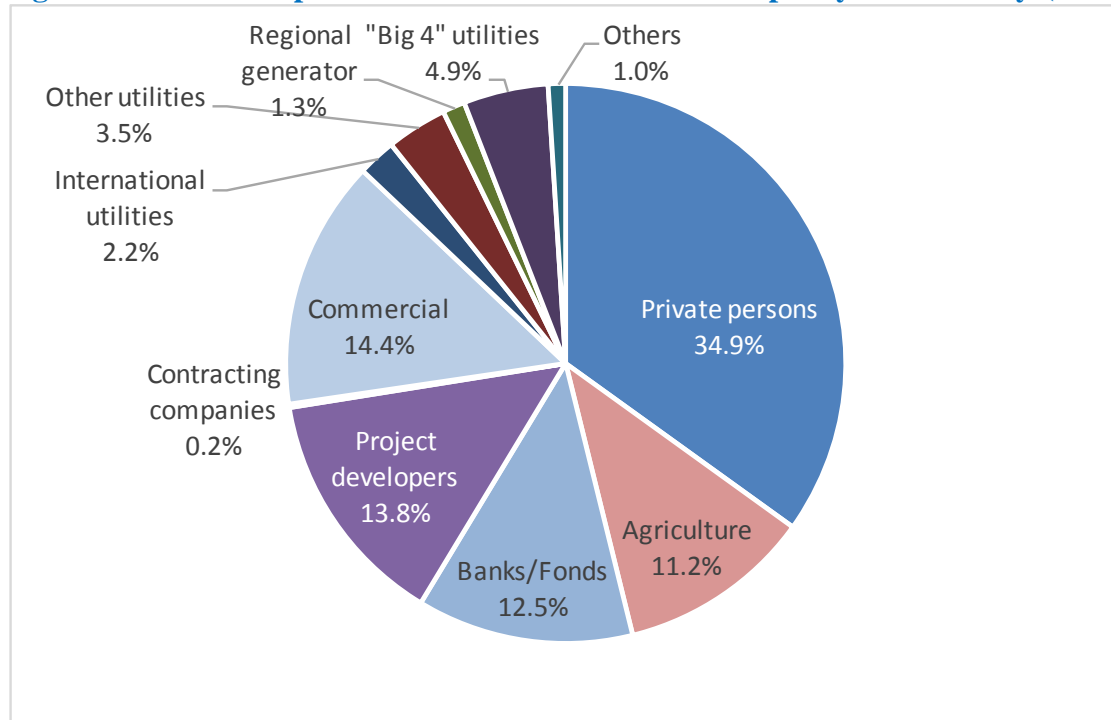


Source: Green Budget Germany 2012

5.2 Main social groups and intangible regime elements

The described technological shift towards renewable energies has been associated with a diversification of German electricity generators and a corresponding reduction of the market share of the ‘big 4’ utilities (RWE, E.ON, Vattenfall Europe, and EnBW) – from 90% of electricity generation in 2003/04 (and owning 82% of capacities) to 74% of generation in 2013 (and 68% of capacities) (Bundesnetzagentur 2007; Bundesnetzagentur, Bundeskartellamt 2014). One key reason for this loss in market share of the ‘big 4’ is that the transition towards renewable energies has not been driven by them (or other incumbent electricity generators) but instead mainly by private persons, farmers, industry, project developers and banks (Agora Energiewende 2013). More precisely, by 2012 the ‘big 4’ owned less than 5% of renewable electricity generation capacities (and all utilities less than 12%), while households and farmers together owned roughly 46% of renewable capacities in 2012 (Figure 30). Another reason for this reduction of the market dominance of the ‘big 4’ is that new players have entered the market for large-scale coal and gas fired electricity generation, particularly since the introduction of the EU ETS with its initially generous free allocations for new build coal, lignite and gas fired power plants. For example, in the period from 2005 until 2014 TRIANEL, a new entrant which offers virtual slices of large scale power plants, e.g. to municipal utilities, started operating both a coal and a gas fired large-scale power plant (Bundesnetzagentur 2014). This opened new options for the many municipal utilities to participate in the build up of own generation capacities.

Figure 30: Ownership shares of installed renewable capacity in Germany (EEG 2012)



Source: Agora Energiewende 2013

In the following we trace key developments and changes in the beliefs and strategies of incumbent utilities (in particular the ‘big 4’) and their interactions with policy makers and other influential actors since 1990, and in doing so we will discuss their responses to landscape factors and niche developments. We will separate our analysis in two parts: We start with a quick overview of regime developments between 1990 and 2004 when there was no monetary carbon constraint affecting the sector, but other key developments were initiated, such as the introduction and improvement of market support for renewable energies, the liberalization of the electricity sector, and the first nuclear phase out. We will then discuss in more detail the period between 2005 and today which coincides with the existence of a price of carbon, but also includes the formulation of ambitious long-term targets for renewables and CO₂ emissions, the confirmation of nuclear phase out and the pursuit of the Energiewende – the German energy transition.

PART I: Electricity generation regime prior to introduction of monetary carbon constraint (1990-2004)

In the early nineties the electricity generation sector in Germany was tightly regulated and constituted of nine vertically integrated public utilities serving eighty regional supply companies and some 900 municipal utilities (Geels et al. 2014). Electricity generation was dominated by large-scale, centralized fossil and nuclear power plants owned by the public utilities and to a smaller extent also by the regional supply companies. Niche actors faced heavy regime resistance in their first attempts to introduce an instrument supporting the

deployment of small-scale renewable power generation technologies. Consequently parliamentary initiatives for creating niche markets for renewables failed in 1987, 1988 and 1989, mainly because of strong opposition from the Economics Ministry with its close links to incumbent generators (Jacobsson, Lauber 2006).

However, a new proposal to implement a feed-in law (FIL) for renewables which was also supported by the manufacturing industry was finally adopted by Helmut Kohl's government in 1991, mainly because regime players were preoccupied with the German reunification and politicians hoping for a greener image in the upcoming elections. The feed-in compensation was attractive for investments in wind energy, but utilities found that wind as small-scale and decentralized technology did not fit their existing business model of large scale generation. They also made negative experiences with their R&D activities on larger scale wind turbines, and thus remained very reluctant (Stenzel, Frenzel 2008). Nevertheless, the wind market started to grow rapidly due to investments by new entrants which led to a previously thought impossible market penetration rate of 5% of renewables by 1994. As such renewables started to impact utilities because as grid operators they were obliged to grant priority grid access and buy all renewables electricity. They responded with legal, political and technical battles in an attempt to limit the continuing growth of renewable energies – and temporarily succeeded as indicated by a period of stagnation and uncertainty for wind between 1995 and 1998 (Stenzel, Frenzel 2008).

The year 1998 brought two major changes: first, the previously tightly regulated German electricity sector was liberalized in 1998, following regulatory pressure from the EU. In addition, generation, transmission and distribution needed to be unbundled. Through a series of mergers and acquisitions this process ultimately led to the emergence of the 'big 4' utilities which by 2003/04 generated 90% of German electricity (Bundesnetzagentur 2007). In addition, the 'big 4' started to expand their activities beyond German borders and saw an increase in their stock exchange values until 2007/08 (Geels et al. 2014). Liberalization also required utilities to change their investment appraisal processes for new plants and led to an increase in their innovation activities (Markard et al. 2004; Markard, Truffer 2006). In addition, liberalization also enabled new entrants to solely sell green electricity, and thus to tap into the green market segment.

The second major change for the electricity regime were the German elections in 1998 which led to the first German government coalition with the Green Party – as junior partner of the Social Democrats under chancellor Gerhard Schröder. This signalled a much greater political commitment to renewable energies, which was confirmed in 2000 when the Renewable Energy Law (EEG) significantly improved market support for renewable energies with its technology-specific feed-in tariffs, guaranteed remuneration for typically 20 years and priority grid access (for further details on the policy design and its impact see (Rogge et al. 2015). In addition, the constitutional compatibility of the EEG's predecessor FIL with EU law was confirmed by the European Court of Justice in 2001 (Stenzel, Frenzel 2008). In addition, the Red-Green government negotiated a nuclear phase out with the nuclear industry in 2000 (and encoded in law in 2002) which limited lifetimes of existing nuclear plants in order to achieve a gradual nuclear phase-out by 2023 (Morris, Pehnt 2014). Also, when the Red-

Green government was re-elected in October 2002 the responsibility for renewable energies was transferred to the Environment Ministry and thus away from the Economics Ministry with its close ties to incumbent utilities.

However, despite these clear political signals and supportive policy developments as well as improving technological performance of renewable energies, such as increasing sizes of wind turbines, investments of German utilities into renewable energies remained low. Instead, in the period from 1990 until 2004 the ‘big 4’ focused their investments in new power plants on lignite for which they built 9 large-scale plants (beyond 75MW) with an overall capacity of approximately 6 GW. They also took online six new coal fired power plants (beyond 75 MW) with a capacity of almost 2 GW. Together with smaller utilities and industry they also invested in 17 gas-fired power plants which amounted to almost 3 GW of capacity additions (Bundesnetzagentur 2014). In contrast, utilities’ investments in renewable energies remained negligibly small.

Part II: Carbon constrained electricity generation regime (2005-today)

After several years of political negotiations in 2005 the EU emission trading system (EU ETS) was introduced as the EU’s flagship policy instrument in response to rising landscape pressures from climate change (Skjaereth, Wettstad 2008). This market-based instrument represented an EU induced change in governance style in German environmental and climate policy which was previously dominated by regulatory measures and financial support. Instead, as cap-and-trade scheme the EU ETS limits overall emissions and obliges large stationary emitters to cover their CO₂e emissions with tradable EU allowances (EUA), thereby establishing a price of carbon. In its first trading phase (2005-2007) all allowances were allocated free of charge according to the so called grandfathering principle where the number of allowances received depended on past emissions. In Germany, the concrete design of this climate policy instrument was discussed with all relevant stakeholders for several years, including the allocation rules for newly constructed power plants (BMUB 2002, 2003, 2004).

These discussions and further negotiations resulted in technology-specific allocation rules for lignite, coal and gas with many exemptions to address special interests, particularly of large incumbents (Eichhammer et al. 2004; Ziesing et al. 2007). Since utilities included the opportunity costs of their allowances into electricity prices this caused large windfall profits of the ‘big 4’ and other utilities, which led to public outcries given that operators had received allowances free of charge. In addition, the free allowances for new-builds acted as distortionary investment subsidies for fossil-fuel fired power plants (Rogge, Linden 2008). The government’s intention behind these indirect subsidies was to quickly substitute dirty old power plants with more efficient ones (Ziesing et al. 2007). As such, the generous level of support was very effective in getting the ‘big 4’ but also municipal utilities and new entrants planning new large-scale, centralized fossil fuel projects with improved technical efficiencies, thereby favoring all three fossil-fuel sub-regimes (Hoffmann 2007). Yet, for a number of reasons in the period from 2005 until 2013 much fewer large scale fossil fuel power plants were installed than originally envisaged (Bundesnetzagentur 2014).

Figure 31: Development of the CO₂ spot market price in the EU ETS (2005-2015)



Source: Own compilation based on Point Carbon and other sources

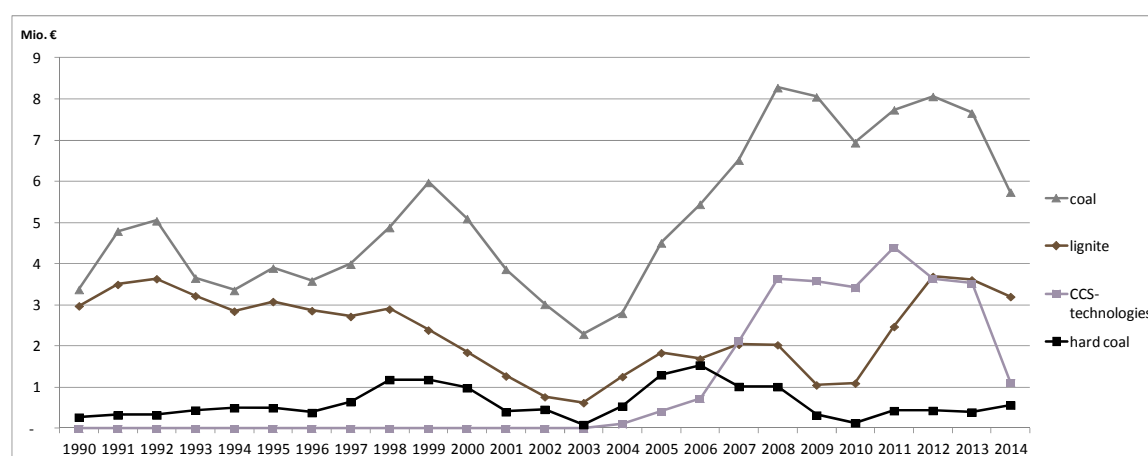
In the first two years after the introduction of the EU ETS prices rose up to 30 Euros (Figure 31). This was when climate change topics and the EU ETS made it into board rooms, as such high prices led to reduced full load hours of coal and lignite fired power plants, including previously unthinkable plant closures (Rogge et al. 2011). In addition, in 2006/07 it became clear that starting from 2013 onwards (trading phase 3) utilities would have to pay for all of their CO₂ emissions (100% auctioning). This led to a paradigm change in thinking of utilities as it underlined that climate change is a serious concern for their business. This prompted a series of strategies, including the reconsideration of their reluctant position toward renewable energies as long-term growth market in Germany (Rogge, Hoffmann 2010). As a start, in 2007 most utilities adopted internal targets for renewable energies of 20% by 2020 which were inspired by the influential EU 2020 targets for 20% renewables, 20% CO₂ emission reductions and 20% energy efficiency improvements. This entry into the renewables market was to be accomplished by new business units or subsidiaries for renewable energies which all ‘big 4’ initiated in 2007/8 (Rogge et al. 2011; Richter 2013). However, given that in 2012 the ‘big 4’ still only owned 4.9% of renewables power generation capacities (Figure 30), their strategy and investments in renewable energies may not have been progressive enough.

In contrast, the introduction of a price of carbon had initially led to fairly optimistic hopes of the ‘big 4’ on carbon capture and storage (CCS), a technology which could ensure the long-term survival of large-scale coal and lignite fired power plants in a carbon constrained world. Indeed, CCS readiness quickly became a permit requirement for new build coal and lignite

fired power plants and was also seen as means to overcome public resistance against new build coal fired power plants. Consequentially, all ‘big 4’ started to get actively involved in setting up and financing joint R&D projects with technology providers and chemical industry players which had already worked on smaller scale R&D projects, as evidenced by patent applications in (Figure 27) (Rogge, Hoffmann 2010; Rogge et al. 2011). Projects often received public R&D support (

Figure 32), aimed for achieving competitiveness at 30 Euros per ton of CO₂ and strived for unique solutions fitting the requirements of individual utilities.

Figure 32: Public R&D spendings on coal and subcategories



Source: Own compilation based on the EnArgus database

Vattenfall and RWE (utilities with lignite in their portfolio) were most active, with Vattenfall leading with its oxyfuel pilot project at Schwarze Pumpe and plans for a demonstration project in Jänschwalde, and RWE pursuing several projects and also plans for a demonstration project (for an overview of German CCS R&D projects see Table 2).

Three of the German CCS projects are classified as notable projects by the Global CCS Institute (Ketzin Pilot Project, Schwarze Pumpe Oxyfuel Pilot Plant, Wilhelmshaven CO₂ Capture Pilot Plant). However, not all projects could be successfully completed and initial plans for large scale CCS demonstration plants by RWE and Vattenfall have been cancelled or put on hold. This decline in CCS activities is also evidenced by the decrease in public R&D funding in 2014 (

Figure 32). The main reasons for these negative development appear to be a lack of public acceptance for CO₂ storage, a CO₂ price well below levels needed to provide sufficient incentives for CCS, and delays in adopting the legal framework conditions for CCS until 2012 and the inclusion of an exit passage for federal states (Duetschke et al. 2015; Duetschke et al. 2014). In addition, given the limited geological CO₂ storage capacities in Germany

there seems to be some recognition that these may be rather needed for mitigating industrial CO₂ emissions.

Table 2: Overview of German CCS research and demonstration projects 2

Project name / location	Type	In operation	Time period	Status	Actors	Financing	Scale
Nordfriesland	Exploration for storage		2008 - 2010	definitely ended in 2011	Industry (RWE) and Research Institutes (University of Kiel i. a.)	Industry; Federal Government	commercial scale (35 to 40 Mt)
Altmark	Testing of new technologies		2009 - 2011	stopped without injection of gas		Federal programmes; Own contribution of the industry	limited storage volume (max. 100.000t)
Ostbrandenburg	Exploration for storage		2009 - 2011	stopped before conducting the exploration	Industry (GDF SUEZ; GFZ)	Federal government; Own contribution of the industry	commercial scale (37,5 Mt)
Ketzin	Exploration of CO ₂ -storage	2008 - 2013	2004 - today	storage monitoring starting 2014		Federal and EU fundings; Industry	limited storage volume (max. 100.000t)
Schwarze Pumpe / Spremberg	Testing Oxyfuel Capture Methode	2008 - 2014	2006 - 2014	finished earlier 2014	Industry (Vattenfall)	Industry (Vattenfall)	small
Niederaußem	Pilot plant CO ₂ -Capture	2009 - today	2009 - today	prolonged by 2 years	Industry (RWE; BASF; Linde)	Federal Ministry (BMW); Industry (RWE; BASF; Linde)	small (max. 2000t)
Hürth	Pilot plant Pre-Combustion IGCC		2016+	hold	Industry (RWE)		large scale (2.6 Mt)
Jämschwalde	Pilot plant Capture Storage		2016+	cancelled in 2011	Industry (Vattenfall)	Federal Government; EU; Industry	small scale (20.000 m ³ /h)
Heyden	Pilot plant CO ₂ flue gas scrubbing	2010	2009 -	undefined further proceeding	Industry (E.ON; Cansolv Technologies)	Industry (E.ON)	small scale (20.000 m ³ /h)
Greifswald / Lubmin	High efficient coal power plant with CCS		2006 - 2009	in the process of planning until 2009, cancelled in 2009	Industry (DONG)		
Heilbronn	Pilot plant of amine scrubbing	2011 - today	2010 - today	practical test running	Industry (EnBW)	Industry (EnBW)	small (300kg CO ₂ /h)
Wilhelmshaven	Testing of CO ₂ -Capture-technology	2011 - today	2011 - today	4,500 operating hours until beginning of 2014	Industry (E.ON & Fluor)		small (70 t/day)
Karlsruhe	Development of CO ₂ -filter membranes		2007 - 2010	completed on time	Industry (EnBW; E.ON; RWE); Research Institutes (Jülich)	Federal Ministry (BMW); Industry (EnBW; E.ON; RWE)	

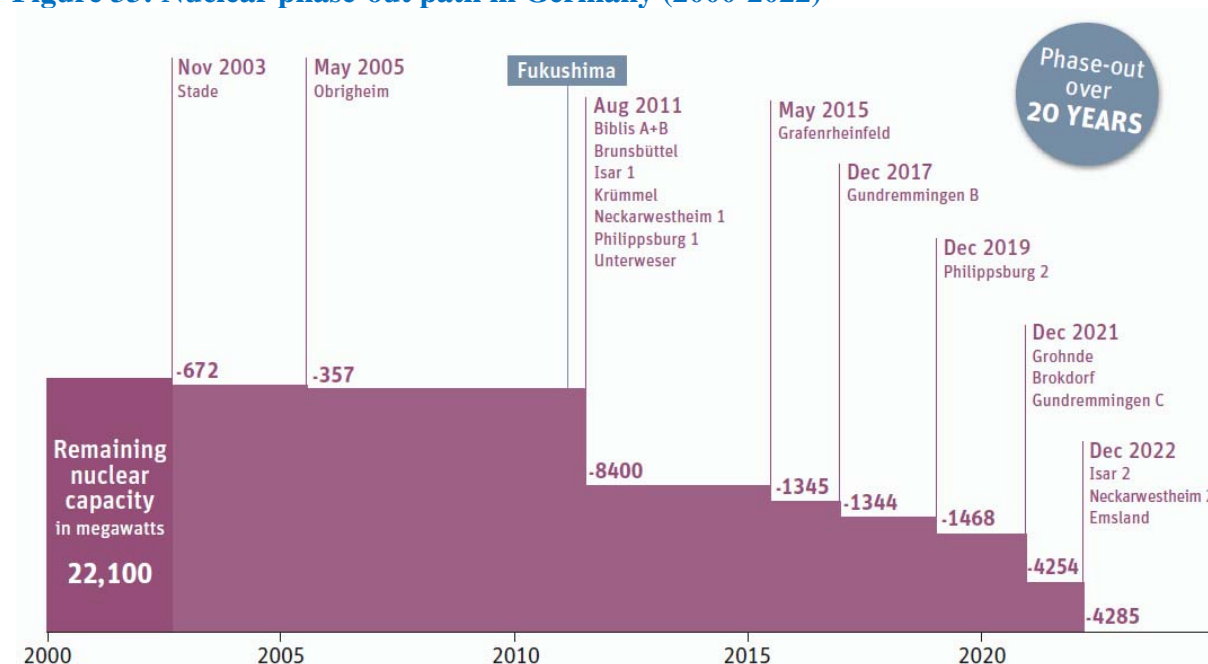
Source: Own compilation based on Duetschke et al. 2015; Duetschke et al. 2014, www.globalCCSInstitute.com, and internet research

A third strategy of the ‘big 4’ in dealing with the realities of a carbon constrained future electricity system was the questioning of the nuclear phase out as negotiated in 2000 with the Red-Green government. Consequentially, in 2005 when Angela Merkel became head of a new grand coalition government the ‘big 4’ started to lobby for changing the nuclear phase out. These efforts intensified under the newly elected conservative-liberal government under Angela Merkel in 2009 and finally succeeded in 2010 when the Merkel government announced the exit from the nuclear exit, leading to renewed anti-nuclear protests, even though the nuclear reversal was embedded in a larger energy concept with ambitious energy transition targets, including a 80% target for renewables in electricity generation in 2050 (Strunz 2014; Geels et al. 2014).

Yet, the landscape shock of the Fukushima disaster of March 2011 made chancellor Merkel rethink her risk assessment and order an immediate moratorium for the 8 oldest nuclear power plants (Morris, Pehnt 2014). However, the federal elections in the conservative state of Baden-Württemberg showed the reactivated strength of the German anti-nuclear movement, with the Green party doubling their votes to 24.2% and the conservatives and liberal party

loosing approx. 5% each⁵. As a consequence, the Green party became senior partner in a coalition with the Social Democrats. After this loss in power it took Merkel's government three months until they announced the phase out of the remaining 17 nuclear power plants by 2022 (Figure 33) – a decision effectively returning German energy policy back on track with the original phase out plan (Morris, Pehnt 2014; Strunz 2014; Geels et al. 2014). Given the cross-party support for this second nuclear phase-out, the fate of nuclear seemed to be sealed and hence the “big 4” needed to search for alternatives. However, while acknowledging this final exit decision the “big 4” are currently suing Merkel's government in an attempt to reduce their financial losses⁶. Regardless of this battle over costs, the Fukushima disaster as external landscape shock came at a critical point in time of the German energy transition. It focused the debate towards how to best achieve a renewables based electricity generation system (e.g. degree of decentralization, kind of investors, relative investments into offshore wind vs onshore wind, role for storage, transmission and distribution grids).

Figure 33: Nuclear phase-out path in Germany (2000-2022)



Source: Morris, Pehnt 2014, p.33

A fourth strategy in a future electricity generation regime based on volatile renewables pursued was to invest in flexible gas fired power plants. Indeed, with the introduction of the EU ETS and initial prices of 20-30 Euros per t CO₂ it looked as if gas would be a winner. This belief in gas is illustrated by the increase in public R&D funding, in the spike of patent applications (particularly after the introduction of the EU ETS in 20005), and the increase of the gas-fired capacity. Actual investments in the period from 2005 until 2013 were dominated

⁵ <http://wahl.tagesschau.de/wahlen/2011-03-27-LT-DE-BW/index.shtml>

⁶ <http://www.faz.net/aktuell/politik/energiepolitik/verfassungsklage-gegen-atomausstieg-kernkraftbetreiber-fordern-15-milliarden-euro-vom-staat-11783254.html>

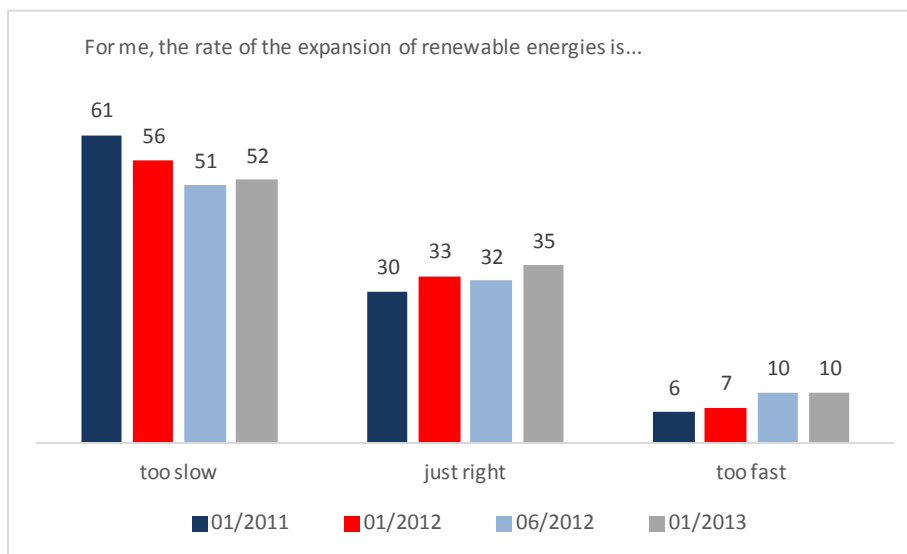
by gas (24 plants, 7.5 GW), followed by hard coal (6 new plants, 4.3 GW), and finally by lignite (4 new plants, 2.8 GW) (Bundesnetzagentur, Bundeskartellamt 2014). That is, despite distortionary incentives and insufficient CO₂ price signals over 50% of new fossil capacities use natural gas (compared to 27% in 1990-2004) which has lower specific CO₂ emissions and with its operational flexibility fits much better with the emerging new electricity regime dominated by volatile renewables. In contrast, lignite is down from a share of 55% of fossil new builds to 19% (with RWE and Vattenfall as remaining large investors).

However, electricity generation from gas-fired power plants only rose until 2010, after which it began to decline again at the expense of lignite and coal which benefited from CO₂ prices as low as 5 Euros (Figure 26). Another reason for this decline and deteriorating economic viability of utilities' business model for fossil fuel power plants is the strong effect of the expanding share of renewables on the merit order curve, leading to a reduction of spot market electricity prices and operating hours of power plants with higher variable costs. The effect is particularly pronounced for PV since solar radiation is highest around midday which coincides with peak demand, thus leading to a displacement of electricity from gas fired power plants (but also lower contribution margins to cover fixed costs) for coal-fired plants (Morris, Pehnt 2014; Strunz 2014; Bode, Groscurth 2011). Thus, even the most efficient gas-fired power plants are faced with lower than expected load hours which currently render gas an economically not viable option. This has led to intensive discussions about capacity markets, with a large variety of suggestions for their design (Agora Energiewende 2013).

Outlook

There is a wide societal support for the ongoing energy transition towards renewables in Germany. According to figures of the BDEW energy monitor, almost 90% of Germans consider the energy transition as very important or important (largely unchanged from previous years), even despite rising costs of feed-in tariffs for renewables (Rogge et al. 2015). This overwhelming public support can be illustrated by the fact that only some 40% think that progress is fast enough, while over 50% of participants think the expansion of renewables is too slow (BDEW 2014, 2013b).

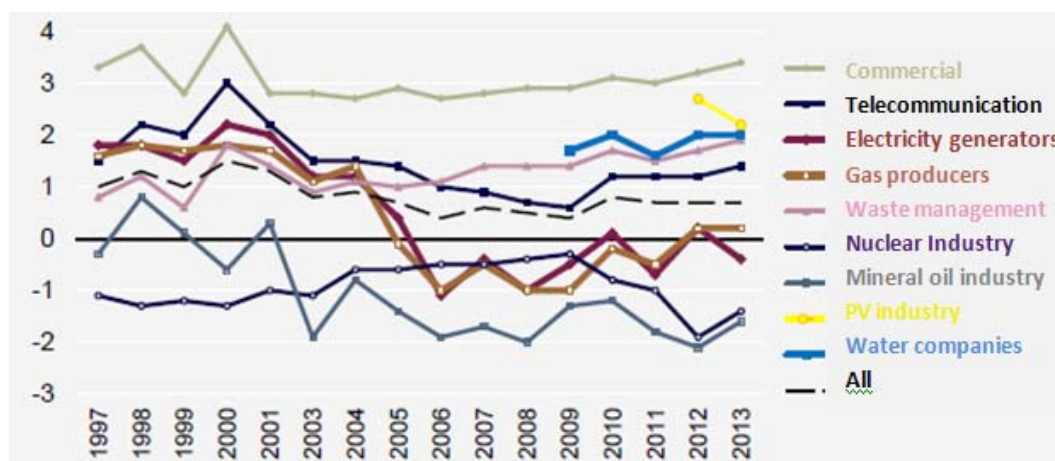
Figure 34: Public content with rate of expansion of renewables in Germany in 2013



Source: BDEW 2013b, p.24

Also, after more than ten years of actively opposing renewable energies – although the technology was commercially available – utilities in Germany have started to embrace renewable energies as new business for their future success, while at the same time exploiting their current core business (mainly nuclear, coal, and lignite). This change in strategy towards renewables seems to go along with a slight improvement of the negative image of utilities which reached its low point in 2006-08 - with negative images worse than the nuclear industry (BDEW 2013b).

Figure 35: Development of image of different infrastructure industries in Germany



Source: BDEW 2013b, p.13 (own translation, base = 1,010, average on scale of -5 (very bad opinion) until +5 (very good opinion))

However, Richter 2013 finds that most utilities – regardless of their size – seem to focus on ramping up large-scale renewable energy projects which fit closely to their traditional business model of operating large-scale power plants to sell electricity to their customers. In contrast, utilities have so far shown little interest for customer side distributed small-scale renewable energy for which they struggle with identifying radically different value propositions and revenue models. This inability of quickly picking up new business opportunities implies that incumbents may experience further market losses when new transition challenges arise, such as designing new business models for electricity storage or demand side management (Richter 2013). However, municipal utilities may find themselves better placed for decentralized generation and upcoming challenges, e.g. given their proximity to customers.

Given this focus of the ‘big 4’ and other utilities on large-scale renewables further resistance of incumbents can thus be expected in the form of providing narratives against a high degree of decentralization and small-scale solutions, including concerns of system integration and cost minimization (Geels et al. 2014). These concerns have featured prominently in recent political debates and have already influenced the design of the EEG in 2014, e.g. by limiting the speed of expansion through target corridors for PV, biomass and wind, and by piloting tenders for large-scale PV and offshore wind. However, alternative narratives and analyses will continue to be provided by a multitude of other social groups, including environmental think tanks and energy policy scholars, economists, environmental NGOs, unions and industry associations (Gawel et al. 2013). Therefore, an active debate and struggles about the future shape of the *Energiewende* (e.g. regarding the degree of decentralization, actors involved, distribution of benefits and costs, trade-offs with nature protection, etc.) will continue. However, given that the future success of the energy transition not only hinges upon system reliability and cost-effectiveness but also upon continuously high levels of public acceptance for the shift towards renewables policy makers may attempt to strike a balance between interests of incumbents and new entrants, rather than reversing to working with incumbent utilities only – despite the recent return of the responsibilities for renewables and the energy transition under the auspices of the economics ministry, which changed its name to Federal Ministry for Economic Affairs and Energy in 2014.

This move signals greater political attention to the success of the energy transition as political flagship project which newspapers cover on their front page as mainstream issue of great public interest. As such, missing policy targets would damage the reputation of key politicians, such as economics minister Sigmar Gabriel. This is exemplified by a highly debated policy proposal by the economics ministry aimed at curbing CO₂ emissions of the dirtiest lignite fired power plants as these endanger Germany’s 2020 target achievement (BMWi 2014h) and thus also Germany’s credibility in the negotiations at the international climate conference in Paris end of 2015. As the proposal faced significant opposition from regime players, including federal governments of coal states benefiting from public income through coal (North Rhine-Westphalia (NRW), Brandenburg, Saxonia), unions concerned about job loss and the affected incumbents (mainly RWE and Vattenfall) it is currently under revision, with new proposals on the table (MAZ 2015; Gabriel 2015).. This initiative can be

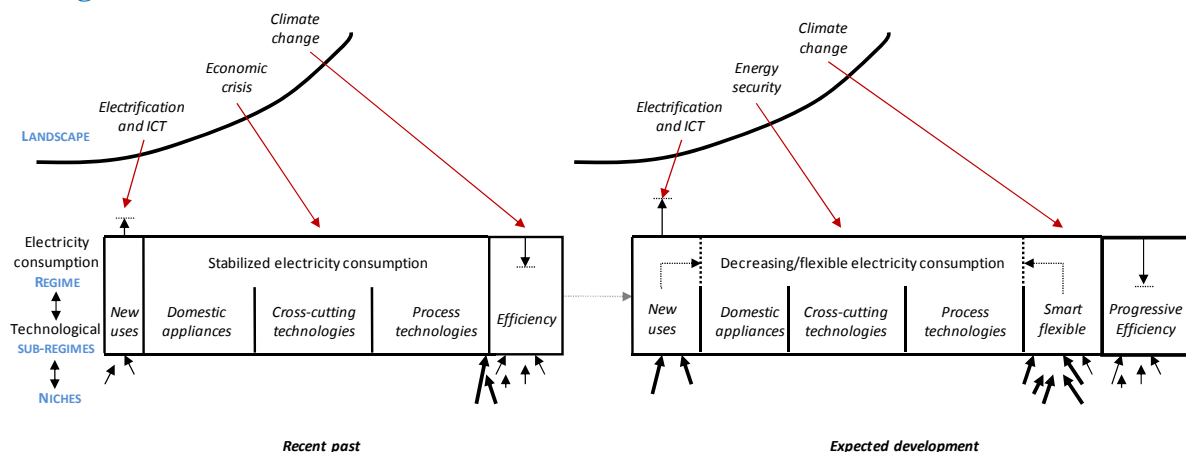
seen as a first step towards an active discontinuation strategy for lignite and coal based power generation. Such a move is supported by green advocacy coalitions (including environmental NGOs, energy policy experts, and green politicians), but may need to be embedded in a smart industrial strategy managing the associated structural change towards renewables.

6 Developments in consumption and end-use regime

6.1 Developments of the main tangible system elements

While the previous chapter has documented a regime undergoing radical changes across several dimensions, we now turn to the electricity consumption and end-use regime which is also under significant landscape pressures and resulting regime reconfiguration (see Figure 36).

Figure 36: Schematic representation of the development of the consumption and end-use regime



Source: Own illustration

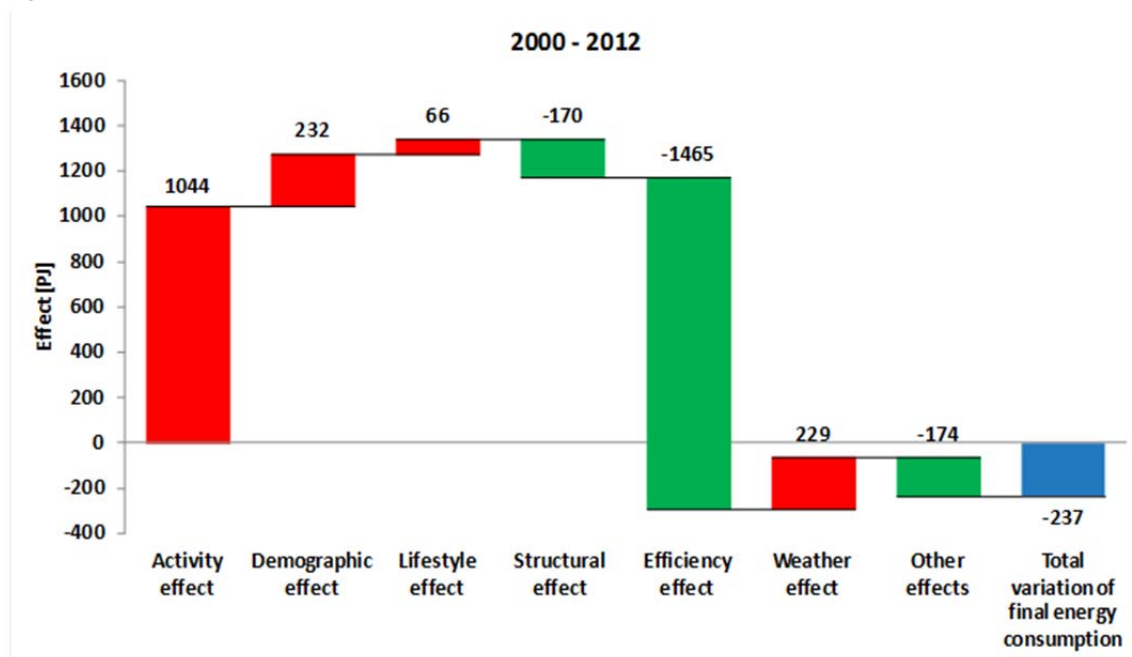
The development of total final energy or electricity consumption in an economy can be explained by the following main factors (compilation based on Almeida et al. 2011; Schlomann 2014):

- an activity effect due to an increase in an activity measured in economic or physical units (as e.g. GDP or number of households)
- structural effects due to several changes in the structure of the economy or a sector (e.g. trend to services)
- a demographic effect due to changes in the number of inhabitants or households

- changes in “lifestyle” due to an increase in comfort (e.g. larger living area per household) or in the number of appliances and new electricity uses (e.g. consumer electronics and information and communication technologies)
- weather fluctuations which are mainly relevant for space heating consumption
- other effects as e.g. behavioural changes in the household sector, changes in the value of products in industry or changes in labour productivity in the tertiary sector
- and an energy efficiency effect showing technical or organizational improvements in the use of energy or electricity; these can either be triggered autonomously by the general technical progress, or induced by rising energy prices and/or by energy efficiency policies.

Figure 37 shows the impact of these factors on total final energy consumption in Germany in the period 2000-2012. In total, final energy consumption decreased by almost 5% or 240 PJ (67 TWh). The activity, demographic and lifestyle effects as well as the weather fluctuations had an increasing impact on energy consumption during this period. This was, however, more than compensated for by the energy savings achieved through a considerable improvement in energy efficiency and, to a lesser extent, some structural changes and other effects.

Figure 37: Decomposition of final energy consumption in Germany for the period 2000-2012



Source: Schlomann 2014, p.207 (calculation based on ODYSSEE database)

When only looking at final electricity consumption, the – increasing - impact of activity, demographics and lifestyle was more pronounced than for total final energy so that efficiency

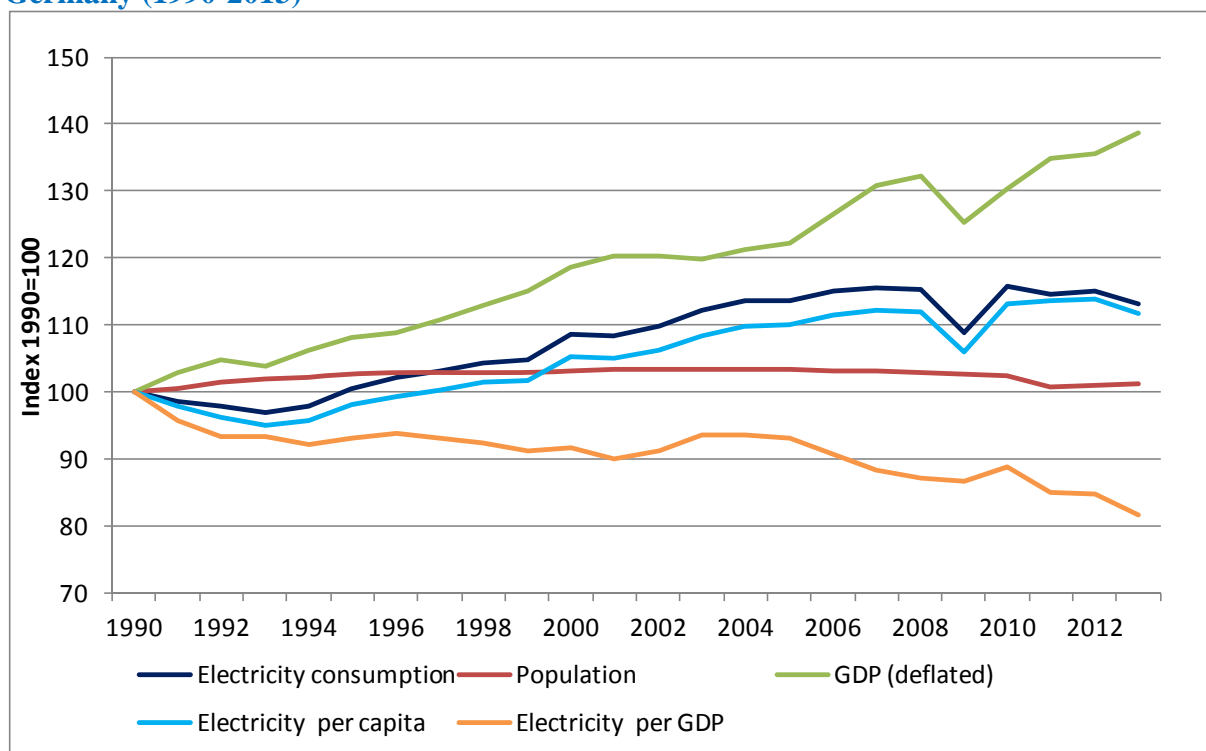
improvements could not fully over-compensate it. As a result, total final electricity consumption in Germany increased by around 13% (or 60 TWh) between 1990 and 2013 (

Figure 38). Nevertheless, there was a clear decoupling of electricity consumption from GDP, which was mainly caused by a more efficient use of electricity and some structural changes. The electricity consumption per capita, however, widely followed total electricity consumption (

Figure 38).

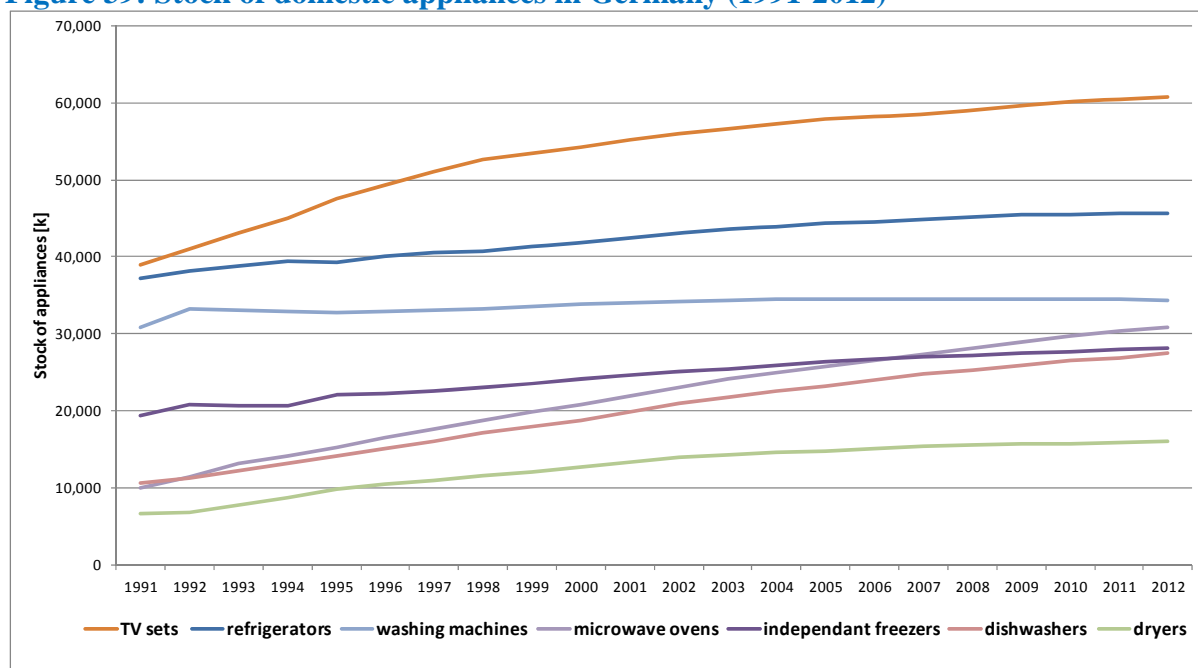
Energy consumption in private households also showed a rising trend during the last decades. It increased from 117.2 TWh in 1990 to 138.4 TWh in 2013, i.e. by 13%. This is mainly due to the increasing number of private households during the same period (Figure 40) and to the still increasing stock of domestic appliances (Figure 39). But energy efficiency improvements at least contributed to a stabilization of the specific electricity consumption per household. This was mainly due to the large efficiency gains for domestic appliances which could be achieved between 1990 and 2013 (Figure 40).

Figure 38: Development of total final electricity consumption and determining factors in Germany (1990-2013)



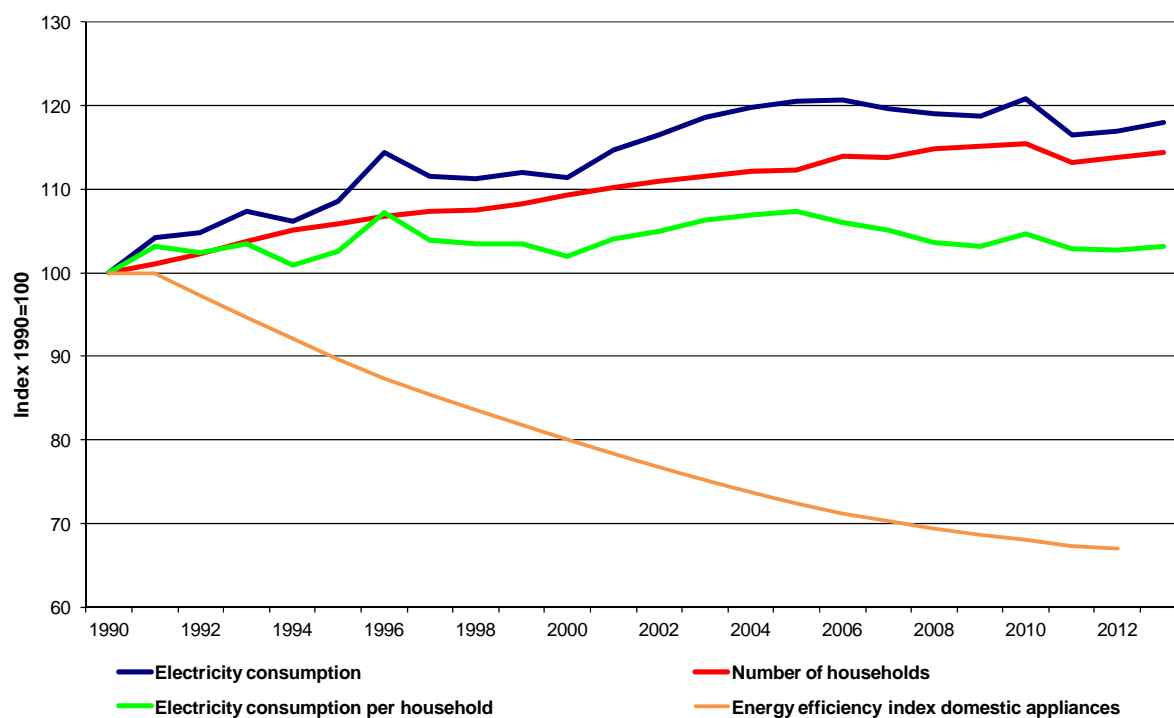
Source: Own calculation based on ODYSSEE database

Figure 39: Stock of domestic appliances in Germany (1991-2012)



Source: Own calculation based on ODYSSEE database

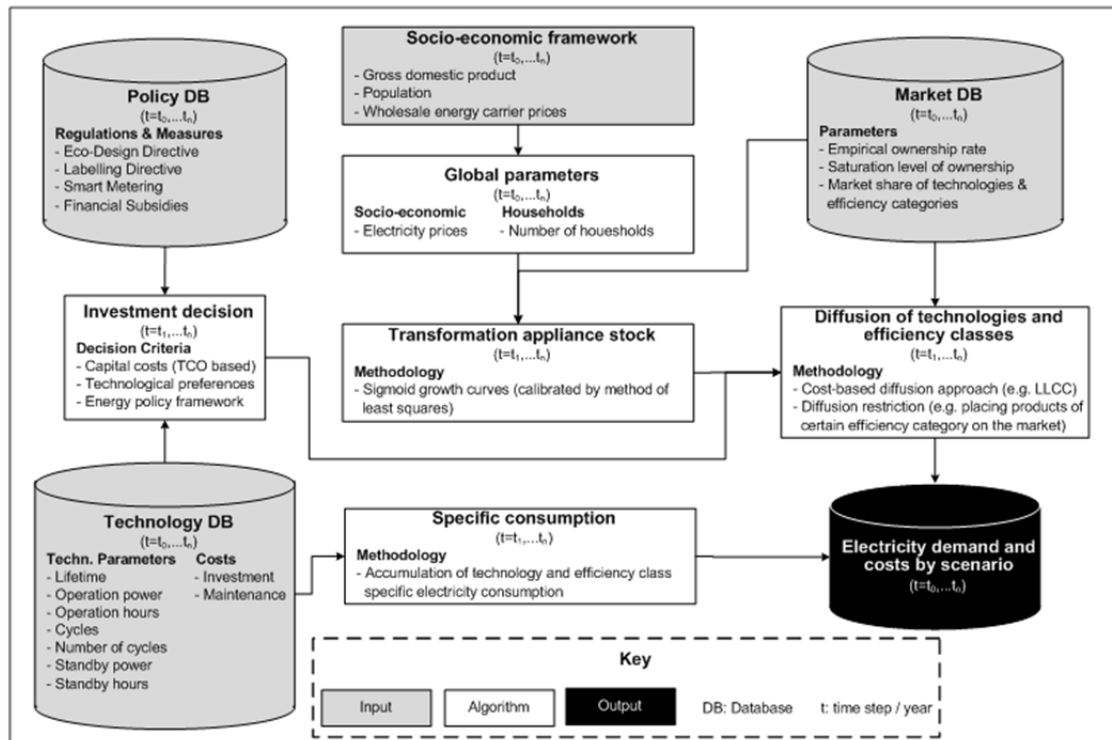
Figure 40: Electricity consumption of private households in Germany (1990-2013)



Source: Own calculation based on ODYSSEE database

The factors mentioned above both determine the development of electricity consumption in the past and in future. Therefore, they also build the structural framework for the determination of future electricity demand and savings potentials (Figure 41).

Figure 41: Structural framework for the determination of electricity demand and savings potentials for the main end-uses in private households

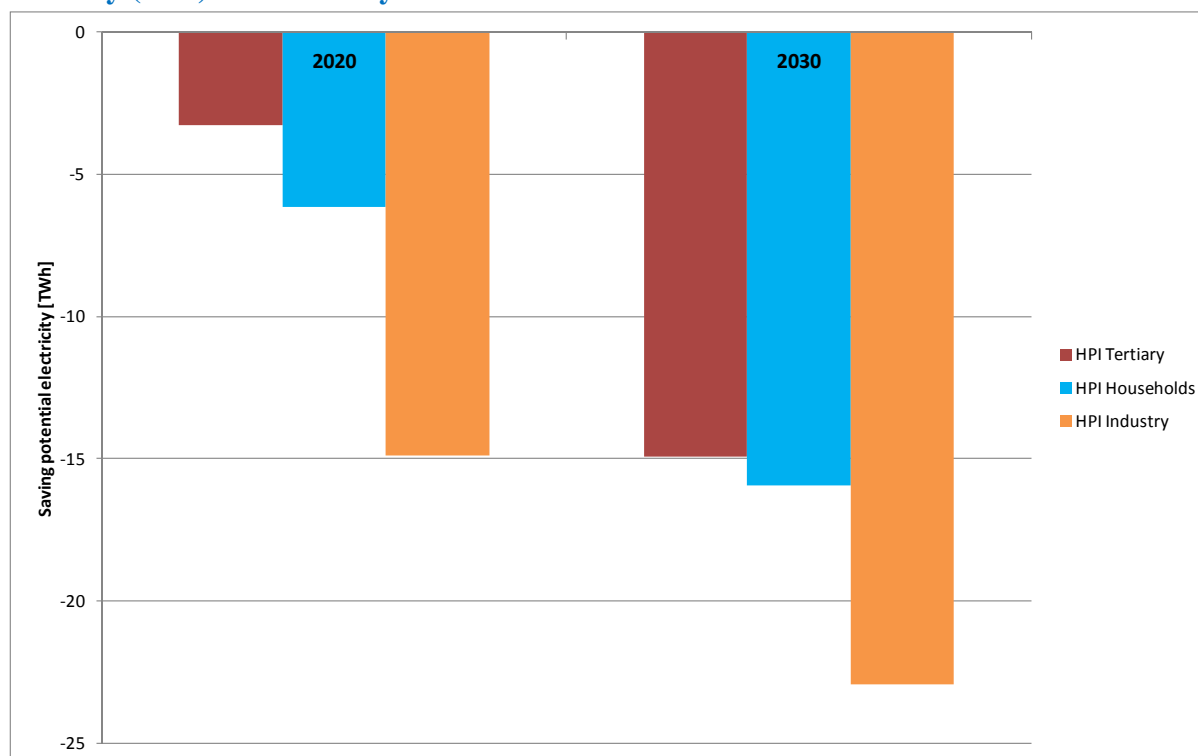


Source: Elsland et al. 2013

For Germany, the latest reference forecast on behalf of the Federal Ministry of Economic Affairs and Energy (Prognos et al. 2014), which shows the most probable development without significant changes in the present policy mix, projects a moderate decrease in total final electricity consumption until 2030 and a stagnation afterwards (Figure 8). A rising electricity demand is especially expected from information and communication technology (ICT) (Schlomann et al. 2015a). There are, however, further electricity savings potentials in all final consumption sectors until 2030 and beyond. For Germany, the additional electricity savings potential in an energy efficiency scenario (compared to a business-as-usual development) assuming a high policy intensity (HPI) lies in the order of 15 TWh in the household and tertiary sector and of more than 20 TWh in industry (

Figure 42). These potentials are cost-effective under current economic conditions, but they will only be tapped if all relevant barriers are widely removed by a suitable mix of energy efficiency policies.

Figure 42: Additional electricity savings potentials in a scenario assuming a high policy intensity (HPI) for Germany until 2030



Source: Braungardt et al. 2014

6.2 Main social groups and intangible regime elements

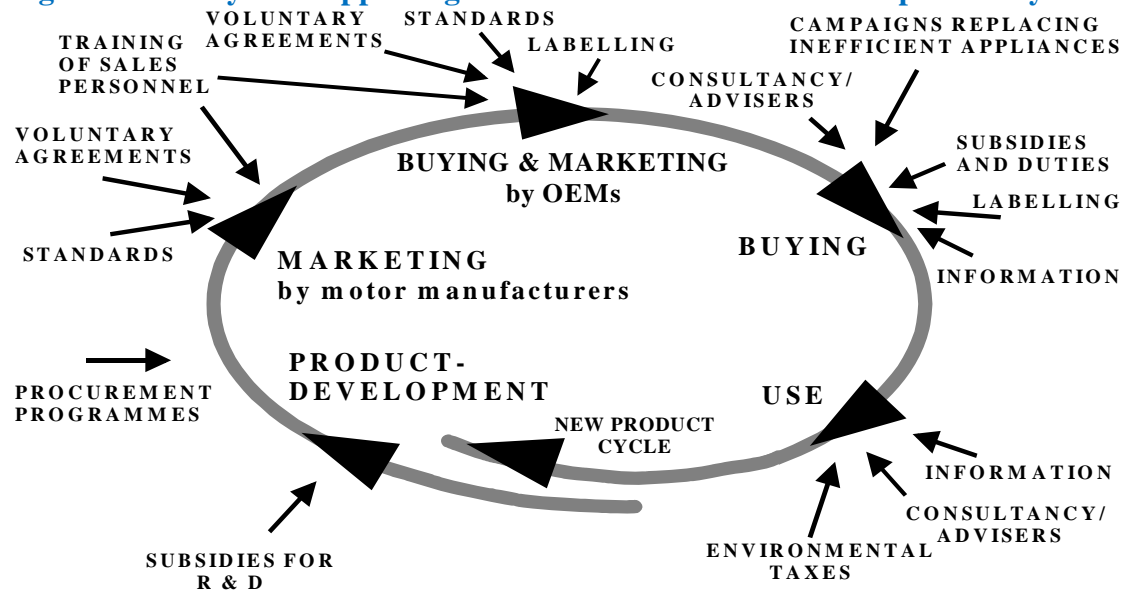
6.2.1 General overview of intangible regime elements

As shown above, the electricity consumption and end-use regime is determined by several factors which may have an opposite impact on the past and future development of electricity consumption. Whereas most of the increasing factors are exogenously given, the more efficient use of electricity, which is able to compensate or even over-compensate an increasing consumption trend, can be influenced directly by the consumers themselves. However, as already mentioned above, there are several barriers preventing private investors in households as well as companies and public organisations from realising energy savings potentials even though they are cost-effective (e.g. IEA 2012; Schlomann 2014; Schlomann, Schleich 2015). According to the classification by Sorrell et al. (2004), these barriers fall into the following broad categories: imperfect information and other transaction costs (e.g. search costs) for identifying energy use of buildings, products and services; hidden costs, such as overhead costs for management or for staff training; technical risks of energy-efficient technologies; financial risks associated with irreversible investments and uncertainties in the returns of energy efficiency measures; lack of access to internal or external capital; split incentives, preventing the investor in energy efficiency measures fully benefiting from the savings (e.g. the well-known landlord-tenant problem); and bounded rationality, which means

that constraints on time, attention, and the ability to process information prevent individuals from making “rational” choices in complex decision problems.

In order to close the gap between the realized and the cost-effective savings potential, several energy efficiency policy instruments are implemented both at the EU and the national level. However, an effective policy design, which simultaneously addresses all major obstacles, requires broad consideration of the perspectives of the different actors and target groups (Schlomann 2014). I.e. the whole chain of relevant actors and targets groups in the product cycle must be considered (Figure 43).

Figure 43: Policy mix supporting the motivations of actors in the product cycle



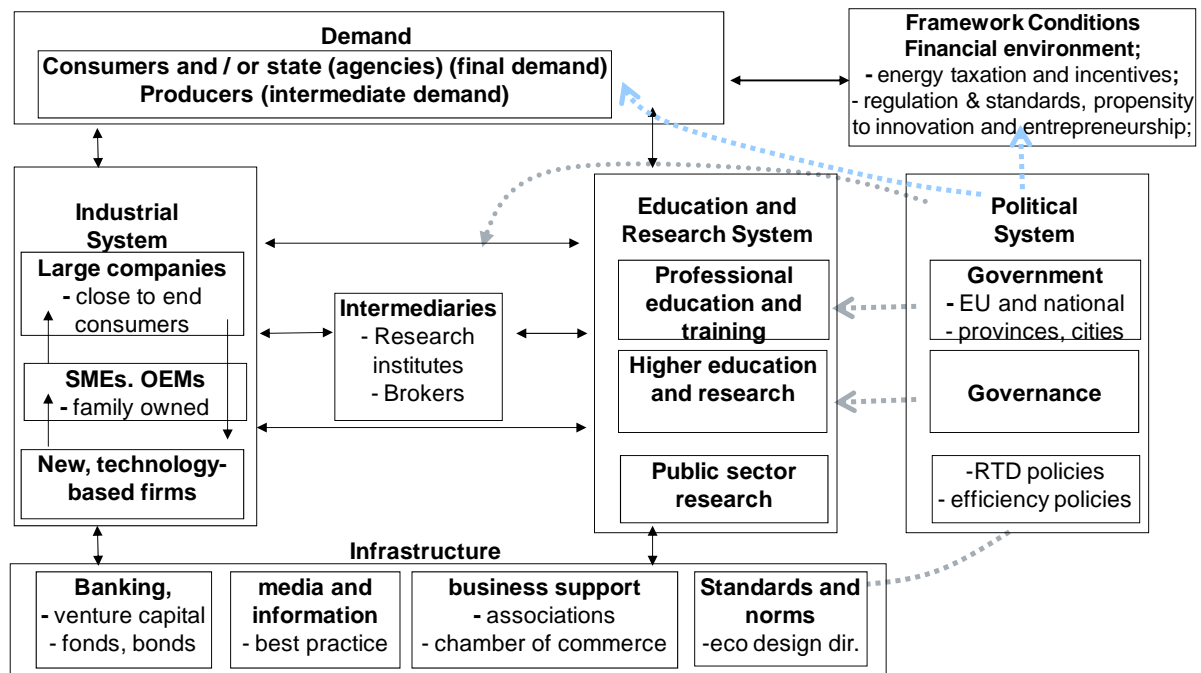
Source: Jochem 2014

In order to address all actors properly, an integrative concept of actors in the innovation system for electricity efficiency is necessary (

Figure 44). This also includes opportunities from the social science and not just “homo oeconomicus” perspective (as e.g. first movers in industry and commerce or the motivations of the actors of the innovation system).

Therefore, in the following Chapter 6.2.2 the specific positions and motivations of the main social groups and actors within the electricity consumption and end-use regime will be analysed in detail.

Figure 44: Innovation system for electricity efficiency – an integrative concept of the actors



Source: Jochem 2014

6.2.2 Main social groups and actors within the consumption and end-use regime

Industry

Actors from industry play a central role within the regime since they act in three different roles:

- First of all, industrial companies (as well as companies in the tertiary sector) are consumers of electricity. Around 70% of the current electricity consumption in Germany falls on these groups (AGEB, 2014).
- Secondly, the German industry is an important producer of energy-using and energy-related products.
- Thirdly, a part of industry, i.e. electricity utilities, produces and sells electricity to all electricity-consuming groups.

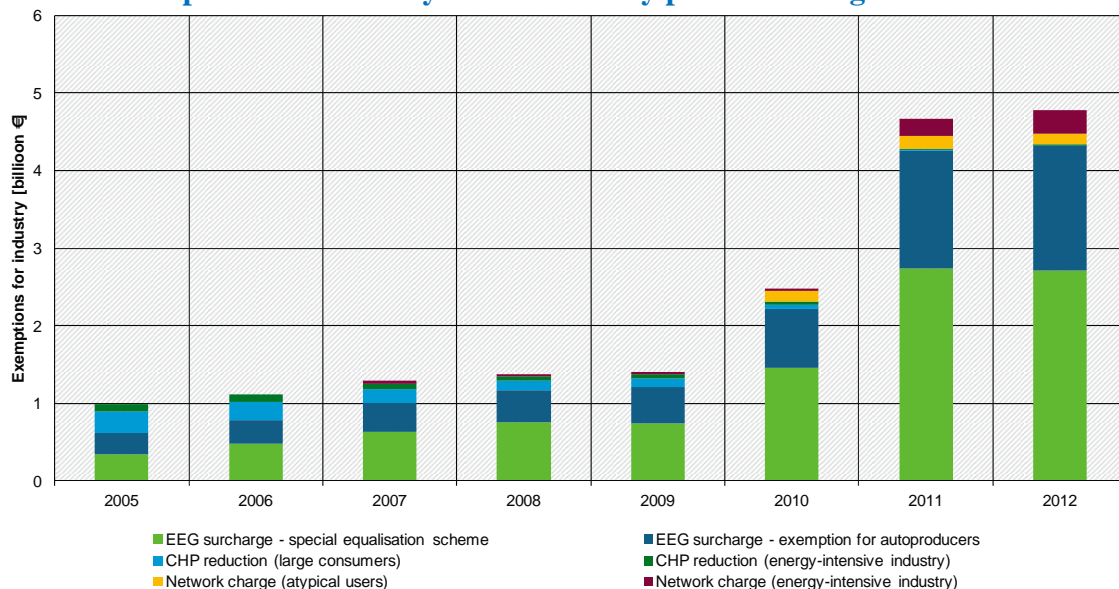
Industry as an electricity-user

The industrial sector is the by far largest electricity user in Germany (Figure 9). Around 55% of total electricity consumption falls to the energy-intensive industry (mainly basic chemicals, paper industry, production of steel, aluminium and glass) (AGEB 2014). For these branches, the share of energy costs in total production costs amounts to a range of 6-10%. Since the liberalisation of the electricity market in 1998, there has been a significant increase in electricity prices in Germany. Especially since 2009, increases in taxes and levies for the increased use of renewable energies (EEG surcharge [EEG = Renewable Energy Sources

Act]) and combined heat and power (CHP surcharge) have resulted in extra costs for consumers. However, the energy-intensive businesses are widely exempted from these surcharges (

Figure 45). This was mainly the result of a successful lobbying of the main associations of the energy-intensive industries in the Federal ministries in charge, especially the Ministry of Economics and Energy. As a result, the average electricity price for electricity-intensive industries is rather low in Germany compared to other European countries and even fell from 6 ct/kWh in 2008 to 4.7 ct/kWh in 2013 (Schlomann et al. 2015b Schlomann, Schleich 2015, p.119). For these industries, this means a competitive advantage, but only little incentive to invest in energy efficiency measures. For household and small business customers, who are not exempt, have to bear additional extra costs in order to finance the support systems for renewable energies and CHP.

Figure 45: Exemptions for industry from electricity price surcharges



Source: BMWi 2014d

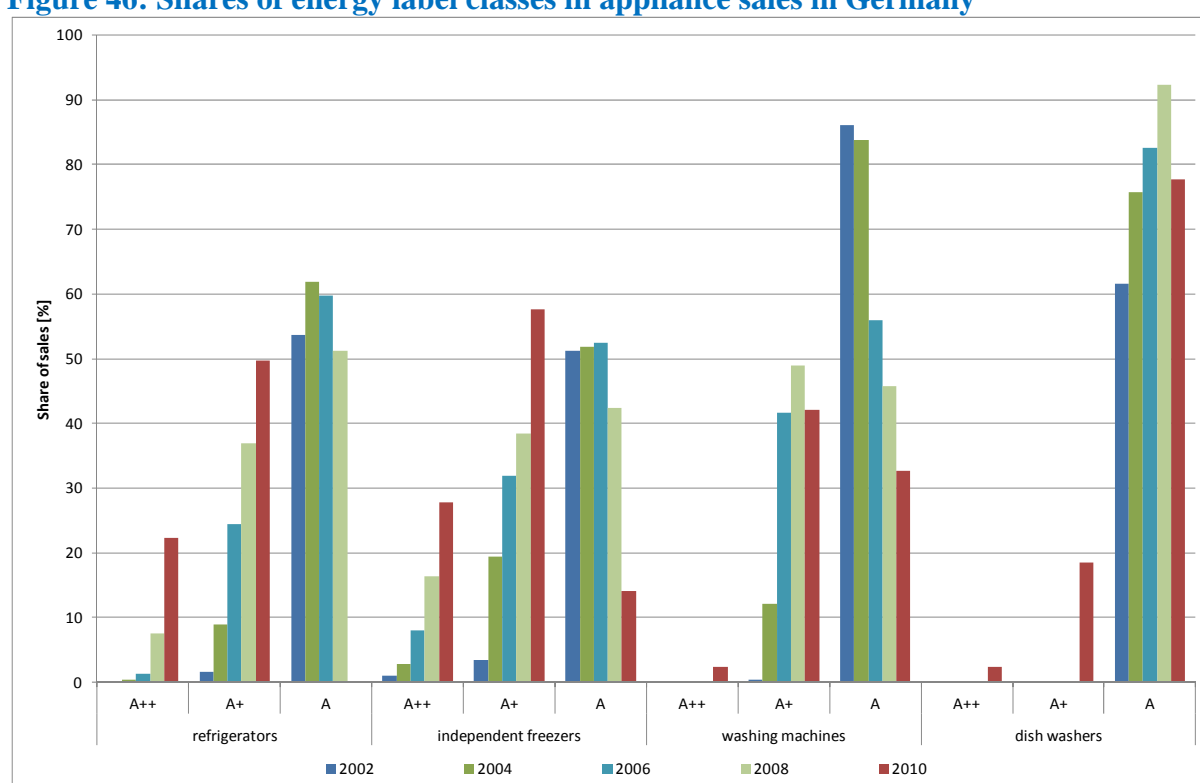
Industry as a producer of energy-using and energy-related products

Germany is still an important producer of energy-using products. This both applies to domestic household appliances, industrial cross-cutting technologies (as e.g. electric motors) and products for the building sector. These industries are strongly affected by the EU regulations on energy-using and energy-related products, i.e. especially the EU Labelling Directive (the original Framework Directive 92/75/EEC already came into effect in 1992 and was revised in 2010: 2010/30/EU) and the EU Ecodesign Directive from 2005 (2005/32/EC; revised: 2009/125/EC) which established minimum energy efficiency standards for many energy-using and with the revision also energy-related products. The attitude of the German towards the Energy Labelling Directive considerably changed during the last decades. During

the 1990, the producers of the domestic appliances and their head association, the “German Electrical and Electronic Manufacturers' Association” (ZVEI) were rather reluctant to the national implementation of the Directive. The tedious discussions with the producers also were the main reason for the very late adoption of the Implementing Directives for the labeled appliance groups in Germany in the beginning of 1998 (Schlomann et al. 2001). During the 2000s, however, the attitude of the producers and the ZVEI towards the Labelling Directive and the upcoming Ecodesign Directive became much more positive. The main reason for this change of mind was the increasing market penetration of cheap imported appliances from producers in China and other Asian countries. The focus of the German producers was on the - more expensive – high-quality products which usually were classified in the higher energy efficiency classes (at that time mainly A and B). Therefore, both Labelling and Ecodesign was more and more regarded as a competitive advantage for the German products.⁷ For the manufacturers, the label offers them the possibility to differ from each other as the energy performance is a high criterion for the purchase decision.

Figure 46 shows the rising share of the high energy efficiency classes in total sales of domestic appliances in Germany since 2002.

Figure 46: Shares of energy label classes in appliance sales in Germany



Source: Own calculation based on ODYSSEE database and GfK

⁷ This assessment is based on interviews with main stakeholders in Germany which were conducted by Fraunhofer ISI between 2007 and 2008 within two projects on behalf of the European Commission (Europe Economics, Fraunhofer ISI 2007; Fraunhofer ISI et al. 2009). The motivation of the interviews was to get views on the operation of the Energy Labelling Directive 92/75/EEC in Germany.

Whereas during the 2000s, especially the ZVEI and its Members dominated the discussion, another association of companies in the field of energy efficiency was founded in January 2011, the “German Industry Initiative for Energy Efficiency” (DENEFF). The mission of DENEFF was to unite frontrunner companies in the field of energy efficiency to collectively represent their political interests for an effective and ambitious energy efficiency regulation in Germany. The focus is both on energy efficiency in the buildings sector as well as industrial processes. DENEFF was able to increase the number of members to more than 100 during the last 5 years and became an important industrial player in the field of energy efficiency. In contrast to the associations of the energy-intensive industry, which usually refuse ambitious energy efficiency policies, DENEFF supports an ambitious implementation of EU regulation (EU Labelling and Ecodesign, Energy Efficiency Directive 2012/27/EU and the Energy Performance of Buildings Directive 2010/31/EU – EPBD) and ambitious energy efficiency policies at the national level. DENEFF was e.g. a strong supporter of a competitive tenders model which is just being established in Germany as a new policy instrument to support electricity efficiency.

The role of electricity utilities

In contrast to DENEFF, the electricity utilities in Germany (especially the “big 4”) are acting rather conservative and reluctant to develop new business models for energy efficiency and services. This was also one main reason why the introduction of an energy efficiency obligation scheme, which could favour such activities, under Article 7 of the EU Energy Efficiency Directive (EED; 2012/27/EU) was not politically enforceable in Germany. Many other European countries have already established such a system mandating energy retailers or distributors to reach energy savings targets. In Germany, however, energy utilities do not play an important role in the energy efficiency market, though there are some activities especially at the level of some regional or local suppliers.

There is, however, a growing interest in the impact of energy saving options on the load curve both from electricity suppliers and from industrial consumers (Bossmann et al. 2013). There are also first attempts to include this aspect into the design of energy efficiency policies, e.g. for the so-called Energy Efficiency Networks. This policy instrument was introduced in Germany in the beginning of the 2000s (Jochem, Gruber 2007). The idea of the networks is to target the idle potential for energy efficiency in medium-sized and large companies by cooperation on a regional level. In future, it is planned to take into account both energy efficiency and load-shifting options.

Private and tertiary consumers

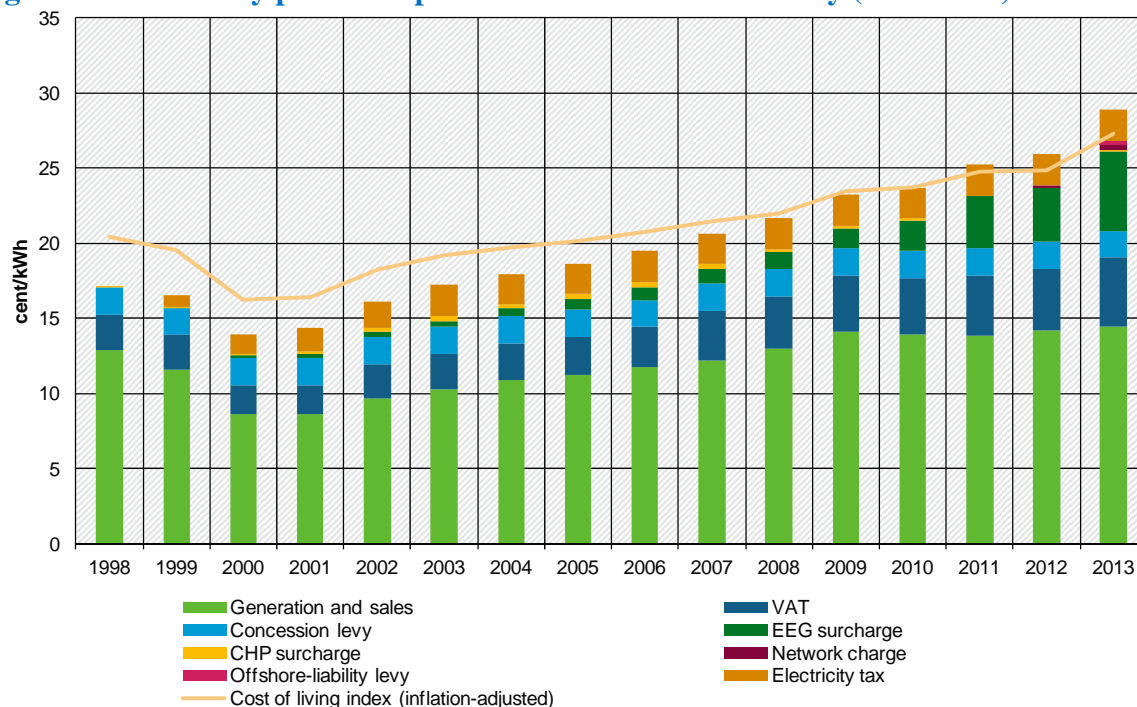
The share of private households in electricity consumption in Germany amounted to around 27% in 2013. If also adding tertiary consumers, which are in a comparable situation with regard to some consumption patterns and electricity prices, it's more than half of total electricity consumption (Figure 9). The average price of electricity for household customers consuming 3,500 kilowatt hours per year rose considerably between 2000 and 2013 from just

under 14 to around 28 cents per kilowatt hour (ct/kWh). This is one of the highest electricity prices for private consumers in Europe. The main reason for this increase especially since 2009 was the surcharges and levies to promote renewable energies and CHP (

Figure 47). Due to the considerable exemptions for large industrial consumers, the financing needs resulting from this exemption is carried one third each by private households, the tertiary sector and non-privileged businesses.

On the one hand, these high electricity prices are a strong incentive for energy savings measures since they increase the profitability of investments. On the other hand, the price increases caused a critical discussion in Germany on the high financial burden for private households and small companies in the tertiary sector and the priority treatment of the large industrial consumers. This discussion was mainly forced by the national consumer agency (Bundesverband Verbraucherzentralen) and regional agencies in the Federal Laender.

Figure 47: Electricity prices for private households in Germany (1998-2013)



Source: Schlomann et al. 2015a (compilation based on data from BDEW)

The general attitude of the consumer agencies in Germany towards energy efficiency policies is positive. But due to the already high electricity prices they refuse policies which would lead to a further increase of electricity prices for private households. They especially promote informational and advice programs and are offering such programs by themselves, too. With regard to legislative policies (Labelling and Ecodesign), the consumer agencies especially criticize the lack of a compliance control in Germany, both with regard to manufacturers and retailers (Europe Economics, Fraunhofer ISI 2007; Fraunhofer ISI et al. 2009). One main

reason for this are the shared responsibilities for compliance control between the Federal state and the Federal Laender.

Nevertheless, despite the deficiencies in the compliance control, the EU Energy Efficiency Label has brought support among the consumers. However, while the understanding of the information provided under the original labelling scheme was very good for the "A – B – C - ..." scheme, there is a strong empirical evidence that the change to "A(+)" was difficult to understand for the consumer (Heinzle, Wüstenhagen 2009).

Policy makers

In the field of *energy efficiency* policy, most of the policy measures introduced during the last years, represent a continuation of well-established measures and policies from the previous decades. This mainly applies to financial and legislative measures, which are dominant in the residential sector and also important in the tertiary and industrial sector, and which are supplemented by some information and advice programmes (Schlomann, Eichhammer 2012). The financing of these policies is for the most part from public budgets, private funds are rarely touched. The same widely applies to the national implementation of the Energy Efficiency Directive (EED; 2012/27/EU)⁸ and to the new “National Action Plan on Energy Efficiency” (BMWi 2014i). The policy measures for the main consumption sectors (buildings, appliances and products, industry and commerce) form a mix of already established types of instruments (mainly funding, regulations and standards, advice and information) and are based on public funds. A completely new policy instrument for Germany is the introduction of a competitive tender model for electricity which is, however, also supported by public funds.

The main reason why the policy mix for energy efficiency in Germany is mainly based on regulation and instruments financed by public funds, are the already high electricity prices for private households and small companies on the one hand and the policy efforts to keep electricity prices for large industrial consumers as low as possible for competitive reasons. As a result, there is no majority for any energy efficiency policies which may lead to further rising electricity prices. This is also valid for the possible introduction of energy efficiency obligations under Article 7 of the EU Energy Efficiency Directive, which has no support in Germany both at the political level and among the energy utilities.

In the past, the ambitiousness and success of energy efficiency policy at the demand side always lagged behind the renewable policy in Germany. This also becomes evident by the gap to the targets of the Energy Concept for 2020, which is considerably larger for the energy efficiency targets than for the renewable targets (Table 1). This was mainly due to the different responsibilities for energy efficiency and renewable energy policy since the Red-Green government in the end of the 1990s. Whereas the Federal Ministry for Economics and

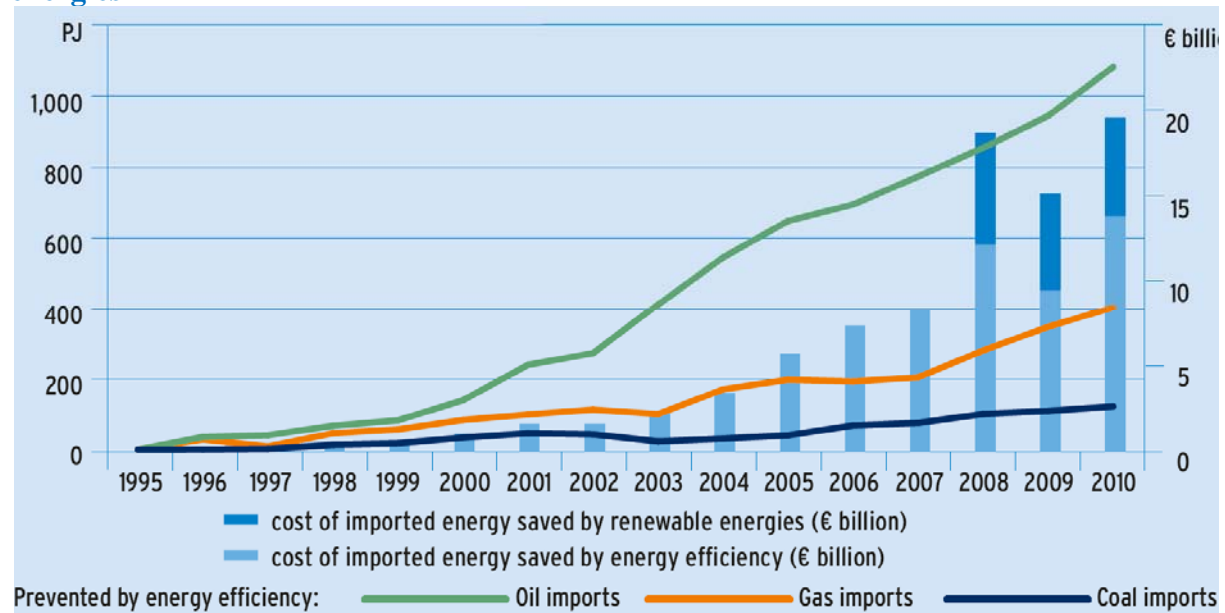
⁸ Article 7 of the EED sets a mandatory energy savings target for each Member State of 1.5% each year from 2014 to 2020 which can either be achieved by the introduction of an energy efficiency obligation scheme or by so-called “alternative measures” (or by a mix of both). Germany decided for a pure implementation by alternative measures, which is mainly a further development of the existing policy mix (The Coalition for Energy Savings 2014, 2014; German Government 2014).

Technology (BMWi) always was in charge of energy efficiency, the Federal Ministry for the Environment, Nature Conservation and Nuclear Safety (BMU) was responsible for renewable energies. Traditionally, the latter was more ambitious with regard to an effective renewable (and also energy efficiency) policy than the BMWi, also in times of conservative Coalitions in Germany. This also had an impact on the German position on energy efficiency policies at the EU level. Especially an ambitious design of the new EU Energy Efficiency Directive (2012/27/EU) in 2012 was rejected by the German delegates from the BMWi at that time.

The German position towards energy efficiency – both at the national and the EU level - considerably changed with the new Coalition of Christian Democrats and Social Democrats which was established in the end of 2013. Since then, the Coalition tried to establish energy efficiency as the second pillar of the “Energiewende”, besides renewable energies. The responsibilities for both were concentrated in the BMWi, which was renamed in “Federal Ministry for Economics and Energy”. In December 2013, the BMWi presented the “National Action Plan on Energy Efficiency” (NAPE), which forms the basis for the future energy efficiency strategy in Germany for the next years. At the European level, Germany supported an ambitious and binding energy efficiency target for 2030 during the discussion process of the new EU framework for energy and climate policies in 2030.

Another pressure for a more ambitious energy efficiency policy which also came up in 2014, following the Ukraine crisis, was the issue of energy security. It became evident that not only the increased use of renewable energies prevented energy imports in an order of magnitude of around 7 billion Euros per year, but that energy efficiency made an even greater contribution to reducing the dependency on imports (Figure 48). These findings became a strong argument to address a more efficient use of electricity, as well as other favourable economic side-effects of energy efficiency on economic growth, employment, competitiveness of the economy and others (the so-called “multiple benefits” of energy efficiency; IEA 2014).

Figure 48: Energy imports and costs prevented by energy efficiency and renewable energies



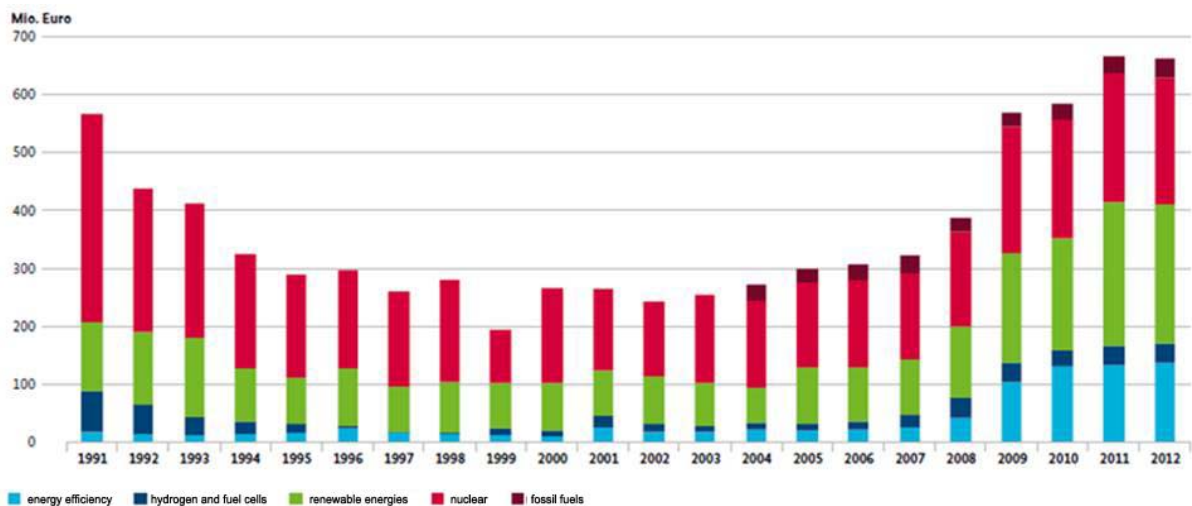
Source: Own calculations Fraunhofer ISI

In spite of the growing political support for energy efficiency, there are two issues which are widely neglected in current energy policy though both could strongly contribute to a reduction of the absolute electricity consumption (Calwell 2010; Oekopol 2014):

- First of all, there is no support for a progressive design of energy efficiency standards and labels favouring smaller electricity-using products. This may be due to the fact that both producers and consumers have a preference for products of higher performance, larger size, and greater amenity and functionality, which usually goes hand in hand with rising electricity consumption.
- Secondly, sufficiency aspects are widely neglected in the design of energy efficiency policy measures. This means that the current policy mix mainly aims at improving energy efficiency, but neglects other factors influencing electricity consumption (as e.g. size of dwellings or products).

Finally, in terms of energy *innovation* policy, Germany has increased its R&D funding since 2002, and has significantly upscaled them even further from 2009 onwards, as illustrated in Figure 48. The dominance of money invested in nuclear in the nineties has been replaced by a more balanced portfolio. One particularly notable development is the increase in spending on energy efficiency research since 2009, after a long phase of neglect prior to that.

Figure 49: Expenditures (in real 2000 figures) for federally funded energy research

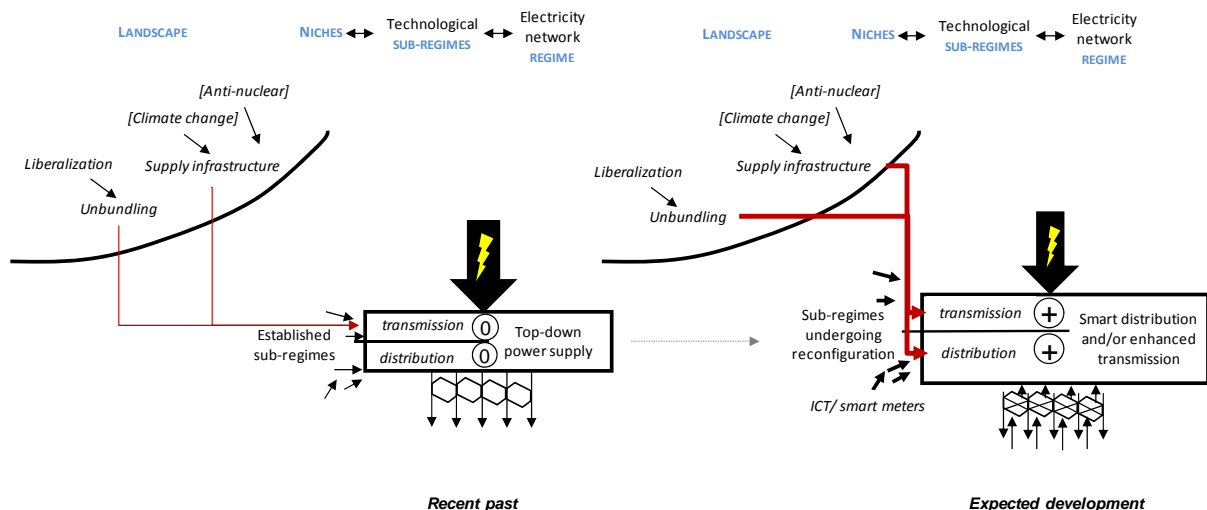


Source: BMWi 2014b. p.79

7 Developments in electricity network regime

We now turn our analysis to the development of the electricity network regime which connects demand with supply through transmission and distribution grids (Figure 50). We again proceed by first depicting the most important developments in the main tangible system elements in transmission and distribution networks (section 7.1). Thereafter in section 7.2 we describe the main actors and institutional changes in the electricity network regime.

Figure 50: Schematic representation of changes in electricity network regime



Source: own illustration

7.1 Developments of the main tangible system elements

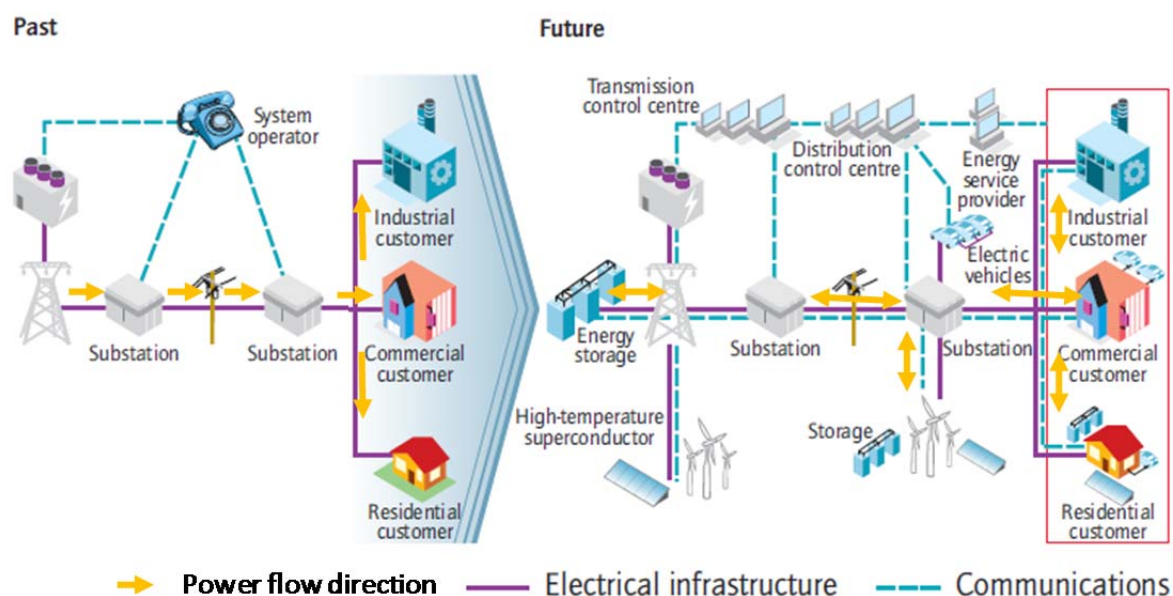
The German transmission network is operated at 220 and 380 kV and has a circuit length of roughly 35,000 km. It is integrated into the European interconnected network. The distribution networks consisting of high voltage, medium voltage and low voltage have a circuit length of around 1.7 Mio km. Networks are subject to incentive regulation. The Bundesnetzagentur as Federal regulator is responsible for networks crossing several states or having at least 100 000 customers. Smaller, within state networks are under responsibility of state level regulators.⁹

The power network enables the transport of electricity from generators to consumers which makes it an essential part of the electricity system. The optimal network configuration is dependent on the structure of supply and consumption. Three important structural changes challenge the electricity network. First, increasing shares of decentralized generation such as PV at household and residential premises overhaul the traditional paradigm of unidirectional top down power flow from big (centralized) power generation via transmission and distribution networks to consumers (Figure 51). Distribution network operators hence may face significant changes in their service definition triggering investment need. The application volume for expansion factor and the investment budget, two instruments to address these special investment needs shows a clearly increasing trend (Figure 52). Importantly, this effect does not hit all networks equally, since decentralized generation is unequally distributed with 80% of renewable generation capacity connected to only 20 of the roughly 880 distribution networks (Bundesnetzagentur 2015b). In particular in regions and/or times of low demand, for example in rural areas in southern Germany, distributed generation may cause reverse power flows. That is power that was traditionally transported top down from central generation to the final consumers, may flow from feeders to substations or even feedback from low voltage networks to medium voltage networks. Adaptations are needed to make the network fit for the changes.

Second, renewable generation is often intermittent in contrast to traditional dispatchable generation. This increases the need for flexibility in the power system e.g. via storage or demand side management. Smart grids that enable intelligent control of generation, demand and storage to optimize the power system via information and communication technology are a technical concept to provide this flexibility are seen as one solution and promoted by the German government. Network investment often reduces the need for flexibility because over a larger (geographical) scope, some fluctuation at both demand and supply side balances itself.

⁹ The states Berlin, Brandenburg, Bremen, Mecklenburg-Vorpommern, Schleswig-Holstein and Thüringen delegated this responsibility to the Bundesnetzagentur at Federal level.

Figure 51: Power system in the past and in the future



Source: IEA 2011 with own additions

Figure 52: Number and financial volume of applications for the expansion factor in distribution networks from 2009-2012

application date	number of applications	max expansion factor	min. expansion factor	max. amount in Mio Euro	min. amount in Mio Euro	total in Mio Euro
2009	133	25	10.014	19.60	830	116.4
2010	111	13	10.024	59.7	7093	317.1
2011	106	123	10.033	28.3	21955	402.4
2012	116	13	1.007	67.8	8915	532.8

Source: Deutscher Bundestag 2014

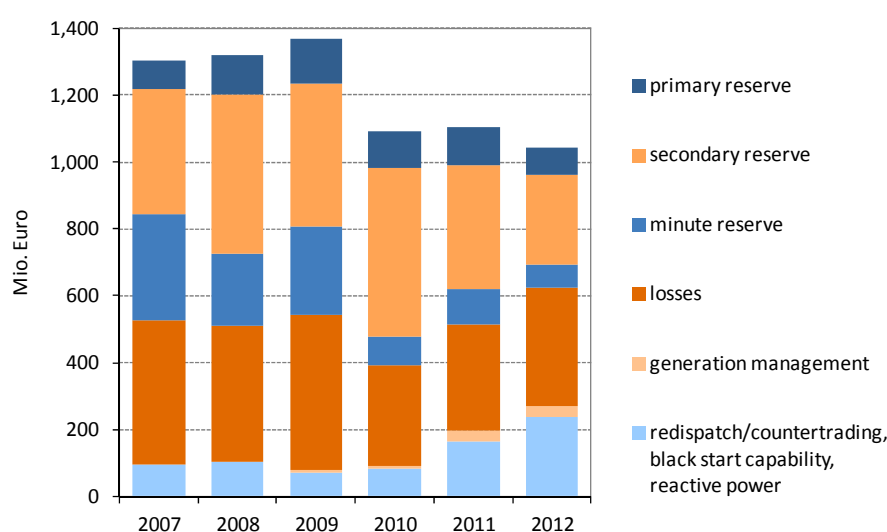
Third, transmission is challenged by the increasing divide between load centers in the South and power generation in the North. Increasing wind feed-in (North) and nuclear phase out that reduces generation capacity and capacity available for redispatch in the South are main drivers. The problem is aggravated by socio-demographic changes. Expansion of transmission lines is therefore considered essential for the integration of renewable power generation. The lack of reliable generation capacity for redispatch in certain regions was countered with the establishment of so called network reserve contracted by network operators and refinanced via network tariffs.

In particular during winter massive interventions by transmission network operators were needed to maintain system stability. The increasing need for active network management becomes visible in the development of redispatch measures. The expenses for ancillary services more than doubled from 2010 to 2012 (Figure 53). The significant decrease in 2010

is the effect of the unification of procurement of balancing power among the four TSOs. The reduction is in particular attributable to lowered minute reserve requirements.

Following challenging network situations in Winter 2011/2012 in the follow-up of nuclear shut-down and scarce reserve capacity in the South, the BNetzA as Federal regulator concluded that administrative measures were needed to guarantee sufficient availability of reserves for the purpose of network management. The directive on reserve power plants (Reservekraftwerksverordnung -(ResKV) was published in 2013 and requires the BNetzA to assess the need for network reserve annually. Plants that are declared system relevant are not permitted to be retired (§13a EnWG and § 10 ResKV).

Figure 53: Development of cost for ancillary services



Source: Own illustration based on the annual monitoring reports of the Federal regulator, Bundesnetzagentur, Bundeskartellamt 2014

Network expansion has progressed slower than planned. 15 of the 23 ongoing priority projects (listed in the energy line expansion law) were expected to be delayed by one to five years and only 352 of 1,877 km of the lines to be build were realized (BMW 2014f). The mentioned reasons for delays in the past were very diverse. A common factor were acceptance problems that required adaptations in the planning or the change to (partial) underground cabling. Such changes were also triggered by changes in the regulations concerning cabling (partially at state level). Problems with the permitting process were another reason for delays in the past (Bundesnetzagentur 2015a). In general, long life time of network assets hinders rapid or dramatic restructuring of networks. Notwithstanding the expansion need in transmission networks (which remains high on the agenda of politicians and regulators, but seems by now adequately addressed), meanwhile restructuring of distribution networks for the energy transition became a big topic, too (dena 2012). More precisely, the biggest share of network investment to accommodate the increasing shares of

renewables is expected in distribution networks. Obviously part of this is caused by the fact that they make up for the larger part of the total circuit length, but looking at the relative share of lines to be built, the investment need is still higher, in particular in medium and high voltage distribution networks. The calculated km of lines to be added here by 2030 make up around 20% of the circuit length. In transmission and low voltage distribution the figure is around 5% (dena 2012 and own calculation based on Bundesnetzagentur 2015a). In particular in regions with high shares of decentralized generation and low demand, distribution networks are prone to experience reverse power flows. If these exceed the construction limits, expansion and upgrade are required. While the transmission network already features a lot of communication, metering, automation and control technology, this is less common in distribution networks. They are largely operated without precise knowledge about the actual network conditions of certain lines. In particular in distribution networks many assets are up to renewal anyhow which opens windows of opportunity to combine replacement with upgrade and thereby gradual change of the networks towards more smartness.

7.2 Main social groups and intangible regime elements

Historically, the entire electricity supply chain was perceived as a monopolistic task. It was (not only) in Germany organized by vertically integrated utilities that were responsible for power generation and transport to the final customer in regional monopolies. Sector restructuring in Germany took place in response to the liberalization directives of the EU in 1998. Closed supply areas as regional monopolies were abolished. Stepwise, free supplier choice was introduced for customers (industrial customers July 2004, household customers July 2007) and network operators were obliged to open their networks for transport of power from other suppliers and third party generators. While the rapid and complete opening for third party access and free supplier choice can be seen as progressive and went well beyond EU requirements, its effects were limited at first. This is attributed to Germany's choice of negotiated third party access. It relied on the potential for self-regulation of the sector allowing network tariff calculation and access conditions to be negotiated between lobby institutions of the German industry (as big network users) and the line bound energy industry. The outcome were the so-called "Verbändevereinbarungen - VV" (associations agreements) in place from 1998-2004¹⁰ and effectively even longer since the energy law (Energiewirtschaftsgesetz – EnWG, dating back to 1935) in 2003 considered their prescriptions to reflect best practice (Bundesnetzagentur 2015b). Since third parties would typically be in a weaker negotiating position than incumbents, negotiated third party access stabilized existing structures and slowed down liberalization.

The second liberalization directive in 2003 (transposed into German national law with EnWG 2005) made regulated network access binding. Furthermore, a sector specific regulator with sufficient power to ensure non-discrimination in order to promote competition had to be installed. This is also a major change in Germany that previously relied on general

¹⁰ with two intermediate reforms (2000: VV II and 2002: VV II plus)

competition law to control by the federal cartel office for abusive practices in the electricity sector.

Not satisfied with the progress made regarding competition and European market integration, the European Commission identified insufficient unbundling of power networks from generation activities as one barrier to infrastructure investment and fair competition (EC 2007a). Subsequently, it pushed for ownership unbundling of the networks in its proposal for the third liberalization package (EC 2007b) to eliminate incentives to strategically withhold network investments as well as incentives and potential for discrimination at the supply stage¹¹. An independent system operator (ISO) was proposed as alternative allowing utilities to retain network ownership while delegating system operation to an independent third party. Germany (and France) strongly opposed and succeeded to install the independent transmission owner (ITO) as what became known as “the Third way” (Brunekreeft 2008). The ITO allows companies to retain both network ownership and management but requires strict legal unbundling including prohibitions on cross-involvement of employees to ensure independence of the network.

In 2008 the debate on the creation of a single German wide transmission network operator that would own and operate the grid was renewed following earlier discussion even pre-liberalization that were all blocked by TSOs referring to system security. Such a “Netz AG” would be government owned and hence ensure public interest in operating and expanding the network. Proponents also argued for increased efficiency of unified balancing markets and administration because of a single contact point, uniform conditions and hence increased transparency for new entrants. According to Charlotte Ruhbaum (2011) actors in favour of the “Netz AG” were the Federal Environmental Ministry,¹² the Green and the Left party, as well as the association renewable energy suppliers (BEE) that expected improved access conditions for new entrants (Charlotte Ruhbaum 2011). Also the Bundesnetzagentur regarded the proposal positive. However, they were against ownership unbundling in line with the Federal Ministry of Economics, the Monopolies Commission and the transmission system operators mainly on the grounds that it would not be the least restrictive measure to achieve the desired goal of non-discriminatory network access and competition on a level playing field. While the TSOs were initially united against ownership unbundling and the “Netz AG”, interestingly Mr. Bernotat, then head of E.On, supported a “Netz AG” in 2008 in the run-up to the sale of E.on which would offer the chance for such a step¹³. The proposal for a “Netz AG” did not succeed since the government aimed for a consensual solution that was blocked by TSOs (Charlotte Ruhbaum 2011). Still, the balancing procedure has been combined for the four TSOs and led to major reductions in the expenses for ancillary services (Figure 53). Interestingly, even though Germany pushed for the ITO, meanwhile, two of the four TSOs

¹¹ Thereby it would level the playing field among incumbent generators and new entrants and foster competition. Competition in turn is expected to reduce prices, foster innovation and thereby benefit consumers. Also, new entrants are often renewable generators which might than directly benefit from unbundling.

¹² <http://www.spiegel.de/wirtschaft/unternehmen/netz-ag-umweltministerium-will-stromnetze-verstaatlichen-a-645411.html>

¹³ <http://www.spiegel.de/wirtschaft/uebertragungsnetze-e-on-chef-will-deutschlandweite-stromnetz-ag-a-542094.html>

have a fully ownership unbundled structure. Of the other two, in one (Amprion), the utility RWE only holds a minority share and only one (Transnet BW) is still owned by a utility (EnBW).

Unbundling can be expected to destabilize the traditional regime since it strengthens the focus on network operation and required companies to review their business models anyhow. Yet, ownership of transmission networks by investors is sometimes mentioned as risk, in case investors would push for short term interest optimization instead of stable long run returns.

Since 1.1.2009 networks are subject to incentive regulation that prescribes a (typically decreasing) revenue cap for network operators for each year of the five-year regulatory period to foster efficiency in the network business. This was a major paradigm change over a basically cost-based regulation before. As desired, it led to tariff reductions in the first years after its introduction, but accompanied by a debate on investment incentives. Network expansion has been a dominant topic in Germany at least since 2005 when a study on the network planning for wind integration was published by the German energy agency (dena 2005). The study and its follow up (dena 2010) found that ambitious expansion of the existing transmission network would be needed to integrate the targeted amount of wind power. Yet, network expansion was lagging behind plans. It was questioned whether incentive regulation and in particular the interest rates and investments incentives would be adequate in view of need to restructure and expand the networks. Subsequently, several amendments have been undertaken to improve investment incentives resulting from regulation: a) investment barriers were reduced by allowing network operators to adjust the revenue cap directly in the year when the investment becomes cost relevant in contrast to cost recognition ex-post which usually lead to a time lag of 2 years. b) expansion factors and investment budgets for distribution network operators allow for refinancing investments mainly driven by renewable integration. c) Cost recognition for the deployment of innovative technologies and R&D expenses was improved. d) A quality element was introduced to complement the cost-efficiency incentives and ensure that network operators would not maximize profits by delaying investments at the expense of long term supply quality (“asset sweating”). Two recent reports find no adverse effects on investments (Bundesnetzagentur 2015b; Cullmann et al. 2015).

A further, major barrier for network expansion has been acceptance problems. The biggest problems arise with respect to overhead lines and their impact on the view of the country side. Further aspects are economic “side” impacts such as reduced value of real estate, health effects from electromagnetic waves, impacts for wildlife (such as birds colliding with overhead lines or pylons) and plants and a general distrust towards network operators and their economic interests motivates resistance towards network expansion (VDI 2014; Deutsche Umwelthilfe 2013). An environmental initiative also criticized the expansion would rather serve improved integration of coal powered generation than renewables (BUND 2012). Plan N was one important project that aimed to identify how acceptance for the necessary network expansion can be achieved. It brought all concerned parties together for developing policy recommendations for the integration of renewable into power networks. The original report was submitted in 2010 and followed by a stock-taking report and an update in 2013

(Deutsche Umwelthilfe 2011, 2012, 2013). Key recommendations were the harmonization of European and German regulation, better planning of network expansion including increased public consultation, an expanded role for the regulator with respect to restructuring the networks and approving the resulting network expansion cost, minimization and optimization of network expansion as well as the increased use of underground cables were possible. Many of the recommendations were already realized. The main points addressed were a) improved planning b) a broader and earlier involvement of the public, c) streamlining of administrative processes.

The expansion needs identified in the 2005 study of the German energy agency (dena 2005) were included in a law on the expansion of energy lines (Energieleitungsausbaugesetz) in 2009 fostering coordinated planning of network expansion needs with the ultimate aim to accelerate network expansion of transmission lines. In 2011 then, the law on acceleration of network expansion (NABEG) created the legal basis for regular and transparent transmission network planning including an increased role for public consultation and participation. Transmission network operators are required to publish an annual network development plan that lists all measures for the two time horizons: next ten and next 20 years. Additionally, a needs assessment for the development of offshore networks has to be carried out and published in an offshore network development plan (§ 17b EnWG). The aim is to foster coordinated development of offshore wind parks and grid connection since lacking coordination as well as regulatory problems¹⁴ caused delays in wind park development initially, but then led wind parks being build remain unable to feed in because of delayed grid connection. The issues caused significant discontent of responsible TSO TenneT and the public calling politicians to act and subsequently led to the EnWG amendment in 2012.

The legislative package from summer 2011 brought a significant improvement concerning transparency and stakeholder involvement and information. Public consultation is now already foreseen when the scenarios for assessing the network expansion need are created and further participation is foreseen in the subsequent steps of the planning process. There seems to be a tendency also to improve the communication among the parties involved e.g. via a project manager as mediator (VDI 2014). It remains to be seen how these opportunities for involvement are adopted and “lived” by both sides. Initial experience showed a distrust of citizens towards network operators accusing them of not being honestly interested in their opinion (VDI 2014). Hence, public involvement could remain ineffective in increasing acceptance. Overlapping consultation phases and short time frames are identified as barriers for effective participation in the Plan N 2.0 (Deutsche Umwelthilfe 2013).

Another discussion dealt with financial participation of citizens in networks expansion. In a joint paper, the economics ministry, environmental ministry and the four TSO proposed to issue so called “Bürgeranleihen” (citizen bonds) that would allow citizens to financially participate (and benefit) in network expansion with a 5% interest and thereby increase

¹⁴ One problem became known as hen-egg problem: project developers needed financing commitment and grid connection. These however, were mutually dependent since banks required a grid connection commitment to agree financing, while TSOs would require financing as indicator for a high probability the project would be realized. Meanwhile the regulatory conditions have been adapted.

acceptance (BMW, BMU, 50 Hertz, Amprion, TenneT, Transnet BW 2013). Demand for these bonds however had been far lower than expected.¹⁵ After public consultation the plans are evaluated and approved by the BNetzA and at least every three years, submitted to the government as draft for the National network development needs plan. With the publication of this plan, the projects included in the list are recognized as necessary for the system and receive high priority (legally binding). The NABEG gave the regulator wide responsibility in the field of network expansion. These changes centralize expansion planning and are expected to facilitate network expansion since they streamline the administrative process and increase certainty for investors.

Innovative transmission technologies are discussed as important component for the future power network. Underground cabling e.g. is a very prominent point in the debate of measures to increase acceptance. For broader use and deployment of underground cables at higher voltage levels, further research is needed on the effects for the ecosystem, power system and acceptance (Deutsche Umwelthilfe 2013). Meanwhile four pilot projects for high voltage cabling are supported under the EnLAG (Bundesnetzagentur 2015a). Another promising technology that is discussed are high-voltage direct current (HV-DC) lines that may offer several advantages such as reduced losses for long distance transmission, no alternative magnetic field and better options for high voltage cabling.

The opinion on the role of bulk storage for the energy transition is not uniform. The German energy agency describes them as central pillar for the energy transition.¹⁶ Pumped hydro is established and used technology in the German power system and can contribute flexibility. But no new capacity is expected because of unfavourable market conditions (Hildmann et al. 2014). A trilateral study for Germany, Switzerland and Austria sees a significant contribution of pumped hydro to network and market integration of renewable only in the longer run (20 years) and with high shares of renewable generation (50% and more). Until then, the contribution would only be minor because existing flexibility were sufficient. Importantly, since pumped hydro is typically not located close to generation sources, its use for balancing peak generation requires high transmission capacity (Hildmann et al. 2014). Hence storage may not obviate the need for transmission expansion.

TSOs cooperate via ENTSO-E, the European Network of Transmission System Operators technically, but also with respect to network planning and development as well as R&D plans. ENTSO-E aims to foster the integration of renewables and the completion of the internal energy market and can be seen as central institution concentrating TSO positions and interest. While this could work in the direction of stabilizing the existing network regime, it rather seems to enable more rapid change by coordinated action.

Distribution networks

¹⁵ FAZ from 16. October 2013. <http://www.faz.net/aktuell/politik/energiepolitik/stromnetz-tennet-flopp-mit-projekt-buergerleitung-12620718.html>

¹⁶ E.g. see the pump storage platform of the German Energy Agency (dena): <http://www.pumpspeicher.info/>, last access 17.12.2014

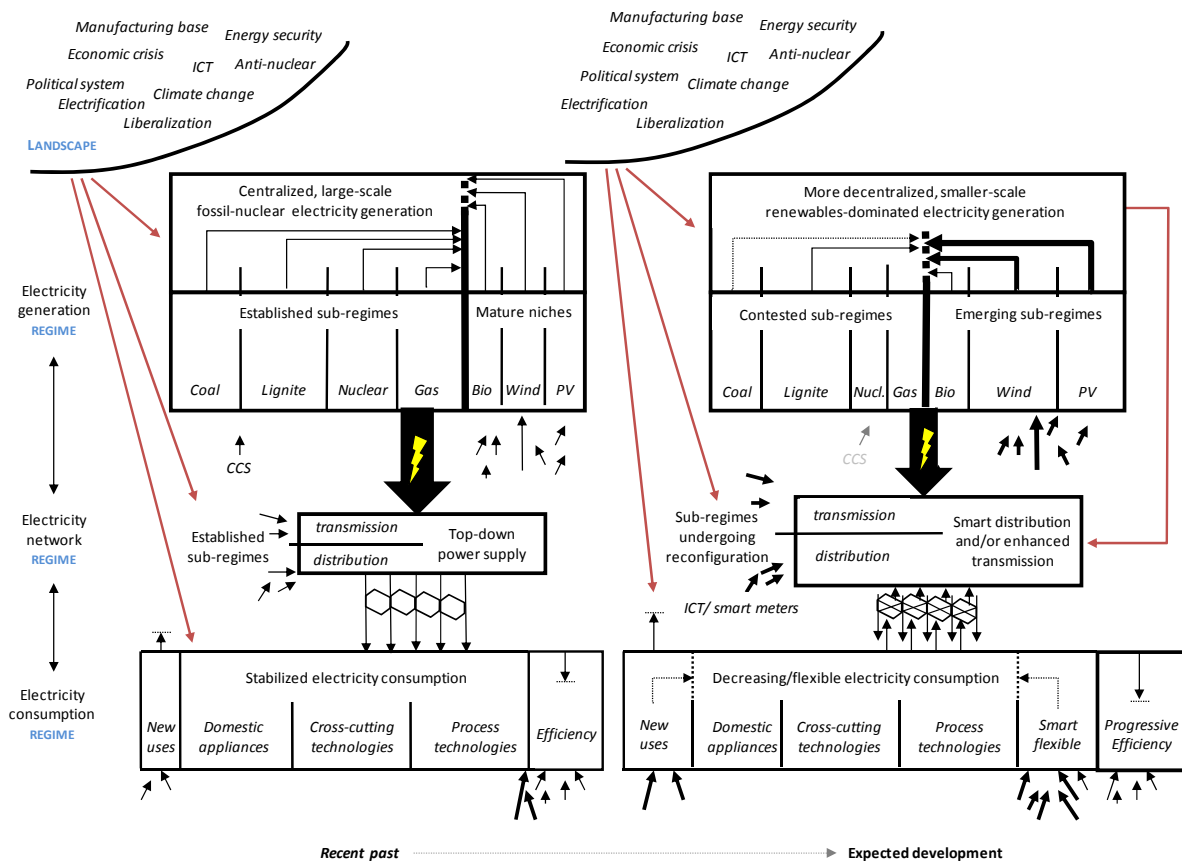
Lower voltage networks serve final distribution to customers. They make up the largest share of the circuit length and are operated by a large number of regional and municipal network operators (~880 DSOs in total). More than 90% of the distribution network operators have less than 100,000 customers and make up for only a small part of the line length. The number of DSOs is more or less stable subject to two countervailing trends: Some municipalities decide to take back responsibility for the power networks when concession contracts are due for renewal which is referred to as re-municipalisation (Rekommunalisierung) which might increase the number of (small) network operators. The contracts typically run for 20 years and many have been and are up for renewal over the last and the next couple of years. Re-municipalisation could be a threat for regulatory effectiveness by increasing number of applicants. It is argued that conditions for such small networks are very positive potentially because of simplified regulation (for DSOs with up to 100,000 customers) and under responsibility of state level regulators as well as because of favourable tax conditions (Deutscher Bundestag 2014). Countervailing are mergers among network operators with the aim to create synergies and raise efficiency.

Under the pressure of high investment need, incentive regulation and acceptance problems, there is a strong vote for optimized network investment and the exploitation of innovative technologies and flexibility options at both generation and demand side to optimize network investment. Such flexibility options are demand side management, storage and coupling with other sectors e.g. heating (power to heat, storage heaters), gas (power to gas, flexible CHP generation) or transport (electric vehicles, vehicles to grid). Smart meters can contribute to access demand and generation resources and partially already do this, but a broad roll-out is currently not economically advantageous (Deutsche Umwelthilfe 2013). Smart grids are promoted and sometimes appear to be the silver bullet to achieve efficient and sustainable power systems at least at distribution level. However, it is not yet clear how this should be realized. One major discussion point is the interaction between market and network (Bundesnetzagentur 2011) and how to mobilize flexibility potentials which requires adequate incentives both for the network operators as well as for the customers/ generators. In the debate the traffic light model developed by the BDEW (the association of the energy industry) received much attention and was broadly adopted as basis for discussion (BDEW 2013a; Deutsche Umwelthilfe 2013). It describes a green phase in which all desired market transactions can be realized without problems for the network. The red phase refers to emergency situations in which the network operator needs to intervene to maintain system stability. Most interesting is the yellow phase in which certain network congestion occurs, but market based measures may be used to relief the system. Currently, the government is calling for proposals to demonstrate intelligent energy for wind and photovoltaic integration (BMWi 2015b). It can be expected that the projects are aimed to demonstrate not only technical solutions but also serve to advance the regulatory framework and business models.

8 Conclusions about stability and tensions

The analysis of developments within the German electricity system has highlighted that the interconnected regimes of electricity generation, transmission and consumption are experiencing significant landscape pressures (anti-nuclear movement, climate change, energy security, liberalization) and knock-on effects from the resulting growth of increasingly mature niches and interactions between the three regimes (see Figure 54).

Figure 54: Schematic overview of changes in German electricity system



Source: Own illustration

The resulting change is most advanced in the supply regime, in which the mature niches of wind, PV and bioenergy have expanded so radically that at least PV and wind are on the brink of becoming new sub-regimes that are driving the regime in the direction of much more decentralized and smaller scale electricity generation based on renewable energies. This transformation of the generation regime creates pressures on the transmission regime, which has started to adjust to the new circumstances of more fluctuating, at times bi-directional electricity flows. Even the quite stable electricity consumption regime, which so far has experienced mainly incremental changes, is coming under increasing pressure to make the changes needed for the overall success of the low-carbon transformation of the German electricity system, both in terms of radical cuts in electricity demand (despite additional uses, such as e-mobility) and increasing the flexibility of use. In the following, for each of the regimes, we summarize our conclusions on the most important stabilizing and destabilizing developments.

8.1 Electricity generation regime

Over the period from 1990 until today the German electricity generation system has witnessed major landscape pressures – most importantly a strong anti-nuclear movement paired with concerns about climate change. Additional tensions have resulted from the increasing impacts of the emerging niches of wind, solar PV and bioenergy, which have expanded significantly and can now start to be viewed as new sub-regimes (see Figure 21 and

Table 3). The sheer size, different ownership structure and characteristics of these emerging green sub-regimes have meant fundamental changes along many dimensions of the German electricity regime. This regime is now transforming from one characterized by centralized, large-scale electricity generation dominated by large utilities to a much more decentralized, and smaller scale electricity generation regime based on renewable energies, with the ownership of generation capacities spread across a multitude of new entrants, including a high share of citizens, farmers and cooperatives. In addition, the established business models of the incumbent utilities are eroding. Indeed, while the large incumbents have undergone multiple changes in beliefs and are now investing in large-scale renewable energies, their long-term survival is still at stake because of their lack of business model capabilities to harness the chances and opportunities from the ongoing energy transition. In 2012 and 2013, however, the decarbonisation of the electricity generation system experienced a setback due to rising shares of lignite and hard coal in the generation mix – despite declining capacities. There have also been recent changes in the key policy instrument supporting the expansion of renewable energies, the EEG, which indicate a change in policy favouring larger investors. This is partly due to pressures to advance the market integration of renewables, and partly due to political concerns about the ever-increasing EEG surcharge, which is largely borne by private electricity consumers because of the exemptions for energy-intensive industries. Hence, while nuclear phase-out and the transition towards renewable energies are not being questioned, there are ongoing disputes about what the future regime will look like (e.g. regarding the degree of decentralization) and who the winners and losers will be.

Table 3: Summary of stabilizing forces and tensions in electricity generation regime

	Lock-in, stabilizing forces	Cracks, tensions, problems
External landscape pressures	<p>WEAK</p> <ul style="list-style-type: none"> - Further electrification of society (heat, mobility, ICT) potentially leading to increased electricity 	<p>STRONG</p> <ul style="list-style-type: none"> - Very strong anti-nuclear movement - Climate change and nature conservation taken very seriously

	<p>demand</p> <ul style="list-style-type: none"> - Maintaining competitiveness of energy-intensive industries 	<ul style="list-style-type: none"> - Federal political system with proportional voting (enabling Green Party in government coalitions and initiatives at national, federal and local levels) - Liberalization and unbundling of electricity markets - Engineering and manufacturing nation benefitting economically from the development and sale of renewable energy technologies - Financial and economic crisis reducing electricity demand and electricity prices - Geo-political tensions with Russia (gas) and security of supply concerns
Utilities	<p>MODERATE</p> <ul style="list-style-type: none"> - Sunk investments in power plants, and commitment to existing technologies and resources (particularly lignite as domestic resource) - Business model and internal knowledge focuses on centralized, large-scale power generation - Attempts to socialize burden from second nuclear phase-out (court cases) - Especially in the early years, hardened fronts between utilities and renewable energies (losing market shares to new entrants) - Critical regime players for reliable electricity production, job creation, generation of public income due to still big, albeit shrinking, market shares - Beginning involvement in larger-scale renewables (e.g. offshore wind) 	<p>STRONG</p> <ul style="list-style-type: none"> - Acknowledgement of climate change and policy target of decarbonisation of electricity system by 2050, but struggling with identifying aligned strategy - Growing realisation of the misalignment between old business model (large-scale fossil-nuclear) and new market realities due to increasing shares of intermittent, decentralized renewable electricity and phase-out of nuclear (similarly pending for coal due to unavailability of CCS and politically stable long-term climate targets) - Financial difficulties, reduction in staff, restructuring in an attempt to survive the energy transition - Loss of influence in policy circles (compared to very close links between policy-makers and the “big 4” utilities (E.ON, RWE, Vattenfall, EnBW) in the past)
Consumers	<p>MODERATE</p> <ul style="list-style-type: none"> - Electricity consumption is an essential part of private and professional life and is taken for granted 	<p>MODERATE</p> <ul style="list-style-type: none"> - Several green electricity tariffs exist, but demand for these is lower than the current share of renewable electricity generation (15 vs. 25%)

	<ul style="list-style-type: none"> - Only limited switching of customers between electricity providers thereby reducing retail price competition and the pressure to pass on spot market electricity price reductions of renewables - Marketing efforts of retailers to sell existing hydropower as “green electricity” (greenwashing) successful to some extent - Consumers are paying for renewables through EEG surcharge, leading to complaints about rising electricity bills and concerns about distributional fairness 	<ul style="list-style-type: none"> - Attempts to reduce electricity demand by switching off lights, using energy saving light bulbs or LEDS, and reading energy labels when buying appliances (see consumption regime)
Policy-makers	<p>MODERATE</p> <ul style="list-style-type: none"> - Strong support of new entrants and private investors in the past, but in recent years, increased attention to cost and management considerations favouring larger investors (having surpassed 25% of electricity generated from renewable energies, debates about rising EEG surcharge and pressure from the EU) - Economics ministry for a long time on the side of large incumbents and blocking transition to decentralized renewables, but with counterpart of environment ministry, which was in charge of renewables and promoted new entrants - Explicit niche protection of offshore wind as large-scale renewable energy technology promoting industrial development of economically deprived coastal regions and accommodating big utilities (since 2002, but recent reduction of 2020/30 targets in 2014) - Regional governments of coal- and lignite-rich federal states block destabilization policies phasing out coal (e.g. NRW) 	<p>STRONG</p> <ul style="list-style-type: none"> - Climate policy has introduced a new environmental policy style with targets supported by economic instruments (eco-tax, EU ETS), but political attention to climate change has ebbed since 2009 (lack of leadership in fixing low CO2 price in EU ETS, high priority to costs and competitiveness). Renewed momentum during the run-up to influential 2015 COP in Paris - German government has focused the most climate change attention on electricity generation, with strong policies supporting the expansion of renewable energies (EEG) and reconfirmed phase-out of nuclear (cross-party support in 2010 after Fukushima) - The energy transition is a political flagship project with front-page coverage - missing policy targets would damage the reputation of leading politicians such as the Economic Minister Gabriel (Vice Chancellor, responsible for energy transition) - Recent shift of energy expertise from environment ministry to economics ministry signals greater political attention to the energy transition's success and cost minimization, but could also undermine the focus on decentralized, citizen-investor- driven

		<p>transition</p> <ul style="list-style-type: none"> - Difficult search for safe site for future storage of nuclear waste
Public debate and opinion	<p>WEAK</p> <ul style="list-style-type: none"> - Debates about rising electricity prices and distributional unfairness caused by exemption rules for energy-intensive industry, but energy transition as such not questioned - Local concerns about loss of jobs in coal regions, but research has shown positive net employment effect from transition to electricity generation based on renewable energies 	<p>STRONG</p> <ul style="list-style-type: none"> - Open and engaged debates about how to achieve a radical transformation of the energy system at all governance levels (including city initiatives), and central media coverage - High public acceptance of transition to electricity system based on decentralized renewable energies linked to strong anti-nuclear movement, negative image of large utilities, large share of private investors benefitting from feed-in tariffs (e.g. rooftop PV) and job creation effect of renewables - Strong opposition to storing CO₂ underground and to shale gas, increasing resistance to coal-fired power plants
Pressure from social movements, NGOs, scientists	<p>WEAK</p> <ul style="list-style-type: none"> - Some neoclassical economists continue to argue for emissions trading as a least-cost solution, i.e. suggest abandoning the EEG, but despite high visibility, they have lost much of their influence in public and particularly policy debates 	<p>STRONG</p> <ul style="list-style-type: none"> - Most NGOs advocate radical, decentralized renewable electricity technologies that deviate from the existing regime, and are important voices in public debates - Growth of environmental think-tanks and scientists with strong modelling capacities, who are actively advising policy-makers, industry and NGOs, highlighting cost-effective ways of achieving decarbonisation and renewables targets without nuclear - Highlighting high costs of nuclear and feasibility of electricity system based on PV and wind
Overall assessment	<p>WEAK</p> <p>The electricity regime is undergoing radical changes which at this point seem irreversible, implying that the main future sub-regimes will be PV and wind</p>	<p>STRONG</p> <p>There are major and most likely irreversible tensions and cracks in the electricity generation regime. The climate change problem and anti-nuclear movement has led</p>

	with some flexible back-up (gas, biomass), but there is an ongoing dispute about the final regime dimensions. Resistance from regime actors is focused on reducing losses, buying time and identifying new business models to ensure survival in the new regime	to significant institutional changes, e.g. ambitious GHG reduction, RES expansion and nuclear phase-out targets and specific policies. The resulting structural changes in infrastructure (renewable energy makes up 50% of generation capacity, with a negligible share owned by large incumbents) with their reduction of electricity market prices and thus decreased profitability of existing conventional plants are forcing large incumbents to rethink their beliefs and strategies
--	---	---

8.2 Electricity consumption and end-use regime

The consumption side of the electricity regime is evolving incrementally through the interplay of several dynamics which may have a reverse effect on the development of electricity consumption. Changes in the range and absolute number of electrical products and to production and employment in the industrial and service sectors have the predominant effect of increasing electricity consumption. These factors dampen the rise of electricity consumption only during periods of economic recession. Another growth-stimulating effect is the still ongoing trend to greater automation and widespread diffusion of new electrically powered applications and technologies (as e.g. information and communication technologies, electric vehicles and electric heat pumps). On the other hand, energy efficiency innovations have helped to suppress increases in electricity consumption. These manifested themselves in manufacturers' efforts to increase the energy efficiency of electric household appliances and cross-cutting technologies (e.g. electric motors, lighting, ICT) and the increasing market penetration of such technologies. This development was stimulated to a large extent by the EU's and national governments' policy measures. However, it is often unclear how behavioural and organisational changes impact the purchase and use of electric appliances and products in private households and companies. They can have a decreasing effect on electricity consumption, often stimulated by informational and advice programmes, but the opposite is also possible, e.g. through rebound effects.

These patterns can be understood in the context of competing landscape pressures (see

Table 4). On the one hand, concerns about climate change and energy security as well as the favourable side-effects of energy efficiency have exerted pressure on the consumption regime, generating the drive towards greater energy efficiency. On the other hand, the trend towards greater electrification of households and companies is an important stabilizing force on the regime.

Table 4 summarizes the countervailing pressures exerted by the different actors in the electricity consumption regime.

Table 4: Summary of stabilizing forces and tensions in electricity consumption regime

	Lock-in, stabilizing forces	Cracks, tensions, problems
External landscape pressures	<p>MODERATE</p> <ul style="list-style-type: none"> - Future trend towards greater electrification in all end-use sectors (ICT, electric mobility, heat pumps) 	<p>STRONG</p> <ul style="list-style-type: none"> - Favourable economic side-effects of energy efficiency on economic growth, employment, competitiveness of the economy and others (the so-called “multiple benefits” of energy efficiency; IEA 2014) are a strong argument to address more efficient use of electricity - Climate change and energy security also place pressure on regime to address electricity consumption levels -
Industry	<p>STRONG</p> <ul style="list-style-type: none"> - For retailers and wholesalers, the energy efficiency of appliances and products sold is not at the top of their agenda - Producers of electricity-using products try to prevent progressive energy efficiency standards which would favour smaller appliances by lobbying activities - Weak control of compliance with the regulations for electricity-related products (minimum energy efficiency standards, labelling) concerning both retailers and producers in Germany limits these groups’ actions on energy efficiency issues - Exemptions from several taxes and surcharges on the electricity price for large industrial electricity consumers lower their incentive to invest in energy efficiency - Electricity utilities (especially the “big 4”) tend to be rather conservative and reluctant to 	<p>MODERATE</p> <ul style="list-style-type: none"> - German producers have a strong market position in the field of high-quality electrical household appliances and electrical cross-cutting technologies for industry and commerce; these products are usually also highly efficient - A relatively new association of the German energy efficiency industry (DENEFF) has become a stronger voice of German energy efficiency businesses

	develop new business models for energy services	
Consumers	<p>MODERATE</p> <ul style="list-style-type: none"> - Tendency to purchase larger and more appliances in the field of consumer electronics (e.g. large TV screens) and information technologies in private households and parts of the service sector (retail trade, hotels and restaurants) - Negative public reaction to energy efficiency standards for some goods, e.g. vacuum cleaners or shower heads, stabilize existing regime dynamics 	<p>MODERATE</p> <ul style="list-style-type: none"> - High electricity prices in Germany, especially for private households and small companies, favour investments in energy-efficient products and – though less pronounced – promote electricity-saving behaviour - Consumer groups and energy agencies at the national, regional and local levels campaign for the purchase of energy-efficient-products and behavioural changes with regard to electricity consumption
Policy-makers	<p>STRONG</p> <ul style="list-style-type: none"> - No support for progressive energy efficiency standards favouring smaller electrical products - Sufficiency aspects about the level of energy demand are widely neglected when designing policy measures 	<p>MODERATE / STRONG</p> <ul style="list-style-type: none"> - Ambitious targets set for energy efficiency (also including a reduction target for electricity) in the Energy Concept of 2010 and implementing the policies from the new National Energy Efficiency Strategy of December 2014 mean that energy efficiency is becoming more and more established as the 2nd pillar of the Energiewende (alongside the expansion of renewable energies)
Public debate and opinion	<p>MODERATE</p> <ul style="list-style-type: none"> - High data protection standards limit the spread of smart metering, smart appliances and smart homes, which otherwise could help to reduce electricity consumption. 	<p>WEAK</p> <ul style="list-style-type: none"> - Debates about the very high electricity prices in Germany for private households and small businesses, but these are mainly directed at the generation sub-regime, rather than at consumption and appliance use
Pressure from social movements, NGOs, scientists	<p>WEAK</p> <ul style="list-style-type: none"> - Some scientists (but not the majority) argue that specific policies addressing electricity efficiency and consumption at the level of end-uses are not necessary or even counter-productive if a well-functioning emissions trading system exists - In general, energy efficiency suffers from a relatively weak lobby, as it has fewer beneficiaries 	<p>WEAK</p> <ul style="list-style-type: none"> - Other scientists and NGOs criticise that rebound effects and sufficiency issues are not taken into account enough by the policy-makers

	than, for example, investments in renewable energy	
Overall assessment	<p>MODERATE / STRONG</p> <p>The future trend towards greater electrification in some fields (ICT, electric mobility, heat pumps) and some rebound effects (e.g. in lighting) may counteract the efforts to reduce electricity consumption.</p> <p>There are some important actors for whom energy efficiency is not a top priority (esp. electricity utilities, retailers and wholesale trade); this may undermine the efforts to increase efficiency and reduce electricity demand.</p>	<p>MODERATE</p> <p>There is a relatively broad consensus of all affected groups on the benefits of energy /electricity efficiency and the political target of reducing electricity consumption.</p>

8.3 Electricity network regime

Over the period from 1998 until 2015, the German electricity networks have been experiencing major challenges to the traditional operating strategies of the power system. Major drivers were developments in the generation structure with the emerging niches of wind, solar PV and bioenergy as well as the nuclear phase-out driven by the anti-nuclear movement. Another major factor at landscape level was the push for liberalization and unbundling of the electricity sector initiated and pursued by the EU from 1996 to 2009 with three waves of liberalization directives.

Changes in generation structure have challenged and are still challenging the system physically and require network expansions. However, since network expansion is not keeping pace with the changes, is plagued by acceptance issues and might not always be the most efficient solution, adaptations in network operation and management are also required. To some extent, this is taking place already with network operators engaging in redispatch and generation management. However, so far, this is mainly being managed centrally via the network operators and (nearly) limited to emergency situations. A wider use of flexibility options is being discussed, but the framework to implement this is still missing. This shifts the focus to the flexible management of generation and supply, optimization via smart grids using intelligent control and metering as well as storage solutions. It may therefore push the niche development of smart metering. Overall, the system is moving from centralized, top-down management towards a more decentralized, interactive system, but so far this is mainly happening on a physical level. This represents a challenge for the networks, some of which are approaching their limits already, but which cope mainly using existing measures. In the future, roles, responsibilities and regulations will have to be modified to be able to adapt operations to these changes. At the same time, transmission networks are also being enhanced

by innovative technologies and it is not yet clear what the network regime of the future will look like and how it will combine smarter distribution and expanded and enhanced transmission (probably also long-distance, high-voltage transmission to connect with other countries).

The network business as a centrally regulated activity is relatively stable per se, but is undergoing reconfiguration. Changes to regulation have been made to adapt it to the investment needs and quality demands which enable further changes in the future.

Table 5: Summary of stabilizing forces and tensions in electricity network regime

	Lock-in, stabilizing forces	Cracks, tensions, problems
External landscape pressures	MODERATE <ul style="list-style-type: none"> - EU directives on network regulation, network tariffs as well as international technical agreements 	HIGH <ul style="list-style-type: none"> - Increase of DG, (fluctuating) renewable generation, phase-out of nuclear and perhaps also coal/lignite within generation regime puts pressure on network with increasing congestion and need for redispatch - Development of ICT and information society -> new technological possibility such as smart grids may foster flexible integration of demand-side and generation-side resources into network management
Industry	MODERATE <ul style="list-style-type: none"> - Investments in grid infrastructure, long-lived assets - Incumbent companies rooted in old model of centralized power generation and transport of power “top-down” - Problems of refinancing, insufficient interest in investments plus time lag in recognition of investments in regulation have since changed. Similarly, problems of refinancing innovative technologies (in particular operational advances) are now being at least partially addressed in the regulation 	MODERATE <ul style="list-style-type: none"> - Some assets, particularly in distribution networks, are at the end of their lifetime and have to be renewed in any case, which may be a good moment to switch to more advanced network management/intelligent components, i.e. combining network renewal with upgrades - Unbundling formerly integrated incumbents (generation and network) makes network companies more focused on solely network operation and cost-efficiency. Incentives for innovation and quality are set separately via regulation to contain cost-efficiency incentives. - Operational model for networks is changing forced by DG and RES -> reverse power flows -> network operators are under pressure to change and changes in the regulatory framework have been necessary

		<p>(partially realized already)</p> <ul style="list-style-type: none"> - New actors promoting the use of flexibility since they see a business model in it
Consumers	<p>MODERATE</p> <ul style="list-style-type: none"> - Recent concerns about rising network tariffs and spatial inequality - Whether or not potential new roles of consumers (e.g. with DSM) will actually have a large impact on the systems remains to be seen 	<p>MODERATE</p> <ul style="list-style-type: none"> - Rising network tariffs partially caused by renewables plus locational inequality - Problem of self-generation and concerns about solidarity in cost sharing of the network (focus of debate is PV and household consumers, industrial self-generation not such a big issue) - Network tariffs and exemptions for industrial consumers are a big issue. More contribution from privileged consumers to relieve network desired and may be required for privileges to be granted in future
Policy-makers	<p>HIGH</p> <ul style="list-style-type: none"> - regulatory system - technical aspects and (international) guidelines (e.g. within the network of European Transmission System Operators ENTSO-E) limit or slow down the options for radical change - grid operators are not allowed to be active on the supply side due to unbundling of the sector; this limits their options to assume new roles, for example, by operation flexibility measures (this obligation derives from EU regulations) - regulatory incentives can help to steer network development, but the Federal regulator seems to be conservative and relatively slow in adapting the framework for network development and recognizing expenditure for innovative activities. However, recent changes mean that some pure R&D activities are now recognized. So far, regulation does not clearly target a low carbon 	<p>HIGH</p> <ul style="list-style-type: none"> - The focus on expanding renewable generation also puts networks in the limelight since they are needed to integrate the renewable power. Several laws to speed up network expansion have been passed. Even though their effectiveness remains to be seen, this seems to be a big step in the right direction. - Attention only paid to transmission networks to start with but now increasingly to distribution networks as well. - Research programmes and financial support for RD&D in smart grids, networks for the future and innovative network technologies with the aim to drive diffusion and practical experiences with new technologies and operational concepts featuring greater flexibility.

	<p>power system.</p> <ul style="list-style-type: none"> - Strong opposition of state/local politicians to the construction of new transmission lines 	
Public debate and opinion	<p>HIGH</p> <ul style="list-style-type: none"> - New transmission lines face massive acceptance problems - Some NGOs argue that the new transmission lines are more useful for lignite power plants than for renewables 	<p>HIGH</p> <ul style="list-style-type: none"> - Plan N as a project to reconcile different positions and find a way forward
Pressure from social movements, NGOs, scientists	<p>MODERATE</p> <ul style="list-style-type: none"> - Local resistance/ citizen initiatives (at local level) against network expansion/ construction - Environmentalists (collision of birds with overhead lines) 	<p>HIGH</p> <ul style="list-style-type: none"> - Scientists claim that more flexibility and more advanced flexible pricing are needed to reduce network congestion and restrict expansion - Inequality with respect to network tariffs and exemptions for energy-intensive industry
Overall assessment	<p>MODERATE</p> <p>A long-lived assets structure and regulation stabilize the existing regime. Regulation changes (such as targeted investment incentives to spur certain developments) can theoretically be realized more easily, but seem to be slow and are not likely to result in radical changes but only gradual adaptations of the regulatory framework.</p>	<p>HIGH</p> <p>Renewable integration and increase in decentralized generation require adaptations to the network management and structure. This has already led to some changes being made to the regulatory framework that allow and encourage network operators to make such adaptations. The changes also improve the incentives for network expansion, increase acceptance and streamline administrative processes. There is a strong consensus that network expansion is needed at the transmission level as well as the expansion and greater intelligence of distribution networks. Further changes are targeted with adaptations in the regulatory framework and network access conditions and could trigger the reconfiguration of the network regime.</p>

Publication bibliography

AGEB (2014): Energieverbrauch in Deutschland im Jahr 2013. AG Energiebilanzen e.V. Available online at www.ag-energiebilanzen.de.

AGEB (2015): Energieverbrauch in Deutschland im Jahr 2014. AG Energiebilanzen e.V.

Agora Energiewende (2013): Die Energiewende im Stromsektor 2013: Erzeugung, Verbrauch, Erneuerbare Energien und CO₂-Emissionen. Auswertung der Daten der AG Energiebilanzen. Agora Energiewende. Berlin.

Almeida, Aníbal de; Fonseca, Paula; Schlomann, Barbara; Feilberg, Nicolai (2011): Characterization of the household electricity consumption in the EU, potential energy savings and specific policy recommendations. In *Energy and Buildings* 43 (8), pp. 1884–1894.

BDEW (2013a): BDEW-Roadmap - Realistische Schritte zur Umsetzung von Smart Grids in Deutschland. Available online at [https://www.bdew.de/internet.nsf/id/816417E68269AECEC1257A1E0045E51C/\\$file/Endversion_BDEW-Roadmap.pdf](https://www.bdew.de/internet.nsf/id/816417E68269AECEC1257A1E0045E51C/$file/Endversion_BDEW-Roadmap.pdf), checked on 5/10/2015.

BDEW (2013b): BDEW-Energiemonitor 2013: Das Meinungsbild der Bevölkerung. Kommentierte Zusammenfassung der Ergebnisse der Meinungsforschungsstudie BDEW-Energiemonitor 2013. BDEW. Berlin.

BDEW (2014): Zahl der Unternehmen in den einzelnen Marktbereichen.

Berkel, Manuel (2013): by-nc-nd/3.0/de/ Autor: Manuel Berkel für bpb.de. Available online at <http://www.bpb.de/politik/wirtschaft/energiepolitik/148524/ausbau-des-stromnetzes>, updated on 2013.

BMBF (2014): Die neue Hightech-Strategie. Innovationen für Deutschland. Bundesministerium für Bildung und Forschung (BMBF). Berlin.

BMU (2010): Nationaler Aktionsplan erneuerbaren Energien für Deutschland gemäß der Richtlinie 2009/28/EG sowie der Entscheidung K(2009) 5174 der Kommission vom 30.

BMUB (2002): Zwischenberichte der Unterarbeitsgruppen I-IV (UAGs) der AGE, Phase II (Feb.-Dez. 2002). Available online at [http://www.bmub.bund.de/service/publikationen/downloads/details/artikel/zwischenberichte-der-unterarbeitsgruppen-i-iv-uags-der-age-phase-ii-feb-dez-2002/?tx_ttnews\[order\]=datetime&tx_ttnews\[dir\]=desc&tx_ttnews\[backPid\]=230&cHash=30f5b9d48f6b8277201787f6a1a269fa](http://www.bmub.bund.de/service/publikationen/downloads/details/artikel/zwischenberichte-der-unterarbeitsgruppen-i-iv-uags-der-age-phase-ii-feb-dez-2002/?tx_ttnews[order]=datetime&tx_ttnews[dir]=desc&tx_ttnews[backPid]=230&cHash=30f5b9d48f6b8277201787f6a1a269fa), checked on 5/19/2015.

BMUB (2003): Zwischenberichte der Unterarbeitsgruppen I-IV (UAGs) der AGE, Phase III (Jan.-Dez. 2003). Available online at [http://www.bmub.bund.de/service/publikationen/downloads/details/artikel/zwischenberichte-der-unterarbeitsgruppen-i-iv-uags-der-age-phase-iii-jan-dez-2003/?tx_ttnews\[order\]=datetime&tx_ttnews\[dir\]=desc&tx_ttnews\[backPid\]=230&cHash=7575dea2602a377ce675823d305fb5dd](http://www.bmub.bund.de/service/publikationen/downloads/details/artikel/zwischenberichte-der-unterarbeitsgruppen-i-iv-uags-der-age-phase-iii-jan-dez-2003/?tx_ttnews[order]=datetime&tx_ttnews[dir]=desc&tx_ttnews[backPid]=230&cHash=7575dea2602a377ce675823d305fb5dd), checked on 5/19/2015.

BMUB (2004): Zwischenberichte der drei Unterarbeitsgruppen (UAG) 1/2, 3 und 4 der Arbeitsgruppe "Emissionshandel zur Bekämpfung des Treibhauseffektes" (AGE) - Phase IV

(Jan.-Dez. 2004) (Anfang 2004 wurden die UAG I und II zur UAG 1/2 zusammengelegt.). Available online at [http://www.bmub.bund.de/service/publikationen/downloads/details/artikel/zwischenberichte-der-drei-unterarbeitsgruppen-uag-12-3-und-4-der-arbeitsgruppe-emissionshandel-zur-bekaempfung-des-treibhauseffektes-age-pha/?tx_ttnews\[order\]=datetime&tx_ttnews\[dir\]=desc&tx_ttnews\[backPid\]=230&cHash=1ef0e9c232164e08254d767925d1b2cb](http://www.bmub.bund.de/service/publikationen/downloads/details/artikel/zwischenberichte-der-drei-unterarbeitsgruppen-uag-12-3-und-4-der-arbeitsgruppe-emissionshandel-zur-bekaempfung-des-treibhauseffektes-age-pha/?tx_ttnews[order]=datetime&tx_ttnews[dir]=desc&tx_ttnews[backPid]=230&cHash=1ef0e9c232164e08254d767925d1b2cb), checked on 5/19/2015.

BMUB (2014): Aktionsprogramm Klimaschutz 2020. Kabinettsbeschluss vom 3. Dezember 2014. Bundesministerium für Umwelt, Naturschutz, Bau und Reaktorsicherheit (BMUB). Available online at www.bmub.bund.de.

BMWi (2014a): Bruttobeschäftigung durch erneuerbare Energien in Deutschland im Jahr 2013. Forschungsvorhaben des Bundesministeriums für Wirtschaft und Energie
Beschäftigung durch erneuerbare Energien in Deutschland: Ausbau und Betrieb - heute und morgen, dritter Bericht zur Bruttobeschäftigung. Bundesministerium für Wirtschaft und Energie (BMWi); DLR; DIW; ZSW; GWS; Prognos.

BMWi (2014b): Energiedaten - Gesamtausgabe. Bundesministerium für Wirtschaft und Energie (BMWi), checked on 2/7/2014.

BMWi (2014c): Gesetzeskarte für das Energieversorgungssystem. Karte zentraler Strategien, Gesetze und Verordnungen, checked on 12/2/2014.

BMWi (2014d): Second Monitoring Report "Energy of the future" - Summary.

BMWi (2014e): Zweiter Monitoring Bericht der Energiewende. "Energie der Zukunft". Bundesministerium für Wirtschaft und Energie (BMWi). Berlin.

BMWi (2014f): Monitoring-Bericht des Bundesministeriums für Wirtschaft und Energie nach § 51 EnWG. zur Versorgungssicherheit im Bereich der leitungsgebundenen Versorgung mit Elektrizität. Berlin.

BMWi (2014g): A good piece of work. The Energy of the future. First "Energy Transition" Progress Report - Summary. Federal Ministry for Economic Affairs and Energy (BMWi). Berlin. Available online at www.bmwi.de.

BMWi (2014h): Die Energie der Zukunft. Erster Fortschrittsbericht zur Energiewende. Ein gutes Stück Arbeit. Berlin.

BMWi (2014i): Mehr aus Energie machen - Nationaler Aktionsplan für Energieeffizienz. Federal Ministry for Economic Affairs and Energy (BMWi). Available online at www.bmwi.de.

BMWi (2015a): Energiedaten: Gesamtausgabe. Bundesministerium für Wirtschaft und Energie (BMWi). Berlin.

BMWi (2015b): Bekanntmachung zur Förderung von Forschung, Entwicklung und Demonstration „Schaufenster intelligente Energie – Digitale Agenda für die Energiewende“ (SINTEG). Available online at <https://www.bmwi.de/BMWi/Redaktion/PDF/B/bekanntmachung-foederung-schaufenster->

intelligente-energie-digitale-agenda-fuer-die-energiewende,property=pdf,bereich=bmwi2012,sprache=de,rwb=true.pdf, checked on 5/10/2015.

BMWi, B. M.U. (2012): Erster Monitoring-Bericht "Energie der Zukunft".

BMWi, BMU, 50 Hertz, Amprion, TenneT, Transnet BW (2013): Gemeinsames Eckpunktepapier des Bundeswirtschaftsministeriums, des Bundesumweltministeriums und der Übertragungsnetzbetreiber 50Hertz, Amprion, TenneT TSO und TransnetBW zur finanziellen Beteiligung der Bürgerinnen und Bürger am Netzausbau auf der Übertragungsebene. Available online at <http://www.bmwi.de/BMWi/Redaktion/PDF/B/buergerdividende-gemeinsame-erklaerung,property=pdf,bereich=bmwi2012,sprache=de,rwb=true.pdf>, checked on 5/20/2015.

Bode, Sven; Groscurth, Helmuth-M. (2011): The Impact of PV on the German Power Market. In *Zeitschrift für Energiewirtschaft* 35 (2), pp. 105–115.

Bossmann, T.; Fleiter, T.; Lickert, F.; Wietschel, M. (2013): The German load curve in 2050: structural changes through energy efficiency measures and their impacts on the electricity supply side. In *eccee 2013 Summer Study proceedings*, pp. 1199–1211.

Braungardt, Sibylle; Eichhammer, W.; Elsland, R.; Fleiter, T.; Klobasa, M.; Krail, Micheal et al. (2014): Study evaluating the current energy efficiency policy framework in the EU and providing orientation on policy options for realising the cost-effective energy-efficiency/saving potential until 2020 and beyond. Fraunhofer ISI; TU Vienna; PwC. Available online at http://ec.europa.eu/energy/en/studies?field_associated_topic_tid=45.

Brunekreeft, Gert (2008): Eigentumsentflechtung, deep-ISO, der dritte Weg - Wohin führt die Reise der europäischen Energiemärkte? In *Zeitschrift für Energiewirtschaft* 3, pp. 33–42.

Bruns, Elke; Ohlhorst, Dörte; Wenzel, Bernd; Futterlieb, Matthias; Kösters, Johanna (2009): Erneuerbare energien in deutschland. Eine Biographie des Innovationsgeschehens.

BUND (2012): BUND-Hintergrund "Kein Netzausbau für Kohlekraftwerke!". Edited by Bund für Umwelt und Naturschutz Deutschland e. V. Available online at http://www.bund.net/fileadmin/bundnet/pdfs/klima_und_energie/120629_bund_klima_energie_netzentwicklungsplan_hintergrund.pdf, checked on 5/20/2015.

Bundesnetzagentur: Netzausbau - Vorhaben aus dem BBPIG. Available online at http://www.netzausbau.de/cln_1422/DE/Vorhaben/BBPIG-Vorhaben/BBPIG-Vorhaben-node.html, checked on 5/11/2015.

Bundesnetzagentur: Netzausbau - Vorhaben aus dem EnLAG. Available online at http://www.netzausbau.de/cln_1422/DE/Vorhaben/EnLAG-Vorhaben/EnLAGVorhaben-node.html, checked on 5/11/2015.

Bundesnetzagentur (2007): Monitoringbericht 2007. der Bundesagentur für Elektrizität, Gas, Telekommunikation, Post und Eisenbahnen. Bundesnetzagentur.

Bundesnetzagentur (2011): "Smart Grid" und "Smart Market". Eckpunktepapier der Bundesnetzagentur zu den Aspekten des sich verändernden Energieversorgungssystems. Available online at http://www.bundesnetzagentur.de/SharedDocs/Downloads/DE/Sachgebiete/Energie/Unternehmen_Institutionen/NetzzugangUndMesswesen/SmartGridEckpunktepapier/SmartGridPapierpdf.pdf?__blob=publicationFile, checked on 5/10/2015.

Bundesnetzagentur (2012): Monitoringbericht 2012. Anhang.

Bundesnetzagentur (2014): Kraftwerksliste. Bundesnetzagentur. Available online at http://www.bundesnetzagentur.de/DE/Sachgebiete/ElektrizitaetundGas/Unternehmen_Institutionen/Versorgungssicherheit/Erzeugungskapazitaeten/Kraftwerksliste/kraftwerksliste-node.html, checked on 5/27/2015.

Bundesnetzagentur (2015a): Stand des Ausbaus nach dem Energieleitungsausbaugesetz (EnLAG) zum ersten Quartal 2015.

Bundesnetzagentur (2015b): Evaluierungsbericht nach § 33 Anreizregulierungsverordnung.

Bundesnetzagentur; Bundeskartellamt (2014): Monitoringbericht 2014. according to § 63 - 4 EnWG i.V.m. § 35 EnWG.

Calwell, Chris (2010): Is efficient sufficient? The case for shifting our emphasis in energy specifications to progressive efficiency and sufficiency. Prepared for the European Council for an Energy Efficient Economy (eceee).

Charlotte Ruhbaum (2011): Eine Netz AG für Deutschland? Die Debatte um die Neuordnung der Stromübertragungsnetze. In *FFU-Report, Forschungszentrum für Umweltpolitik* (03-2011). Available online at http://edocs.fu-berlin.de/docs/servlets/MCRFileNodeServlet/FUDOCSS_derivate_000000001633/Ruhbaum_FFU_Report_03_2011.pdf, checked on 5/10/2015.

Cullmann, Astrid; Dehnen, Nicola; Nieswand, Maria; Pavel, Ferdinand (2015): Keine Investitionshemmnisse in Elektrizitäts und Gasverteilnetze durch Anreizregulierung DIW Wochenbericht Nr. 6.2015. Available online at http://diw.de/documents/publikationen/73/diw_01.c.496232.de/15-6-3.pdf, checked on 5/10/2015.

dena (2005): dena-Netzstudie Energiewirtschaftliche Planung für die Netzintegration von Windenergie in Deutschland an Land und Offshore bis zum Jahr 2020. Available online at http://www.dena.de/fileadmin/user_upload/Publikationen/Energiesysteme/Dokumente/dena-Netzstudie.pdf, checked on 5/11/2015.

dena (2010): dena-Netzstudie II. Integration erneuerbarer Energien in die deutsche Stromversorgung im Zeitraum 2015 – 2020 mit Ausblick 2025. Available online at http://www.effiziente-energiesysteme.de/fileadmin/user_upload/PDF-Dokumente/Publikationen/Endbericht_dena-Netzstudie_II.PDF, checked on 5/11/2015.

dena (2012): dena-Verteilnetzstudie. Ausbau- und Innovationsbedarf der Stromverteilnetze in Deutschland bis 2030. Available online at

http://www.dena.de/fileadmin/user_upload/Projekte/Energiesysteme/Dokumente/denaVNS_Abschlussbericht.pdf, checked on 5/10/2015.

Deutsche Umwelthilfe (2011): Plan N - Handlungsempfehlungen an die Politik.

Deutsche Umwelthilfe (2012): Plan N 2010- Handlungsempfehlungen an die Politik zur künftigen Integration Erneuerbarer Energien in die Stromnetze -Eine Bilanz im April 2012.

Deutsche Umwelthilfe (2013): Plan N 2.0 - Politikpfehlungen zum Um- und Ausbau der Stromnetze.

Deutscher Bundestag (2014): Unterrichtung durch die Bundesregierung - Bericht der Bundesnetzagentur nach § 112a Absatz 3 des Energiewirtschaftsgesetzes zu den Erfahrungen mit der Anreizregulierung. Drucksache 18/536.

Duetschke, Elisabeth; Schumann, Diana; Pietzner, Katja (2015): Chances for and Limitations of Acceptance for CCS in Germany. In Axel Liebscher, Ute Münch (Eds.): Geological Storage of CO₂ – Long Term Security Aspects. Cham: Springer International Publishing (Advanced Technologies in Earth Sciences), pp. 229–245.

Duetschke, Elisabeth; Wohlfarth, Katharina; Schmidt, Alexandra; Pietzner, Katja; Schwarz, André; Carpentier, Rike; Schumann, Diana (2014): Akzeptanz von CO₂-Speicherprojekten in Deutschland - Eine Tiefenanalyse basierend auf Fallstudien.

EC (2007a): Report on Energy Sector Inquiry (SEC(2006)1724, 10 January 2007. European Commission, DG Competition.

EC (2007b): Proposal for a Directive of the European Parliament and of the Council amending Directive 2003/54/EC of the European Parliament and of the Council of 26 June 2003 concerning common rules for the internal market in electricity. Proposal for a directive. European Commission.

Eichhammer, W.; Schleich, J.; Betz, Regina (2004): Designing National Allocation Plans for EU-Emissions Trading - A first Analysis of the Outcomes A1. In *Energy and Environment* 15 (3), pp. 375–424.

Elsland, R.; Schlomann, Barbara; Eichhammer, W. (2013): Is enough electricity being saved? Impact of energy efficiency policies addressing electrical household appliances in Germany until 2030. ecee summer proceedings.

Europe Economics; Fraunhofer ISI (2007): Impact assessment study on a possible extension, tightening or simplification of the framework directive 92/75 EEC on energy labelling of household appliances. Report on behalf of the European Commission (DG TREN). London.

Fraunhofer ISI; GfK; BSR Sustainability (2009): Survey of Compliance Directive 92/75/EEC (Energy Labelling). Report on behalf of the European Commission (DG TREN). Karlsruhe, Nuremberg.

Fraunhofer ISI; IEF-STE; Öko-Institut; Ziesing, Hans-Joachim; Jakob, Martin (2008): Wirtschaftlicher Nutzen des Klimaschutzes. Umweltbundesamt (Climate Change, 14/08).

Fraunhofer ISI; Öko-Institut (2014): Klimaschutzszenario 2050. 1. Modellierungsrunde. Studie im Auftrag des Bundesministeriums für Umwelt, Naturschutz, Bau und Reaktorsicherheit. Berlin.

Gabriel, Sigmar (2015): Bundesminister Sigmar Gabriel vor dem Deutschen Bundestag zu Klimaschutzzielen im Bereich alter Kohlekraftwerke. Berlin. Available online at <http://www.bmwi.de/DE/Presse/reden,did=707702.html>, checked on 5/22/2015.

Gawel, Erik; Strunz, Sebastian; Lehmann, Paul (2013): Germany's Energy Transition Under Attack: Is There an Inscrutable German *Sonderweg* ? In *Nat Cult* 8 (2), pp. 121–133.

Geels, F. W. (2004): From sectoral systems of innovation to socio-technical systems - Insights about dynamics and change from sociology and institutional theory. In *Research Policy* 33 (6-7), pp. 897–920.

Geels, F. W. (2005): Processes and patterns in transitions and system innovations: Refining the co-evolutionary multi-level perspective. In *Technological Forecasting and Social Change* 72 (6), pp. 681–696. Available online at <http://linkinghub.elsevier.com/retrieve/pii/S0040162505000569>.

Geels, F. W.; Fuchs, G.; Hinderer, N.; Kern, Florian; Kungl, G.; Neukirch, M.; Wassermann, S (2014): Unleashing new entrants versus working with incumbents: A comparative multi-level analysis of the German and UK low-carbon electricity transitions (1990-2013). In *Research Policy* submitted 26 November, 2014.

German Government (2010): Energiekonzept für eine umweltschonende, zuverlässige und bezahlbare Energieversorgung, checked on 7/24/2014.

German Government (2012): Nationale Nachhaltigkeitsstrategie · Fortschrittsbericht 2012. Edited by Die Bundesregierung.

German Government (2014): Communication from the German Federal Government to the European Commission pursuant to Article 7 of Directive 2012/27/EU of the European Parliament and of the Council of 25 October 2012 on energy efficiency. Die Bundesregierung.

Global CCS Institute (2015): List of projects. Global CCS Institute, checked on 5/15/2015.

Green Budget Germany (2012): The full costs of power generation. A comparison of subsidies and societal cost of renewable and conventional energy sources. With assistance of BWE, Greenpeace Energy. Forum Ökologisch-Soziale Marktwirtschaft e.V. (FÖS).

Heinrich Boell Foundation (2013): Ressourcenschwindel Schiefergas. Schriften zur Ökologie. 34th ed. Heinrich Boell Stiftung / Heinrich Boell Foundation; Bund für Umwelt und Naturschutz Deutschland (BUND); Friends of the Earth Europe (Ressourcenschwindel Schiefergas).

Heinzle, S.; Wüstenhagen, R. (2009): Consumer survey on the new format of the European Energy Label for televisions -Comparison of a "A-G closed" versus a "beyond A" scale format. Working Paper No. 3 within the project: Soziale, ökologische und ökonomische Dimensionen eines nachhaltigen Energiekonsums in Wohngebäuden. St. Gallen.

- Hildmann, Marcus; Pirker, Benedikt; Schaffner, Christian; Spreng, Daniel; Ulbig, Andreas (2014): Pumpspeicher im trilateralen Umfeld Deutschland, Österreich und Schweiz. Bericht erstellt auf Basis dreier wissenschaftlicher Studien zur „Bewertung des Beitrags von Pumpspeichern in der Schweiz, Österreich und Deutschland zur elektrischen Energieversorgung“. ETH Zürich.
- Hoffmann, Volker H. (2007): EU ETS and Investment Decisions: The Case of the German Electricity Industry. In *European Management Journal* 25 (6), pp. 464–474.
- IEA (2011): Technology Roadmap Smart Grids. Available online at https://www.iea.org/publications/freepublications/publication/smartgrids_roadmap.pdf, checked on 5/8/2015.
- IEA (2012): World Energy Outlook 2012. Executive Summary. International Energy Agency (IEA). Paris.
- IEA (2014): Capturing the Multiple Benefits of Energy efficiency. International Energy Agency (IEA). Paris.
- Jacobsson, S.; Lauber, V. (2006): The politics and policy of energy system transformation - explaining the German diffusion of renewable energy technology. In *Energy Policy* 34 (3), pp. 256–276. Available online at <http://www.sciencedirect.com/science/article/pii/S0301421504002393>.
- Jochem, E. (Ed.) (2014): Energy efficiency policy as a multi-level governance task. Plenary presentation at the eceee 2014 Industrial Summer Study on energy efficiency. eceee. Arnhem, The Netherlands, October, 2-5.
- Jochem, Eberhard; Gruber, Edelgard (2007): Local learning-networks on energy efficiency in industry – Successful initiative in Germany. In *Applied Energy* 84 (7-8), pp. 806–816.
- Laes, Erik; Gorissen, Leen; Nevens, Frank (2014): A Comparison of Energy Transition Governance in Germany, The Netherlands and the United Kingdom. In *Sustainability* 6 (3), pp. 1129–1152.
- Markard, J.; Truffer, B. (2006): Innovation processes in large technical systems: Market liberalization as a driver for radical change? In *Research Policy* 35 (5), pp. 609–625.
- Markard, Jochen; Truffer, Bernhard; Imboden, Dieter M. (2004): The impacts of market liberalization on innovation processes in the electricity sector. In *Energy & Environment* 15 (2), pp. 201–214.
- MAZ (2015): Sigmar Gabriel knickt im Kohlestreit ein. Umstrittene Kohleabgabe wird überarbeitet. In *Märkische Allgemeine*, 2015. Available online at <http://www.maz-online.de/Brandenburg/Sigmar-Gabriel-knickt-im-Kohlestreit-ein>, checked on 5/13/2015.
- Morris, Craig; Pehnt, Martin (2012): Energy Transition. The German Energiewende. Heinrich Boell Stiftung / Heinrich Boell Foundation.
- Morris, Craig; Pehnt, Martin (2014): Energy Transition. The German Energiewende. Heinrich Boell Stiftung / Heinrich Boell Foundation.

Oekopol (2014): Beyond Efficiency. Anchoring absolute energy savings in the ecodesign directive and the energy labeling directive. Bund für Umwelt und Naturschutz Deutschland (BUND).

Prognos; EWI; GWS (2014): Entwicklung der Energiemärkte - Energiereferenzprognose. Studie im Auftrag des Bundesministeriums für Wirtschaft und Technologie. Basel, Cologne.

Quitrow, Rainer; Walz, Rainer; Köhler, Jonathan; Rennings, Klaus (2014): The concept of “lead markets” revisited: Contribution to environmental innovation theory. In *Environmental Innovation and Societal Transitions* 10, pp. 4–19.

Richter, Mario (2013): Business model innovation for sustainable energy: German utilities and renewable energy. In *Energy Policy* 62, pp. 1226–1237.

Rogge, Karoline S.; Boedeker, Paul; Dallinger, David; Fleiter, Tobias; Friedrichsen, Nele; Klobasa, Marian et al. (2015): Analysis of green niche-innovations and their momentum in the two pathways. Electricity domain: Germany. PATHWAYS project - Deliverable 2.1. Edited by Karoline S. Rogge.

Rogge, Karoline S.; Hoffmann, Volker H. (2010): The impact of the EU ETS on the sectoral innovation system for power generation technologies – Findings for Germany. In *Energy Policy* 38 (12), pp. 7639–7652.

Rogge, Karoline S.; Linden, Christian (2008): Cross-country comparison of national allocation plans (2008-12) for the power sector. Karlsruhe.

Rogge, Karoline S.; Schneider, Malte; Hoffmann, Volker H. (2011): The innovation impact of the EU Emission Trading System — Findings of company case studies in the German power sector. In *Ecological Economics* 70 (3), pp. 513–523.

Rohde, Clemens (2012): Status und absehbare Einsparpotenziale beim Stromverbrauch im Haushalts- und Gewerbebereich in Deutschland bis 2020. Fraunhofer ISI, checked on 12/2/2014.

Schlomann, Barbara (2014): Design of Effective Energy Efficiency Policies. An analysis in the frame of target setting, monitoring and evaluation. Stuttgart.

Schlomann, Barbara; Eichhammer, W. (2012): ODYSEE-MURE 2010. Monitoring of EU and national energy efficiency targets. Fraunhofer ISI. Karlsruhe.

Schlomann, Barbara; Eichhammer, W.; Gruber, Edelgard; Kling, Nicola; Mannsbart, Wilhelm; Stöckle, Friedemann (2001): Evaluierung zur Umsetzung der Energieverbrauchskennzeichnungsverordnung (EnVKV). Report on behalf of the Federal Ministry of Economics and Technology. Fraunhofer ISI; GfK. Karlsruhe.

Schlomann, Barbara; Eichhammer, W.; Stobbe, Lutz (2015a): Energy saving potential of information and communication technology. In *Int. J. Decision Support Systems* 1 (2), pp. 152–163.

Schlomann, Barbara; Reuter, Matthias; Eichhammer, W.; Ziesing, Hans-Joachim (2015b): Methoden- und Indikatorenentwicklung für Kenndaten zum Klimaschutz im Energiebereich. Umweltbundesamt (UBA). Dessau-Rosslau (UBA-Texte, 17/2015).

- Schlomann, Barbara; Schleich, Joachim (2015): Adoption of low-cost energy efficiency measures in the tertiary sector—An empirical analysis based on energy survey data. In *Renewable and Sustainable Energy Reviews* 43, pp. 1127–1133.
- Schneider, Malte; Rogge, Karoline; Hoffmann, Volker H. (2010): Market-based environmental policies: What is their impact on technological change? ETH Zuerich, Fraunhofer Institute Systems and Innovation Research (ISI). Karlsruhe, Zuerich.
- Skjaereth, Jon Birger; Wettestad, Jorgen (2008): EU Emissions Trading: Initiation, Decision-Making and Implementation. Farnham, Burlington: Ashgate Publishing.
- Soini, Katriina; Pouta, Eija; Salmiovirta, Maija; Uusitalo, Marja; Kivinen, Tapani (2011): Local residents' perceptions of energy landscape: the case of transmission lines. In *Land Use Policy* 28 (1), pp. 294–305.
- Sorrell, Steve; Schleich, Joachim; Scott, Sue; O'Malley, E. (2004): The Economics of Energy Efficiency. Barriers to Cost-Effective Investment.
- Stenzel, Till; Frenzel, Alexander (2008): Regulating technological change—The strategic reactions of utility companies towards subsidy policies in the German, Spanish and UK electricity markets. In *Energy Policy* 36 (7), pp. 2645–2657.
- Strunz, Sebastian (2014): The German energy transition as a regime shift. In *Ecological Economics* 100, pp. 150–158.
- The Coalition for Energy Savings (2014): Implementing the EU Energy Efficiency Directive: Analysis of Article 7 Member States reports.
- UBA (2014): Umweltschädliche Subventionen in Deutschland. Umweltbundesamt (UBA).
- UBA (2015): Emissionsdaten 2014 zeigen Trendwende beim Klimaschutz. Emissionen sinken auf niedrigsten Wert seit 2010, checked on 3/31/2015.
- VDI (2014): Standortbezogene Akzeptanzproblem in der deutschen Industrie- und Technologiepolitik - Zukünftige Herausforderungen der Energiewende. Available online at http://www.vdi.de/uploads/media/VDI-Studie_Akzeptanzprobleme_Energiewende.pdf, checked on 5/20/2015.
- Ziesing, Hans-Joachim; Diekmann, Jochen; Kohlhaas, Michael; Betz, Regina; Bradke, Harald; K"wner, Dirk et al. (2007): Entwicklung eines nationalen Allokationsplans im Rahmen des EU-Emissionshandels. Dessau, Germany.