PATHWAYS project

Exploring transition pathways to sustainable, low carbon societies

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Deliverable D2.3: 'Integrated analysis of the feasibility of different transition pathways'

Country report 1: Feasibility of transition pathways in German electricity system

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Executive summary

In this report we combine niche and regime analyses conducted for the German electricity regime to assess the feasibility of transition pathways. For this, we consider the niches of solar PV, on- and offshore wind, bioenergy, CFL/LED lighting and smart meters, while the regime analysis is broken down into the electricity generation regime, the electricity consumption regime and the electricity network regime. Based on the developments in these niches and regimes in the past 10-15 years we make an interpretive assessment of the feasibility of the German energy transition of the electricity system *in the present*. That is, in this report we are focusing on the current status of the Energiewende, while a forward-looking analysis of future developments is reserved for a later PATHWAYS deliverable.

Breakthrough feasibility of the various niche-innovations

As a first step in this assessment we take a closer look at niche dynamics and their momentum. In particular, we assess the internal drivers in the niche and external circumstances at the regime and landscape levels to determine in which transition phase the development of the niche can be categorized. Our results are summarized in Table A. The following main results emerge from this analysis:

- All generation niches are well or very well aligned with the landscape pressures arising from climate change and the anti-nuclear movement and benefit from Germany's strong manufacturing base. The same is true for CFL/LED lighting, but in addition energy security concerns are a further driver for this niche given its potential to achieve electricity demand reductions. Misalignments arise from environmental concerns which relate to wider sustainability impacts, such as on species or habitats (e.g. wind) and conflicting land-uses (most pronounced for bioenergy).
- In order to assess the alignment of a niche with the regime it is usually necessary not only to look at the most evident regime (e.g. generation regime for onshore wind) but to also asses the alignment with the interconnected network regime (e.g. delays in grid access in network regime for offshore wind, slowing down its momentum).
- Our analysis suggests that three of the six studied niche innovations have entered phase three, meaning that they have started diffusing more widely with largely self-maintaining momentum: onshore wind, solar PV and LED lighting.
- The majority of analysed niches anchored in the generation regime follow pathway B as actors tend to be new entrants and changes are evident in multiple dimensions (solar PV, onshore wind, bioenergy). In contrast, the analysed niches anchored in the network or consumption regime follow a pathway A type of transition pattern.

Table A: Breakthrough analysis of niche-innovations in the electricity domain in Germany

Niche	**Internal Momentum**	**Regime and landscape alignment**	**Breakthrough potential**	**Pathway**
Solar PV	High (down from very high)	Very good (due to climate change, anti-nuclear movement, manufacturing base, and proportional voting system, and resulting cracks in generation regime; alignment with generation regime > network regime > consumption regime)	Entered phase 3, but with setback in 2013 (investments by new entrants, attractive FIT, unexpectedly strong LCOE reductions, target overachievement, EEG levy increase, compe-tition and consoli-dation, policy mix adjustments)	Pathway B (but some recent attempts to explore large-scale free field PV through the introduction of tender, interest of incumbents suggests some potential for pathway A characteristics)
Onshore wind	Very high (up from high)	Good (due to climate change, anti-nuclear movement, manufacturing base, and proportional voting system, but some conflict with environmental concerns; alignment with generation regime > network regime > consumption regime)	Entered phase 3 (investment by new entrants, attractive FIT, LCOE reductions, leader in the race for cheapest renewable energy technology, main challenge may be continued high level of public acceptance)	Pathway B (but cost-reduction tendency and interest by incumbents may lead to increasing number of large-scale parks, which for the future suggests some pathway A characteristics)
Offshore wind	Medium (fairly unchanged)	Fair - good (very good due to climate change, anti-nuclear movement, manufacturing base, mainstreaming in marine regime, but weak due to delays in grid access within network regime, mismatch between supply in North and demand in South and initial reluctance by (and against) incumbents)	Phase 2 (higher economic costs and technological risks than onshore wind, grid access delays, 2030 target reduction, may only enter phase 3 if cracks in onshore wind may call for alternatives)	Pathway A (but initial niche development was mainly driven by small project developers, onshore wind manufacturers, policy makers and regional utilities, while incumbents were late in joining this niche)

Table A: Breakthrough analysis of niche-innovations in the electricity domain in Germany (continued)

Niche	Internal Momentum	Regime and landscape alignment	Breakthrough potential	Pathway
Bio-energy	Low (down from medium)	Good (due to climate change concerns, anti-nuclear movement, manufacturing base and possibly being a good complement to fluctuating renewables; but wider sustainability concerns and conflicting land uses)	Phase 2 (investment by new entrants, advantage of flexible generation, but high costs and limited reduction potential, competing uses, sustainability concerns, limits to further expansion)	Pathway B (mainly due to involvement of new entrants, including farmers and municipalities, and often small-scale character of plants, does not require radical change across all regime dimensions but can functions as complement to fluctuating renewables)
CFL/LED lighting	Very high (LED) Medium (CFL) (up for LED))	Very good (due to alignment with climate change and energy security concerns as well as pressures to reduce energy demand)	On the verge to phase 3 (LED) (high techno-economic progress, favoured by EU ban on competing incandescent bulbs)	Pathway A (technological substitution, so far without broader behavioural changes)
Smart meters	Low (with potential to increase to medium or even high)	Good (due to offering solution to challenges arising from intermittency of renewable power generation within smart grids by increasing flexibility)	Phase 2, with potential for breakthrough (positive CBA only for larger consumers, data protection concerns, but now 80% roll-out target until 2020)	A (if full potential of smart meters within a smart grid were harnessed, this could shift to pathway B, although small consumers likely not to be equipped with smart meters due to negative CBA rations and data protection concerns)

Regime orientation towards environmental problems

The electricity *generation regime* is undergoing radical changes, implying that the main future sub-regimes will be wind and PV with some flexible back-up (natural 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. In addition, there are major tensions and cracks in the electricity generation regime. The climate change problem and anti-nuclear movement have led to significant institutional changes, e.g. ambitious targets for GHG reduction, RES expansion and nuclear phase-out and specific policy instruments. 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, strategies and organisational structures.

Table B: Assessment of regime trends in the electricity domain in Germany

	Lock-in, stabilizing forces	**Cracks, tensions, problems in regime**	**Orientation towards environmental problems**	**Main socio-technical regime problems**
Generation Regime	Lock-in has weakened significantly, regime in flux, as transition is unfolding, resistance from incumbents focused on reducing losses and ensuring survival in the new regime	Strong, given major tensions due to pressure by growing share of fluctuating renewables (wind, PV) challenging business model and beliefs of incumbents due to merit order effect and firm political commitment to 'Energiewende' with nuclear phase out	Strong orientation towards expansion of renewables (at least 80% by 2050), phase-out of nuclear (by 2022) and ambitious GHG reduction target (-80 to 95% in 2050 for Germany's total GHG emissions)	Difficulty of phasing out coal leading to rising CO2 emissions, concern about deployment costs, market and system integration, potential public acceptance issues
Consumption Regime	Moderate / strong given future trend towards greater electrification (ICT, e-mobility, heat pumps), lack of supporting interest groups (lobbies) and rebound effects	Moderate given broad consensus on the benefits of energy efficiency, but only since 2014 seriously established as second pillar of 'Energiewende'.	Moderate (some incremental change leading to increased energy efficiency, but counter-effects partly overcompensating efficiency gains)	Lack of political will for progressive energy efficiency standards, little consideration of sufficiency options to reduce electricity consumption
Network Regime	Moderate as fairly stable regime, locked-in by rather conservative, slow-to-change regulation and public acceptance concerns	High, given strong tensions because of unfolding transition of generation regime and high political will to address delay in supportive changes in network regime to make 'Energiewende' a succses	Must-be enabler of 'Energiewende' by integrating rising share of fluctuating, decentralized renewables into electricity system (so far gradual change, but tendency for wider reorientation towards smart grids)	Low public acceptance of grid expansion, motivational and financial barriers to flexibilization of consumption regime, regulatory rigidity, conflicting interests of Federal States

In contrast, the electricity *consumption regime* remains partly strongly locked-in. The 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. Also, 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. Yet, there is a relatively broad consensus of all affectted groups on the benefits of energy efficiency and the political target of reducing electricity consumption. In addition, energy efficiency has seen increased political attention since 2014.

The *network regime* is fairly stable with moderate lock-in. It is particularly the long-lived asset structure and regulation which 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. However, pressures are very high. 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 allowing and encouraging network operators to make such adaptations. The changes also improve the incentives for network expansion, increase acceptance and streamline administrative processes. Also, 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.

Transition unfolding in electricity generation regime with knock-on effect on network regime

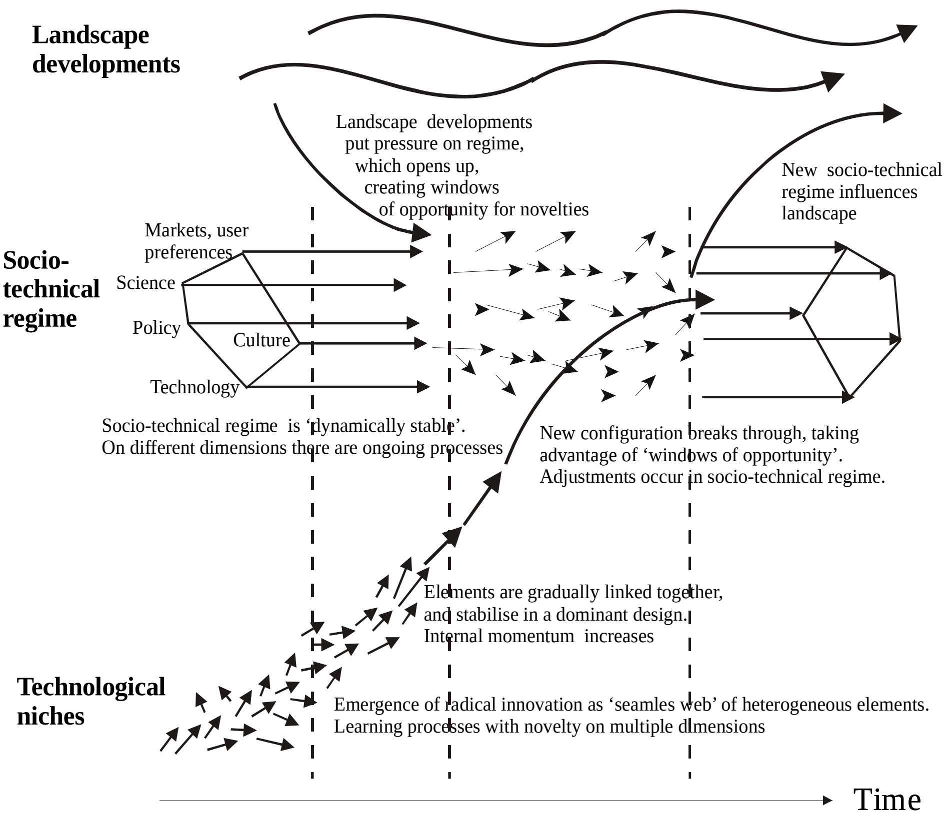
Based on developments so far, we find that the transition challenge is smallest for the electricity generation regime and largest for the consumption regime, with the electricity network regime placed in the middle. However, all three regimes face substantial and unique socio-technical challenges, as summarized in the last column of Table B. These problems are often connected to a lack of political will, resistance by vested interests, concerns regarding public acceptance and barriers to more radical changes.

As all three regimes are interconnected, the unfolding and carefully managed transition in the generation regime with the two break-through niches of onshore wind and solar PV (following pathway B) may have knock-on effects, particularly and most directly on the network regime that links generation and demand and therefore has an enabling function within the electricity system. The network regime is on the verge of moving to a reconfiguration pathway driven by changes in generation– albeit fairly slowly due to its conservatism. That is, given the great political commitment to the transition of the electricity generation regime towards renewable energies we argue that the network regime will eventually be tagged along, as the success of the 'Energiewende' project requires a reorientation of the network regime, as well. In contrast, so far the trickling through effect from the unfolding transition in the generation regime to the consumption regime is fairly limited. As a consequence the consumption regime has not moved beyond an incremental transformation pathway with gradual improvements in energy efficiency. However, most recent developments suggest an increase in political attention to energy efficiency as second pillar of the energy transition.

1) Introduction

In this report we combine niche and regime analyses conducted for the German electricity regime to assess the feasibility of transition pathways. In doing so, it draws on deliverables D.2.1 (niche analysis) and D2.2 (regime analysis) to analyse the (mis)match between green niche-innovations and incumbent regimes in the German electricity system (Rogge et al., 2015a; Rogge et al., 2015b). For this, we consider the niches of solar PV, on- and offshore wind, bioenergy, CFL and LED lighting and smart meters[1], while the regime analysis is broken down into the electricity generation regime, the electricity consumption regime and the electricity network regime. It is our goal to use our analyses of the developments in these niches and regimes in the past 10 years or so to make an interpretive assessment of the feasibility of the German energy transition of the electricity system *in the present*. That is, in this report we are focusing on the current status of the Energiewende, while a forward-looking analysis of future developments is reserved for a later PATHWAYS deliverable.

Figure 1: Four phases in transition according to Multi-Level-Perspective



Source: *Geels (2006), p. 1006*

[1] We do not include those niches in our integrated analysis which have a very low momentum and therefore exclude vehicle-to-grids (V2G) and power-to-gas (P2G).

One important step in this assessment is to take a closer look at niche dynamics and their momentum. In particular, we assess the present state and momentum of niches to determine in which transition phase the development of the niche can be categorized. This is done by focusing on the dynamics for further up-scaling and breakthrough. In doing so, we follow Geels (2006) who distinguishes four general phases in transitions, as shown in Figure 1, ranging from predevelopment (1), early market niches (2), breakthrough (3) and stabilization of new system (4). The question we ask is whether niche developments suggest that niches are moving into the breakthrough phase characterized by wider diffusion of niche-innovations, competition with the established regime and a self-sustaining momentum. To answer this question we assess the internal drivers in the niche and external circumstances at the regime and landscape levels.

Table 1: Ideal-type transition pathways and their defining elements according to the PATHWAYS project

	Pathway 0: Business as Usual	**Pathway A: Technical component substitution**	**Pathway B: Broader regime transformation**
Departure from existing system performance	Minor (no transition)	Substantial	Substantial
Lead actors	Incumbent actors (often established industry and policy actors)	Incumbent actors (often established industry and policy actors)	New entrants, including new firms, social movements, civil society actors
Depth of change	Only minor incremental change	Radical technical change (substitution), but leaving other system elements mostly intact	Radical transformative change in entire system (fundamentally new ways of doing, new system architectures, new technologies)
Scope of change	Dynamic stability across multiple dimensions	1-2 dimensions: technical component and/or market change, with socio-cultural and consumer practices unchanged	Multi-dimensional change (technical base, markets, organisational, policy, social, cultural, consumer preferences, user practices)

Source: PATHWAYS project

In addition, we pay specific attention not only to the phase but also to the nature of the ongoing transition. Up to now, the PATHWAYS project has differentiated between two generic, stylised pathways (see Table 1): one characterized by *technical component substitution* (pathway A) and one with *broader regime transformations* in multiple dimensions (pathway B). In this deliverable we extend this classification by considering two further transition pathways

(Geels and Schot, 2007). The first captures transitions characterized by g*radual/incremental regime transformation* (pathway C) in which incumbent actors respond to landscape pressures and regime tensions by adjusting the direction of existing development paths and innovation activities. However, these incremental changes do not lead to fundamental changes to the basic system architecture, but go significantly beyond business-as-usual (as described in pathway 0) and in total lead to a significant reduction of the environmental impact of the regime. The second additional transition pathway is referred to as *reconfiguration* (pathway D) in which niche innovations are adopted into the regime, and subsequently trigger adjustments and knock-on effects in the basic system architecture. In contrast to the broader regime transformation pathway (pathway B) in which new entrants function as lead actors this fourth transition pathway often entails collaborations between new entrants and incumbent actors.

In this report, therefore, we provide answers to the following overarching research questions:

1. Do the analyses of recent developments in green niche-innovations (D2.1) and regime (in)stability (D2.2) suggest that a transition is beginning to take place and, if so, which transition pathway does it follow?

2. If niche-innovations are not about to break through more widely: how can the dominant system/regime trends (based on D2.2) be assessed?

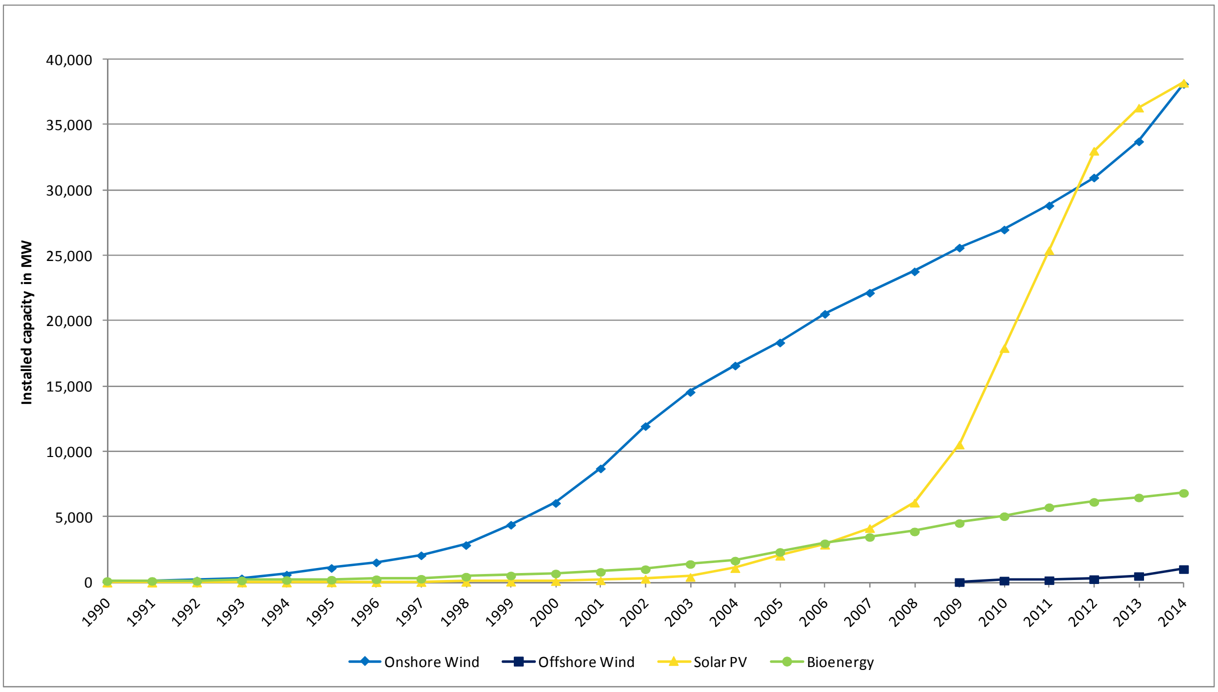
    a. Are these trends continuing as Business as Usual, with limited regime change to address environmental problems, or,
    b. Are existing regime actors implementing incremental changes to address environmental problems?

The remainder of the report is structured as follows. Section 2 assesses the feasibility of niches to break through more widely. After discussing this for six niche innovations in section 3 we turn to the assessment of regime reorientation, differentiated by the three regimes of electricity generation, consumption and network. The report closes with conclusions and a wider discussion of the German electricity transition in its final section 4.

2) Assessment of breakthrough feasibility of niche-innovations

In this section, we discuss for each of the six niche-innovations the following three issues: first, the internal momentum of the niche-innovation; second, how the niche-innovation aligns or conflicts with wider regime and landscape developments – focusing on finance, public debates and policies – and third, whether the niche-innovation is about to break through more widely, and if not, what is holding it back. This assessment draws largely on the niche and regime analysis compiled by Rogge et al. (2015a; 2015b).

Figure 2: Installed electricity generation capacity from renewable energies in Germany (1990-2014)



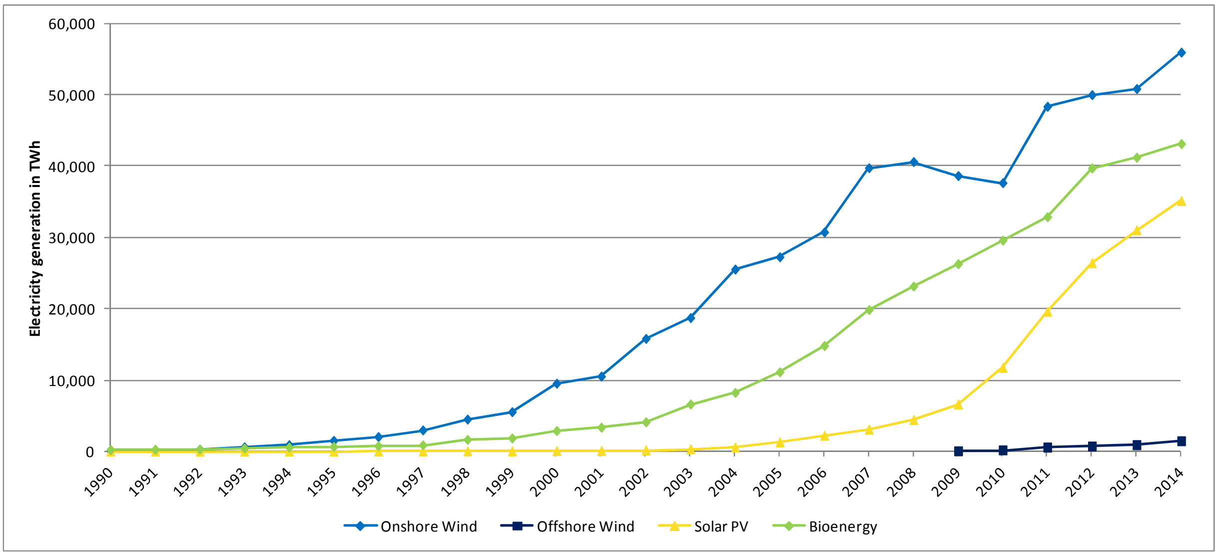
Source: BMWi (2015b)

We start by discussing four green niche innovations for generating electricity from renewable energy sources, namely solar PV (2.1), onshore wind (2.2), offshore wind (2.3) and bioenergy (2.4). For these, Figure 2 shows their diffusion over time from 1990 until 2014 in terms of installed capacities (in MW) for electricity generation (BMWi (2015b)). It can be seen that overall onshore wind has been the leader in the expansion of renewable energies in Germany. However, over the past ten years and particularly within the time frame from 2010-2012 solar PV – with its temporary albeit massive momentum in those years – has caught up with onshore wind. More precisely, by 2014 both onshore wind and solar PV had reached roughly 38 GW of installed capacities. However, given the current comparatively higher momentum of onshore wind it is regaining its leadership position. By comparison, the growth of the generation capacities of the diverse niche of bioenergy is much smaller, having reached slightly below 7

GW in 2014. [2] Finally, the deployment of offshore wind has only started in 2009 and its installed capacities remain the lowest of the four green niches, with slightly above 1 GW in 2014. Most of this has being added in the past two years. [3] In 2014, these four niches have reached a share of almost 42% of German electricity generation capacities.

In contrast, when looking at gross electric generation for these four green niche innovations, Figure 3 reveals a different picture. Here, onshore wind is clearly outperforming generation by solar PV (approximately 56 GWh compared to 35 GWh in 2014). What is more, bioenergy is contributing a significantly larger share of electricity generation than solar PV, namely some 43 GWh, thus coming in second place, not too far after onshore wind. By comparison, and similar to capacity figures, the niche of offshore wind remains the smallest, so far only contributing to 1.4 GWh of generated electricity. Finally, the figure shows that there has been a steady upward trend for electricity generation of all four niches (with a brief exception for onshore wind in 2009/10). By 2014, the figure also reveals that the green niches of onshore wind, bioenergy and solar PV all three play a significant role in Germany's electricity generation system, as together they have reached roughly 135 GWh or 22% of overall generation. [4]

Figure 3: Gross electricity generation from renewable energies in Germany (1990-2014)



Source: BMWi (2015b)

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2 The data used for bioenergy contains biogas and bio-methane, solid biomass, liquid biofuels, landfill and sewage gas, but excludes the biogenic fraction of waste (Figure 2). The same applies for the data on electricity generation based on bioenergy (Figure 3).

3 Installations not yet connected to the grid are excluded.

4 Note that this figure excludes other renewable energy sources, such as hydropower, with which the share of renewable energies of overall electricity generation rises to slightly above 27% in 2014.

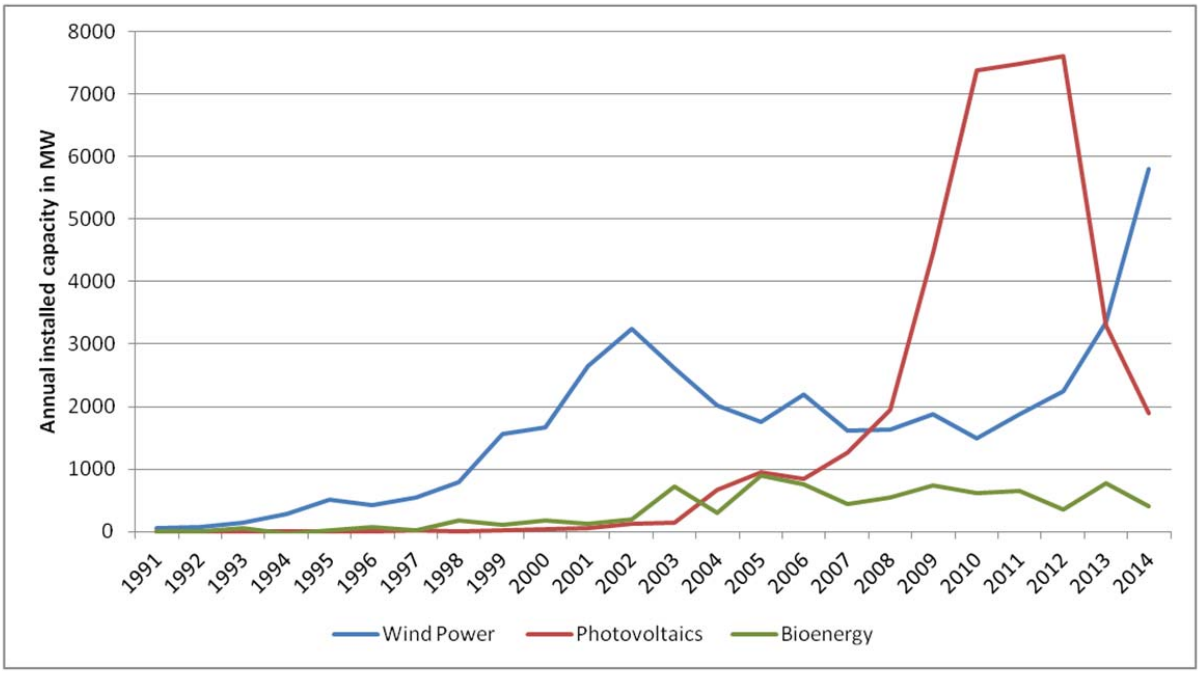
In the following, we start our survey of niche developments in the German electricity system by taking a closer look at the aforementioned green niches, starting with solar PV.

2.1 Solar PV

(1) High internal momentum

In Germany, solar Photovoltaics (PV) represents – alongside with onshore wind - the most widely deployed renewable power generation technology (RPGT) which both have reached a capacity of approximately 38 GW in 2014 (see Figure 2). This massive growth of the green niche of solar PV was accomplished through an exceptionally high momentum, particularly between 2010 and 2012, as can be seen in Figure 4 which clearly shows the peak in annually added capacity for solar PV and compares this with capacity additions for wind and bioenergy.

Figure 4: Annual added capacity (in MW) of solar PV, wind (on- and offshore) and bioenergy (1991-2014)



Source: BMWi (2015b)

However, as can be seen in Figure 4, with the beginning of 2013 the niche's momentum has dampened significantly. This is mainly due to changes in the policy mix, both in terms of large cutbacks in the level of support granted through feed-in tariffs (Grau, 2014) and the introduction of a "breathing cap" which attempts to limit the speed of niche growth by lowering the support if a certain level of annual capacity additions are reached. The most important reasons behind these policy mix adjustments were significant reductions in levelised cost of electricity generation (LCOE) and the resulting overshot of added capacities relative to deployment targets, resulting in high cost burdens for final customers (through a rising level of the EEG levy). The still ongoing cost reductions resulting from technological progress (Kost et al., 2013; Roland Berger Strategy Consultants and Prognos AG, 2010) were and are driven by economies of scale, strong technology learning and intense global competition among manufactures of PV modules and equipment, particularly from China (Grau et al., 2012; Dunford et al., 2013)

Losses in PV jobs due to industry consolidation and increasing levels of the EEG levy mainly paid by households and SME undermined previously high levels of legitimacy. Despite these developments and the initiation of pilot schemes for large-scale PV, investments in decentralized, small-scale PV systems remain fairly attractive, particularly since the still ongoing cost reductions have started to lead to positive margins even without financial support from feed-in tariffs if a large part of the self-generated electricity can be consumed on site (self-consumption) (Breitschopf, 2015). Therefore, further capacity additions are envisaged to achieve roughly the same level as onshore wind. Still, given that the momentum used to be much higher in the past we have rated it as high and not very high anymore (see chapter 3.4 by Boedeker et al., in Rogge et al. (2015a)).

(2) Very good alignment with wider regime and landscape developments

The continued growth of solar PV benefited from the positive alignment of this green niche with wider regime tensions and landscape developments (Bruns et al., 2011). These include the concern about climate change, the anti-nuclear movement and public opposition to storing CO_2 underground (effectively ruling out Carbon Capture and Storage (CCS) technologies). While R&D activities have been going on for several decades, only the introduction of a technology-specific feed-in law in the year 2000 – the Renewable Energy Sources Act EEG – enabled the diffusion of solar PV in a protected niche market. However, investors in solar PV have been new entrants rather than regime actors, due to the latter's preference for large-scale power generation plants. With hindsight this policy which was adopted by the first German national government under participation of the Green party – can be interpreted as catalyst of change. This catalyst could only be enacted because of the German proportional voting system which gave green concerns a parliamentary voice and later legislative power due to the participation in a government coalition.

In addition to designing the EEG this red-green coalition government under chancellor Schröder also set in motion a prime institutional change factor: the move of responsibilities for renewable energies, including solar PV, from the economics ministry to the environment ministry in the year 2002. This institutional change enabled more progressive policy making promoting the growth of the green niche of solar PV. The resulting favorable policy mix for solar PV created investment opportunities for new entrants, such as farmers, private households and cooperative, who sought independent and clean power supply which solar PV had to offer. Interestingly, investors into solar PV were not only green voters but also conservative voters who turned into spokespersons for continued support for solar PV. In essence, this meant a mainstreaming of political support for solar PV into political programs of non-green parties which helps explain the past stability of the political support for the niche.

Another landscape factor that played into the hands of solar PV was Germany's engineering and manufacturing base which enabled the development of an industry active in solar PV. This helped creating many jobs which originally further increased the legitimacy of the technology. Combined with this was the political recognition of the potential of renewable energies, such as solar PV, to promote green growth, jobs and export, thereby providing a non-environmental rationale alongside with environmental rationales for active government intervention.

Finally, the preoccupation of the 'big 4', Germany large utilities, with the opportunities arising from the liberalization and their misjudgment of the potential of solar PV and other renewable power generation technologies may have further widened the window of opportunity for solar PV because regime resistance to establishing favorable niche conditions was not as fierce as could have otherwise been expected. These favorable niche conditions allowed new entrants to step in with private investments, thereby leading to a faster than expected and steady growth of the niche from very low levels to eventually regime destabilizing levels of deployment. As a consequence of their lock-in in the existing regime and preoccupation with expansion strategies utilities were very late in realizing the misalignment between their old business model (large-scale fossil-nuclear) and new market realities due to increasing shares of fluctuating, decentralized renewable electricity and the phase-out of nuclear. Today, a tipping point has been reached regarding the diffusion of renewable energies, particularly solar PV and onshore wind, which is underlined by the clear vision of solar PV and wind as backbone of the future electricity generation regime (Agora Energiewende, 2012). PV played a vital part in reducing revenues of incumbents due to its effect on the merit order curve: around noon, electricity prices used to be very high due to high demand, this generating high income especially for base-load power plants. The increasing PV generation has reduced the average price around noon significantly. That is, as the sun is shining most at high peak lunch time hours solar PV is scraping away peak load profits of conventional power plants.

Consequentially, the emerging instabilities in the electricity generation regime can partly be traced back to the impact of the fast deployment of solar PV with its negligible marginal costs and its regime shaking effect due to its effect on the merit order curve. In addition, there is a combined effect on the merit order curve arising from solar PV and (onshore) wind as the two most important fluctuating technologies in the German electricity system. Their deployment and rising levels of electricity generation significantly change the merit order curve - due to the "old" electricity market design - and have led to a general erosion of the electricity price, thereby further reducing the margins of conventional power generation technologies. To address these concerns incumbents strongly advocated for the introduction of capacity markets.

However, as a consequence of all these developments, big incumbent players lost political influence and will therefore have to adjust to the changing regime rules which favor the integration of renewable energies. However, they struggle with finding their place in the new electricity generation regime, given their capabilities being based on large-scale, centralized electricity generation. They also face strong competition by new entrants who have specialized in providing electricity generation from renewable energies, such as solar PV. Therefore, we argue that windows of opportunities for regime change not only arise from the pressure of landscape factors, such as climate change and anti-nuclear movement, but also from the destabilizing impact of the growth of the niche on the regime.

(3) Clear break-through: green niche has entered phase 3

Despite recent cut-backs in the attractiveness in the policy mix for solar PV it can be argued that this green niche has matured and is on the verge of becoming one of the two new sub-regimes within the electricity generation system. While slowed down the expansion of solar PV is continuing, and has become lucrative even without taking advantage of feed-in tariffs. We therefore argue that solar PV has entered phase 3 with more wide spread diffusion and self-sustaining momentum.

The resulting changes in the generation regime create pressure on the fairly stable network regime to react both because power flows are changing, which requires operational adaptations, but also because the revenue structure is impacted by household PV installations with on-site consumption. Because of the volume-based structure of network tariffs and other price components, growth of self-generation (mainly from PV) triggered a debate on necessary adaptations in network financing and renewable energy levy.

Finally, the German government remains committed to its 'Energiewende' vision and acts as manager of implementing this vision with step-wise changes to the political framework conditions. Hence, further policy developments are geared towards achieving an energy system based on renewable energies. While the focus of attention has been on the generation regime, the government is now increasingly addressing adaptations within the network regime. If the government and regulatory agencies fail in adapting the grid regime to the changes especially from PV, this might become a limiting factor: an increasing share of consumers that produce more and more of its electricity on its own challenges the current network tariff structure for recovering the cost of the grid. Currently, grid fees are volume based adding to the per-kWh electricity price. If the energy consumed from the grid decrease, the network tariff has to be raised, making self-consumption from PV even more attractive. This spiral acts as a stabilizing factor for the emerging PV sub-regime, but could lead to serious destabilisation of the network regime. This is a key development, as the network regime so far has been very slow to adapt and could thus also be seen as a barrier to the unfolding transition of the electricity regime. However, recent policy changes underline the continued commitment of the German government and thus knock-on effects on the network regime are becoming stronger. This implies that the emerging new sub-regime of electricity generation based on solar PV will become increasingly stabilized and a crucial technological aspect of the novel decentralized and renewables-based electricity generation regime. In this new regime, solar PV is likely to play an influential role – next to onshore wind, which we will discuss in the subsequent section.

2.2 Onshore Wind

(1) Very high internal momentum

The highest momentum for all six niches was found for onshore wind. This assessment is mainly due to techno-economic reasons as by now onshore wind constitutes the largest potential to achieve Germany's energy transition goals at the lowest costs. In addition, socio-cognitive acceptance is still relatively high, but may come under more pressure with further deployment due to acceptance problems and landscape concerns. The question that arises is whether there actually may be an upper acceptance level after which the newly emerging regime may see limits to its further growth and whether such an upper level may be overcome by repowering in existing, relatively sparsely populated locations. Finally, although a 'breathing cap' was established in the EEG 2014 in order to better control the rate of deployment the policy mix is still supportive and continues to provide a largely unchanged feed-in tariff level for a guaranteed period of time (for details, see Chapter 3.1 by Klobasa et al., in Rogge et al. (2015a)).

(2) Good alignment with wider regime and landscape developments

Similarly to solar PV, the green niche of onshore wind is fairly well aligned with landscape pressures and regime tensions (see section 2.1, Bruns et al. (2011)). Most notably, the relevant landscape pressures that support onshore wind as a niche innovation are climate change and anti-nuclear concerns, in combination with Germany's strong manufacturing base for wind technologies (Michaelowa, 2005). However, in contrast to solar PV there is a more pronounced conflict regarding the issue of environmental impacts, e.g. due to bird collisions or visual and noise impacts (Valentine, 2014). This may have been one of the main reasons that in some regions the generation regime remained fairly restrictive in terms of regional regulations, e.g. by not changing the zoning law to allow for wind park developments or by introducing minimum standards for the distance of parks from settlements. However, the magnitude and impact of anti-wind protests is much smaller than that of resistance to onshore wind in the UK, and seems to be carefully managed.

In terms of the alignment with the generation regime, onshore wind has benefited from a favorable policy mix and stable and predictable support by the German environment ministry in the past. Onshore wind – similarly as solar PV – is also well placed in terms of the mistrust against large incumbents since new entrants and not the 'big 4' have been main investors in onshore wind, although this may change in the future given the recent move towards tenders rather than feed-in tariffs.

In terms of the alignment with the network regime the increasing share of onshore wind – and other fluctuating renewables – requires changes to the fairly stable and only gradually transforming network regime. That is, the network regime has been increasingly recognized as barrier to the unfolding transition of the generation regime. However, there is a strong political commitment to adjust the network regime so as to improve the alignment of the network regime with the newly emerging decentralized generation regime based on fluctuating renewable energy sources, such as onshore wind. Therefore, the changes in the generation regime have knock-on effect to the interconnected network regime, therefore improving the alignment of fluctuating renewables as onshore wind with this regime.

Finally, the lowest degree of alignment between onshore wind is in place with the consumption regime for two main reasons: First, electricity demand (particularly high in the South) and supply by onshore wind (particularly high in the North) are geographically dislocated, thus also requiring significant grid extension, creating pressure in the transmission regime. Second, demand is not synchronized with supply, i.e. electricity consumption does not yet react to peaks in electricity generation on windy days. This would require more flexible and smarter consumption, but developments in the consumption regime so far have remained fairly slow in this regard. The green niche of smart meters (see section 2.6) has the potential to function as bridging technology which could lead to or accelerate knock-on effects from the unfolding transition in the generation regime to the consumption regime as well.

One of the noteworthy complementarities between onshore wind and solar PV is their combined effect on the merit order curve. By driving down electricity prices together these technologies thereby clearly lead to tensions in the generation regime. However, solar PV intensifies these tensions through its impact on the merit order curve at lunch time hours, thereby further eroding profits and old business models based on high peak prices of electricity.

(3) Clear break-through: green niche has entered phase 3

Onshore wind has so far continuously been the leader in the race for the cheapest renewable energy technology, and by now is thus the preferred choice of many analysts and policy makers alike. Cost arguments and political commitment make investments in onshore wind very attractive. As a consequence, current expansion trends indicate a shift away from investments in solar PV – at least in terms of rooftop PV – and an increase in investments in onshore wind. However, wind suffers from greater concerns regarding public acceptance than solar PV on rooftops. Both technologies are seen as complements rather than competing new sub-regimes of the emerging generation regime based on fluctuating and decentralized power generation, and thus both of them continue to expand. However, in the case of wind the further expansion may need to be particularly well managed in terms of space and availability of locations (e.g. through repowering), among others to secure continued public acceptance of the further growth of onshore wind. Another key factor to ensure is the continued transition of the electricity network regime to enable the wider diffusion of this fluctuating technology which is concentrated in the Northern part of Germany due to higher physical potentials up North. Nonetheless, model runs show no realistic scenario in which onshore wind does not become the major electricity source in the 'Energiewende'.

2.3 Offshore Wind

(1) Medium internal momentum

The internal momentum of offshore wind is much lower than for onshore wind, mainly for techno-economic reasons: costs and technological uncertainties are significantly higher than for onshore wind, with costs being comparable but slightly lower than those of solar PV (Rohrig et al., 2013, p. 19). While much happened in terms of RD&D and innovation system build up, actual deployment only materialized in 2009 with the small pilot park 'Alpha Ventus' (12 turbines, each 5 MW). The positive experience gathered was instrumental for stimulating investor's interests. However, despite several parks being planned and constructed, delays in grid connection contributed significantly to limiting the momentum of the niche, since some investors had to delay construction of planned parks while others had to wait for already constructed parks to be connected to the grid (Reichardt and Rogge, 2014). However, in a joint effort by policy makers and industry the grid access problem was – when it threatened the further growth of the niche – addressed by changing the regulatory framework within the Energy Industry Act (EnWG) in the beginning of 2013 (Reichardt et al., 2015).

Yet, the momentum of offshore wind was also slowed down due to the reduction of long-term targets for offshore wind from 25 GW to 15 GW of installed capacity by 2030 decided in 2013. This marked a departure from a very stable and highly ambitious policy strategy which had been in place since 2002. However, despite comparatively high costs there is still a strong advocacy coalition supporting the industry, including due to its positive effects on regional economic development arising from the creation of jobs in the Northern part of Germany and higher than expected full load hours (Reichardt et al 2015). Also, according to the Offshore Wind Foundation capacity additions in 2015 are expected to lead to a doubling of installed capacity, based on which it was suggested that the reduced intermediary target of 6.5 GW for 2020 (formerly 10 GW) could potentially be increased to 7.7 GW to not artificially slow down the market growth.

Another notable observation is the policy style which can be characterized by pragmatic and cooperative problem solving, implying that the instrument mix implementing the offshore wind strategy – the only technology-specific strategy for a specific renewable power generation technology – has been eventually adjusted when problems arose (Reichardt et al., 2015). In addition, the EEG as core instrument continues to provide a high level of support, including after the amendment of the EEG in 2014. That is, despite the reduction of the 2030 target the actual policy support to achieve this reduced target remains fairly high which helps explaining why the offshore wind manufacturers perceive a comparatively smaller reduction in political commitment than other renewable energy branches (Rogge, 2015). However, the future design of the demand pull instrument (changing to a tendering system instead of feed-in tariffs) and overall policy mix for offshore wind (including permitting procedures) is currently being discussed, implying that there is some uncertainty about long-term investment prospects. In addition, while onshore wind and solar PV in the foreseeable future may no longer need investment support, the costs of offshore wind are expected to remain at a level which requires continued technology-specific political support to play a major role in the future electricity system.

Yet, so far industry actors remain firmly committed to this technology which by now has diversified from a focus on new entrants to much greater involvement of large utilities (for details, see Chapter 3.2 by Rogge, in Rogge et al. (2015a)).

(2) Medium alignment with wider regime and landscape developments

Similarly to onshore wind and solar PV the green niche of offshore wind benefits from landscape pressures arising from climate change and the anti-nuclear movement, as well as Germany's strong base in manufacturing, particularly the onshore wind industry.

However, the green niche of offshore wind is not as well aligned with the wider generation regime, although its large-scale character may suggest otherwise. It is exactly this large-scale character which fits well with the old electricity generation regime and capabilities of incumbents, but which – given the magnitude of investments required – also creates financing problems for smaller investors which were key for the early success of the 'Energiewende'. In the beginning the big incumbents in Germany were reluctant to push forward offshore wind, so that the niche was rather driven by new entrants who struggled, however, with project finance. By the time the 'big 4' started to seriously commit and invest in offshore wind, the competing small-scale technologies of onshore wind and solar PV had already gained very high momentum, which led to a significant growth in installed capacities and large cost reductions. In addition, the involvement of the large incumbents is viewed with some skepticism by civil society, particularly from those stakeholders which mistrust the environmental sincerity of the 'big 4' and envision a decentralized electricity generation system with small-scale generation units owned by a diversity of players, including households, cooperatives, and farmers.

In a related manner, the large-scale character of offshore wind parks and their location in the North of Germany raises problems with the alignment with the network and consumption regime. The most immediate issue is the lack of network infrastructure connecting parks – most of them being located in the North Sea – to the transmission grid. In addition, the grid needs to deal with the mismatch between electricity generation in the North – where offshore wind and the majority of onshore parks are located – and electricity consumption centres in the South. With the network regime moving fairly slowly, albeit continuously, this led to a delay of grid access which slowed down momentum of offshore wind. In addition, the geographical differences in electricity consumption due to industrial clusters in the Southern part of Germany are very stable, and therefore this misalignment is attempted to be solved through investments in the transmission infrastructure. However, this misalignment may partly have contributed to the reduction of the 2030 expansion target for offshore wind in favor of alternative renewable power generation technologies, most prominently onshore wind.

Finally, offshore wind benefited from a potentially good alignment with a very different regime, that of the marine industry. Actors in the green niche worked continuously and eventually quite successfully in integrating offshore wind as one legitimate component of the marine regime. This was not a straightforward exercise, as different interests (transport, fishery, tourism, military, etc) needed to be balanced. Yet, since offshore wind can offer several benefits, including generation of green electricity, income and jobs, the proponents of offshore wind eventually managed to link up with the marine regime. This mainstreaming of offshore wind within marine industry contributes positively to the assessment of a medium alignment with the wider regime.

(3) No breakthrough yet, despite recent deployment successes in this early market niche

Offshore wind is not breaking through yet, which is mainly due to techno-economic internal factors – the technology is much more expensive than onshore wind. In addition, there is a mis-match with the network regime which has been slow in extending the network and providing grid access. While the latter external problem is in the process of being solved, the difference in costs between onshore and offshore wind are likely to remain in place but may reduce in magnitude. Therefore, should in the future onshore wind encounter difficulties in reaching ever greater shares of deployment, e.g. due to conflicts with alternative land-uses, nature protection concerns or public resistance or perhaps also the need to provide business opportunities for incumbents to ensure their survival, these cracks in the emerging onshore wind sub-regime may open up a window of opportunity for offshore wind breaking through more widely. Only then we expect a wider diffusion and a self-sustaining high momentum.

2. 4 Bioenergy

(1) By now only low internal momentum

Bioenergy has by now a rather low momentum, mainly for its high costs and little cost reduction potential (Held et al., 20 (Portman, 2010)14). However, compared to wind and solar PV it exhibits the technological advantage of being a non-fluctuating energy source (Reise et al., 2012). Still, policy commitment for a further expansion of this niche is limited, also for wider sustainability concerns and competing uses of biomass for the decarbonisation of other sectors (for details, see Chapter 3.3 by Lehmann and Rogge, in Rogge et al. (2015a)).

(2) Alignment with wider regime and landscape developments

The growth of the green niche of bioenergy has, similarly to onshore and offshore wind and solar PV, benefitted significantly from its alignment with the landscape pressures of climate change and the anti-nuclear movement, as well as Germany's strong engineering base in manufacturing bio-based power generation technologies (Bruns et al., 2011). However, the further development of the niche is constrained, among others, because of overriding environmental concerns regarding the sustainability of the production of ever increasing amounts of bio-fuels, not only within Germany but also on a global level.

This concern is aggravated due to competing uses of agricultural land for the production of food, bio-fuel and bio-based materials which implies that the development of non-electricity regimes and here particularly the land use and agricultural regime are of crucial importance to the future development of bioenergy (Reise et al., 2012; Emmann et al., 2013). In addition, bio-fuels cannot only be used for electricity generation but also for the generation of heat and as bio-fuel for the transport sector. These sectors are also under significant landscape pressure from climate change and non-bio-fuels alternatives tend to be less advanced than onshore wind and solar PV in the case of electricity generation. This makes bio-fuels a scarce resource and implies that biomass might be better used outside the electricity sector in which more advanced alternatives exist.

These competing land uses and uses of bio-fuels may explain why the window of opportunity offered by cracks and tensions in the electricity generation regime could only to a limited extent be harnessed by bioenergy. As a first instance, this may be surprising as bioenergy is excellently positioned in the emerging electricity generation regime because actual electricity generation from bioenergy can be adapted to demand since its energy can be stored (Reise et al., 2012). This makes bioenergy an excellent low-carbon complement to the new emerging sub-regimes of onshore wind and solar PV with their fluctuating electricity generation depending on weather conditions and time of day. Moreover, bioenergy is well aligned with the electricity network and demand regime as its physical characteristics can contribute to balancing supply and demand without putting severe pressures on the electricity grid and without requiring adaptations at the demand side. These advantages help explain the very favorable policy mix promoting the deployment of bioenergy up to recently, but also underline the need to look beyond windows of opportunities created by a single regime and instead also consider interdependencies between multiple regimes.

(3) Break-through unlikely due to competing (land) uses and wider sustainability concerns

In general, bioenergy is a well established energy carrier, and in the past the green niche of electricity generation based on bioenergy has grown substantially. However, the growth of the niche has slowed down significantly. Reasons for this are both niche internal as well as external: The most important niche internal reason for the limited future growth of bioenergy in electricity generation is its comparatively high costs and low cost reduction potentials; the most relevant niche external factors are wider sustainability concerns regarding the production of bio-fuels as well as competing uses in multiple regimes, such as transport, buildings, electricity and agriculture.

2.5 CFL and LED lighting

(1) Very high internal momentum

LED lighting technologies have a very high momentum, mainly for techno-economic reasons: LEDs have witnessed rapid technological progress and exhibit massive technological and economic advantages (including total cost of ownership, TCO) (Azevedo et al., 2009; Haitz and Tsao, 2011). In contrast, for CFL lighting the momentum is only medium, as the economic advantages (TCO) cannot outbalance the reluctance of consumers and environmental disadvantages related to the technology (e.g. mercury) (Bertoldi and Atanasiu, 2008). However, political support is high for both technologies (Menanteau and Lefebvre, 2000), largely originating from the EU, with the most prominent instrument being the ban of incandescent lamps since 2009 in the frame of the EU Eco-design Directive (Howarth and Rosenow, 2014) (for details, see Chapter 3.6 by Fleiter, in Rogge et al. (2015a)).

(2) Very good alignment with wider regime and landscape developments

CFL and LED lighting is well aligned with the landscape pressure of climate change and energy security concerns, as by its reductions in electricity consumption it has the potential to alleviate both concerns.

The green niche also answers to tensions in the electricity consumption regime regarding greater levels of energy efficiency and energy demand reductions. For these concerns, it provides technical components which can easily substitute less energy efficient incandescent light bulbs. The expected reductions in energy demand can help reduce pressures on the grid and generation regime. Finally, there are no constraints from other regimes.

(3) LEDs on the verge of entering phase 3 and starting to rapidly breaking-through

Thanks to rapid technological progress and cost reductions as well as the EU ban on incandescent light bulbs, LEDs (but not so much CFLs) are step-by-step substituting old lighting components with the green technology. In addition, eco-halogen lights have substantially increased market shares, clearly outperforming both CFL and LEDs in the year 2013 (dena/GfK). However, a speedy breakthrough of LEDs is expected. This can further be explained by the comparatively short life time and thus limited lock-in of incandescent light bulbs when compared to other technologies, such as the long lifetime of coal-fired power plants. In addition, another advantage of LEDs is that their adoption does not require multi-dimensional changes to the electricity consumption regime, which may further facilitate rapid breakthrough.

2.6 Smart meters

(1) In the past low internal momentum with potential for increase

The momentum of smart meters as a relatively new technology on the demand side is assessed as rather low, mainly due to techno-economic reasons. More precisely, the high implementation costs lead to the effect that cost-benefit ratios rarely become positive for individual households. In addition, socio-cognitive acceptance is rather low mainly due to data protection concerns. As a consequence, policy makers have been hesitant to show significant commitment to an accelerated deployment of smart meters (for details, see Chapter 3.5 by Friedrichsen and Klobasa, in Rogge et al. (2015a)).

Yet, in 2015 some policy developments indicate that momentum might increase. One reason to believe so is that the Federal government increased the attention towards information and communication technologies (ICT) as supporting technologies for the energy transition. Following a consultation at the beginning of 2015 the government published a draft for a law on the digitalization of the energy transition in the fall of 2015. This draft law demands a roll-out ratio of 80% by 2020. While this may sound very ambitious the target is actually a requirement by the European Commission’s third package on the internal market from 2009. Member states are allowed to pursue different roll-out strategies conditional on a cost-benefit analysis. Germany has been reluctant in following a mass roll-out strategy. Based on the cost-benefit analysis that found a roll-out to be beneficial only for specific cases, Germany opted for a stepped roll-out strategy that has a strong emphasis on positive cost-benefit ratios that have been found for bigger consumers and generators. Most other European countries went for a much wider roll-out including all household customers. Hence, this new policy target can still be considered as rather conservative.

Apart from cost-efficiency, the German roll-out strategy for intelligent metering systems emphasizes the importance of data protection. In the past years, the development of a security profile for smart meters had substantially slowed down momentum, but may on the other hand have been necessary to address acceptance problems resulting from privacy concerns (Ernst & Young, 2013).

(2) Good alignment with wider regime and landscape developments

Smart meters are well aligned with wider landscape and resulting regime developments regarding climate change and following the anti-nuclear movement as these have driven the electricity generation system towards renewable and decentralized technologies. As a consequence, the newly emerging electricity generation system requires increased flexibility that can be delivered by several options such as storage, demand side management, or coupling with other sectors. All these options require a more intelligent control of the power system. Smart meters in principle fit well with these changing characteristics of the electricity system towards more flexibility since they enable dynamic tariffs and better (short term) information on load and generation dynamics. They are therefore now pictured as important component for the energy transition. The potential of smart meters within a smart grid at distribution level is receiving growing attention and might ultimately also push the diffusion of smart meters. Interestingly, even though they are seen as one means to further demand reduction and increased energy efficiency (Ernst & Young, 2013) which are important pillars of German energy policy, this does not seem to be a major driving force for the development of smart meters so far. Furthermore, to realize the potential of smart meters for flexibility, pilot projects found that changes in billing and tariffs (towards more dynamic offers) as well as behavioral changes are necessary (Karg et al., 2014).

The growing amount of renewable and decentralized generation is challenging the traditional way the power system was managed. Feed-in of a large part of the generation system has become more fluctuating, which increasingly becomes difficult to be balanced solely by the other dispatchable power plants. This leads to a call to make demand more flexible to make a better fit with the availability of renewable generation. Also, in contrast to top-down power flows, network operators now need to cope with power flowing from lower voltage levels to higher voltage networks. Hence, the energy transition and the significant changes in generation are a challenge for the power system and in particular the network regime. Smart meters in the context of smart grids have the potential to address part of these problems. The idea behind smart grids is to control both the feed-in by equipping generators with smart meters as well as changing consumption patterns and making demand more flexible.

Hence, changes in generation and the knock-on effects for network and system operation open a window of opportunity for the wider diffusion of smart meters.

(3) Still caught in early market niche phase

So far smart meter diffusion in Germany is low. Yet, EU policy requires an 80% roll-out ratio by 2020 unless a cost-benefit analysis is carried out to motivate a diverging approach. The Federal government followed this route and aims for a stepwise roll-out initially focusing only on bigger consumers and generators for which cost-benefit ratios are found to be positive. Roll-out for smaller household consumers is foreseen starting in 2020, but suppliers must not exceed cost thresholds based on the potential benefit.

Hence, diffusion will broaden over the next years and smart meters may escape from a niche market and break through to phase 3 with wider diffusion, at least with industrial consumers. Yet, diffusion at household level will likely remain low for the next years given the unfavourable cost-benefit calculations.

3) Assessment of regime reorientation

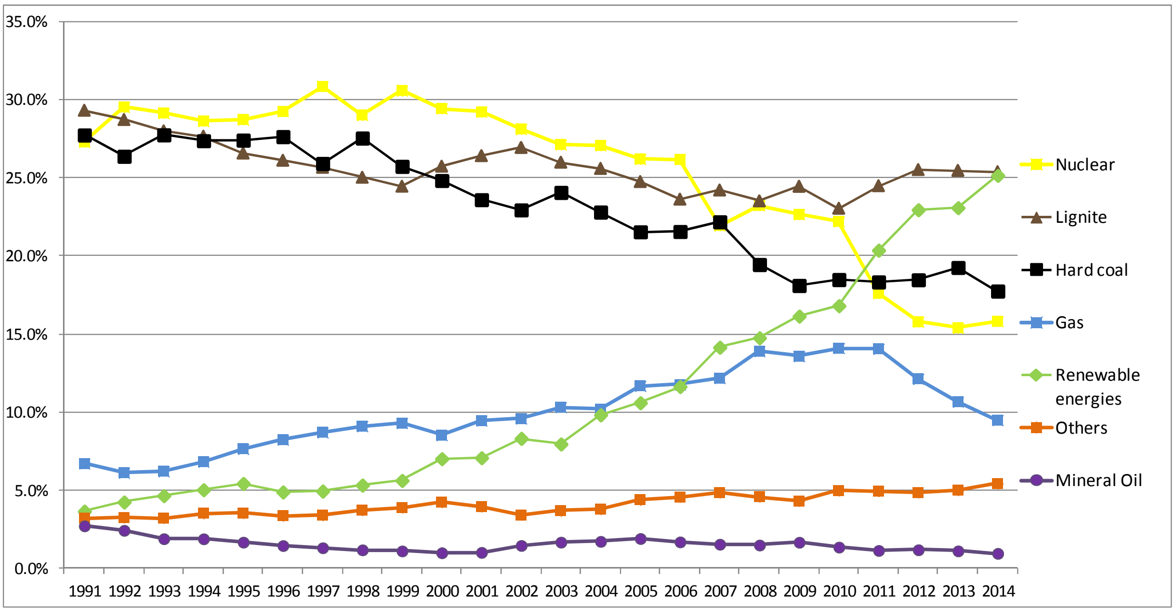
The following assessment of the electricity regimes – broken down into electricity generation, network and consumption regime – is based on the PATHWAYS deliverable 2.2 in which a more detailed analysis of these regimes and their past development was conducted (Rogge et al., 2015b). These findings which are summarized in the beginning of each sub-section will be interpreted in light of the following aspects: the remaining scale of the transition challenge, and the main socio-technical problems.

3.1 Electricity generation regime

(1) Summary of regime development (based on D2.2)

Over the period from 1990 until today the German electricity generation regime has witnessed major landscape pressures – most importantly a strong anti-nuclear movement paired with concerns about climate change (Morris and Pehnt, 2014). Additional tensions have resulted from the increasing impacts of the emerging niches of wind, solar PV and bioenergy, which have expanded significantly (see Figure 5) and can now start to be viewed as new sub-regimes.

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



Source: BMWi, 2014c

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 (Geels et al., 2014; Strunz, 2014). 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 (Richter, 2013).

Notably, in 2012 and 2013 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. A major reason for this are the low CO_2-prices within the EU emissions trading system which do not sufficiently penalize high carbon emissions, and thus make lignite and hard coal cheaper than gas fired power generation (Agora Energiewende, 2013). The increase was also facilitated by the nuclear phase out, allowing coal and lignite to replace nuclear base load. 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 (EEG 2014). 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.

(2) Scale of the transition challenge

The German 'Energiewende' is well underway in the electricity generation regime (BMWi, 2014b, 2015a). The unfolding transition by and large follows the broader regime transformation pathway B given the involvement of many new entrants and change along multiple dimensions other than technologies. The 'Energiewende' project is a top political priority and there is a clear and stable political vision regarding the direction of change away from nuclear and towards renewable energies (BMWi, 2014a). Overall, the transition is managed in a fairly systematic manner, with much of the focus on techno-economic aspects. However, policy makers are also aware of non-technological challenges of this transition project, including public acceptance and legitimacy (Bruns et al., 2009; Laes et al., 2014).

Despite this clear political commitment and ongoing implementation of the 'Energiewende' vision the scale of the transition challenge remains formidable given the scale of the necessary system changes across multiple dimensions – particularly as the next decades will move forward from a share of 25% renewables in electricity generation (in 2014) to 80% (in 2050) (BMWi, 2014d). However, in terms of overarching political support the scale of the challenge seems comparably low, as following the Fukushima incident all political parties are committed to the Energiewende (Morris and Pehnt, 2014). Despite this agreement in terms of the long-term vision several socio-technical problems remain to be addressed, some of which will be difficult to solve, as described below. However, given the strong political will to make the 'Energiewende' work it can be expected that these problems will eventually be solved under the leadership of the Ministry in charge (since 2014 Ministry for Economic Affairs and Energy, BMWi, prior to this the Environment Ministry, BMU). This move exemplary signals the increased 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.

(3) Main socio-technical problems

In the following we will highlight some of the most important socio-technical problems with the unfolding transition of the German electricity generation regime which have emerged within the analysis conducted in D2.2 (Rogge et al., 2015b).

- *Environmental performance (CO_2) and lack of strategy for coal phase out:* CO_2 emissions from electricity generation in Germany have decreased from 353 Mt CO_2/a in 1990 to 294 Mt CO_2/a in 2009. However, this general decarbonisation trend has been reverted since 2010 with once again rising CO_2 emissions, reaching 317 MtCO_2/a in 2013, representing an overall reduction between 1990 and 2013 of 12.7% or 40.4Mt CO_2 (BMWi, 2014e, p. 46). This recent increase in CO_2 emissions has been coined the Paradoxon of the 'Energiewende' (Agora Energiewende, 2013): while electricity generated by renewable energies 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, owing, among others, to low CO_2 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 plants, which, however, was faced with fierce resistance from vested interests from industry, unions and federal states (BMWi, 2014e).
- *Costs (EEG levy)*: There is a much greater emphasis on the costs of the energy transition, as much attention is been put towards the development of the EEG-levy – the burden of the EEG being rolled-over to electricity consumers - which rose drastically (0.58 to 5.28 €Cents/kWh from 2004 to 2013), and has continued to increase, if only slightly, in 2015. This challenges the legitimacy of the EEG and risks the danger of focusing on short-term costs rather than longer-term benefits (arising from innovation, jobs, exports, climate protection).

- *Market and system integration:* the increasing share of fluctuating renewables and the breakthrough status of onshore wind and solar PV imply that the rules of the regime need to be rewritten so as to integrate renewables into the electricity system and market. In the recent past, there have been increasing policy efforts devoted to developing instruments to facilitate such integration of renewable energies (Breitschopf, 2015).
- *Resistance of incumbents:* Further resistance of incumbents can 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). 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.
- *Public acceptance issues:* While there currently is a wide societal support for the ongoing energy transition towards renewable energies in Germany (BDEW, 2013b, 2014), public acceptance issues do not only affect CCS and fracking (both currently hardly feasible due to German regulation) but also slow down the expansion of grids (Duetschke et al., 2014; Duetschke et al., 2015). In addition, if the deployment of onshore wind continues there may also be larger concerns with securing public acceptance. Therefore, public acceptance is on the radar screen of policy makers, and expansion pathways are scrutinized in terms of their effect on public acceptance and effort is put into designing useful procedures for stakeholder participation in policy making and implementation
- *EU interference:* The Germany support policy has been criticised by several EU institutions, including DG Competition. Discussions on whether the EEG constitutes a case of illegal state aid distorting the internal electricity market have led to adjustments of the policy instruments in place. Some of these adjustments have created uncertainties in the market. Without judging in which cases the interference are justified or purposeful, it has to be noted that the EU plays a significant role in the restructuring process and policy making of Germany.

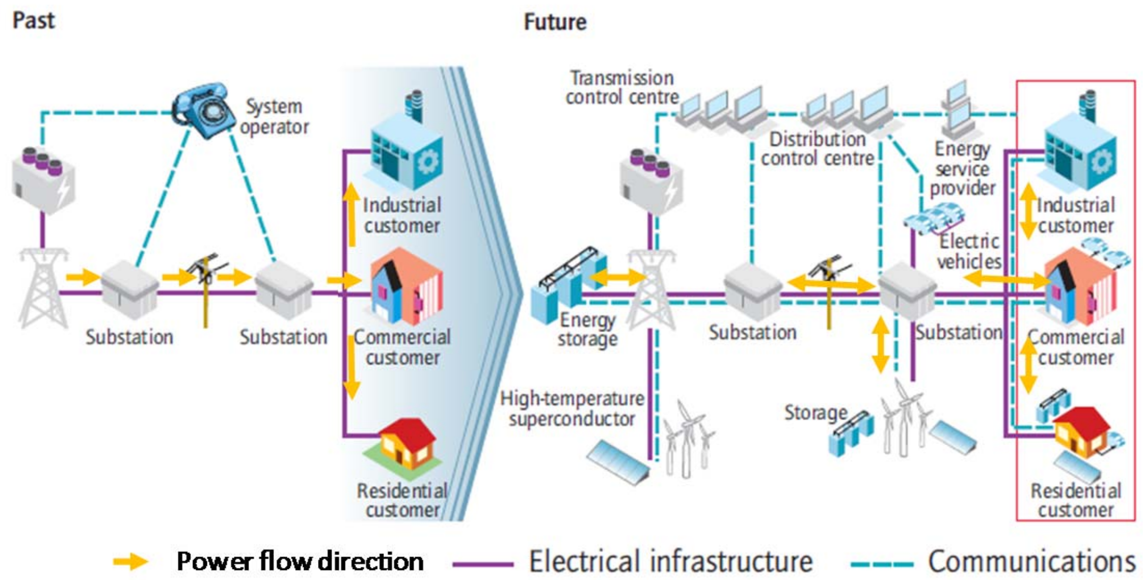
Some other challenges the electricity regime is faced with include the need to strike a political agreement on a permanent site for nuclear waste disposal as well as the actual decommissioning of nuclear power plants. Another challenge concerns the question of how to deal with incumbents whose business model is failing.

3.3 Electricity network regime

(1) Summary of regime development (based on D2.2)

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.

Figure 6: Power system in the past and in the future, with a focus on changes in the network regime



Source: IEA, 2011 with own additions

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 (Deutsche Umwelthilfe, 2013; VDI, 2014) and might not always be the most efficient solution, adaptations in network operation and management are also required (Deutsche Umwelthilfe, 2013; BDEW, 2013a). 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. While the debate initially concentrated on transmission networks that need to be expanded to accommodate North-South power flows originating from mainly wind at the coast, there are now also massive challenges in distribution networks apparent (dena, 2012). Decentralized generation in sparsely populated network areas needs to be transported from the low voltage level to upstream networks to be further distributed, i.e. power flows in the opposite direction than customary and fluctuation add to the challenge. Hence, there are also tensions in the network regime at distribution level.

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 (see Figure 6), but so far this is mainly happening on a physical level – which suggests that currently the transition of the network regime follows the pattern of gradual or incremental transformation without changes to the basic system architecture (additional pathway C). 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).

Overall, the network business as a centrally regulated activity is relatively stable per se, but is likely to eventually lean towards a transition pattern which then would be best captured as undergoing regime reconfiguration (additional pathway D). Given the great and increasing pressures arising from the physically connected generation regime and the firm political will to go forward with the 'Energiewende' the network regime is destined to go beyond incremental changes. Several regulatory changes have already been made to adapt it to the investment needs and quality demands. The process of adjusting the regulation is ongoing. In an evaluation of the incentive regulation that was published at the beginning of the year 2015, the Federal regulator highlighted further areas in which adjustments should be made to support the energy transition. This lays the ground for further reconfigurations in the future.

(2) Scale of the transition challenge

The energy transition at generation level has significant effects for the electricity networks already. While the transmission expansion need has been projected and recognized for a long time, given the high stability of the network regime the realization progressed slower than desired. On the one hand this is related to permitting procedures and financing, issues that have been significantly improved with adjustments towards the legal and regulatory framework for network expansion planning and realization. On the other hand, a lack of public acceptance is a severe problem for network expansion. While several new instruments such as a stronger focus on public participation in network expansion planning from very early stages, more transparency and evaluation of alternative routes as well as a stronger focus on underground cabling were possible, network expansion still seems to be a significant challenge. The issues are likely to grow in the future, as the need for new overhead lines will increase with growing shares of renewables in the system. In the current discussion, this fact is to some degree neglected, as the discussed grid expansions are often perceived as sufficient, ignoring the fact that they are only the first step with many others to follow.

The transition challenge in distribution networks seems to be more manageable. Transformer upgrades are likely less fraught with acceptance problems. Hence, the adjustments in regulation to enable these investments – as already realized – will likely sufficiently address the investment challenge with respect to traditional network assets. The change of the operational paradigm towards smart grids and a more intelligent control of the network to foster the integration of renewable energies is more challenging and might also require a fundamental change in regulation in the sense of how to regulate. Currently, the government is starting five projects to showcase “intelligent energy” and the role of digitalization for the energy transition (BMWi, 2015c).[5] 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. They are aimed to inspire the blueprint for subsequent upscaling of the developed solutions for intelligent renewable based electricity supply and broad diffusion at national level.

The German ‘Energiewende’ is a top political priority and there is a vision to make the necessary adjustments in the networks such that they do not become the bottleneck of the transition towards renewable based power supply. Recent changes towards network expansion planning and permitting procedures as well as the review of incentives regulation all link up with the challenge of the changing generation structure and integration of renewable energies. This underlines the impression gained in the generation regime that the approach towards the transition is quite systematic and commitment towards realizing the transition is high.

[5] Federal Minister Gabriel announced the start of the funding program in a press release from 01.12.2015: http://bmwi.de/DE/Presse/pressemitteilungen,did=742740.html

Politicians seem to have realized the enormous importance of public acceptance and it seems acceptance issues are taken seriously both with respect to network expansion but also with respect to smart meters that could become an integral part of future smart grids.

(3) Main socio-technical problems

We identify the following aspects as main socio-technical problems for the unfolding of the transition of the network regime.

- *Public acceptance challenged by wider system benefits of network expansion:* The general support and public acceptance for the energy transition in Germany is high. However, even though network expansion is partially driven by the needs of the energy transition, it is fraught with acceptance problems. Lines usually do not only benefit renewables generation, but have a wider system benefit. Also, flexibility measures that contribute to managing a system with fluctuating renewables may also benefit fossil generation. This is a massive problem for the legitimacy of measures that are said to further the energy transition but have "undesired" side effects in the system. Acceptance is furthermore weakened by state interests with policy makers trying to re-route already planned lines out of their electoral states. An agreement on the necessity of a grid expansion on national level is therefore not sufficient for its implementation but also has to undergo often lengthy discussions between states.
- *Financial and motivational challenges of integrating electricity consumers into smart grids:* Looking more into the future, the active integration of the demand side into smart grids remains a challenge. Financial benefits with respect to smart meters are likely small or even negative – in which case smart meter are unlikely to be installed – and it is unclear to which degree consumers can successfully be motivated to participate actively in the power market and network management by variable tariffs or non-financial measures.
- *Weak lock-in of regulatory style, but not a major barrier:* Regulatory rigidity and a focus on the traditional system could be a barrier towards system transformation. Yet, at the moment this does not seem to be a prevalent problem and the evaluation of the regulation has taken the needs of the energy transition into account. If this continues in the future, regulation does not seem to be a barrier for the energy transition, but can be used as a tool for support.

Further issues that challenge the network regime may be the trend towards remunicipalisation, i.e. cities taking back network ownership. Also, self-generation and the risk of grid-defection is a debate since under the current tariff regime it changes the cost allocation towards different customers. Financing the significant investment need itself does not seem to be a major problem (Cullmann et al., 2015; Bundesnetzagentur, 2015). This likely also applies to the expansion of interconnectors.

3.2 Electricity consumption regime

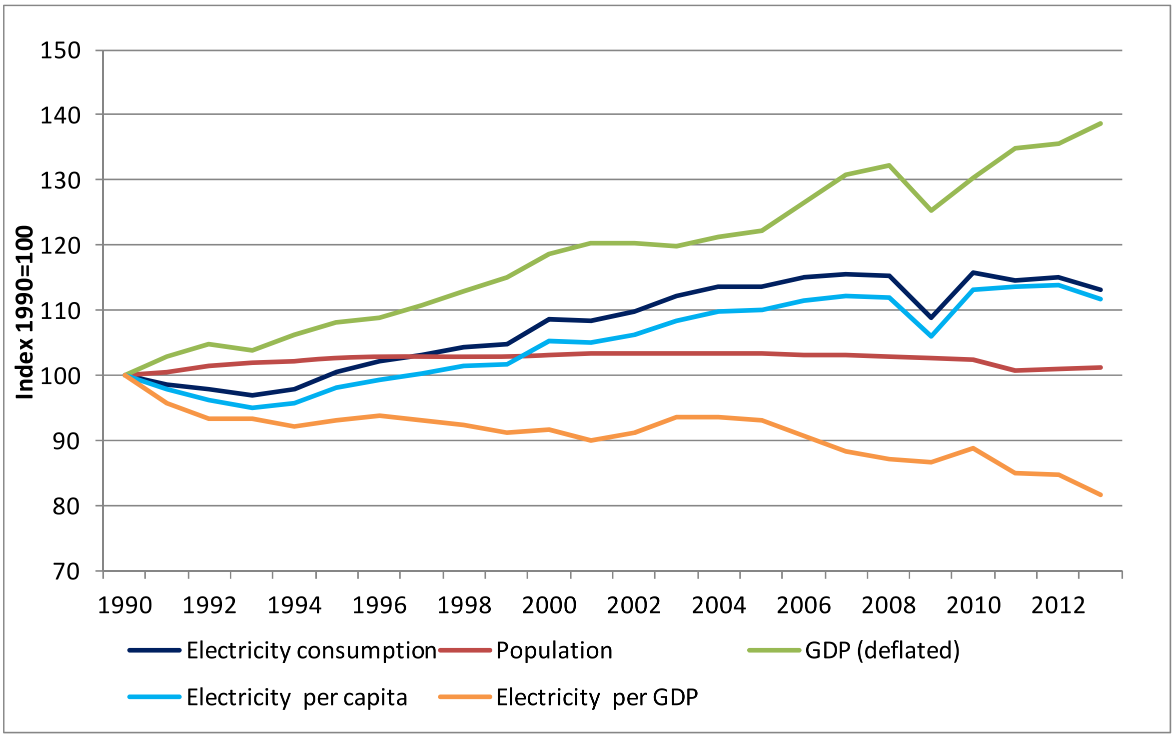
(1) Summary of regime development (based on D2.2)

Based on the analysis conducted in D2.2 we argue that the electricity consumption regime is fairly stable and has evolved incrementally through the interplay of several dynamics which may have a reverse effect on the development of electricity consumption (based on de Almeida et al. (2011) and Schlomann et al. (Schlomann et al., 2014)). 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) (Schlomann et al., 2015).

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 policy measures and – to a lesser extent – by national ones.

However, it is often unclear how behavioral and organizational 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 programs, but the opposite is also possible, e.g. through rebound effects. Figure 7 shows the resulting development of electricity consumption from 1990 until 2013, which has decoupled to some degree from economic growth but only recently also started to decline in absolute levels.

Figure 7: Development of total final electricity consumption and determining factors in Germany (1990-2013)



Source: Own calculation based on ODYSSEE database

Together, these patterns can be understood in the context of competing landscape pressures. On the one hand, concerns about climate change and energy security as well as the favorable 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, especially in the field of ICTs.

(2) Scale of the transition challenge

Germany has set itself ambitious energy efficiency targets but despite the recognition of multiple benefits of energy demand reductions and the coining of the term 'Energieeffizienzwende' (energy efficiency transition) energy efficiency has been treated with much less political attention than the transformation of the energy generation regime towards renewable energies. This only changed since mid 2014, when energy efficiency has been established as the second pillar of the 'Energiewende' besides renewable energies (BMWi, 2014f). Therefore, the scale of the transition challenge is fairly large, both in terms of distance to target as well as in terms of political will to go beyond incremental energy efficiency improvements. That is, while the electricity consumption regime has incorporated incremental efficiency improvements as cornerstone of its regime rules, which leads to gradual improvements in energy efficiency, it is debatable whether these incremental business-as-usual improvements will be sufficient. The question that arises is how much can be achieved with the current incremental approach to the transition of the energy consumption regime leading to increases in specific energy efficiency levels, and to which extent the government will be willing to significantly step up its efforts to achieve more radical improvements in energy efficiency and reductions in energy demand.

(3) Main socio-technical problems

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

- *Lack of support for progressive energy efficiency standards favouring smaller products:* There is little 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.
- *Lack of consideration of sufficiency as option to reduce electricity consumption:* 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).

4) Conclusions and wider discussion

4.1 Conclusions

(1) Niche innovations breaking through

Our analysis suggests that three of the six studied niche innovations have entered phase 3 and have thus started diffusing more widely with largely self-maintaining momentum. In

Figure 8 these are depicted in the left with dark shaded colours and include: first, German onshore wind, which originally was enacted by new entrants (citizens, farmers, city authorities, project developers, entrepreneurial manufacturers, NGOs) under favourable political conditions. By now onshore wind can be seen as one of the two major new future sub-regimes of the transforming electricity generation regime, next to solar PV. Its biggest advantage are its low costs – which makes it well aligned with increasing political concerns over costs for the expansion of renewable energies and particularly the increasing EEG levy. Onshore wind's greatest potential future concern could be the availability of sites and continued public acceptance, but this remains to be seen.

The second niche which has reached break-through is solar PV. This niche development was also enacted by new entrants, civil society enthusiasm and a supportive instrument mix. Solar PV has recently lost, however, some legitimacy with job losses due to consolidations arising from international competition, particularly with Chinese module manufacturers. Also, it continues to be more expensive than onshore wind, but has seen massive reductions in costs over the past years. By now it has become economically attractive for private households even without feed-in tariffs when using the generated electricity largely for their own consumption. Both onshore wind and solar PV have followed a broader regime transformation (pathway B). However, it also needs to be noted that the financial burden (the EEG levy) caused by PV borne by electricity consumers is much higher than that of wind, despite generating less electricity.

Finally, energy efficient light bulbs (mainly LEDs) have seen massive techno-economic improvements and started to diffuse with a self-sustaining momentum, mainly driven by a European ban in incandescent light bulb and massive technological advances. They can thus also be said to have entered phase 3, but their diffusion better fits transition pathway A characterized by technical component substitution.

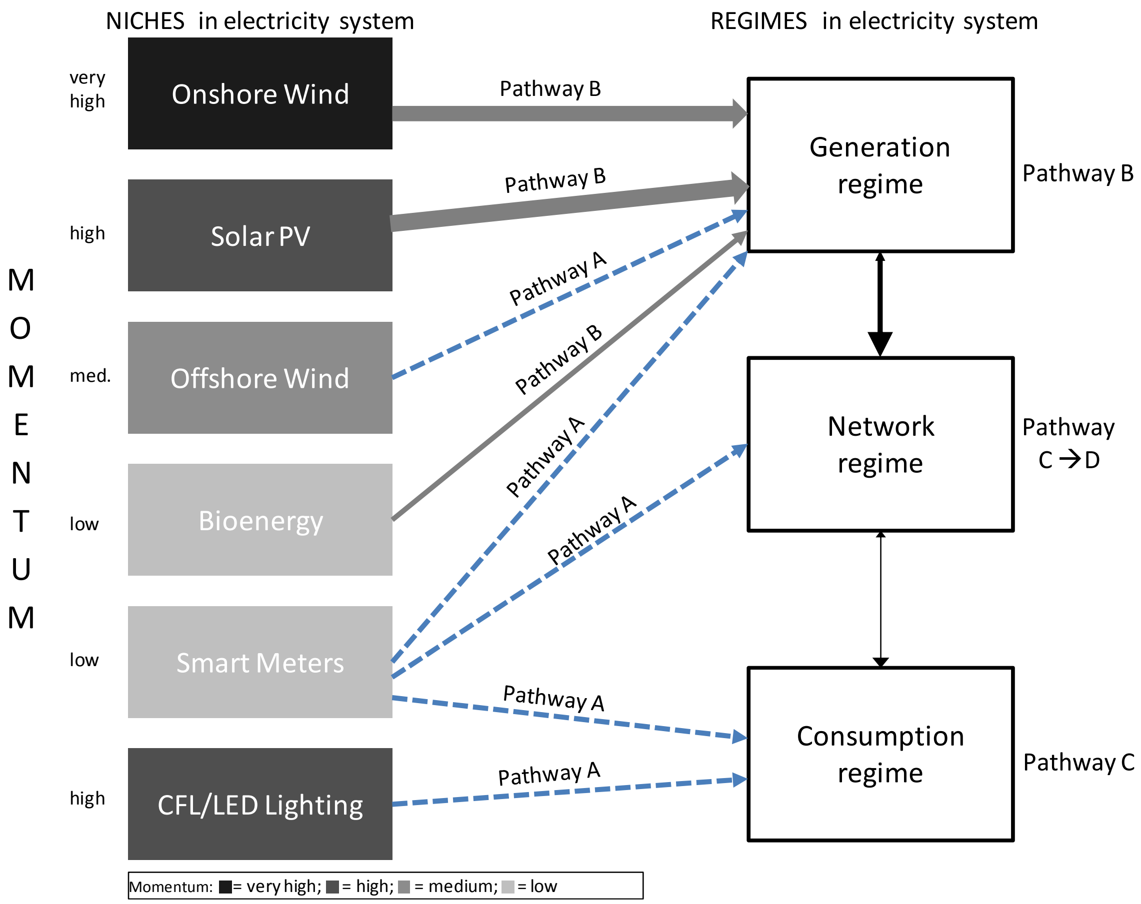
(2) Status of transition

The combined effect of onshore wind and solar PV has massive effects on the electricity generation regime (as indicated by bold arrows in

Figure 8 below). By now, it is widely accepted that these two break-through niches will become the two most important new sub-regimes of the transformed electricity generation regime, thereby putting the generation regime on track for the broader regime transition pathway B. At present the requirements arising from the specificities of onshore wind and solar PV, such as their fluctuating and decentralized nature, are determining how the new rules of the game are being written. The resulting multi-dimensional changes are not only occurring in the electricity generation regime but also have knock-on effects to the network regime, although with a lag. These include temporal and spatial changes of network utilization and a shift towards lower voltage levels; or grid-defection in distribution networks because of customers self-generating electricity for their own use. The transition in the conservative and highly regulated network regime has been fairly slow so far, but it has been gradually moving forward (which would suggest pathway C) and may be on the verge towards a complete reconfiguration to fit the new requirements of the emerging electricity generation regime based on fluctuating and decentralized renewable energies (pathway D).

In contrast, the green niche of LEDs has so far not had a significant impact on the consumption regime, despite its high momentum. However, in the future reductions in electricity consumption in lighting can be expected to arise from the substitution of incandescent light bulbs with energy efficient lighting. In this case, the transition is characterized by technical component substitution (pathway A). However, in general we argue that a better way to characterize the ongoing changes in the German electricity consumption regime is one which acknowledges the gradual improvements in energy efficiency. However, the ongoing gradual transformation towards greater levels of energy efficiency may be too slow given the urgency of the climate change challenge. In addition, it may be insufficient in its absolute effect on electricity demand reductions, may this be due to rebound effects or new uses (ICT, e-mobility, heat pumps). Either way, while reduction targets for the absolute level of electricity consumption and primary energy demand are in place, so far their implementation is lacking behind which suggests limited political commitment to these absolute reductions in the level of energy demand. So in the (near-term) future we may see more flexibility in consumption patterns, but an overall decline in electricity demand is much less likely. Yet, given the unfolding transition in the generation regime the environmental impact of the consumption regime will decrease in any case.

Figure 8: Changes in the German electricity system: from niches to regimes (incl. pathways)



Source: Own illustration

Our analysis suggests that the transition pathway followed by a regime cannot automatically be deducted from the pathway suggested by a particular niche. This is the case as we are dealing with multiple niche innovations breaking through, but their relative role within the wider regime and its transition may be fairly small and thus limited. Therefore, in order to determine the pathway a regime is following in an unfolding transition we argue it is necessary to look at the combined effect of all relevant niche developments as well as regime-internal developments. In addition, from the analysis of transition pathways followed by the generation (B), network (C/D) and consumption regime (C) it cannot be straightforwardly concluded which pathway the transition of the overarching electricity system is following. However, for the case of Germany we can say that the strong political will for the unfolding transition of the generation regime ensures knock-on effects on the fairly stable network regime despite some resistance from the network regime given its stability (as indicated by the thick arrow connecting the two), but that the link so far is much weaker for the consumption regime (as indicated by the thinner arrow between these two), particularly regarding the reduction of electricity consumption. This may be partly the case because of current overcapacities in the generation regime. However, in the future pressures on the consumption regime could increase, although this may depend on a number of factors, including rising shares of renewable energies in electricity generation, progress with grid expansion, or development of costs.

4.2 Wider discussion

(1) Scale of transition challenge

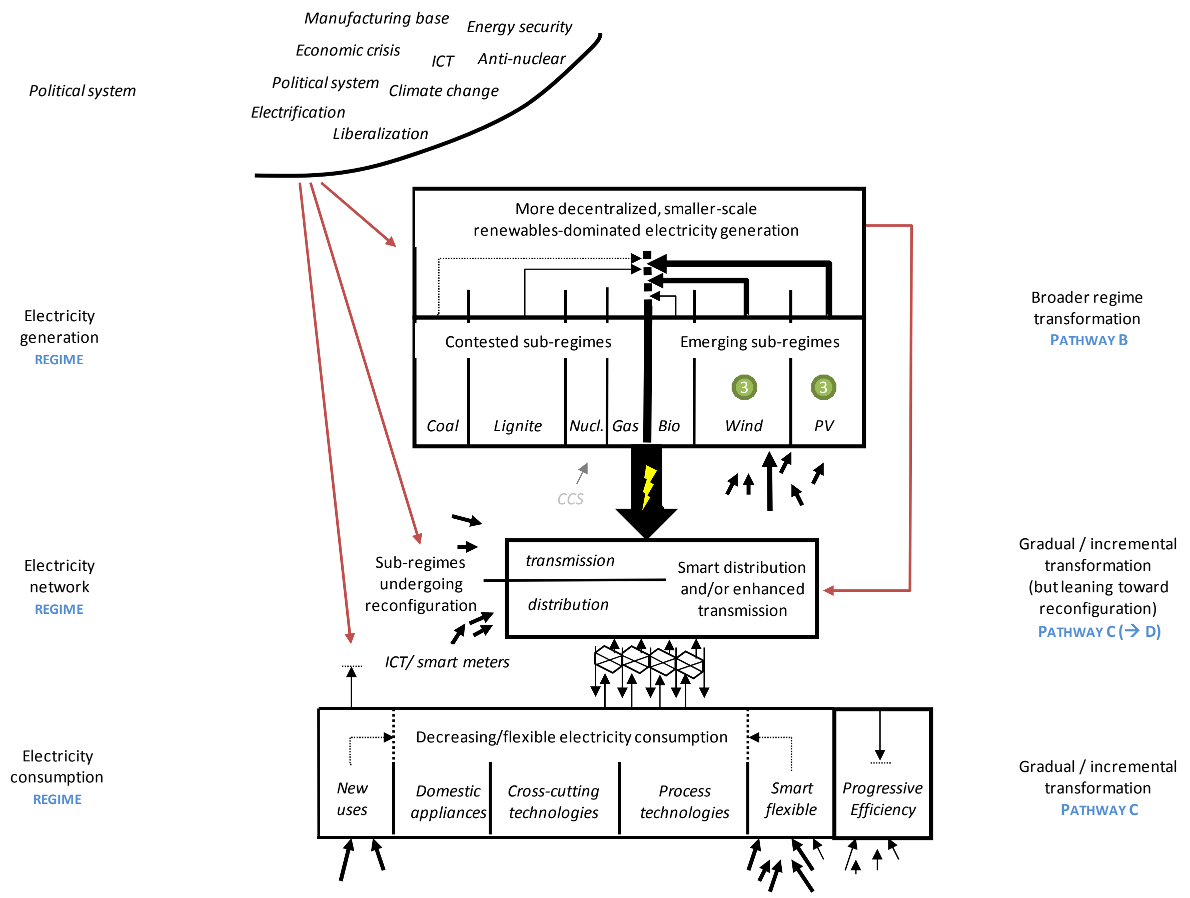
Based on developments so far, the transition challenge is smallest for the electricity generation regime and largest for the consumption regime, with the electricity network regime placed in the middle. However, as all three regimes are interconnected (see

Figure 8), the unfolding and carefully managed transition in the generation regime with the two break-through niches of onshore wind and solar PV may have knock-on effects, particularly and most directly on the network regime. The latter is on the verge of moving to a reconfiguration pathway – albeit fairly slowly due to its conservatism. That is, given the great political commitment to the transition of the electricity generation regime towards renewable energies the network regime will eventually be tagged along, as the success of the 'Energiewende' project requires a reorientation of the network regime, as well.

In contrast, so far the trickling through effect from the unfolding transition in the generation regime to the consumption regime is fairly limited. As a consequence of much less political attention up to 2014 the consumption regime has not moved beyond an incremental transformation with gradual improvements in energy efficiency. In addition, the need to make demand more flexible is increasingly discussed, but there seems a long way to go. For example, household consumers have no variable tariffs yet. Smart meters would enable that, but for most household customers their introduction has been postponed with a roll-out focusing on customers with consumption above 10MWh/a. In addition, flexibility of other consumers and storage is debated and fostered with some instruments. However, in part these are criticized for merely rewarding industry for something they would do anyhow.

One idea of accelerating the change within the network and particularly within the consumption regime could be the strengthening of the (institutional) links and interdependencies of these regimes with the generation regime. For example, regarding the consumption regime the goal of such strengthened links should be to stimulate radical demand reductions alongside with increasing the flexibility in timing of demand. In addition, the recent developments of framing energy efficiency as second pillar of the energy transition may help overcome the moderate progress made in the consumption regime so far, if the increasing political will is translated into effective policy actions, such as the strengthening of the instrument mix supporting radical increases in energy efficiency and reductions in electricity demand.

Figure 9: Snapshot and prospect of unfolding German energy transition and its transition pathways



Source: Adjusted based on Rogge et al. (2015a)

(2) Indications of picking up the challenge

Today, political support for realizing the energy transition also in the fairly slowly moving network regime is there, at least on the national level. In the past slow developments and uncertainties at the network regime slowed the developments in green niches for generation technologies down (cf. offshore niche), but changes over the past years show a political will to improve the conditions and prevent the network from being the barrier for the energy transition. While this concerns mainly transmission network expansion, generation change also starts to challenge distribution networks. So far incremental changes have been realized. The fact that in many networks assets reach the end of their lifetime, however, opens a window of opportunity to not only replace old components, but modernize the networks and make them more intelligent.

The current draft law for the digitalization of the energy transition and the announced showcase projects for intelligent energy indicate that the government may intend to use this opportunity. Even though the roll-out strategy for smart meters focuses on bigger consumers and generators given cost-benefit concerns and acceptance issues, it may be the first step towards broader diffusion with potential further expansion towards households after 2020.

There also seems to be increasing attention of policy makers, international institutions and NGOs to energy efficiency. For example, terms such as ‘energy efficiency transition’ and the multiple benefits of energy efficiency have been coined, e.g. in the context of the EU Energy Union (Energy Efficiency First) or of the IEA (Energy Efficiency and the First Fuel). Germany has adopted the National Action Plan Energy Efficiency (NAPE) in December 2014 which includes some new instruments, but concrete additional action has remained fairly low. However, while ambitious targets are in place the political commitment to implement stringent energy efficiency measures, particularly those raising the costs of energy, remains limited, often due to strong opposition of industry lobbies. In addition, the public debate about energy demand reductions is not very active, and the focus still rests with renewable energies and, of course, also other political concerns. However, without more radical changes in the consumption regime which align the regime with the landscape pressure of climate change, the stability of the consumption regime may make the continued unfolding of the generation transition more costly and more difficult than would otherwise the case. Some promising developments contributing to the destabilization of the consumption regime include electricity self-consumption (e.g. using solar rooftop PV systems) and the intended smart meter roll-out, particularly for larger consumers.

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