Federal Ministry
for Economic Affairs
and Energy

*Discussion Paper*

# Electricity 2030

*Long-term trends – Tasks for the coming years*

## Imprint

**Publisher**
Federal Ministry for Economic
Affairs and Energy (BMWi)
Public Relations
11019 Berlin, Germany
www.bmwi.de

**Design and production**
PRpetuum GmbH, Munich

**Status**
September 2016

**Print**
Spree Druck Berlin GmbH

**Illustrations**
Getty – Caminade Berenger/EyeEm (cover)
This brochure is published as part of the public relations work of the Federal Ministry for Economic Affairs and Energy. It is distributed free of charge and is not intended for sale. The distribution of this brochure at campaign events or at information stands run by political parties is prohibited, and political party-related information or advertising shall not be inserted in, printed on, or affixed to this publication.

Zertifikat seit 2002
audit berufundfamilie

The Federal Ministry for Economic Affairs and Energy was awarded the audit berufundfamilie® for its family-friendly staff policy. The certificate is granted by berufundfamilie gGmbH, an initiative of the Hertie Foundation.

FSC
www.fsc.org
MIX
Paper from responsible sources
FSC® C125128

**This publication as well as further publications can be obtained from:**
Federal Ministry for Economic Affairs
and Energy (BMWi)
Public Relations
E-mail: publikationen@bundesregierung.de
www.bmwi.de

**Central procurement service:**
Tel.: +49 30 182722721
Fax: +49 30 18102722721

# Contents

# Introduction

**Germany's energy transition has made significant progress in this legislative term.** This is particularly true with regard to renewable energy, grid expansion and energy efficiency. The reforms of the Renewable Energy Sources Act *(Erneuerbare-Energien-Gesetz)* stabilise costs, set out a clear path for the continued expansion of renewable energy and bring renewable energy closer to the market. The Electricity Market Act *(Strommarktgesetz)* lays the foundation for a further developed electricity market – the electricity market 2.0. This electricity market design guarantees that we can continue to rely on a secure supply of low-cost electricity even when a large share of the electricity is derived from renewable energy sources. Measures facilitating underground cabling for the electricity superhighways from north to south improve acceptance of the urgently needed expansion of the power grid. In addition, the Act on the Digitisation of the Energy Transition *(Gesetz zur Digitalisierung der Energiewende)* creates the key prerequisites for a sustainable grid infrastructure. Lastly, the National Action Plan on Energy Efficiency, in particular, is rolling out numerous new measures to increase energy efficiency, including a comprehensive package of new funding programmes for the efficient use of electricity and heat, and the strengthening of existing funding programmes in the building sector.

**The energy transition continues.** Germany has set itself ambitious goals: by 2050 it intends to reduce greenhouse gas emissions by 80 – 95 % compared with 1990 levels, with intermediate goals set out for 2020, 2030 and 2040. Together, all sectors of the national economy will help contribute to delivering on these goals. While efficiency measures and renewable energy can reduce emissions in the industrial and agricultural sectors, they cannot prevent such emissions entirely. Therefore the other sectors should reduce their energy consumption significantly and largely manage without fossil fuels.

**The energy transition is an enormous modernisation and investment programme.** Electricity generation plants, power grids, heat networks, heat storage systems, electric vehicles and appropriate recharging infrastructures will be built, high-efficiency heat pumps installed and buildings retrofitted for energy efficiency. The aim is for efficiency technologies and renewable energy to largely replace fossil fuels, such as oil, coal and gas, by 2050. This will involve structural changes: investment must move away from technologies that use fossil fuels and towards energy efficiency and renewable energy.

**We will be setting the course for 2050 in the coming years.** Decisions we make will have a long-term impact in the energy sector and are therefore of central importance for 2050: heating systems are often used for 20 years or longer, while buildings, power plants and industrial installations are frequently even in service for more than 40 years. Therefore, investments made in the 2020s and 2030s will shape our energy system in 2050. To a large degree, such investment should be made in technologies that are not dependent on fossil fuels so that businesses can avoid stranded investments and society avoids expensive repair measures in the energy system in the future.

**The priority is to deliver the energy transition at a low cost.** Studies such as the long-term scenarios commissioned by the Federal Ministry for Economic Affairs and Energy (BMWi)[1] demonstrate what form a largely decarbonised energy system can take in 2050. They therefore provide guidance for decisions in energy policy in the decade ahead and are thus an important basis for this Discussion Paper. In this context, it is essential to remain open to new technological developments.

**Electricity will become the most important source of energy in the energy system.** Electricity is a valuable commodity. For this reason, the energy efficiency of power consumption in buildings, the transport sector and the business sector will be increased based on the "efficiency first" principle.[2] Renewable energy sources will cover the remaining energy needs to the greatest extent – directly in the individual sectors or in the form of renewable electricity, particularly from wind and solar energy. In 2050, electricity will cover roughly one half of all our energy needs – compared with around one quarter today. We will increasingly use renewable electricity to drive cars, generate heat and produce goods in factories, and in doing so primarily use technologies that replace a large amount of fuel with a small amount of renewable electricity.

**The majority of the electricity will be derived from wind and solar power.** The costs of wind power and photovoltaic installations are decreasing continuously. They offer enormous potential, while the sustainable potential of generating

1 Fraunhofer ISI, Consentec et al. (2016): Long-term scenarios for the transition of Germany's energy system (publication expected in the fourth quarter 2016); Öko-Institut, Fraunhofer ISI (2015): Climate change scenario 2050; Fraunhofer IWES et al. (2015): Interaction of renewable electricity, heat and transport.

2 Cf. Green Paper on Energy Efficiency.

electricity from biomass is limited due to associated conflicts of use. The contribution of hydropower and deep geothermal energy can also only be increased to a limited extent.

**The electricity system will become increasingly flexible.** Electricity generated from wind and solar power fluctuates depending on the weather. An increasingly flexible and digitised electricity system balances electricity generation and consumption and guarantees a secure, low-cost supply of electricity. This will be contingent upon well developed national and European grids and the pan-European coupling of national electricity markets.

**The use of electricity for heating, mobility and industrial processes additionally increases flexibility.** Heat pumps, electric cars and even electric boilers in certain cases – for example in industrial processes - can act as flexible consumers, as heat can be stored and electric cars can use their battery as a buffer. Together, these flexible consumers can quickly increase or decrease their demand by several gigawatt. In this context, it is clear that the electricity should always be converted as efficiently as possible and the demand patterns of the consumers must be taken into consideration.

**Digitisation will help us implement these new uses of electricity in an efficient manner.** For example, smart meters allow users of electric cars and heat pumps to benefit from low electricity prices and help balance supply and demand. Digital solutions will give rise to new business fields and new players will enter the market. For example, service providers can technically pool the distributed flexibility of electric cars or heat pumps and sell it on the electricity market.

**The electricity market 2.0 stands for fair competition between the various flexibility options.** Effective price signals in the electricity market ensure a level playing field for these options. Market players are free to decide which flexibility options to use. This keeps the overall cost of electricity supply down and encourages innovation. Following the Green Paper and White Paper process, a decision was therefore made to gradually eliminate distortions in the regulatory framework and strengthen electricity price signals in a further developed electricity market – the electricity market 2.0.

**The electricity market 2.0 will be part of the energy market 2.0.** The liberalisation of the electricity market in the 1990s was a first major step towards a sustainable supply of energy. It broke up the monopoly structures in the electricity sector and sparked competition between electricity providers. The second major step is the electricity market 2.0. It will create competition between the flexibility options and ensure that the electricity supply will remain secure and inexpensive even with higher shares of renewables in the electricity mix. The third big step is the energy market 2.0. In the energy market 2.0, efficiently used renewable electricity will largely replace fossil fuels – for heating, mobility or industrial processes. In this respect, the priority here must be to develop the regulatory framework further and thereby improve the competitive conditions for wind power and solar power in the heating and transport sectors.

**Together, we want to devise a common path from the electricity market 2.0 to the energy market 2.0.** The energy transition is a joint task and will not happen automatically. Therefore the BMWi has published this paper as a discussion paper to stimulate a broad debate. In addition, the BMWi has started a process focussed on energy efficiency. The Green Paper on Energy Efficiency opens the debate as to how energy efficiency can be further increased in all sectors. In this way, the BMWi will pursue a supply-side and demand-side dialog on the next steps to be taken in shaping the energy transition.

- **12 trends: This Discussion Paper identifies twelve robust, long-term trends of a secure, low-cost and climate-friendly electricity supply system through to 2050**. It takes as its goal the reduction of greenhouse gas emissions by 80 – 95 % by 2050 while ensuring security of supply and competitiveness. The trends describe solid developments that are reflected in the current scenario studies, particularly the long-term scenarios commissioned by the BMWi. These scenarios describe how producers, consumers and grid infrastructures reach the climate goals aimed for by 2050 while also jointly ensuring a secure supply of electricity at minimum cost.

- **12 tasks: Tasks for the coming years with a 2030 horizon are derived from every trend.** It is clear that the trends identified in the scenarios are not a given and will not happen automatically. In many cases the energy policy framework must be developed further for the trends identifiable in the scenarios to actually become reality and for the climate goals to be efficiently and reliably reached in this way. It is important to now look ahead and plot the right course in order to avoid inappropriate investment and to follow a cost-effective path.

- **Guiding questions: The tasks raise questions that will structure the debate.** At their core, every guiding question is based on two central questions that are important for all trends and resulting tasks: (1) Which investments will take us from the electricity market 2.0 to the energy market 2.0 and (2) what regulatory framework will ensure that the market provides the incentives for these investments to actually be made?

**The BMWi is conducting the debate with the public and the stakeholders particularly in the Electricity Market Platform *(Plattform Strommarkt)* and the Energy Grid Platform *(Plattform Energienetze)*.** The aim of the debate is to pin down the areas where consensus exists and, where opinions diverge, to capture the range of views and positions. Representatives of the Länder, parliamentary groups, ministries and competent federal authorities participate in the platforms as do stakeholders from business, science and social groups.[3] In addition to the platform-based debate, citizens and interested parties also have the opportunity to submit their opinion by e-mail to strom2030@bmwi.bund.de by 31 October 2016.

**A joint plenary session will kick off the debate in the Electricity Market and Energy Grid Platforms.** The trends and tasks identified in this Discussion Paper will then be discussed in depth in the platform working groups. The working groups will report on the results of the debate to the joint plenary of the Electricity Market Platform and the Energy Grid Platform in early 2017. The results will be summarised in a concluding paper.

We look forward to the debate!

3 Trend 5 "Electricity will be used much more efficiently" in this paper will be discussed as part of the Green Paper on Energy Efficiency process in the Energy Efficiency Platform.

## The energy transition: a three-pronged approach

**Principles for the efficient use of electricity:** This Discussion Paper focuses on the cost-efficient supply of electricity (generation, use in heating, the transport sector and industry, and transportation via the power grids). Electricity is a valuable and scarce commodity. Macro-economic and micro-economic cost efficiency must be considered in the triad of energy efficiency, the direct use of renewable energy, and the use of electricity derived from renewable sources. The following principles can be identified for this triad:

**First: The demand for energy must be significantly and permanently reduced in all sectors ("efficiency first").** Germany has set itself ambitious climate goals. It follows that the use of fossil fuels in the form of oil, coal and gas must be reduced to a minimum. The fastest and direct route to achieving these goals is to reduce our energy consumption by investing in efficiency technologies. Renewables will cover the remaining energy needs to the greatest extent.

**Second: Direct use of renewable energy.** Technologies such as solar thermal, geothermal or biomass use renewable energy directly without converting it into electricity. Solar thermal and geothermal technologies are used particularly for heating and air conditioning in buildings and for warm water supply. If the use of such technologies is not feasible for economic or other reasons, renewable electricity is used. Biomass plays an important role particularly in industry (e.g. in production processes) and in the transport sector (e.g. aviation). This is also true of solid biomass for existing buildings. Biomass is a universal yet scarce source of energy. Therefore it is specifically used wherever it is not feasible to use solar thermal or geothermal technologies and wind and solar power.

**Third: Renewable electricity is used efficiently for the heating, transport and industry sectors (sector coupling).** The energy needs that remain for economic or other reasons despite efficiency measures and the direct use of renewable energy are covered by wind and sun – primarily in technologies that replace a large amount of fossil fuels with a small amount of electricity (such as in heat pumps and electric vehicles) or convert the electricity to other forms of energy, such as hydrogen (power-to-gas).

## Overview

| | 12 TRENDS | 12 TASKS |
|---|---|---|
| 1 | The system is shaped by the **intermittent generation of electricity from the wind and sun**. | Make the electricity system more **flexible** |
| 2 | There is a significant decline in the use of **fossil fuels in the power plant fleet**. | **Reduce carbon emissions reliably,** shape **structural change** |
| 3 | The electricity markets are **more European**. | **Integrate and flexibilise** the European electricity markets further |
| 4 | **Security of supply** is ensured within the framework of the European internal market for electricity. | **Assess** security of supply in a European context **and develop common instruments** |
| 5 | Electricity is **used far more efficiently**. | Strengthen i**ncentives for the efficient use of electricity** |
| 6 | **Sector coupling:** The heating sector, cars and industry use more and more renewable electricity instead of fossil fuels. | **Improve competitive conditions** for renewable electricity in the heating and transport sectors |
| 7 | **Modern CHP plants** produce the residual electricity and contribute to the energy transition in the heating sector. | Provide **incentives for modern power and heat systems** |
| 8 | **Biomass** is used increasingly for transport and industry. | Provide incentives so that **biomass is increasingly used for transport and industry** |
| 9 | **Well developed grid infrastructures** create flexibility at a low cost. | Expand the grid i**n a timely, needs-based and cost-efficient** manner |
| 10 | **System stability** is guaranteed even with a large share of renewables in the energy mix. | **Continue to develop and coordinate** measures and processes for system stabilisation |
| 11 | **Grid financing** is fair and meets the needs of the system. | **Further develop** regulations governing grid charges |
| 12 | The energy sector takes advantage of the opportunities offered by **digitisation** | Roll out **smart metering**, build **communication platforms,** guarantee **system security** |

# Trend 1: The system is shaped by the intermittent generation of electricity from the wind and sun

- **The share of wind and solar power in the overall production of electricity increases significantly.** In line with the goals of the Federal Government, wind energy and photovoltaics see strong expansion given the enormous potential these energy sources currently offer at a low cost. They dominate and shape the system: in 2030 they generate more than twice as much electricity as they do today; by 2050 they will even be responsible for the majority of total electricity production. At the same time, the share of electricity in the heating and transport sectors will increase (sector coupling), making wind and solar power the most important sources of energy in the overall system.

- **A flexible electricity system integrates the increasing share of electricity derived from wind and sun in a cost-effective manner.** Electricity generated from wind and solar power depends on the weather. Well developed power grids in Germany and Europe balance the fluctuations of wind and sun. Controllable generators and consumers, as well as storage systems to an increasing extent, flexibly adapt to the conditions.

- **The market coordinates electricity supply and demand**. Flexible generators, flexible consumers and storage systems respond to the price signals of the electricity market and in doing so compete for the most economical solution. For example, if there is a large supply of electricity from wind and solar power and demand is low, consumers can offer their flexibility and thereby benefit from the low electricity prices.

## Task: Make the electricity system more flexible

- **Expand the power grids further.** Grids enable the geographical balancing of electricity and are the most cost-effective flexibility option. For this reason, grid expansion should follow the expansion of renewables. While the regionally distributed expansion of renewable energy sources cannot replace grid expansion, it can be advantageous as long as insufficient progress is made in the expansion of the grid.

- **Make electricity generators more flexible.** Most power plants have already become far more flexible. However, some power plants still remain in the market even when prices are very low or negative because they provide balancing capacity or heat in addition to electricity. Therefore it is important to open up balancing capacity markets for alternative providers such as flexible consumers or renewable installations. Combined heat and power (CHP) plants can increase their flexibility with heat storage systems and by using power to heat. It should also be possible to run biomass installations with more flexibility in the future. Furthermore, it should also be more attractive for electricity consumers with private onsite generation facilities to draw electricity from the grid when electricity prices are low instead of generating electricity themselves. At the same time, it is ensured that the competitiveness of electricity-intensive self-suppliers (undertakings that generate power primarily for their own use) remains unaffected. Existing privileges are also maintained.

- **Make electricity consumers more flexible.** Electricity consumers have an incentive to adapt their demand to the supply of electricity if they are actually affected by the fluctuations in the price of electricity. Currently, however, certain price components override the electricity price signals on the wholesale market, thereby impeding flexibility. These barriers should be removed to minimise the costs of electricity supply (cf. Fig. 1 “Target model for flexibility and sector coupling”). If the electricity price signal is effective, industrial electricity consumers, for example, can temporarily increase or decrease their demand in line with their commercial considerations and thereby benefit from low electricity prices or offer balancing capacity.

## Guiding questions

1. The Electricity Market Act *(Strommarktgesetz)* requires the Federal Network Agency *(Bundesnetzagentur)* to evaluate minimum generation in a report. In addition, the Federal Network Agency opened a procedure to stipulate auction rules for balancing capacity in 2015. What additional approaches should be pursued to flexibilise generation? How can we better align private electricity generation and the electricity market?

2. The White Paper on the Electricity Market Design envisages the revision of special grid charges to allow for greater demand side flexibility. In addition, in March 2016 the Federal Network Agency initiated a discussion on uniform and fair rules for aggregators in the provision of balancing capacity. What approaches should be pursued in this context and additionally to flexibilise demand? In particular, how could individual price components be developed further in a meaningful way?

**Figure 1: Further development of surcharges, grid charges and levies for flexibility and sector coupling ("target model")**

| CURRENT SITUATION | TARGET | OPTIONS FOR ACTION |
|---|---|---|
| **The current structure of surcharges, grid charges and levies hampers flexibility (Trend 1) and sector coupling (Trend 6)** | **Facilitate flexibility and sector coupling – remove barriers to low-cost energy supply.** | |
| **BARRIER 1:**<br>**More surcharges, grid charges and levies are placed on electricity for the financing of the energy transition than on fuels, particularly for heating.** This can hamper sector coupling and energy efficiency and/or increase the need for support and funding.<br><br>**BARRIER 2 :**<br>**Electricity consumers have to pay price components in full even if the price on the electricity exchange is low and the grid is uncongested.** As a result, consumers still pay a high electricity price even if renewable electricity is curtailed when prices are negative. This discourages self-suppliers from taking energy from the grid and hinders sector coupling. | **In doing so, consider the cost efficiency of the overall energy system, preserve system stability, maintain the financing function and strengthen energy efficiency.** | **OPTION 1:**<br>**Improve competitive conditions for efficient sector coupling.** The sectors that reduce their carbon emissions by using renewable electricity make an appropriate contribution to the financing of the energy system (user-pays principle). This enables market-driven advances in the efficient use of renewable produced electricity in other sectors (sector coupling).<br><br>**OPTION 2:**<br>**Reduce price components if the price on the exchange is negative and the grid is uncongested**. Value added tax is levied on the electricity price on a percentage basis, so the absolute amount is lower when the electricity price is low. Lower grid charges also already apply at times when a low load on the grid is anticipated. These approaches can be developed further and applied to other price components. In so doing, it is important to avoid misdirected incentives that reduce energy efficiency or increase carbon emissions.<br><br>**The two options can be combined.** |

Source: Own graphic

### There are many options to flexibilise the electricity system

There are many options to synchronise generation and consumption in a secure, cost-effective and environmentally compatible manner (flexibility options):

- **Flexible generators:** Thermal power plants adapt their electricity production to fluctuating demand and the intermittent generation of electricity from wind and solar power. Wind and solar installations reduce their output in times when there is a lot of wind and sun and when demand is very low or grid capacity is limited.

- **Flexible consumers:** Industrial, commercial and residential consumers shift and reduce their electricity consumption if this brings down their electricity purchase costs. If a lot of electricity is produced from wind and sun and if demand for electricity is low, the electricity can also be used to efficiently generate heat, thus saving fuel oil or gas. In addition, batteries of electric cars are charged up increasingly in these situations.

- **Storage systems:** Pumped storage reservoirs traditionally provide balancing capacity. The provision of primary balancing capacity – i.e. the fast, automated offsetting of frequency fluctuations in the grid - is particularly attractive for battery storage units. So far, however, additional storage has been more expensive than other flexibility options. A first economic field of application for novel storage facilities is likely to be in ancillary services. Additional, novel long-term storage systems are only required when the share of renewable energy is very high.

- **Power grids:** Power grids balance the fluctuations in demand and electricity production deriving from wind and sun on a supra-regional basis. Furthermore, the various technologies available are used more efficiently in coupled electricity markets (e.g. wind and sun in Germany, hydro-electric storage installations in the Alps and Scandinavia). Overall, substantially fewer reserve power plants or grid-supporting ancillary services are needed; the total costs of electricity supply decrease.

### Selection of current studies

**Fraunhofer ISI, Consentec et al. (2016)**: Langfristszenarien für die Transformation des Energiesystems in Deutschland; Fraunhofer-Institut für System- und Innovationsforschung, Consentec GmbH, Institut für Energie- und Umweltforschung Heidelberg GmbH on behalf of the Federal Ministry for Economic Affairs and Energy (publication expected in the fourth quarter 2016)

**IEA-RETD (2016):** Re-Transition. Transitioning to Policy Frameworks for Costcompetitive Renewables; International Energy Agency Renewable Energy Technology Deployment

**Consentec (2014):** Mindesterzeugung durch konventionelle Kraftwerke u. a. zur Sicherstellung der Systemstabilität – Sachverhalt und Ausblick, Präsentation auf der Plattform Strommarkt des BMWi, AG Flexibilisierung; Consentec GmbH on behalf of the Federal Ministry for Economic Affairs and Energy

# Trend 2: There is a significant decline in the use of fossil fuels in the power plant fleet

- **In 2050 the generation of electricity is largely carbon-free.** Electricity generation is currently still associated with high carbon emissions. Efficiency measures reduce the consumption of electricity. For the remaining electricity needs, emissions can be reduced in a relatively cost-effective manner. Through sector coupling, electricity with largely zero emissions also contributes to the decarbonisation of the heating and transport sectors (cf. Trend 6).

- **Investment in the coal infrastructure decreases over time.** New coal-fired power plants and extensions of existing mines with a life cycle beyond 2050 would lead to stranded investments and are therefore avoided. They are replaced by renewable energy installations, and gradually over the longer term by gas-fired power plants that are generally operated as combined heat and power generation plants. The supply of electricity remains secure.

## Task: Reduce carbon emissions reliably, shape structural change

- **Together we develop a reliable framework for reducing carbon emissions.** All parties concerned require and demand planning security in order to make sustainable investments and facilitate gradual structural change. Therefore we need to discuss how we can achieve the post-2020 climate goals in the electricity sector.

- **Shape structural change through new investments and new opportunities for the regions.** In intensive talks with businesses, trade unions, the *Länder* and regions, we can develop new areas of investment and opportunities for workers and added value in the lignite mining regions. The Federal Government and the *Länder* are already providing funding to support structural change. The Federal Government will examine additional support measures.

## Guiding questions

1. Apart from the further development of the ETS, is there additional need for action in order to achieve the reduction in carbon emissions that is required by 2030 and 2050? What are our options for action? How can we prevent misguided investment in fossil-based structures?

2. In which areas can new investment and added value be developed in the regions and in businesses?

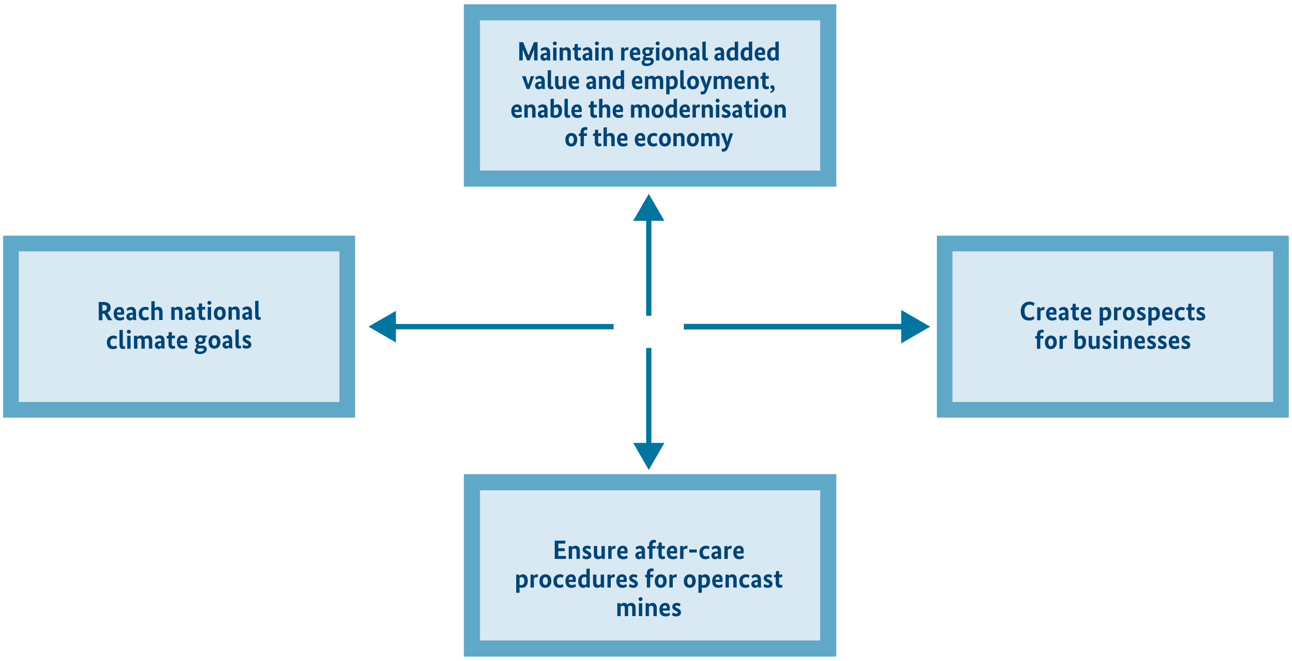
3. Which measures at regional, national and European level can foster structural change in the regions?

### Selection of current studies

**Fraunhofer ISI, Consentec et al. (2016):** Langfristszenarien für die Transformation des Energiesystems in Deutschland; Fraunhofer-Institut für System- und Innovationsforschung, Consentec GmbH, Institut für Energie und Umweltforschung Heidelberg GmbH on behalf of the Federal Ministry for Economic Affairs and Energy (publication expected in the fourth quarter 2016)

**Öko-Institut, Fraunhofer ISI (2015):** Klimaschutzszenario 2050; Öko-Institut e.V., Fraunhofer-Institut für System- und Innovationsforschung on behalf of the Federal Ministry for the Environment, Nature Conservation, Building and Nuclear Safety

**Figure 2: Requirements for a reliable framework for coal-fired power stations**




Source: Own graphic

# Trend 3: The electricity markets are more European

- **European electricity markets grow closer.** The electricity wholesale markets are already largely coupled today in the form of an internal market for electricity. Electricity is traded across borders on a large scale. Over the coming years, the internal market for electricity will grow even closer. Additional countries, particularly those in eastern Europe, will take part in market coupling and the products on the exchange will continue to converge. This, in turn, will trigger more cross-border electricity trading. At the same time, the continued expansion of cross-border power grids will also make it possible to physically exchange more electricity between the countries.

- **The European electricity system becomes more flexible.** Flexible generators, flexible consumers and storage systems respond to the price signals of the electricity market. In doing so, they also compete across Europe for the most cost-effective solution. More ambitious solutions, such as regional solutions, remain possible beyond the European framework. The flexible internal market for electricity reduces the cost of electricity supply – irrespective of the electricity market design in the individual Member States (no-regret measure).

- **The flexible European electricity system and the European emissions trading system reduce support needs for wind energy and photovoltaics in Germany and the other Member States.** Where necessary, support for renewable energy bridges the gap between decreasing production costs and the returns on the electricity market. The higher the returns of wind energy and photovoltaic installations on the electricity market the lower the support needs. A reformed ETS provides greater incentives for investment in technologies that reduce emissions: increasing prices for carbon emissions push up the price on the wholesale market for electricity and increase the returns of renewable energy installations. In addition, a flexible electricity system enables the better balancing of supply and demand and reduces price volatility on the electricity exchange. If, for example, the supply of electricity derived from wind and solar power is relatively large and the demand relatively low, flexible consumers and generators can respond. Their demand prevents the electricity price from dropping even further during these hours. Thermal power plants reduce their output if the current wholesale price no longer covers their variable operating costs. Price volatility on the wholesale market increases the value of flexibility and incentivises corresponding investment.

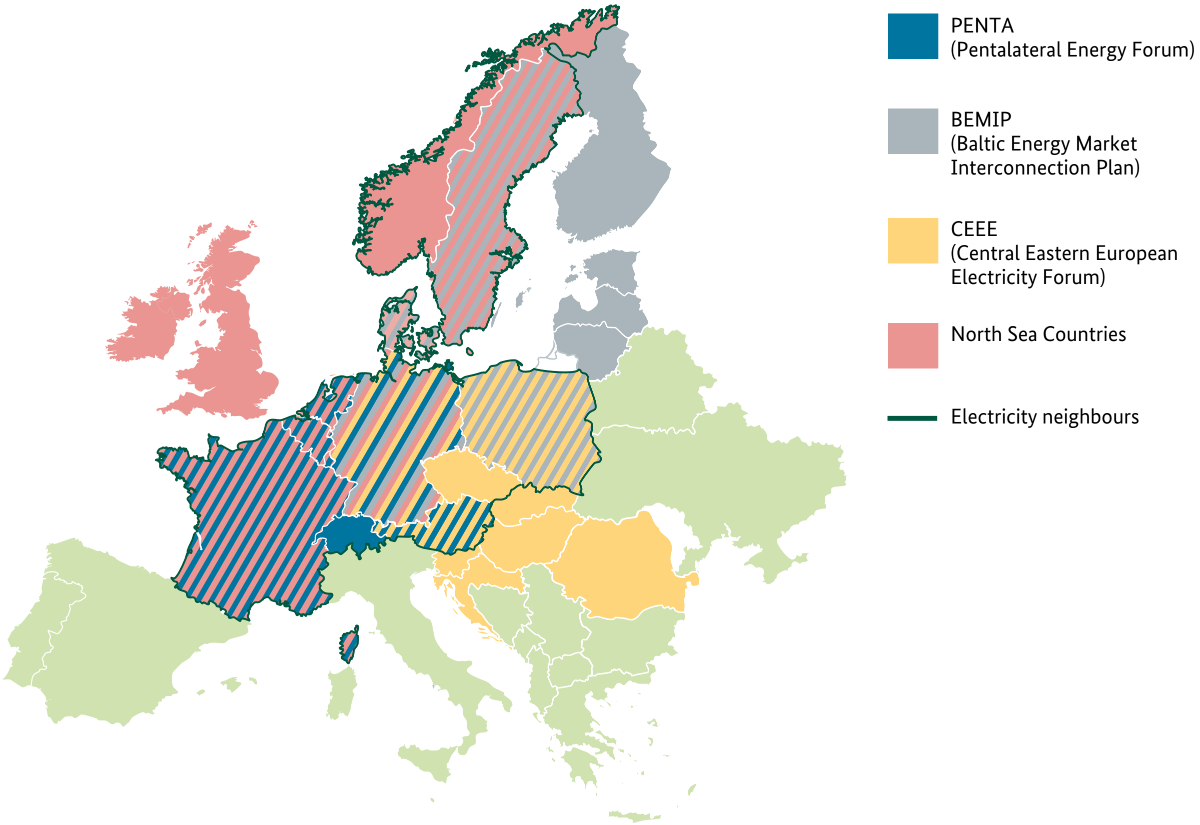
### Task: Integrate and flexibilise the european electricity markets further

- **Set the right course in Europe.** The European Commission intends to present suggestions for the continued development of the internal market for electricity in its “winter package” at the end of 2016. This legislative package sets key framework conditions for the European electricity supply system. The priority is to oversee this process and present proposals for a secure, competitive and flexible European electricity market with a large share of renewables.

- **Encourage greater integration of electricity markets at the European and regional level.** The coupling of wholesale electricity trading in various market segments should be completed swiftly. Further to this, deeper integration should specifically be encouraged wherever a more European approach delivers greater cost efficiency and improves security of supply. A common European framework and greater cooperation – for example between transmission system operators – are crucial for this. Furthermore, regional solutions such as regional initiatives to remove barriers to flexibility or initiatives in the area of supply security can also support pan-European integration.

- **Push ahead with the flexibilisation of the electricity markets in Europe.** As a no-regret measure, the removal of barriers to flexibility should become a guiding principle for the new European electricity framework. It makes sense to flexibilise the European electricity system, irrespective of the particular electricity market design in a Member State. When flexibility options compete with one another, the best and most economical options win through. More flexibility reduces the support needs for renewable energy.

**Figure 3: Political collaboration in the European electricity market (including observer status)**




Source: Own graphic

## Guiding questions

1. In which areas should the integration of the electricity markets move forward in order to leverage the potential of the internal market for the electricity transition? What political and legal framework would this require?

2. Precisely which barriers to the flexibilisation of the European electricity markets still exist? How can these barriers be removed?

3. In which areas should the framework conditions be further developed and aligned at the European level, and where do regional approaches show more promise? What form could such regional approaches to collaboration take?

### Selection of current studies

**European Commission (2015):** Launching the Public Consultation Process on a New Energy Market Design, Communication from the Commission, accessible at http://eur-lex.europa.eu/legal-content/EN/TXT/?uri=CELEX%3A52015DC0340

**European Commission (2015):** Preliminary Results from the Public Consultation on Electricity Market Design, accessible at https://ec.europa.eu/energy/sites/ener/files/documents/First%20Results%20of%20Market%20Design%20Consultation.pdf

**Fraunhofer ISI (2015):** Leitstudie Strommarkt, Arbeitspaket 4, Analyse ausgewählter Einflussfaktoren auf den Marktwert erneuerbarer Energien; Fraunhofer-Institut für System- und Innovationsforschung on behalf of the Federal Ministry for Economic Affairs and Energy

# Trend 4: Security of supply is guaranteed within the framework of the European internal market for electricity

- **Security of supply is ensured in a European context.** Electricity flows between countries in the EU internal market. It is traded across borders on the exchange: electricity producers can sell their products to customers in Germany and abroad; power utilities and large electricity consumers buy electricity wherever it is the cheapest. Therefore both domestic and European capacities combined guarantee the security of supply. This is based on two prerequisites: for one, sufficient capacity must be available in the single internal market even in times of shortage; secondly, the electricity must actually be transported across borders.

- **Guaranteeing the security of supply in a European context is cost-efficient.** Peak demand occurs at different times in different countries. In addition, strong winds in Germany, for example, usually do not coincidence with equally strong winds in France. Or the weather-dependent production of electricity from German wind energy installations can be linked to hydroelectric power plants in the Alps and in Scandinavia – with enormous advantages for both sides. In this way, electricity generation and consumption can be balanced across Europe: capacities that are not needed at one particular time in France or Austria can cover the demand in Germany and vice versa. Less capacity is required overall, thereby driving down costs.

## Task: Assess security of supply in a european context and develop common instruments

- **Consider the European internal market when monitoring security of supply.** Security of supply in Germany is assessed at least every two years in a regular monitoring process. In future, the monitoring process must consider the entire market area that is relevant for Germany, including all neighbouring countries and cross-border flexibility and balancing potential.

- **Jointly assess security of supply.** Given that security of supply is ensured in a European context in the internal market, a coordinated assessment – i.e. a common methodology and coordinated data – makes sense as a first step. This increases the quality of the assessment; compared against a purely national approach, measures to maintain superfluous, expensive capacity can be avoided. As a second step, the European countries could jointly monitor security of supply.

- **Guarantee security of supply with common instruments.** If an analysis from a European dimension reveals the need for additional measures, such measures could, potentially, be implemented where they are really needed or where they work best and are cost-effective. Measures such as reserves can be coordinated and, where technically feasible, also shared.

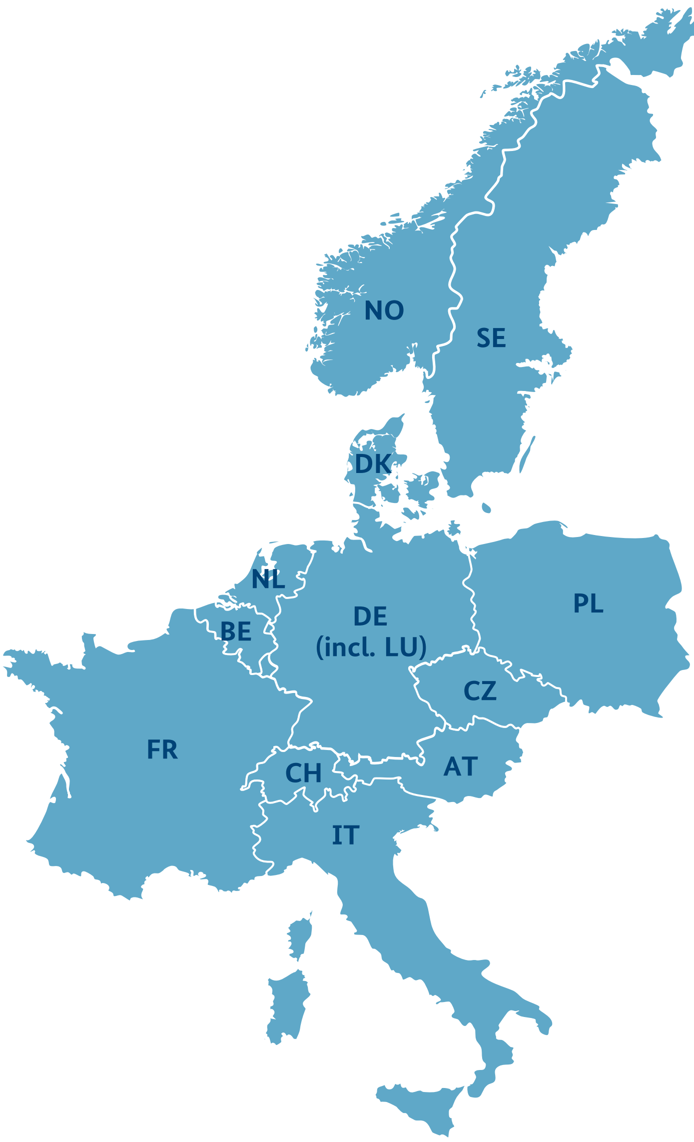
## Guiding questions

1. In recent years, new calculation methods have been developed that take, in particular, the effects of the cross-border exchange of electricity into consideration when assessing security of supply (Consentec, r2b (2015), 2015 Regional Generation Adequacy Assessment on behalf of the Pentalateral Energy Forum). Where should these calculation methods be expanded upon or developed further? In particular, which indicators and thresholds make sense for security of supply?

2. How can we remove any barriers to a common European security of supply monitoring system? Where should such a monitoring system be anchored from an institutional perspective (e.g. ENTSO-E, ACER or regional partnerships such as the Pentalateral Energy Forum)?

3. Could reserves be developed together with neighbouring countries? What opportunities – such as cost-cutting potential – and what risks would be associated with a common reserve?

**Figure 4: Relevant geographical scope for security of supply in the electricity market**




Source: Consentec, r2b (2015)

## Selection of current studies

**Consentec, r2b (2015):** Versorgungssicherheit in Deutschland und seinen Nachbarländern: Länderübergreifendes Monitoring und Bewertung; Consentec GmbH, r2b energy consulting on behalf of the Federal Ministry for Economic Affairs and Energy

**Elia et al. (2015):** Generation Adequacy Assessment; Elia, RTE, Swissgrid, Amprion, TenneT, APG, Creos on behalf of Support Group 2 of the Pentalateral Energy Forum, accessible at https://www.bmwi.de/BMWi/Redaktion/PDF/G/gemeinsamer-versorgungssicherheitsbericht,property=pdf,bereich=bmwi2012,sprache=de,rwb=true.pdf

# Trend 5: Electricity is used far more efficiently [4]

- **Electricity efficiency increases significantly.** By 2030 and 2050, electricity will be used efficiently both in traditional applications of electricity and in new applications arising from sector coupling.

- **The electricity saved must be neither generated nor distributed.** Less generation and transportation capacity will be needed as a result of efficiency measures. This reduces the cost of the provision of energy and increases acceptance of the energy transition.

- **Electricity efficiency supports sector coupling.** With the growing use of electricity for heating and mobility, the demand for electricity will increase considerably overall. A major increase in efficiency will limit this increase to the absolute minimum.

- **Flexibility and electricity efficiency are jointly addressed.** Interactions between energy efficiency and flexibility can be both positive and negative. One positive example is that only well insulated and therefore efficient cold storage depots can temporarily switch off their refrigeration systems and thereby reduce their short-term electricity demand. In other processes on the other hand, flexible access to energy can mean that installations are not operated at full capacity, thereby reducing efficiency. Striking the right balance between flexibility and electricity efficiency increases the value of electricity savings and creates incentives for the flexible use of electricity.

## Task: Strengthen incentives for the efficient use of electricity

- **Reliably increase electricity efficiency: strengthen time-tested incentives for the efficient use of electricity, remove barriers.** The less electricity we use, the fewer renewable energy installations and grids we need to build in order to replace fossil fuels. The priority is to continue to develop the framework conditions, while taking macro- and micro-economic cost efficiency into account, in such a way that the technologies used are those that prevent a maximum amount of greenhouse gases with minimum renewable electricity. In so doing, both the technical feasibility – such as the possibility of integrating heat pumps into local heating networks and combining technologies with large-scale heat accumulators – and economic efficiency must be considered.

- **"Efficiency First": factor the criterion of electricity efficiency into all energy policy decisions.** In future, energy policy decisions should be examined to determine whether they can provide incentives for the efficient use of electricity or whether they create new barriers to the efficient use of electricity.

## Guiding questions

1. What can we do to ensure that electricity efficiency is taken into consideration in energy policy decisions?

2. Where do flexibility and electricity efficiency positively and negatively interact? How can the framework for the use of electricity be designed to achieve a cost-effective balance between increasing energy efficiency and the provision of flexibility?

### Selection of current studies

**BMWi (2015):** Energie der Zukunft: Vierter Monitoring-Bericht zur Energiewende; Federal Ministry for Economic Affairs and Energy

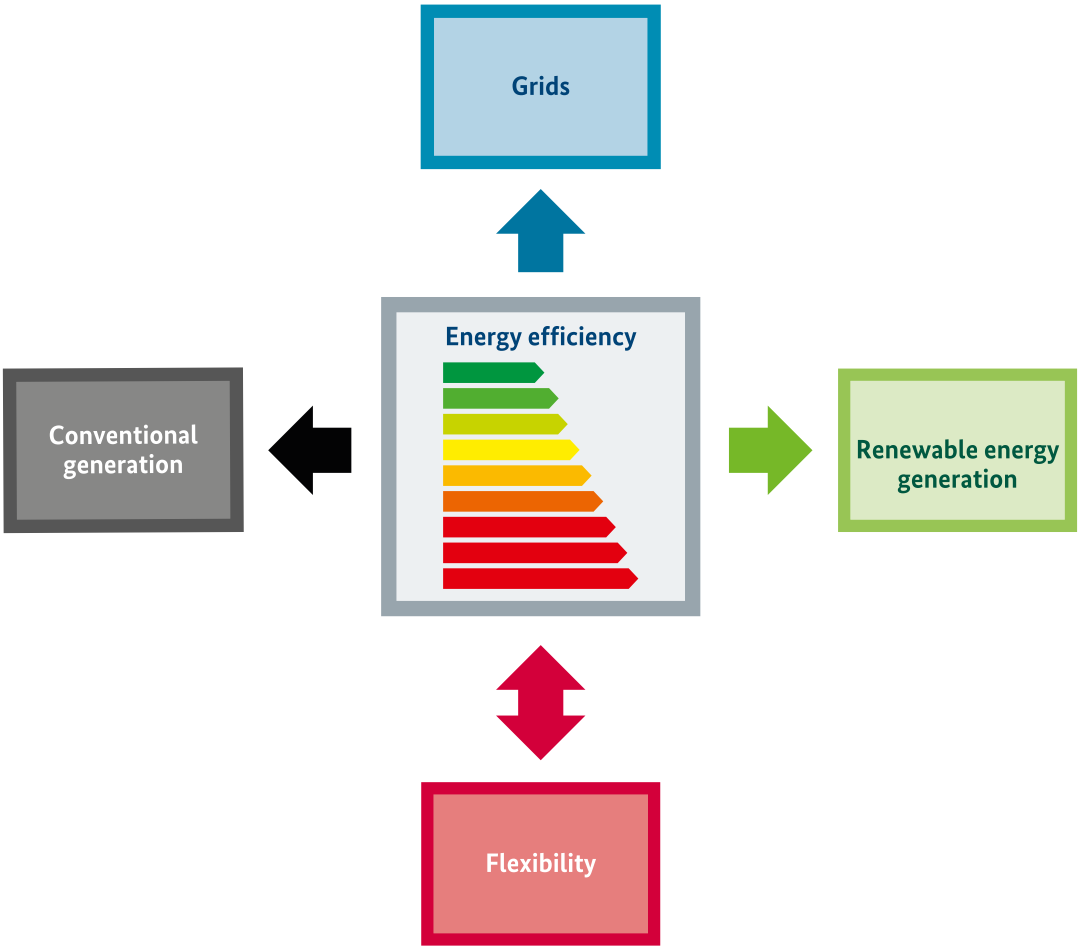
**Fraunhofer ISI, Consentec et al. (2016):** Langfristszenarien für die Transformation des Energiesystems in Deutschland; Fraunhofer-Institut für System- und Innovationsforschung, Consentec GmbH, Institut für Energie- und Umweltforschung Heidelberg GmbH on behalf of the Federal Ministry for Economic Affairs and Energy (publication expected in the fourth quarter 2016)

**Fraunhofer IWES et al. (2015):** Interaktion EE-Strom, Wärme und Verkehr; Fraunhofer-Institut für Windenergie und Energiesystemtechnik, Fraunhofer-Institut für Bauphysik, Institut für Energie- und Umweltforschung Heidelberg, Stiftung Umweltenergierecht on behalf of the Federal Ministry for Economic Affairs and Energy

**Ecofys (2016):** Flex-Efficiency. Ein Konzept zur Integration von Effizienz und Flexibilität bei industriellen Verbrauchern; Ecofys on behalf of Agora Energiewende

4 This trend will be discussed as part of the Green Paper on Energy Efficiency of the BMWi and in the Energy Efficiency Platform.

**Figure 5: The role of electricity efficiency in the electricity supply**




Source: Own graphic

# Trend 6: The heating sector, cars and industry use more and more renewable electricity instead of fossil fuels (sector coupling)

- **Renewable electricity becomes the most important source of energy.** Energy is used far more efficiently. The energy needs of buildings, the transport sector and industry decrease dramatically as a result. Renewable energy sources cover the remaining energy needs – directly in the individual sectors or in the form of renewable electricity, particularly from wind and solar energy. Consequently, the electricity sector is "coupled" ever more closely with the building, transport and industry sectors. Renewable fuels (e.g. biomass) are used wherever electricity cannot be used effectively, particularly in aviation and shipping and in parts of industry.

- **Technologies that replace as many fossil fuels as possible with a small amount of electricity are favoured.** This is particularly true of high-efficiency heat pumps and electric vehicles. Both require comparatively little electricity. They can make a major contribution to long-term decarbonisation and efficiency improvements in the heating and transport sectors. Less efficient technologies include electric boilers and heating elements or electrolysers (power-to-gas). As their electricity needs are far higher, these technologies are only used if renewable electricity would otherwise be curtailed due to negative prices or grid congestion and more efficient technologies are not practical.

- **Sector coupling makes the electricity system more flexible.** Electric cars, heat pumps and electric boilers are flexible consumers. Electric cars use their battery as a storage system and heat can be stored more easily than electricity. In future, they will be able to reduce or increase their demand by several gigawatt very quickly and adapt to the supply of electricity derived from wind and solar power.

## Task: Improve competitive conditions for renewable electricity compared to fuels in the heating and transport sectors

- **Improve competitive conditions for renewable energy in the heating and transport sectors.** Electricity is currently at a competitive disadvantage in the heating and transport sectors: for consumers, fossil fuels for heating and transport are cheaper than electricity since electricity contributes more to financing the energy transition through surcharges, taxes and levies. This applies in particular to the heating sector (cf. Fig. 1 "Further development of surcharges, grid charges and levies for flexibility and sector coupling"). Added to this, fuel prices are currently very low on the global market. These two factors run counter both to the use of electricity in the heating and transport sectors, and the efficient use of energy in these sectors. Public funding measures can only partially offset this situation. What is needed are competitive conditions for renewable electricity that facilitate efficient sector coupling, incentivise energy efficiency and reduce the support requirements for efficiency measures, heat pumps and electric vehicles for instance.

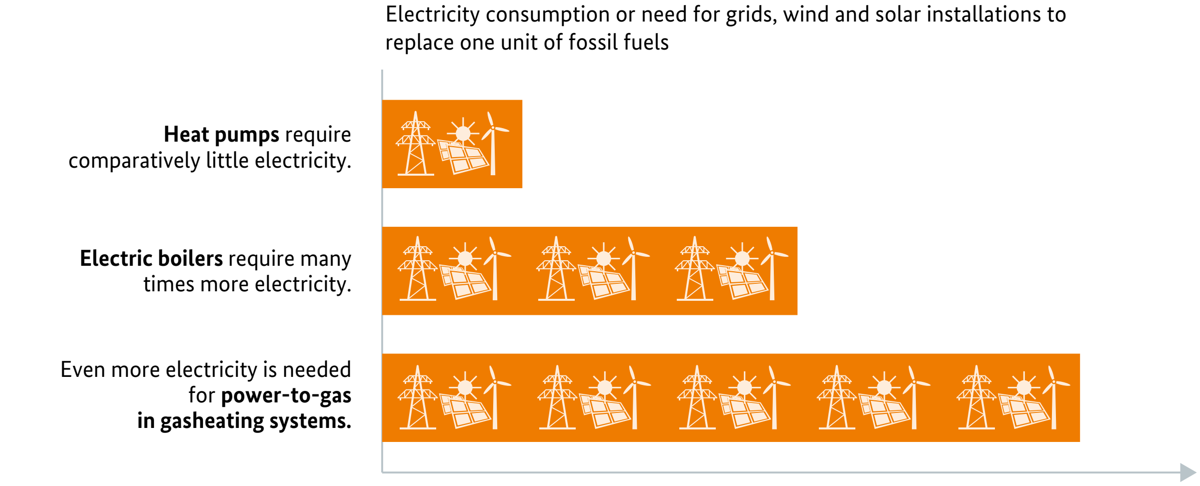
- **Enable efficient load connection for electricity from renewable energy sources.** Shifting electricity consumption to times when there is an abundance of renewably-produced electricity on the grid and the prices of electricity on the exchange are negative should be economically viable. The temporary connection of sector coupling technologies during such times can also make sense if fossil fuels are replaced as a result. Currently this is often not financially attractive. This is due in part to the fact that certain price components are calculated statically, i.e. the absolute amount is always the same irrespective of the electricity price. In contrast, value added tax is levied on the electricity price as a percentage and therefore the absolute amount charged depends on the electricity price. Lower grid charges at times when a lower load on the grid is anticipated have also already been introduced. These are approaches we should build on. It is worth examining whether price components can be levied on a more situation-specific basis in the future, and in which particular cases. This way, efficient load connection is facilitated when electricity prices are negative or the more efficient use of the grid is enabled. In doing so, it is important to avoid any wrong incentives that could result in the continued operation of inefficient technologies or increased emissions.

## Guiding questions

1. How can we improve the competitive conditions for renewable electricity in the heating and transport sectors and give electricity a fair chance against fuels in the areas of mobility and heating? How can we make sure that other sectors reasonably contribute to the costs of renewable electricity?

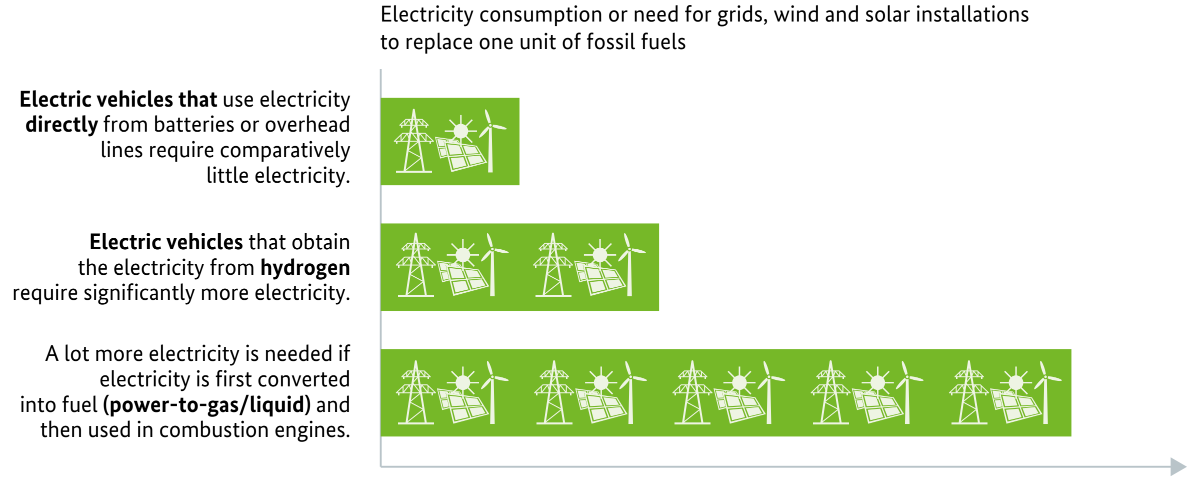
2. How can we facilitate load connection when electricity prices are low?

**Figure 6a: Electricity consumption of various technologies to replace one unit of fossil fuels in the heating supply system**




Source: Own graphic

**Figure 6b: Electricity consumption of various technologies to replace one unit of fossil fuels in the transport sector**




Source: Own graphic

## Selection of current studies

**Fraunhofer ISI, Consentec et al. (2016):** Langfristszenarien für die Transformation des Energiesystems in Deutschland; Fraunhofer-Institut für System- und Innovationsforschung, Consentec GmbH, Institut für Energie- und Umweltforschung Heidelberg GmbH on behalf of the Federal Ministry for Economic Affairs and Energy (publication expected in the fourth quarter 2016)

**Fraunhofer IWES et al. (2015):** Interaktion EE-Strom, Wärme und Verkehr; Fraunhofer-Institut für Windenergie und Energiesystemtechnik, Fraunhofer-Institut für Bauphysik, Institut für Energie- und Umweltforschung Heidelberg, Stiftung Umweltenergierecht on behalf of the Federal Ministry for Economic Affairs and Energy

**UBA (2016):** Integration von Power to Gas/Power to Liquid in den laufenden Transformationsprozess; Umweltbundesamt, accessible at https://www.umweltbundesamt.de/publikationen/integration-von-power-to-gaspower-to-liquid-in-den

# Trend 7: Modern CHP plants produce the residual electricity and contribute to the energy transition in the heating sector

- **The role of low-emission, efficient and flexible CHP (combined heat and power) plants changes over time.** Compared with non-combined generation, CHP plants are particularly efficient because they produce heat in addition to electricity. We will continue to expand the CHP landscape through to 2030 and in so doing replace non-combined generation. CHP will also remain an important component after 2030: in the electricity sector, CHP installations will cover a significant share of the residual electricity demand, while in the heating sector CHP installations will primarily provide heat for industrial processes and room heating for buildings that are difficult to energy-retrofit. CHP will become less significant after 2030, however. This is because more and more buildings will be built or energy-retrofitted in such a way that the demand for heating will drop, In addition, renewable energy will be increasingly responsible for the supply of electricity and also for the supply of room heating and warm water, either directly (e.g. through solar thermal technology) or in combination with heat pumps. CHP installations can only play a long-term role if they run on renewable fuels.

- **CHP plants become part of modern power and heat systems.** Operators adapt the operation of the CHP plants in order to be efficient and flexible and to lower emissions. As a result, CHP plants respond with flexibility to electricity prices and demand for heat. At the same time, the operators make increasing use of other technologies: Flexible balancing technologies, such as heat storage units, can respond flexibly and at a low cost to particularly high or low electricity prices, and a particularly high demand for heat, for a few hours in the year. They are less energy-efficient, however. Therefore high-efficiency heat pumps also provide flexibility. As a highly efficient power and heat technology, heat pumps connect the electricity and heating sector, just like CHP installations. However, in contrast to fuel-powered CHP plants, heat pumps consume electricity rather than produce it (cf. Trend 6). Renewable heat technologies such as solar thermal plants support low-emission heat production.

- **Heating networks support this modernisation particularly in rather densely built-up areas.** If there is demand for heat, local and district heating networks can easily combine various technologies. This includes flexible balancing technologies as well as power and heat technologies and renewable heat technologies. They can also make use of additional sources of heat, such as waste heat from industrial processes. This can ensure that electricity and heat are always produced by the cheapest technologies, depending on how the demand for heat or electricity production from wind and PV installations develops. In this way, heating networks can absorb fluctuations as they can easily integrate a heat storage system, for instance, if the demand for flexibility increases.

## Task: Provide incentives for modern power and heat systems

- **Maintain incentives for investment in low-emission, efficient and flexible CHP installations.** The 2016 CHP Act *(Kraft-Wärme-Kopplungsgesetz)* points the way forward: it promotes low-carbon, gas-based electricity generation, improves support for heat storage facilities and puts emphasis on CHP installations in supplying the public. We should build on this. We should increasingly integrate renewable heat technologies and flexible balancing technologies and continue to flexibilise CHP plants.

- **Promote viable infrastructures like heating networks.** There are different types of heating networks: Local heating networks can supply heat to individual residential blocks in a neighbourhood or provide heat for industrial processes in industrial areas. District heating networks primarily provide heating to densely populated areas and can transport heat over long distances. All heating networks require long-term investment as they have a service life of 40 years or more. Where practicable, therefore, we should support heating networks at an early stage and adapt existing heating networks to long-term requirements.

- **Think long-term.** When it comes to CHP funding, the decisions we make today will shape the energy system of the future, considering that CHP installations are frequently in operation for over 20 years and heating networks generally have a service life of more than 40 years. Therefore, we should already be considering how they can be part of a sustainable and economically efficient energy system in the long term.

## Guiding questions

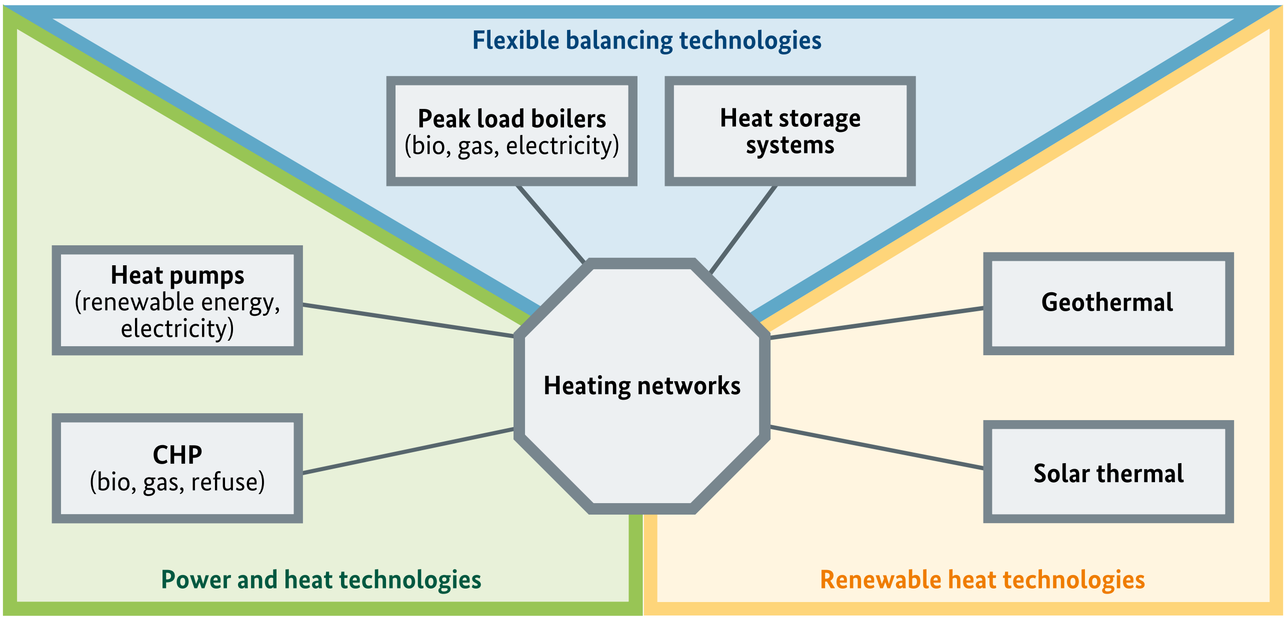
1. What role do the different types of CHP plants play in mapping out an efficient development path for CHP? What role is played both by central plants in supply to the public and distributed plants? How will the role of industrial CHP plants develop with the increasing decarbonisation of the industrial sector? What waste heat potential can be used and how?

2. What constitutes a sustainable infrastructure?

3. CHP installations are already subject to the ETS. Apart from this, how can we maintain incentives for investment in a flexible, low-emission and energy-efficient CHP landscape? How can we ensure that these installations are also used efficiently? How can we guarantee the development of a sustainable infrastructure?

4. How can we ensure that investments made today will be compatible with long-term developments? Which CHP plants can we build and by when, and what is the service life of these plants? What features and properties are essential in heating networks in the long term?

**Figure 7: Modern power and heat system based on heating network** (schematic representation)




Source: Own graphic

## Selection of current studies

**Prognos et al. (2014):** Potenzial- und Kosten-Nutzen-Analyse zu den Einsatzmöglichkeiten von Kraft-Wärme-Kopplung (Umsetzung der EU-Energieeffizienzrichtlinie) sowie Evaluierung des KWKG im Jahr 2014; Fraunhofer-Institut für Fertigungstechnik und Angewandte Materialforschung; Institut für Ressourceneffizienz und Energiestrategien, BHKW-Consult, Prognos AG on behalf of the Federal Ministry for Economic Affairs and Energy

**Fraunhofer IWES et al. (2015):** Interaktion EE-Strom, Wärme und Verkehr; Fraunhofer-Institut für Windenergie und Energiesystemtechnik, Fraunhofer-Institut für Bauphysik, Institut für Energie- und Umweltforschung Heidelberg, Stiftung Umweltenergierecht on behalf of the Federal Ministry for Economic Affairs and Energy

**Fraunhofer ISI, Consentec et al. (2016):** Langfristszenarien für die Transformation des Energiesystems in Deutschland; Fraunhofer-Institut für System- und Innovationsforschung, Consentec GmbH, Institut für Energie- und Umweltforschung Heidelberg GmbH on behalf of the Federal Ministry for Economic Affairs and Energy (publication expected in the fourth quarter 2016)

**Ifeu et al. (2013):** Transformationsstrategien von fossiler zentraler Fernwärmeversorgung zu Netzen mit einem höheren Anteil erneuerbarer Energien; Institut für Energie- und Umweltforschung Heidelberg, GEF Ingenieur AG, AGFW on behalf of the Federal Ministry for the Environment, Nature Conservation, Building and Nuclear Safety

**Fraunhofer ISE et al. (2013):** Erarbeitung einer integrierten Wärme- und Kältestrategie (Phase 2) – Zielsysteme für den Gebäudebereich im Jahr 2050; Fraunhofer-Institut für Solare Energiesysteme, Fraunhofer-Institut für System- und Innovationsforschung, Fraunhofer-Institut für Fertigungstechnik und Angewandte Materialforschung, Öko-Institut, TU Wien on behalf of the Federal Ministry for the Environment, Nature Conservation, Building and Nuclear Safety

# Trend 8: Biomass is used increasingly for transport and industry

- **Biomass is a universal yet scarce source of energy.** The applications of biomass for energy purposes are many and varied: it can be used as a fuel in the transport sector, to generate heat in domestic households and process heat in industry, or for the production of electricity. However, the local potential of biomass for energy purposes is limited particularly because of the conflict of use with the production of food and feedstuffs and the use of wood as a material. There is also some competition with other sectors of energy consumption over the use of biomass, such as in the case of liquid biomass in the transport sector. Further to this, a sustainable energy policy dictates that only limited amounts of biomass can additionally be imported. This is because in a globally decarbonised energy supply system, all countries will need to be able to draw on some of the potential of biomass, which is in scarce supply overall.

- **Biomass is specifically used where it benefits the energy system most.** Looking beyond CCS and CCU, the aviation and shipping sectors as well as parts of industry (process heat) can potentially only be decarbonised through the use of renewable fuels. In the transport sector, liquid biomass in the form of biokerosene and other biofuels will be used for this purpose, while solid biomass, in particular, will be required in industry and in the hard-to-insulate building stock. Overall, sufficient biomass will only be available for the individual sectors if electricity from wind and solar power is increasingly used wherever technically feasible and economically viable. For example, electric cars can replace biomass in road transport. The same applies in new buildings, and frequently also in energy-retrofitted existing buildings, where solar thermal technology and efficient heat pumps can provide renewable heat. In existing buildings that can only be retrofitted with insulation to a limited extent – such as listed buildings for example - biomass is, however, often an indispensable renewable source of heat even after energy efficiency measures have been implemented.

- **A limited amount of biomass is available for electricity and heating, and is used with maximum efficiency and flexibility.** CHP (combined heat and power) is the most efficient technology when it comes to using biomass in the electricity and heating sector. The flexible operation of CHP installations compensates for the intermittent feed-in of electricity from wind and solar power and in doing so makes an overall contribution to a more flexible electricity market. Alongside this, solid biomass, such as in the form of wood pellets, will also continue to be necessary to a limited extent for the non-combined provision of heat. This is particularly true in cases where premises are not connected to a heating network and the use of a heat pump is not practicable due to restrictions on insulation.

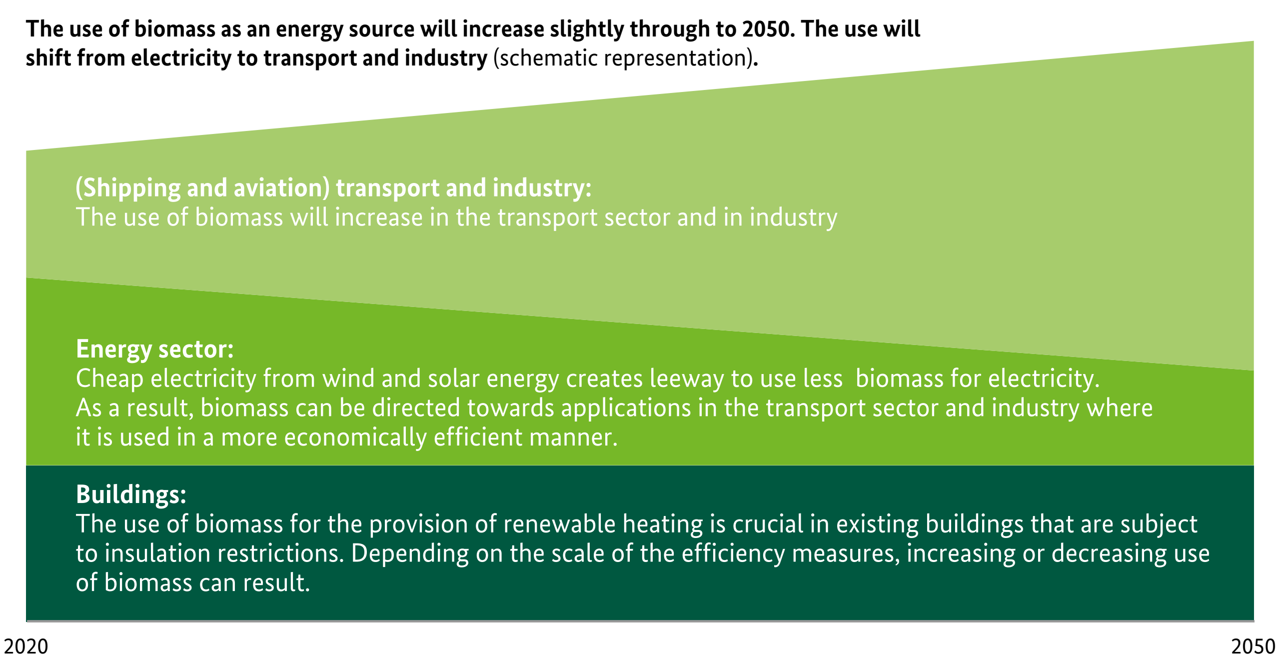
## Task: Provide incentives so that biomass is increasingly used for transport and industry

- **Clarify the available, sustainable potential of using biomass for energy purposes.** The potential of German domestic biomass is limited. Additionally, net imports of biomass should also remain limited if we are to pursue a sustainable global energy policy. Therefore it is important to first clarify the exact long-term potential Germany has of using biomass as an energy source.

- **Create incentives for uses as an energy source that are efficient over the long term in a macroeconomic context.** The incentives should be designed to encourage the long-term use of biomass in those areas that do not have a cheaper alternative for long-term decarbonisation. From today's vantage point, these are the industry and transport sectors and the provision of heating in existing buildings that cannot be fully retrofitted for energy efficiency. On the other hand, biomass can be replaced in the electricity sector by wind and solar power in conjunction with more flexible demand and storage systems.

- **Flexibilise the use of biomass for electricity and heating.** The Renewable Energy Sources Act and the CHP Act already provide incentives for the flexible operation of biomass installations for electricity generation. New installations and existing installations that receive follow-up financial support should be operated flexibly. At the same time, we should strive for a high fuel efficiency rate through heat extraction.

**Figure 8: The use of biomass as an energy source**




Source: Own graphic

## Guiding questions

1. In which areas and sectors should biomass be used to a limited extent as an energy source in the long term for it to support the attainment of energy and climate goals at optimal cost?

2. How can we avoid lock-in effects concerning the cost-optimal use of biomass in the long term and how can we incentivise the greater, more efficient use of biomass in industry, aviation and shipping?

3. If biomass is used in cogeneration, how can we guarantee the flexible operation of the plants? What future opportunities will the electricity market 2.0 offer for flexibility that is provided through the use of biomass?

### Selection of current studies

**Öko-Institut, Fraunhofer ISI (2015):** Klimaschutzszenario 2050; Öko-Institut e.V., Fraunhofer-Institut für System- und Innovationsforschung on behalf of the Federal Ministry for the Environment, Nature Conservation, Building and Nuclear Safety

**Fraunhofer IWES et al. (2015):** Interaktion EE-Strom, Wärme und Verkehr; Fraunhofer-Institut für Windenergie und Energiesystemtechnik, Fraunhofer-Institut für Bauphysik, Institut für Energie- und Umweltforschung Heidelberg, Stiftung Umweltenergierecht on behalf of the Federal Ministry for Economic Affairs and Energy

**Fraunhofer ISI, Consentec et al. (2016):** Langfristszenarien für die Transformation des Energiesystems in Deutschland; Fraunhofer-Institut für System- und Innovationsforschung, Consentec GmbH, Institut für Energie- und Umweltforschung Heidelberg GmbH on behalf of the Federal Ministry for Economic Affairs and Energy (publication expected in the fourth quarter 2016)

# Trend 9: Well developed grid infrastructures create flexibility at a low cost

- **The transmission systems allow electricity to be transported over long distances across Germany.** Electricity generation becomes more irregular ("the wind does not blow everywhere at all times"). Supra-regional extra-high-voltage lines allow electricity to be transported between various regions and particularly from the north to the south, and thereby offer flexibility both in terms of time and geographical location when it comes to balancing supply and demand in the electricity market.

- **Cross-border lines (interconnectors) enable us to benefit from the advantages of the EU internal market.** The European internal market increases security of supply and enables competitive electricity prices. By balancing variations in demand and supply (wind and sun) even across borders, the internal market also facilitates the cost-effective integration of renewable energy. All this can only be achieved, however, if the power grids of the Member States are interconnected and expanded sufficiently.

- **Distribution grids ensure the smart integration of many geographically distributed generation facilities and increasingly flexible consumers.** 90 percent of the capacity installed in renewable energy installations are connected to distribution grids. These grids account for roughly 98 percent of the total German power grid. The expansion and smart connection of the distribution grids, including with the transmission system, are therefore key preconditions for a successful transition to a renewables-based energy system.

## Task: Expand the grid in a timely, needs-based and cost-efficient manner

- **Implement the grid expansion projects approved by law.** The models on which the energy transition is based are centred on the assumption that all the grid expansion projects in the transmission system approved by law will be implemented by the middle of the next decade. The right structures for identifying and approving necessary expansion projects and comprehensive opportunities for citizens to participate have already been established to a large degree. Despite a clear increase in efforts to encourage public participation and acceptance, and the increased use of innovative technologies (e.g. through underground cabling), the actual implementation of each individual project (route planning) remains a challenge. All stakeholders must rise to this challenge together and take a solution-based approach.

- **In the grid development plan, identify additional grid expansion projects beyond the current projects adopted through to 2030 and discuss these with the public.** Bringing the energy transition to fruition in a cost-efficient manner will likely require additional expansion of the transmission and distribution grids above and beyond the projects already approved. This requires a frank, all-encompassing debate that also takes into account the consequences of implementing the projects that have already been approved and not realising additional projects. Local acceptance for such additional projects is absolutely essential.

- **Make the distribution grids ready for the challenges of the future.** The reform of the Incentive Regulation Ordinance *(Anreizregulierungsverordnung)* has provided the necessary framework for ensuring that the distribution grids can reliably and innovatively perform their central role in the energy supply system. The framework conditions for decisions concerning grid expansion must be reviewed continuously in future for the various voltage levels and adapted where necessary. This grid expansion will be different at the high-voltage level (110 kV) than at the low-voltage level, for instance, where innovative equipment, such as controllable distribution transformers, can help to resolve problems.

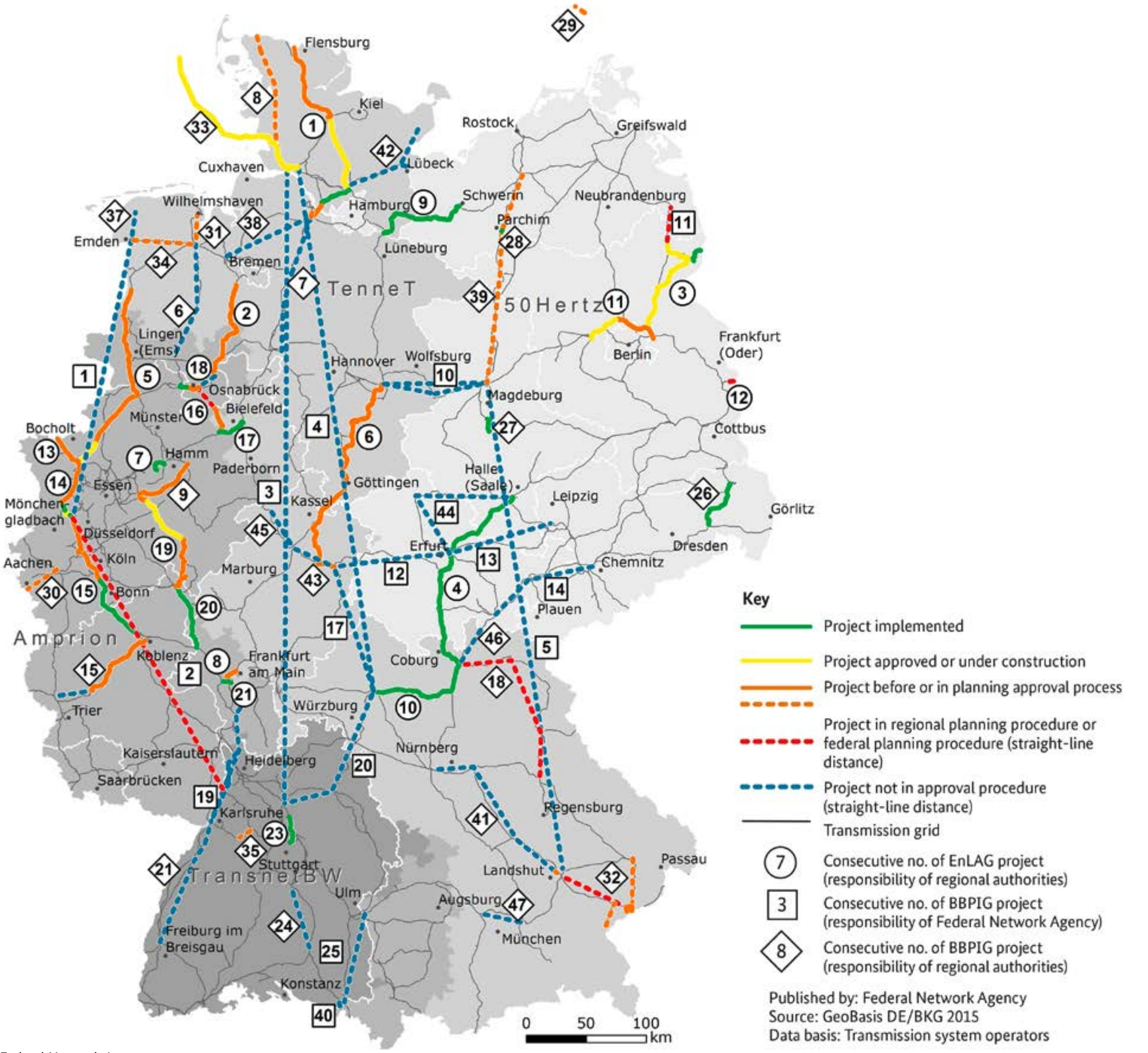
## Guiding questions

1. How can we ensure that the approved grid expansion, which is necessary for the energy sector, actually materialises and is implemented faster than in the past? What changes or additional resources are needed among the Federal Government, the *Länder* or the project promoters in this respect?

2. To what extent can additional large-scale grid expansion, which goes beyond the grid expansion projects already approved, be accepted by society and realised? What would be the alternatives?

3. In the course of the energy transition, the distribution networks will receive even more electricity from distributed installations in the future; consumers and customers will also become increasingly flexible. What framework conditions guarantee an efficient expansion of the grid also at the distribution grid level?

**Figure 9: Grid expansion projects according to the Power Grid Expansion Act (EnLAG) and the Federal Requirements Plan Act (BBPIG)**




Source: Federal Network Agency

## Selection of current studies

**ÜNB (2016):** Szenariorahmen für die Netzentwicklungspläne 2030; 50Hertz, Amprion, TenneT, TransnetBW

**Bundesnetzagentur (2015):** Netzentwicklungsplan 2024

**E-Bridge et al. (2014):** Moderne Verteilernetze für Deutschland (Verteilernetzstudie); E-Bridge Consulting GmbH, Institut für Elektrische Anlagen und Energiewirtschaft, Institut für Informatik Oldenburg on behalf of the Federal Ministry for Economic Affairs and Energy

**ENTSO-E (2014):** Ten-Year Network Development Plan 2014

**e-Highway2050:** Modular Development Plan of the Pan-European Transmission System 2050

**Fraunhofer ISI, Consentec et al. (2016):** Langfristszenarien für die Transformation des Energiesystems in Deutschland; Fraunhofer-Institut für System- und Innovationsforschung, Consentec GmbH, Institut für Energie- und Umweltforschung Heidelberg GmbH on behalf of the Federal Ministry for Economic Affairs and Energy (publication expected in the fourth quarter 2016)

# Trend 10: System stability is guaranteed even with a large share of renewables in the energy mix

- **Flexible generation plants, consumers and storage systems contribute to stabilising the power grids.** In an electricity system increasingly characterised by the intermittent feed-in of renewable energy, the market players can, to some extent, contribute to the stabilisation and optimised use of the grids by adapting electricity consumption or generation to the current load situation on the grid as much as economically feasible. This not only reduces the need for additional grid expansion measures but also ensures secure and efficient grid operation.

- **Ancillary services adapt to an electricity system with a high percentage of energy from renewable sources.** The ancillary services that are required for system and grid stability (frequency control, voltage stability, restoration of supply, system control) are provided in a cost-efficient manner by conventional power plants, renewable energy, storage systems and demand side management, as well as by new technical facilities (such as regulated distribution transformers), depending on the circumstances. In situations involving high feed-in of renewable electricity, the ancillary services provided are increasingly independent of conventional power plants.

- **Critical grid situations are managed safely and efficiently.** Increasing intermittent feed-in of renewable energy and the geographical distribution of load and generation place stricter demands on the control of the electricity system. The grid operators have suitable and efficient tools to intervene in critical situations. Stable grid operation continues to be guaranteed.

## Task: Continue to develop and coordinate measures and processes for system stabilisation

- **Continuously develop ancillary services (frequency control, voltage stability, restoration of supply, system control) through to 2030 and adapt them to the system.** Apart from developing technical solutions, there may also be the need to introduce new market rules and adapt technical regulations and regulatory requirements. The increased provision of ancillary services at lower grid levels (e.g. balancing energy for frequency control) requires new processes of coordination between transmission and distribution system operators as well as market players.

- **Continuously develop grid operators' scope to manage critical grid situations through to 2030 so that it is in line with system conditions.** It is essential to continue to develop the market- and grid-related scope of transmission and distribution system operators to intervene. This concerns redispatch, feed-in management and the grid reserve, for instance, as well as the associated operational processes.

- **Increasingly coordinate system stability from a European perspective.** While the increasing cross-border flow of electricity in the European internal market offers potential for synergy, it also poses new, cross-cutting stability issues. System control and the associated planning processes based on European requirements (network codes) are increasingly coordinated across balancing zones and national borders. This includes transnational grid security and contingency plans as well as the further development of cross-border redispatch.

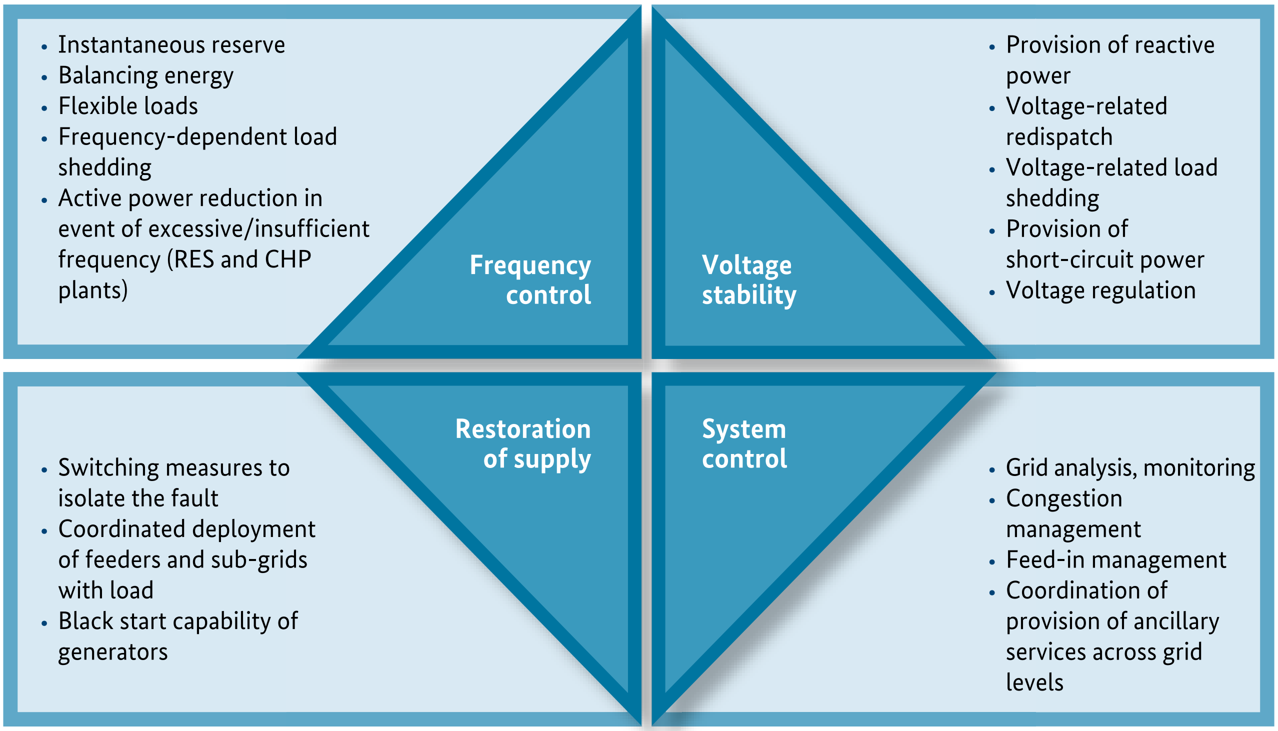
## Guiding questions

1. A system with an ever increasing share of electricity from renewable sources poses a considerable challenge when it comes to guaranteeing system stability. What measures are needed to continue to ensure system stability?

2. How can system stability still be guaranteed if the grid expansion projects which have been identified as necessary and approved by law are not implemented in time?

3. What specific changes need to be made to the regulatory framework to initiate in a timely manner the desired development of ancillary services through to 2030?

**Figure 10: Ancillary services for stable power grid operation in 2030**




Source: Modelled after dena (2014a)

## Selection of current studies


**dena (2014a):** Systemdienstleistungen 2030. Sicherheit und Zuverlässigkeit einer Stromversorgung mit hohem Anteil erneuerbarer Energien; Deutsche Energie-Agentur GmbH

**dena (2014b):** Roadmap Systemdienstleistungen 2030; Deutsche Energie-Agentur GmbH

# Trend 11: Grid financing is fair and meets the needs of the system

- **The financing of grid operation and investment in the power grids involves fair and transparent burden sharing.** The restructuring of the electricity supply system poses new challenges for transmission and distribution grids – whether with regard to the additional transportation of electricity from north to south or the smart networking of market players. Grid and system costs are borne by the grid users in a fair and transparent manner – both from a regional perspective and with regard to different user groups.

- **Many smaller, distributed generation facilities and increasingly flexible consumers change the requirements concerning a modern regulatory framework for the grids.** More and more market players will cover their electricity needs through private onsite generation facilities, for example, and will no longer draw their electricity exclusively from the public grid. Despite this, the grids must be designed so that all users can reliably receive and feed in electricity at all times. Furthermore, there will be increased feed-in to distribution grids and the consumption patterns of grid users will change.

- **By providing local flexibility, users contribute to an efficient energy system.** An increasing percentage of intermittent feed-in of renewables increases the need for flexibility in the electricity system. Flexible grid users that meet the need of the system, on the generation side as well as the demand side, contribute to the cost-efficient operation of the grid.

## Task: Further develop regulations governing grid charges

- **Ensure the fair distribution of network costs to grid users and guarantee transparency regarding cost allocation.** The grid charges chiefly determine the distribution of the future costs of the grid infrastructure and grid operation to the grid users. The fair and transparent distribution of these costs among grid users remains necessary in the future. In this context, incentives for efficient grid operation should be increased further.

- **Take account of increasingly complex supplier-side/demand-side structures.** A sustainable regulatory framework for calculating grid charges guarantees, inter alia, that grid users make an appropriate contribution towards the costs of providing grid access and operating the grids.

- **When developing the grid charge system further, facilitate the use of flexibility that meets the needs of the system.** Flexible generators and consumers are increasingly important in a further developed electricity market that involves the increasing participation of intermittent renewable energy. Behaviour patterns that serve the needs of the energy system should not be impeded. At the same time, the efficient and stable operation of the power grids and the efficient use of electricity must be ensured.

## Guiding questions

1. How can the system of grid charges be developed further to ensure the fair and transparent distribution of the costs for the construction and operation of the grids among grid users?

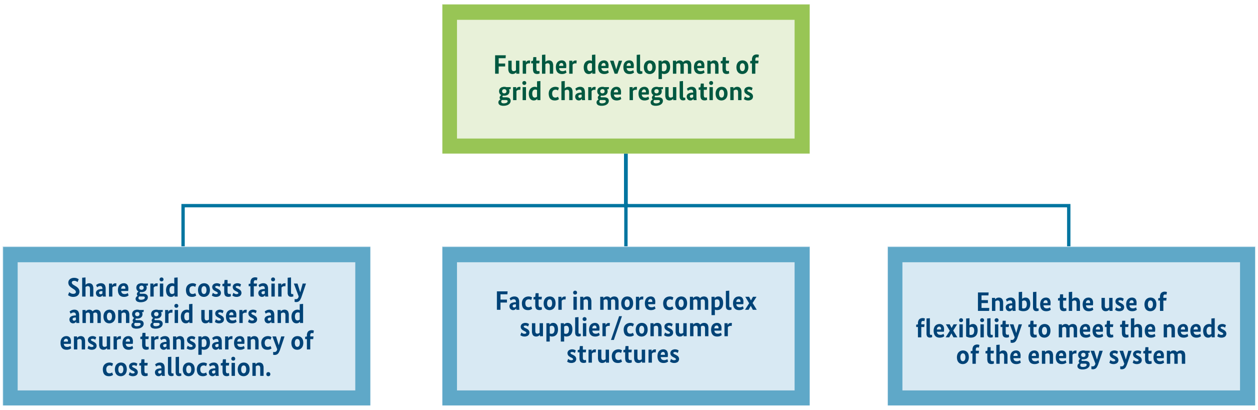
2. What role does the cost efficiency of the overall energy system play in the design of the grid charge system? What interactions are there between the financing of the grids and sector coupling?

3. How can we optimally leverage the flexibility potential of generators, storage systems and consumers in a way that makes sense for the energy sector? What implications will this have for the continued development of the grid charges? How can we provide incentives for the stable operation of the power grids and what criteria would be useful for assessing measures for the flexibilisation of demand and generation from a grid perspective?

### Selection of current studies

**Federal Ministry for Economic Affairs and Energy (2015):** An Electricity Market for Germany's Energy Transition – White Paper; Federal Ministry for Economic Affairs and Energy

**Figure 11: Requirements concerning the further development of grid charge regulations**




Source: Own graphic

# Trend 12: The energy sector takes advantage of the opportunities offered by digitisation

- **Digitisation combines the energy sector with cutting-edge information and communication technology.** In 2030, renewable energy will cover at least one half of all electricity consumed. Digitisation ensures the efficient interaction between generation, consumption and the grid, and in so doing safeguards the supply of electricity and opens up new opportunities for additional energy efficiency. Standards and norms facilitate the trouble-free control of equipment and applications.

- **Digitisation respects data privacy and data security.** As the energy sector goes increasingly digital even more emphasis is put on security. Reliable strategies, architectures and standards build safety and trust. Standards set down by the Federal Office for Information Security (BSI) allow smart meter gateways to be deployed as an open communication platform for the smart grid. Not only can they be used to transmit readings or for demand side and generation management but, looking ahead, can also potentially ensure services in the area of assisted living and facility management.

- **New business models emerge, offering added value for customers.** Interlinked generation, distribution and consumption and the availability of large data volumes give rise to innovative business models and allow services to be linked with applications outside the traditional energy sector. Automated metering and feedback to users from each individual device drive new services and customer relations.

## Task: Roll out smart meter, build communication platforms, ensure system security

- **Benefit optimally from the technical potential afforded by digitisation.** The electricity market with a high percentage of electricity derived from renewables actively taps the potential of digitisation. This facilitates the use of flexibility options to balance generation and demand at all times, for instance, and leverages efficiency potential. Standardised interfaces give business and users the necessary latitude to find cost-effective solutions.

- **Maintain the security of the energy system.** Given that the energy sector is a critical infrastructure, data security and data privacy are top priority issues. Acceptance among the public must be maintained through trust in secure technologies.

- **Take advantage of digitisation as an engine for the cost-effective delivery of the energy transition.** The regulatory framework of the energy sector is organised in a way that facilitates competition among flexibility options on the basis of uniform standards. Various new business models generate added value in Germany.

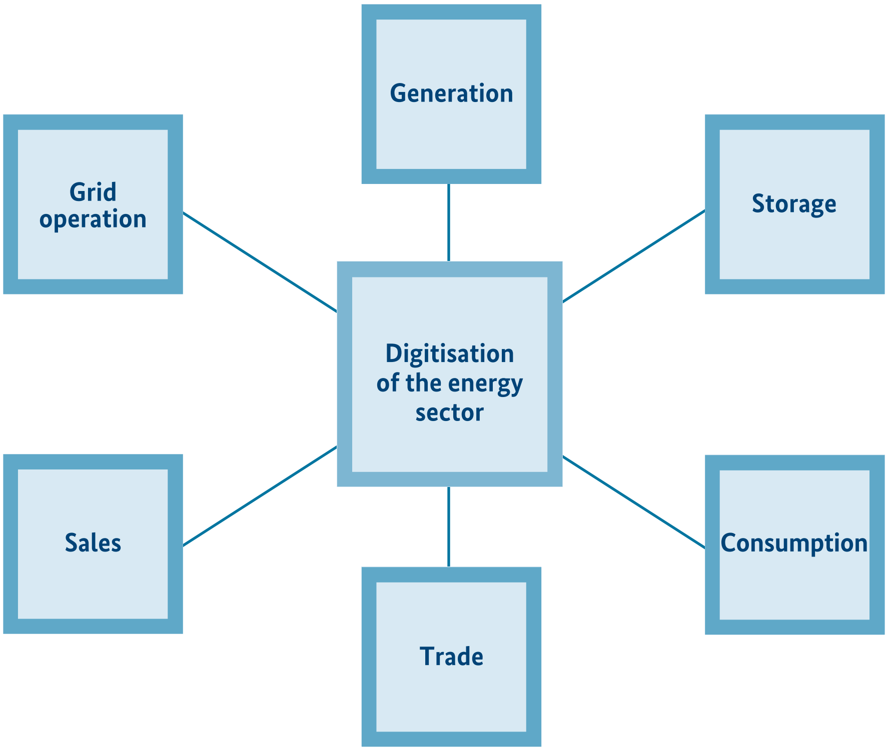
## Guiding questions

1. The Act on the Digitisation of the Energy Transition *(Gesetz zur Digitalisierung der Energiewende)* adopted in the German Bundestag is an important step towards defining the framework for digitisation in the electricity sector. What additional regulatory steps are required?

2. Digitisation is an enormous opportunity for the energy transition. At the same time, this development is hard to predict – precisely because of its highly dynamic nature – as it is largely driven by new applications on the end customer side and shaped by advances in technology. How can we define a framework that provides scope for planning by setting reliable standards while also giving digitisation the necessary leeway to achieve the core goals of the energy transition?

3. Digitisation in the field of energy requires considerable investment. To what extent is the digitisation of the energy sector (generation, transmission, consumption) part of the public infrastructure and what role do market players have in this process?
   As a result of digitisation, more and more players primarily involved in data capture and processing will enter the market. Are new business models beginning to emerge and what implications will this have for the structure of the energy sector?

**Figure 12: Digitisation as an opportunity for the energy sector**




Source: Own graphic

### Selection of current studies

**BMWi (2016):** Digitale Strategie 2025; Bundesministerium für Wirtschaft und Energie

**Forum für Zukunftsenergien (2016):** Chancen und Herausforderungen durch die Digitalisierung der Wirtschaft; Schriftenreihe des Kuratoriums, Band 9

**BDEW (2015):** Digitalisierung in der Energiewirtschaft; Bundesverband der Energie- und Wasserwirtschaft

www.bmwi.de