SWP Comments

Stiftung
Wissenschaft und
Politik

German Institute
for International and
Security Affairs

SWP
1962–2012

Germany's Energy Transition, the Internal Electricity Market and Europe's Future Energy System

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The neglect of Europe's Internal Electricity Market in the public debate on Germany's "Energiewende" (energy transition) is surprising, given its role as the main transit country for electricity in Europe. The transformation of the country's energy sector will further exacerbate network fluctuations and intensify the need for modifications in Europe's power system. Cross-border power transfers will have to increase in order to overcome national limitations on absorbing large volumes of intermittent renewables like wind and solar power. As the Nordic power market demonstrates, only a truly integrated, supranational electricity market can provide the capacity needed for synergetic interaction of diverse national power systems. In order to establish such an infrastructure on a European scale, the energy transition needs to be guided by an economic approach designed to prevent further fractures in the Internal Electricity Market. Moreover, constructive negotiations with neighbouring countries on market designs and price signals will be important preconditions for a successful "Energiewende" in Europe.

The German government proclaimed its "revolution of Germany's energy sector" (Angela Merkel) without consulting its neighbours. Eighteen months later the country is still searching for an operational approach for transforming its energy system for a sustainable future. The neglect of Europe's Internal Electricity Market is one of the most surprising aspects of these public debates, since increasing use of decentralized generation units such as wind turbines not only subverts the hierarchical top-down logic of electricity distribution on the national level, but has implications for the supranational dimension as well: National power systems do not function in isolation from one other and cross-border power flows are daily routine. Taking a European perspective on the consequences of Germany's energy transition may therefore produce new insights (see *SWP Comment 33/2011* and *SWP-Aktuell 37/2012*).

A major blackout in November 2006 illustrated the transnational nature of

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Europe's power sector. Beginning in northwestern Germany, the outage cascaded through Austria, Belgium, France, Italy, and Spain before finally crossing the Strait of Gibraltar to affect the Moroccan power system. Analogously, the repercussions of the *Energiewende* do not stop at Germany's borders and may end up being more far-reaching than originally intended. While the transition could stimulate the trend to a more deeply integrated Internal Electricity Market and a more sustainable European power sector, the risk of disintegration of the European market and recourse to fossil fuels is equally present.

The backdrop to this dichotomy is the growing share of intermittent renewable energy sources such as wind and solar power. Depending on natural forces which are difficult to forecast and impossible to control, these forms of electricity generation cause growing fluctuations in the system and make it difficult to match output and consumption. Compared to past decades where baseload power generation defined the system, with power plants adapting their output to (predictable) shifts in demand, renewables turn the logic of power generation and distribution upside down. Nowadays grid management must match fluctuating generation to power consumption. Such a system is never far from blackout (overcharge) and brownout (voltage drop), making network management a Sisyphean task. Irrespective of whether it is indeed a revolution or rather an evolutionary process, Germany's energy transition amplifies the "ups" and "downs" in the network as intermittent renewables largely replace the phased-out nuclear power stations. Hence the *Energiewende* creates the need to adapt the power system.

In this context uncontrolled power flows of surplus German wind energy to neighbouring countries indicate the limitations of national systems in meeting the challenge (see SWP Comments 5/2012). One of the main tasks of energy policy therefore is to advocate a power system which is flexible enough to fulfill several tasks at once at different levels – local, national, and supranational. The difficulties involved in bringing enough units from Germany's "cold reserve" into operation to counterbalance the "downs" point in a similar direction.

Cross-border electricity swaps will have to increase to keep the networks stable. Germany's role as main transit country for electricity in the centre of Europe makes the the country's energy transition implausible without taking interactions with neighboring systems into account: A truly integrated Internal Electricity Market could provide the capacity needed for synergetic interaction of diverse national power systems. Moreover, the ongoing discussions about which energy sources could provide a climate-neutral and economic operating load to counterbalance intermittent renewables show that the *Energiewende* could become a factor on international energy markets.

Best practice in the North: Denmark's "grønne omstilling"

The Nordic electricity market is a "best practice" case of integrated electricity markets with high shares of renewables: A state-of-the-art transmission infrastructure densely interconnects the national systems, making electricity a commodity which is traded across borders. Moreover, with 64.9 per cent in Norway, 47.3 per cent in Sweden, and 30.3 in Finland the share of renewables in gross electrical consumption is well above the EU average. Yet with the exception of Denmark these high numbers for renewables cannot be compared to other EU member states due to the widespread availability of hydroelectric power in the Nordic countries. The Danish energy sector has otherwise been described as a microcosm of current major energy issues.

With 19.9 per cent, renewables in Denmark's energy system already exceed the German 18 per cent target set by European Directive 2009/28/EC for the year 2020 (and set to rise to 100 per cent according to the

Danish government). These high numbers are primarily based on electricity generation (see below) and have to be seen against the backdrop of external shocks and a successful energy saving programme. In contrast to other European countries, Denmark never put its plans for a large nuclear sector into operation and phased out its world-leading nuclear research programme in the aftermath of the 1970s oil crisis. In the long run the Danes gave energy efficiency and renewable energy high priority.

Starting from a very low level of 1.8 per cent in 1973, renewables grew steadily to today's 29.1 per cent of Denmark's gross electricity consumption despite GNP growth of about 50 per cent since 1980. Since Denmark became the EU member state with the lowest energy intensity and world leader in energy efficiency the country's energy consumption remained stable over this period. Hence the transformation of Denmark's energy system did not have to keep pace with economic growth. Wind power plays a role similar to the *Energiewende* concept, with wind turbines generating about 20 per cent of the country's electricity demand (Germany: 6 per cent in 2010). Given the absence of major storage capabilities due to geological conditions in Denmark, this success of Danish energy policy is striking.

Best practice 1:
Storage and interconnection

Denmark's energy system has undergone radical change since the 1970s and is today one of the world's most decentralized. This structure imposes particularly high requirements on the national power grid. With regard to intermittency, interconnections with neighbouring countries play a major role. Whenever there is too much electricity from Danish wind farms, the energy can be discharged to pumped-storage stations to the north (Norway, Sweden), or to consumption centres to the south (Germany, Netherlands). Since the surrounding power systems are much larger, electricity from Denmark is insignificant and can easily be absorbed. Conversely Denmark can rely on electricity (re-)imports. Denmark's superb interconnections with neighbouring countries can therefore be considered the backbone of the country's energy system. Without that infrastructure the integration of wind power would hardly be possible.

Hourly alternation from energy import to export thus keeps the Danish energy system stable despite the country's large and growing proportion of intermittent renewables. The energy from wind power actually consumed in Denmark thus ultimately accounts for only the less striking average of 12 per cent of total electricity generated. Connecting electricity generation to local heating systems is another way to discharge parts the wind power surplus. During peak hours electric heaters replace fossil fuel combustion for the production of hot water, which is storable for many hours in pipes and tanks. With 62 per cent of Danish households connected to district heating the system has huge thermal storage capabilities for energy from Danish wind farms.

Best practice 2:
Operating load and biomass

High shares of intermittent renewables in the energy system require power stations to provide the network's base load, yet flexible enough to counterbalance the fluctuations in the system. After phasing out its nuclear programme Denmark switched to coal as the prime conventional energy source for network stabilization. But in recent years gas and biomass have become more important, whereas coal combustion is to be phased out by 2030 according to the Danish government's latest plans. Biomass is slated to become the most significant climate-neutral energy source to reduce coal consumption.

Accordingly, biomass already accounts for approximately 14 per cent of Denmark's energy consumption. In the electricity sector the growing use of biomass dates back to the biomass agreement of 1993, which forces power stations to include biomass in their fuel mix. Biomass already exceeds 10 per cent of electricity generation. Since this energy source can be used in the "co-firing" process, modern Danish power stations like Avdedøre near Copenhagen burn coal together with a mix of gas, wood and straw. Hence, no new power stations had to be constructed, as existing ones needed only marginal modifications. But Denmark's biomass resources are limited, and large amounts of the fuel therefore have to be imported.

Germany's Energiewende: Avantgarde of a European energy transition?

For 2020 the government in Copenhagen is seeking to cover 50 per cent of electricity consumption using wind power, and this share is set to increase further by 2035 supposed. However, the example of Denmark's "grønne omstilling" shows that such developments do not take place in a vacuum, but encounter and interact with a European context. Integrating large volumes of intermittent renewables into the Danish energy system would not work without interdependent electricity markets. Accordingly, Denmark's "grønne omstilling" and world leadership in the manufacturing of wind turbines led to greater rather than less interdependency with countries to the north over the years.

Two elements are decisive: the availability of suitable technical infrastructure and a legal framework that allows (short-term) trading in liberal transnational electricity markets. Being a member of the Nordic electricity market, which integrates Norway, Sweden, Finland and Denmark (with the Netherlands and Germany in its orbit), Denmark offered excellent energy policy conditions. The *Energiewende* likewise interacts with its environment, but compared to the Nordic market it encounters a less developed European frame: whereas the Nordic power market is fully integrated and based on appropriate infrastructure, power systems and energy markets in the rest of Europe remain largely nationally defined. The European Union's limitations in energy-related topics are unfavorable in this respect, with member states only slowly adopting European legislation to deepen the integration of their electricity markets.

As in Denmark, German surplus wind energy flows to neighbouring countries. But in the German case these power flows are random and cause technical, economic and political difficulties, since they overload foreign networks and affect the market shares of local operators. In the coming years this option will no longer be given: Germany's neighbours are discussing the installation of technical equipment to physically block electricity imports at peak times, while they will themselves also be producing power surpluses from renewables according to national action plans and projections. The resulting unforeseen power flows will further increase congestion of interconnectors.

Yet Germany's "Energiewende" appears to be the avant-garde of a developing European energy policy: With an overall target of 34.5 per cent renewables in the EU's gross final electricity consumption in 2020, EU policy corresponds almost exactly to German policy, which aims for 35 per cent. In the light of the Danish experience, the German targets could end up being exceeded, since the integration of large volumes of intermittent renewables requires large-scale electricity markets to absorb the "ups" and "downs" in the energy system. The "Energiewende" could therefore force Germany to support a policy of deeper integration of electricity markets in the EU and beyond. Moreover, the demand for a climate-neutral operating load could stimulate international energy markets.

Storage and Interconnection in a European perspective

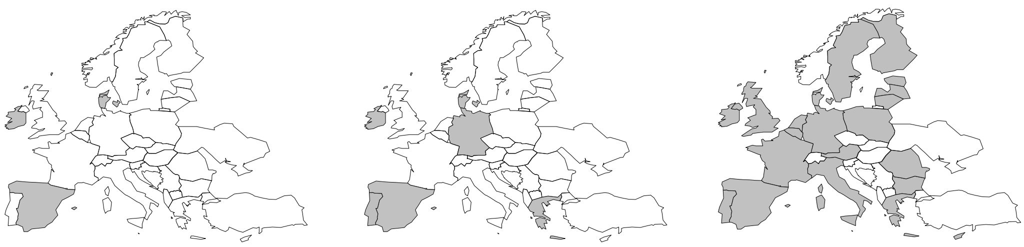
According to the International Energy Agency (IEA) and the European Commission (see COM(2012) 271), network balance is considered to be in jeopardy if intermittent renewables exceed 5 per cent in the power system. Yet in 2010 they already amounted to 5.6 per cent of electricity consumed in the EU-27 (compared to 2.6 per cent in 2005) and will rise to 17.1 per cent by 2020 according to national renewable energy action plans (http://ec.europa.eu/energy/renewables/action_plan_en.htm). Europeans will therefore be compelled to distribute electricity more efficiently. European legislation acknowledges this necessity insofar as it aims for completion of the Internal Electricity Market by creating additional capacity for electricity exchange between national power transmission systems (see 1364/2006/EC).

In the logic of the internal market, this may be considered sufficient to reduce monopolisation. Moreover, this policy goes hand in hand with the need for a power grid which is able to absorb electricity from decentralised generation units via dense "smart" networks for flexible distribution to centres of consumption and storage facilities. But except for the rather vague proposal of different "priority corridors" (see Brussels European Council, 19/20 March 2009, Presidency Conclusions), existing European legislation offers no solution for the challenge of efficient long-distance transmission from regions of electricity production to points of consumption or storage in one or several member states (or third countries).

The latest initiative of the European Commission to overcome deficits in the European power grid therefore includes not only trans-border power transmission and distribution networks (cross-border transport of electricity to consumers on high-, medium- and low-voltage systems) but also high- and extra-high-voltage transmission ("electrical highways"; see regulation proposal COM (2011) 658 final). The North Sea Countries Offshore Grid Initiative, as well as single projects as the Kriegers Flak wind farm in the Baltic Sea which is designed for simultaneous use by Denmark and Germany, point in this direction and could form the nucleus of a European overlay network or supergrid. The inclusion of Norway suggests that such a network would be pan-European. In this respect it is noteworthy that the integration of the North African and European grids has already reached an advanced stage.

In the logic of the internal market, this may be considered sufficient to reduce market concentrations. Moreover this policy goes hand in hand with the need for a power grid which is able to absorb electricity from decentralised generation units by dense and "smart" networks for flexible distribution of electrical charges to centres of consumption and storage facilities. But except for the rather vague proposal of

Maps
EU countries exceeding five per cent intermittent renewables in the power system in 2005, 2010, and 2020



2005 **2010** **2020**

different "priority corridors" (see Brussels European Council 19./20. March 2009 Conclusions), existing European legislation offers no solution for the challenge of an efficient transmission of electricity over long distances from regions of power production to power consumption or storage in one or several Member states (or third countries).

The latest initiative of the European Commission to overcome curtailments in the European power grid therefore not only includes trans-border power transmission and distribution networks, that is the transport of electricity on high-voltage, medium-voltage and low-voltage systems to consumers across borders, but also the electricity transmission on the high- and extra high-voltage level, that is to say "electrical highways" (see regulation proposal COM (2011) 658 final). The North Sea Countries Offshore Grid Initiative as well as single projects as the Kriegers Flak wind farm in the Baltic Sea which is based on simultaneous use by Denmark and Germany point in this direction and could be the nucleus of a European supergrid.

Operating load and biomass in a European perspective

The Internal Electricity Market helped to implement the first steps of Germany's transition. Interconnections with neighbouring countries not only enabled wind energy surpluses to be discharged, but also permitted electricity imports to bridge the supply gap after the quick phase out of nuclear plants in the wake of the Fukushima disaster. But transmission capacities are scarce and already heavily congested.

Hence, the deployment of large volumes of intermittent renewables increases the urgency of creating new power transmission infrastructure in Europe. In a complete Internal Electricity Market, that is to say where capacity for transmission of generated current exists, it is irrelevant which side of the border these power plants are located and it can be expected that electricity will be generated in those plants that have the lowest marginal costs. In the course of its *Energiewende* Germany resorted to its "cold reserve" of fossil fuel plants to provide a stable electricity supply. Hence the *Energiewende* might lead not only to growth in renewables, but oddly enough might also underpin the current trend for cheap coal in Europe since 2009.

But not every technology based on renewable energy exhibits large fluctuations in output. On the contrary, biomass, hydro and geothermal are stable in their electricity output and capable of providing the necessary operating load to counterbalance wind and solar power. But since continental Europe lacks sufficient hydro potential, only the combustion of carbon can fulfill the task of counterbalancing the fluctuations caused by wind and solar power. If recourse to large-scale use of coal in the Internal Electricity Market is to be avoided, alternatives must be found that can compete with its price levels.

In this respect it is noteworthy that the first signs of an international biomass market are emerging. Based on new technologies such as pelletization, briquetting and torrefaction, wood biomass such as forest residues becomes a cost-effective alternative for co-firing in coal power plants. In the interests of sustainability and energy security the European Union aims to develop its own supply chains (see COM(2012) 60 final) to meet the growing demand. Although high labour costs limit the prospects for large-scale exports from the forest-rich Nordic countries, the lower wages and high levels of biomass per unit of land in the new EU member states, especially the Baltic countries, promise great potential. Russia's vast forests could also be taken into account as a potential source of biomass.

Prospects

With growing feed-in from decentralized and intermittent sources like wind and photovoltaic, the risks of grid outage increase, therefore making the construction of new power lines imperative. A limit of approximately 5 per cent on intermittent renewables in the system is regarded as critical for network stability. Their share in the EU exceeded that margin in 2010, and according to the Energy Roadmap 2050 (see COM(2011) 885/2) will increase further. Depending on the underlying scenario, between 25 and 65 per cent of the EU's electricity consumption will be supplied by this form of energy by 2050. The *Energiewende* will accelerate this process since the nuclear phase-out increases the need for new generation capacity. Renewables, especially wind power, will have to take the place of decommissioned plants. The *Energiewende* therefore increases the pressure on Europe's electricity networks and makes the inclusion of neighbouring countries in planning an imperative. The European electricity market could be the missing cornerstone in the transition process, opening up scope for political steering and offering untapped potential for conversion of the energy system.

Denmark's green energy transition, or "grønne omstilling", began in the aftermath of the 1970s oil crisis and shows that "green transition" is a long-term project. But successful energy-saving policies to decouple economic growth and electricity consumption can help to speed up the process: With stable energy consumption the deployment of renewables does not have to keep pace with movements in the gross domesic product. But binding targets for energy saving could yet be decided on the European level. In growing economies this will certainly limit the proportion of renewables which can be achieved in the short term. In particular rapidly growing countries like Poland will face difficulties reaching their targets.

Denmark's green transition also reveals the limitations of national systems for absorbing large volumes of intermittent renewables and the need for supranational infrastructure and markets to ease the pressure on the grid by cross-border power transfers. Yet transmission capacity is still scarce and heavily congested in Europe and different electricity tariffs and market models in different EU member states make market opening a delicate task. All the more in case of the *Energiewende*, since deeper integration could lead to increasing imports of fossil-based or even nuclear electricity.

In order to set up an infrastructure which allows smooth interaction of power production and consumption in Europe, the *Energiewende* should be guided politically by an economic approach designed to overcome the fractures in the Internal Electricity Market. A successful transformation of Germany's energy sector therefore depends on competitiveness. Yet electricity tariffs in Germany are already way above the European average, both for private households and for industrial consumers (see Figs. 1 and 2, p. 8). Limiting tariffs is therefore the crux of Germany's energy transition. Backup power generation using coal and second-generation biomass to counterbalance wind and solar power could keep costs down and allow further market opening. Moreover, constructive negotiations with neighbouring countries to match market designs and price levels and develop common infrastructure projects are important elements for making Germany's energy transition work.

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ISSN 1861-1761

Figure 1
Private households

	EUR/kWh
Denmark	0.3078
Germany	**0.2781**
Belgium	0.2215
Netherlands	0.2202
Italy	0.2164
Ireland	0.2162
Spain	0.2154
Cyprus	0.2131
Austria	0.2128
Sweden	0.2066
Luxembourg	0.2013
Portugal	0.1925
Malta	0.1822
Slovakia	0.1815
United Kingdom	0.1676
Slovenia	0.1649
Poland	0.16
Finland	0.1574
Czech Republic	0.1541
France	0.1478
Greece	0.1403
Lithuania	0.1378
Romania	0.1207
Latvia	0.1174
Estonia	0.113
Bulgaria	0.0934
EU 27	0.182307692

Figure 2
Industrial consumers

	EUR/kWh
Malta	0.1927
Cyprus	0.1822
Italy	0.1565
Germany	**0.134**
Slovakia	0.1327
Ireland	0.1303
Spain	0.1271
Austria	0.1213
Czech Republic	0.1195
Hungary	0.1194
Greece	0.1188
Belgium	0.1182
Netherlands	0.1181
Luxembourg	0.118
Slovenia	0.1162
United Kingdom	0.1149
Poland	0.1142
Denmark	0.1091
Portugal	0.1064
Latvia	0.1015
Romania	0.0925
Sweden	0.0887
Estonia	0.0817
Finland	0.0784
France	0.0763
Bulgaria	0.0746
EU 27	0.099328571