Federal Ministry for Economic Affairs and Energy

Energiewende
Switch to the Future

Concluding paper

Electricity 2030

Long-term trends – tasks for the coming years

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Introduction

The goal: the secure supply of clean energy at a low cost

The energy transition is a modernisation strategy for the fundamental transformation of our energy supply system. Specifically, this requires consistent improvements in energy efficiency, the broad use of renewable energy beyond the electricity sector, and optimum dovetailing of all the elements. This document looks at the future role of electricity supply, bedded into the energy transition overall.

Renewable energy is already our most important source of electricity today. By 2050 at the latest, we want Germany's power supply to stem from clean energy sources primarily. ***This modernisation strategy is known as the "energy transition".*** By pursuing the energy transition, we are heading towards a future with a secure, economic and environmentally friendly energy supply whilst also contributing to growth and employment. We want to deliver on our climate targets and reduce our dependency on oil and gas imports. The security of supply and the development of energy prices are central to Germany's competitiveness as a place for business and investment.

The Federal Government's concrete goals for the energy sector

- By 2050, the aim is to reduce greenhouse gas emissions by 80 – 95 % compared with 1990 levels, and to cut primary energy consumption by 50 % compared with 2008. At the same time, the share of renewables in electricity consumption should increase to 80 % at least.

- By 2030, greenhouse gas emissions should already be down by 55 % compared with 1990 levels, and renewables should have a share of around 50 % in electricity consumption.

The path to take: more wind and solar power, more flexibility, more Europe

The Energy Concept maps the route for the modernisation of our energy supply system: ***electricity produced from wind and solar power*** will gradually become the central source of energy. This also means that we will use electricity from wind and solar energy increasingly to power cars, heat buildings and manufacture goods. Sound use is made of this renewable electricity if demand for energy in these sectors is reduced through aggressive efforts to improve energy efficiency. With electricity supplied from wind and solar energy, well-developed ***power grids as well as flexible power stations and consumers are imperative***, allowing us to bring electricity production and consumption together at a low cost. Storage systems will also play their part wherever they are a cost-effective solution. European capacities collectively guarantee security of supply, which is why the exchange of electricity between European countries is becoming more and more important. Therefore we must ***consider security of supply in a European context, and no longer from just a national perspective***.

Five good reasons for wind and solar power, flexibility and Europe

1. Wind and solar power are cheap sources of energy.

The costs of producing electricity from renewable sources are falling steadily. Ten years ago, support of around 40 cent/kWh was provided to incentivise investment in large-scale PV plants. By 2016, the costs of support had dropped to less than 7 cent/kWh. Further cost reductions are also expected in wind energy, particularly offshore wind. This global trend is also set to continue: the International Energy Agency expects the costs for solar power to drop by another 40 – 70 % by 2040, and the costs for wind power by 10 – 25 %. This means that it will be increasingly cheaper to produce electricity from renewable sources and, in the near future, it will be more economical to produce electricity from renewables than from coal and nuclear energy.

2. Electricity from the wind and sun reduces the CO_2 emissions of vehicles, buildings and industry.

Fossil fuels, such as gas and oil, are still the predominant energy source today for heating, transportation and in industry. If we are to meet our climate targets, it is imperative that these sectors also cut their CO_2 emissions. To this end, the consumption of energy first needs to be reduced. Secondly, renewables – such as solar thermal, geothermal and biomass – are used directly. Thirdly, the demand for energy that remains for economic or other reasons despite efficiency measures and the direct use of renewable energy is covered by electricity derived from wind and solar power.

The efficient use of electricity also for transportation, to heat buildings and in industry allows us to reduce CO_2 emissions in these sectors in a cost-effective manner. This is what is meant by “sector coupling”. For example, electric cars can run with electricity drawn directly from batteries, generating zero emissions, or heat pumps and electric boilers can convert electricity to heat in order to warm our homes. However, there are sectors where electric mobility will be difficult to introduce, such as in the case of the aviation sector, shipping and heavy-duty traffic, or construction equipment and agricultural machines. Here it is important to also keep other options open, such as the use of biofuels, or liquid and gas-based fuels produced using renewable energy. To enable the use of electricity in the transport, buildings and industry sectors, exemptions from surcharges, fees and levies are not the way forward. Rather, what we need is free-market competition among the technologies so that electricity prices remain affordable. A level playing field calls for the general reform of surcharges, fees and taxes.

3. Power grids, flexible power stations, flexible consumers and storage systems balance intermittent feed-in from wind and sun in a cost-effective manner.

The amount of power available from the wind and sun depends on the weather. Feed-in from these renewable sources therefore varies during the day and throughout the year. Despite these fluctuations, the supply of electricity must always remain secure and affordable – an ever-greater challenge with an increasing share of renewables in the electricity mix. What options are available to flexibly balance these fluctuations? Power grids ensure that cheaper wind power from the north and east of Germany or from Denmark, for example, covers the demand in the major centres of consumption in the south of the country. The consumer side also offers serious potential by being able to adapt flexibly to the fluctuations. Where economically viable, large consumers in industry or cold-storage depots can shift their demand for electricity when winds are low, for instance. In addition, flexible power stations and storage systems can balance the fluctuations. The power stations respond flexibly and start up or shut down depending on the availability of wind and solar power. The major hydropower storage installations and pumped storage reservoirs in Germany, the Alps and Scandinavia can store and release electricity as needed.

4. A secure supply of electricity is cheaper in a European setting.

In the European internal market, electricity flows between countries via cross-border lines. Electricity is traded across borders on the exchange: producers of electricity can sell their products to customers at home and abroad. Anyone consuming electricity can buy electricity wherever it is the cheapest. This European network offers advantages for everyone involved: electricity that is not needed in one particular country at a certain time can cover the demand in another country, and vice versa. This means that less capacity is required overall, thereby driving down costs. The fact that we can, if necessary, access the electricity production capacities of our neighbours increases the security of supply in Germany. Therefore, the times when we considered security of supply from a “national” perspective are long gone. A combination of power stations, consumers and storage systems both in Germany and abroad are responsible for guaranteeing security of supply nowadays.

5. Green technologies “Made in Germany” create export and growth opportunities.

The energy transition creates new opportunities for German businesses. It is the showcase for innovative, green technologies made in Germany. According to experts, environmental and climate-friendly technologies are expected to have a global market volume of €5.4 trillion by 2025. This gives German industry enormous export opportunities, as well as opportunities for growth and jobs. By 2013, German companies had already achieved a market volume of roughly €350 billion in this sector, thereby securing a global market share of 14 %.[1]

What needs to be done in the coming years?

Couple the electricity, heating and transport sectors.

Electricity is currently at a competitive disadvantage in the transport sector, and particularly in the heating sector: fossil fuels are more cost-competitive than electricity because more surcharges, fees and levies apply to electricity. However, we should not make electricity for heating and transport cheaper through new exemptions for heating

1 Roland Berger Strategy Consultants (2014): GreenTech-Atlas 4.0, Environmental Technology Atlas for Germany

pumps, electric cars or power-to-X technologies, as this would increase the price of electricity for other electricity consumers. A reform of the system of surcharges, fees and taxes should facilitate sector coupling and involve all consumers under fair conditions.

Make the electricity system more flexible.

Regulations are still in place that hamper flexible behaviour on the part of the market players. These are known as "barriers to flexibility". These barriers need to be removed if all technologies are to enjoy the same access to the market. For example, aggregators can bundle and market flexibility for small consumers. It is also important to grant wind and solar power, flexible consumers and storage systems greater access to the market for balancing capacity. Grid charges can also influence the flexible behaviour of the market players. Competition among the various options for the provision of this flexibility guarantees low-cost solutions. We must not favour certain technologies by providing unilateral support and making individual exceptions. Such decisions are best left to the market.

Expand the grids.

Germany has one of the most powerful and reliable power grids in the world. The grids constitute the central infrastructure that brings together the generation and consumption of electricity in a cost-effective manner. We need more grids to ensure that we can continue to maintain a high degree of supply security in the future with the increasingly decentralised production of electricity.

Therefore we will continue to expand and upgrade our power grids in the years ahead, while bearing in mind the concerns of the parties affected. To this end, it is essential that the Federal Government, the *Länder* and municipalities all pull together and seek early dialog with the public. Grid planning should give greater consideration than hitherto to measures that reduce future additional grid expansion.

Modern heating networks are central to a largely climate-neutral heating supply system. The heating networks will be modernised and upgraded to allow heat from combined heat and power plants, large-scale heat pumps, electric boilers, solar thermal, geothermal and waste heat into buildings.

Integrate and flexibilise European markets further.

More European competition in the electricity markets means lower prices. It is therefore right to rapidly complete the integration of the electricity wholesale sector in Europe. Regional cooperation and partnerships promote the integration of the European electricity markets. Flexible European electricity markets respond to the intermittent feed-in of electricity from wind and solar power. When winds are low in the north of Germany, stronger wind conditions in other European countries can compensate this, for instance. This presupposes, for example, that market players across Europe balance and bill production and consumption on a quarter-hour basis, and not only on an hourly basis as is often the case today.

Assess security of supply in a European context.

We have made tremendous progress in the assessment of security of supply in recent years. Growing interconnectedness in Europe leaves no doubt that assessments from a purely national perspective are clearly outdated in the internal market for electricity. The logical conclusion, therefore, is to conduct a "state of the art" assessment of the security of supply, i.e. in a European context. Conversely, in this context it is also important to check whether – in critical situations – we can also rely on the cross-border availability of generation capacities in neighbouring countries for national security of supply.

Electricity 2030: from the discussion paper to the concluding paper

In September 2016, the Federal Ministry for Economic Affairs and Energy (BMWi) published a discussion paper that opened the discussion process on "Electricity 2030". This discussion ran in parallel to the consultation on the Green Paper on Energy Efficiency. The energy transition in the electricity sector has made good progress in this legislative term. Milestones reached include the new Renewable Energy Sources Act (EEG), the Electricity Market Act, the Underground Power Cables Act and the Act on the Digitisation of the Energy Transition. The Federal Ministry for Economic Affairs and Energy is setting its sights on the future with the "Electricity 2030" discussion process.

In the discussion paper, 12 trends describe the path to a low-cost, secure and environmentally friendly electricity system. These are based on robust developments from current studies, such as the long-term scenarios[2] commissioned by the Federal Ministry for Economic Affairs and Energy. These trends show the following: electricity derived from renewable sources, particularly wind and solar power, will become the central source of energy in the energy system. Increasingly, wind and solar power will also be used efficiently in the heating, mobility and industry sectors (sector coupling). At the same time, the European electricity markets will grow even closer. In the face of the growing importance of intermittent wind and solar power, the electricity system must remain secure and become more flexible. Modern, well developed power grids, as well as flexible power stations and flexible consumers, bring generation and consumption together at a low cost. Digital solutions enable the use of distributed consumers, such as electric cars or heat pumps, to serve the needs of the system.

On the basis of these 12 trends, the discussion paper identified central tasks for the years ahead and put these tasks forward for discussion. For these trends to actually materialise, policy-makers must ensure that the proper framework is in place. Therefore "Electricity 2030" also involves a debate on which energy policy tasks need to be addressed in the years ahead to guarantee a power supply that is secure, affordable and climate-friendly on the long term.

The Federal Ministry for Economic Affairs and Energy led the discussion on "Electricity 2030" over a period of several months. In the Energy Transition Platforms on the Electricity Market and Energy Grids, the Federal Ministry for Economic Affairs and Energy discussed the trends in the discussion paper with representatives of the *Länder*, parliamentary groups, ministries and federal authorities, as well as with stakeholders from business, science and social groups. In addition, the Federal Ministry for Economic Affairs and Energy also hosted a public consultation on the discussion paper, and received 136 opinions from *Länder*, associations, business enterprises, non-governmental organisations, scientific institutes and private citizens. The Federal Ministry for Economic Affairs and Energy has published the opinions on its website where consent was given by the authors.

This paper summarises the conclusions of the discussion process. Based on the trends and tasks described in the discussion paper, this concluding paper report on the key points from the discussions in the Energy Transition Platforms and the public consultation. Where necessary, it also highlights the need for further discussion and research.

2 Fraunhofer ISI, Consentec et al. (2017): Long-term Scenarios for the Transformation of the Energy System in Germany (publication expected in the second quarter of 2017)

The concluding paper at a glance

<table>
<tr><th>Trends</th><th>Outcome of the discussion</th></tr>
<tr><td>

Trend 1

The system is shaped by the intermittent generation of electricity from the wind and sun.

- Wind energy and photovoltaics offer enormous potential at a low cost. These technologies will be strongly expanded.
- Electricity generated from wind and solar power depends on the weather. A flexible electricity system ensures that electricity supply and demand is balanced.
- It is particularly economical if the various flexibility options compete with one another (electricity market 2.0).

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From the electricity market 2.0 to the energy market 2.0: five steps for more flexibility and sector coupling:

- **Improve upon the system of surcharges, fees and taxes in a way that market players can respond to price signals that are as unbiased as possible**. The aim is to have a level playing field for all technologies, and particularly between electricity and fuel.
- **Enable the same market access for all technologies**, e.g. in the balancing capacity market and by incorporating decentralised flexibility using smart meters.
- **Expand and modernise infrastructures** such as power grids, heating networks and charging infrastructure for electric mobility.
- **Conduct research into technologies with support instruments and bring them closer to the market**.
- **Develop quality standards further** in other to prevent misguided investments.

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Trend 2[3]

Sector coupling: The heating sector, cars and industry use more and more renewable electricity instead of fossil fuels.

- Renewable electricity becomes the most important source of energy and thereby reduces emissions in the buildings, transport and industry sectors.
- To this end, the competitive conditions for renewable electricity compared with fossil fuels should be improved in the heating and transport sectors (energy market 2.0).

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Trend 3

There is a significant decline in the use of fossil fuels in the power plant fleet.

- In 2050 electricity generation is largely carbon-free. As a result, emissions can be reduced in a relatively cost-effective manner.
- Investment in the coal infrastructure decreases over time.
- It is replaced by renewable energy installations and gas-fired power stations that are generally operated as combined heat and power (CHP) generation plants.

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Implement the Energy Concept and the 2050 Climate Action Plan:

- **Gradually reduce CO_2 emissions of coal-fired power plants**. Develop future prospects for the local area; discuss and reach decisions concerning the gradual withdrawal from coal-based electricity production on a step-by-step basis.
- Use **flexible CHP plants as interim technologies** over the medium term.
- **Strengthen CO_2 price incentives in the European emissions trading system (ETS)**. While the ETS is not designed to specifically reduce emissions in individual countries, it can influence the use of fossil fuels in the power plant fleet through stronger price incentives and thereby help us meet our national climate targets.

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3 The trend towards sector coupling was “Trend 6” in the “Electricity 2030” discussion paper. The numbering of the trends has been changed in the concluding paper to accommodate the joint discussion on “flexibility” and “sector coupling”.

Trends	Outcome of the discussion
Trend 4 **The electricity markets are more European.** • Over the coming years, the European internal market for electricity will grow even closer. • The European electricity system helps us to respond to flexible generation and consumption and thereby reduces the overall cost of electricity production.	**Integrate and flexibilise the European electricity markets further:** • Integrate wind and solar power into the energy system, particularly using **intraday trading in Europe *until shortly before real-time***. • **Strengthen the intraday and day-ahead lead markets** – *no* weakening by other market segments such as redispatch markets. • **Cooperate regionally while** maintaining leeway for the Member States.
Trend 5 **National security of supply is ensured within the framework of the European internal market for electricity.** • Security of supply is ensured in a European context: electricity flows between countries and is traded across borders on the exchange. • Guaranteeing the security of supply in a European context is cost-efficient, as less capacity is required overall. • 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.	**"State of the art" analysis of security of supply:** • Exploit the opportunities of an interlinked Europe for a secure supply of power, and consider security of supply from a **cross-border** perspective. • To assess the security of supply, further develop a **probabilistic approach** modelled on probability theory. • **Define the desired level of supply security** in order to gauge the actual security of supply and identify necessary measures where applicable.
Trend 6 **Electricity is used far more efficiently.** • Electricity efficiency will increase significantly in the coming years. • With the use of electricity for heating, mobility and in industry, the demand for electricity will increase overall. A major increase in efficiency will limit this increase to the absolute minimum.	**Strengthen incentives for efficiency:** • Implement the principle of **Efficiency First** (cf. Green Paper on Energy Efficiency). • With the increasing use of electricity for heating and mobility (**sector coupling**), maintain and strengthen incentives for electricity efficiency. • Make the energy system **more efficient *and* more flexible**.
Trend 7 **Modern CHP plants complement electricity production from renewable sources and contribute to the energy transition in the heating sector.** • From today's vantage point, CHP plants can still play an important role until about 2030 if they undergo modernisation. They must cut emissions in the electricity and heating market and respond with flexibility to the intermittent feed-in of renewable energy. • Heating networks support the modernisation of CHP plants, particularly in densely populated areas.	**Promote modern, flexible CHP systems:** • Use **heating networks** to flexibly incorporate different technologies and allow heat from CHP plants, power-to-heat, solar thermal, geothermal or waste heat into buildings, depending on the situation. • Make **municipal heating plans** standard. • Remove **barriers to flexibility** in industry.

Trends	Outcome of the discussion
Trend 8 **Biomass is used increasingly for transport and industry.** • Biomass is a universal yet scarce source of energy. • Therefore biomass is specifically used wherever it is not feasible to use solar thermal or geothermal technologies and wind and solar power.	**Use biomass where it *cannot* be substituted or can only be substituted at a high cost:** • In the **transport sector**, use biomass for air traffic, maritime transport and heavy duty traffic on the long term. • In **industry**, increasingly use biomass to decarbonise medium-temperature processes. • In the **buildings sector**, use biomass primarily in buildings that are difficult to modernise. • In the **electricity sector**, only use biomass to provide flexibility with minimum full-load hours and additional heat extraction.
Trend 9 **Well developed power grids create flexibility at a low cost.** • Power grids balance electricity generation and consumption in terms of time and over large distances in order to transport cheap wind power from north and east Germany to the south of the country, for example. • Cross-border cables connect us to our European neighbours, allowing us to tap into flexible electricity markets across Europe and safeguard our supply of electricity. • Distribution grids allow the integration of many distributed generation facilities and new consumers in the heating, transport and industry sectors.	**Expand and modernise the grids:** • With active **support for grid expansion on the part of the Federal Government, the *Länder* and municipalities, implement planned projects on time and** make use of well developed and modern **power grids as a key flexibility option** for low-cost energy supply over the long term. • Devote more attention than hitherto to discussing **measures that reduce future additional grid expansion** and, where applicable, consider such measures in grid planning.
Trend 10 **System stability is guaranteed even with a large share of renewables in the energy mix.** • Flexible generation plants, consumers and storage systems stabilise the power grids. • Renewable energy sources are increasingly responsible for the stability of the electricity system. • Critical power grid situations are managed safely and efficiently.	**Continue to develop and apply measures for system stabilisation:** • Ensure **coordination and cooperation between the transmission system and distribution system operators and market players**; on the basis of cost-benefit analyses, grid operators decide at which grid level ancillary services are provided. • Define **the responsibilities of grid operators and market players**; ensure the efficient and secure exchange of data. • Develop **smart control concepts** further so that distributed generators, storage systems and demand side management can increasingly assume system responsibility. • Increasingly coordinate system stability from a **European** perspective.

Trends	Outcome of the discussion
Trend 11 **Grid financing is fair and meets the needs of the system.** • The costs of the power grid are shared in a fair and transparent manner – both regionally and with regard to the various grid users. • The system of grid charges helps grid users to contribute to a secure and low-cost power supply system through their behaviour.	**Adapt the system of grid charges to a modern electricity system:** • **Remove barriers to the market-driven flexibility of electricity generators and consumers** without providing incentive for an inefficiently sized grid. • Given the changing demands being placed on the power grids, **gradually phase out payments for avoided grid use charges**. • Investigate the **efficient interaction between grid expansion and the expansion of renewables** by factoring in network costs in pilot projects for joint RES auctions for solar installations and onshore wind.
Trend 12 **The energy sector takes advantage of the opportunities offered by digitisation.** • The digitisation of the energy sector ensures the efficient interaction between electricity generators, consumers and the grid. • Customers benefit from new business models that can make Germany a leader in the field of smart grid and smart home technology. • As the energy sector goes increasingly digital, more and more importance is attached to data protection and data security.	**Move digitisation forward:** • Unlock the **potential that smart grids** present – as a result of the Act on the Digitisation of the Energy Transition – **for a low-cost energy supply**. • Trial new business models in **test regions** and gather **knowledge as to where changes need to be made to the legal framework** (SINTEG funding programme sponsored by the Federal Ministry for Economic Affairs and Energy). • Enable **the integration of flexible generators and consumers in the distribution grid**.

The energy transition: a three-pronged approach

Principles for the efficient use of electricity: The "Electricity 2030" discussion process focuses on the low-cost 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 three-pronged approach:

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).

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 in-creases significantly.** In line with the goals of the Federal Government, wind energy and photovoltaics see strong expansion given the enormous potential these energy sources 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 energy 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 energy 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 private producers 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.

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

CURRENT SITUATION

The current structure of surcharges, grid charges and levies hampers flexibility (Trend 1) and sector coupling (Trend 2)

BARRIER 1:
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.

BARRIER 2 :
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.

TARGET

Facilitate flexibility and sector coupling – remove barriers to low-cost energy supply.

In doing so, consider **the cost efficiency of the overall energy system,** preserve **system stability,** maintain **the financing function** and strengthen **energy efficiency.**

OPTIONS FOR ACTION

OPTION 1:
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).

OPTION 2:
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.

The two options can be combined.

Source: Own graphic

Trend 2: Sector coupling: The heating sector, cars and industry use more and more renewable electricity instead of fossil fuels[4]

- **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.

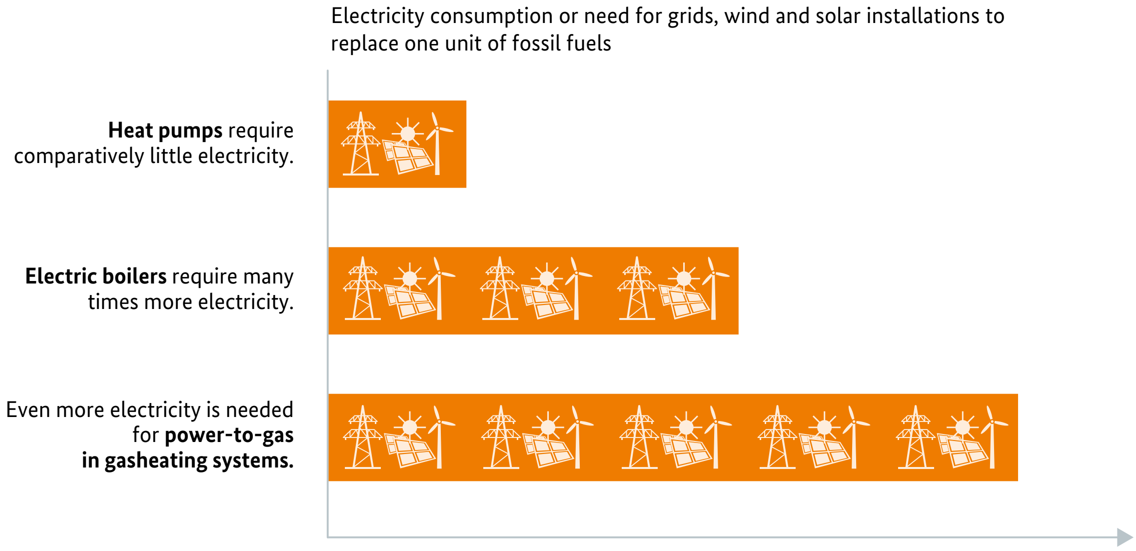
Task: Improve competitive conditions for renewable electricity compared to fuels in the heating and transport sectors

- **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 "Target model for flexibility and sector coupling" and Fig. 3 "Different burdens on electricity, gas and diesel deriving from surcharges, fees and taxes"). 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. 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 ex-change are negative should be worthwhile. 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 yet 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, so as to facilitate specific, efficient load connection when electricity prices are negative, or to enable the more efficient use of the grid. In doing so, it is important to avoid any wrong incentives that could result in the continued operation of inefficient technologies or increased emissions.

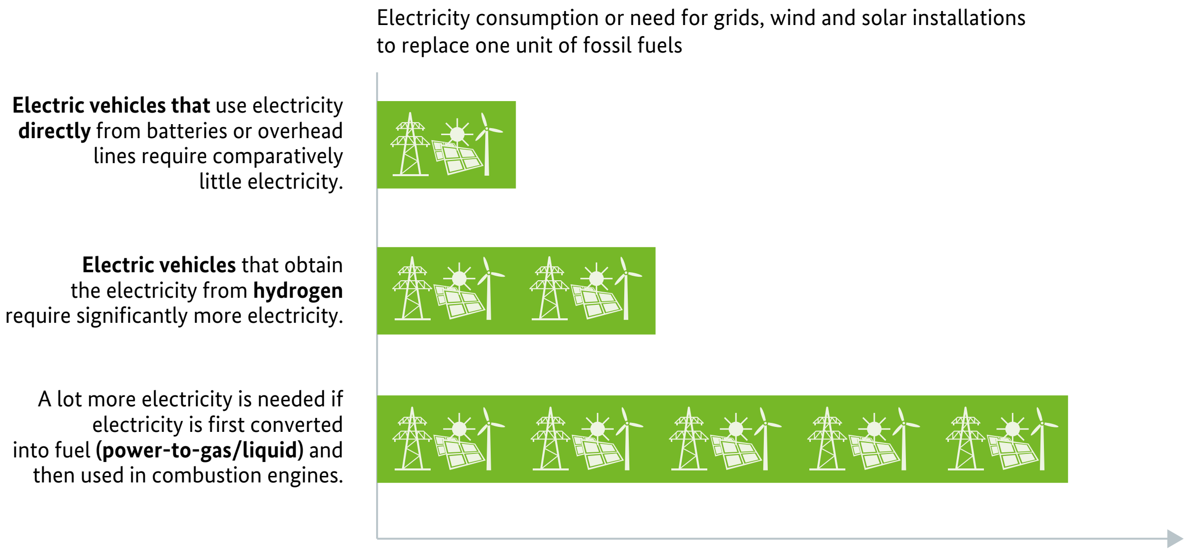
4 The trend towards sector coupling was "Trend 6" in the "Electricity 2030" discussion paper. The numbering of the trends has been changed in the concluding paper to accommodate the joint discussion on "flexibility" and "sector coupling".

Figure 2a: Electricity consumption of various technologies to replace one unit of fossil fuels in the heating supply system



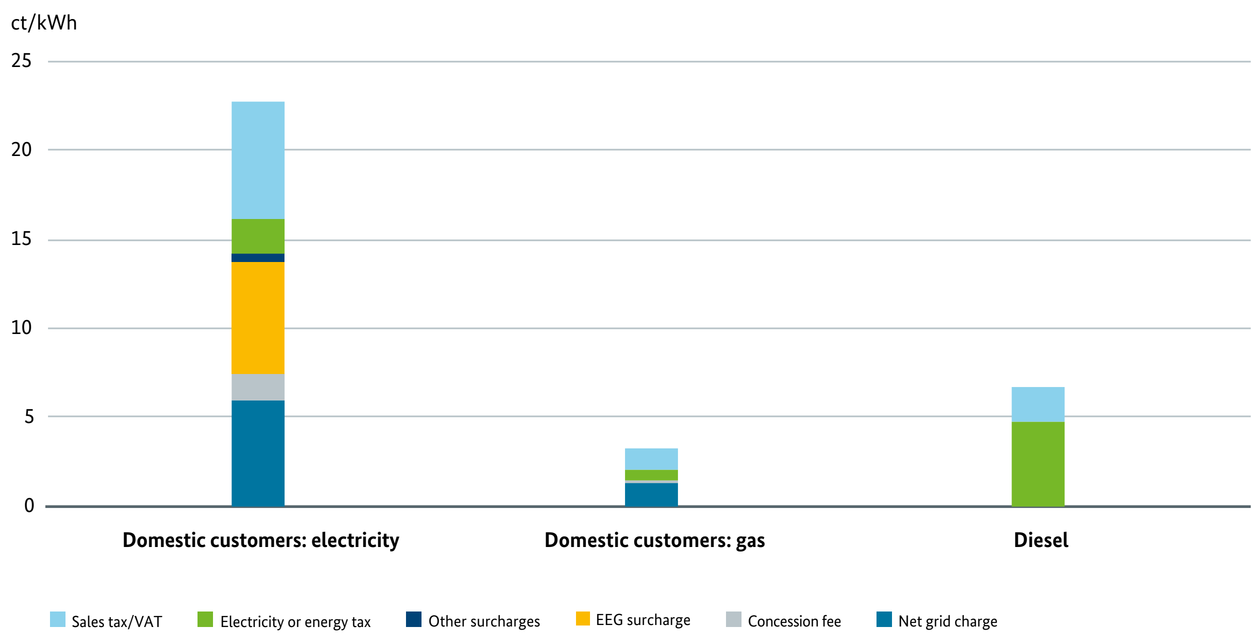
Source: Own graphic

Figure 2b: Electricity consumption of various technologies to replace one unit of fossil fuels in the transport sector



Source: Own graphic

Figure 3: Different burdens on electricity, gas and diesel deriving from surcharges, fees and taxes



The graphic illustrates the state-imposed price components, not the price components determined through competition, for final energy in 2015.

Source: Fraunhofer ISI

Outcome of the discussion on trends 1 and 2

Trends 1 and 2 were discussed together at a joint meeting of the Platform on Energy Efficiency and the Platform on the Electricity Market. The results below therefore reflect a common set of conclusions on the two trends:

- **Flexibility means real cash savings.** Wind and solar energy have tremendous potential in Germany. Costs are decreasing steadily. It is therefore logical to generate more and more electricity from wind and solar. However, wind and solar power are distinctive from other energy sources in that they depend on the weather. It is often demanded to build additional storage capacity to address this issue – without considering the consequential costs. However, conventional storage solutions are only able to store electricity for few hours and are not suited for a prolonged period without wind and sun. New technologies, such as power-to-gas, could serve as long-term-storage solutions, but are still extremely expensive due to conversion losses. Their use is sensible only with much higher shares of renewables in the electricity mix. It works out cheaper to balance supply and demand over a wide area via national and European grids. In this way, flexible generators, flexible consumers and storage solutions compete for the cheapest solution and save money for the consumers.

- **Sector coupling as a means to achieve climate targets.** A cost-efficient climate-saving policy should first of all significantly increase energy efficiency in all sectors (“efficiency first”). Then renewable energy is used directly in the respective sectors without converting it to electricity given this is reasonable from an ecologic and economic point of view (e.g. solar thermal installations in buildings or biofuels in the transport sector). To achieve the climate goals, the remaining energy demand is covered by carbon-free electricity. This is what is known as sector coupling. To limit the need for renewable installations and the grid infrastructure, the most efficient technologies possible are used.

- **The central technologies for sector coupling are also flexible consumers:** Heat can be stored and electric cars can use their battery as a buffer. Combined, these flexible consumers can quickly increase or reduce their demand by several gigawatts, and thereby respond to the variable supply of wind and solar power. The price reflects the scarcity of electricity and serves as the central coordination mechanism.

- **Complete the electricity market 2.0, create the energy market 2.0.** The technologies that are used to meet flexibility needs should be decided in a competitive setting. Barriers to competition are removed so that flexibility technologies can compete with one another. This further developed electricity market is the electricity market 2.0. To also enable competition between the technologies for sector coupling, we need an energy market 2.0 in the future.

- **From the electricity market 2.0 to the energy market 2.0 – five steps en route for more flexibility and sector coupling at a low cost:**

  1. **Improve upon the system of surcharges, fees and taxes so that price signals are as undistorted as possible.** Players decide which technology and which use of energy and technology make optimum business sense from their perspective on the basis of the price signals for electricity and fuels. To ensure that this results in a sustainable energy system at the lowest cost to the economy, distortions from price components must be removed. External costs must also be internalised, i.e. market players bear the costs that they generate. The system of surcharges, fees, taxes and carbon price signals must be further developed to this end. In this context, new exemptions from levies, surcharges and fees – such as exemptions from the EEG surcharge, for example – for certain technologies is *not* the answer, as electricity consumers would end up cross-financing the use of carbon-free electricity in other sectors.

  2. **Enable the same market access for all technologies.** A range of technologies are available for flexibility and sector coupling. If these technologies compete with one another in a fair, technology-neutral setting, the costs remain low. For this, **aggregators**, for example, are able to bundle and market the flexibility of smaller consumers. The **balancing capacity market** gradually becomes open to wind and solar power, flexible consumers and storage solutions. Grid operators increasingly procure ancillary services, such as reactive power, from renewable energy installations, flexible consumers, storage solutions or grid infrastructure components (cf. Trend 10). **Smart meters** and a **mechanism for flexibility in the distribution grid** allow smaller, controllable consumers and producers, such as electric cars, heat pumps, solar power facilities and batteries, to respond better to the prices on the exchange and in a way that serves the needs of the grid (cf. Trend 12).

Figure 4: Requirements concerning the further development of surcharges, fees and taxes

Source: Consentec, ISI, SUER, Ecofys

3. **Expand and modernise the infrastructures.** Well developed **power grids** balance fluctuations in electricity generation and consumption over large distances, connecting areas with favourable conditions for the generation of wind and solar power with consumption hubs. Distribution grids tap into technologies for flexibility by incorporating electric cars and heat pumps, for example, into the electricity system. Electric cars, in turn, require a nationwide **charging infrastructure**. A well developed **rail infrastructure** is needed if we are to shift fossil fuel-based passenger car and HGV traffic to electric rail, and electric HGVs require a **trolley wire infrastructure** on the motorways. **Heating networks** are strategically important, particularly in densely populated areas, to allow heat from CHP plants, power-to-heat (large-scale heat pumps, electric boilers), solar thermal, geothermal and waste heat into buildings (cf. Trend 7). The **gas infrastructure** will also be needed in the future. Its structure may change due to the locations of new gas-fired power stations, for example. In all likelihood, fossil gas consumption will also decrease as a result of advances in efficiency, and the share of renewable gas will increase.

4. **Bring technologies closer to the market.** Support instruments help us to explore and develop innovative technologies and demonstrate such technologies in pilot projects, and enable the first steps to be taken in the market. This applies to budget-funded **support for research and development into certain technologies**, such as batteries, power-to-gas and the use of electricity for industrial processes, but is also true of budget-funded **support for the market introduction of technologies**, such as electric mobility ("premium for car purchases") and heat pumps. The **Combined Heat and Power Act** and the promotion of biomass in the **Renewable Energy Sources Act** should provide incentive for the efficient integration of heat storage systems and power-to-heat facilities. Overall, it is important that any support should be transparent and provided through explicit programmes – and *not*

provided in a non-transparent manner in the form of privileges for surcharges, fees or taxes. The latter hamper competition among technologies and result in hidden additional costs for consumers.

5. **Develop quality standards further.** European and national quality standards for products (such as heaters), vehicles, buildings and the production and distribution of energy prevent misguided investments in inefficient technologies. They protect consumers from rising carbon and fuel prices and should therefore undergo continued development on an ongoing basis. Such standards include the European **CO_2 standards for passenger cars**, the European **Ecodesign Directive**, the **Energy Savings Ordinance** and the **Renewable Energies Heat Act**. Fuels in the transport sector are increasingly low carbon as a result of the European **Fuel Quality Directive** and the planned self-regulation to be adopted by the International Civil Aviation Organisation (**ICAO**).

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Trend 3: 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 2).

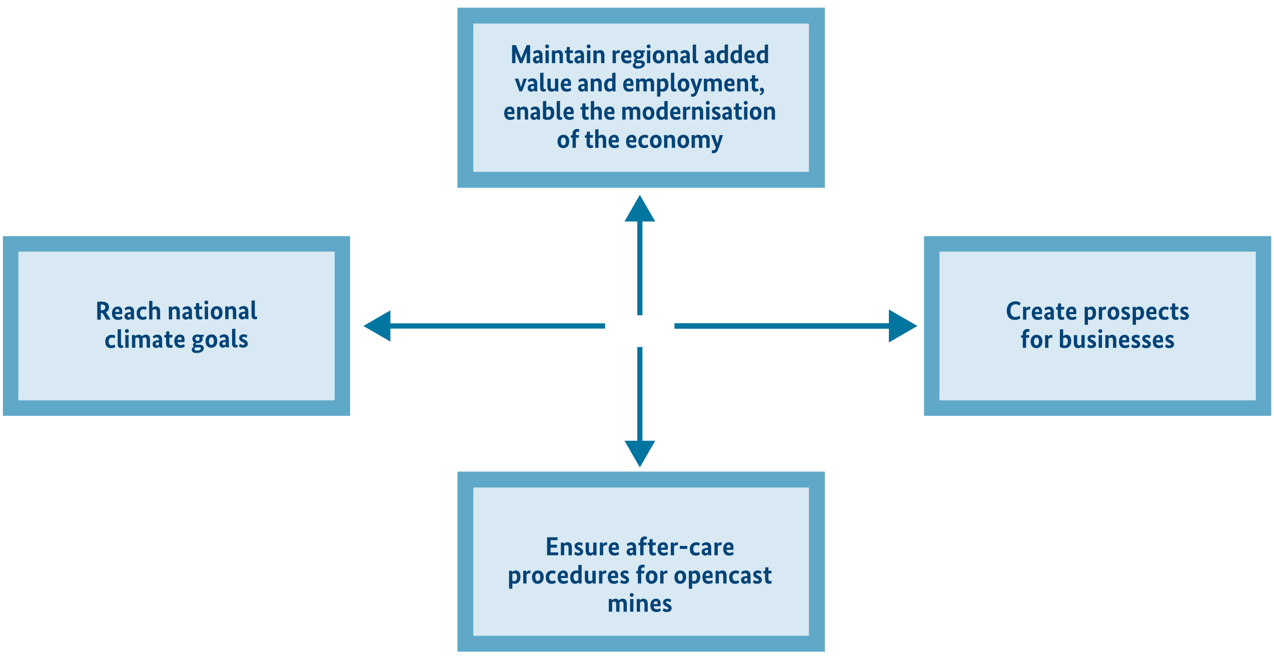
- **Investment in the coal infrastructure decreases over time.** New coal-fired power plants and extensions of existing mines with a life cycle beyond 2050 would lead to stranded investments and are therefore avoided. They are replaced by renewable energy installations, and gradually over the longer 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.

Figure 5: Requirements for a reliable framework for coal-fired power stations



Source: Own graphic

Outcome of the discussion on trend 3

The following results reflect the discussion held as part of the 2050 Climate Action Plan:

- **The Energy Concept and the 2050 Climate Action Plan define the framework of Germany's energy policy**. The energy supply system is to become more environmentally friendly, while remaining cost-effective and secure. The reorganisation of the energy supply system is guided by the goals of the Energy Concept: greenhouse gas emissions are to be reduced by 55 % by 2030, and by at least 80 – 95 % by 2050 compared to 1990 levels. The 2050 Climate Action Plan adopted on 14 November 2016 reaffirms these goals, and also defines them in more concrete terms for the energy, buildings, transport, industry and agriculture sectors. This will sometimes call for far-reaching structural change, also in the electricity sector, which is why the ambitious climate goals require effective initiatives for growth and jobs in the regions affected. This is a prerequisite for bringing about structural change on socially acceptable terms.

- **Coal-fired power stations gradually reduce their carbon emissions**. By 2030 the energy sector will cut its emissions by almost half, from 358 million tonnes of CO_2 equivalent in 2014 to 175 – 183 million tonnes of CO_2 equivalent. Coal-derived electricity will be gradually decreased to reach these goals.

- **Shape structural change**: More than anything, it is essential to mobilise investment in order to safeguard local jobs, income and prosperity in the regions. Decisions on the gradual withdrawal from the lignite industry will then need to be made on a step by step basis. The Federal Government is setting up a Commission for "Growth, Structural Change and Regional Development", which is affiliated to the Federal Ministry for Economic Affairs and Energy. In addition to other federal ministries, the Commission will also involve *Länder*, municipalities, representatives from affected businesses and sectors as well as regional stakeholders. The Commission will start work at the beginning of 2018 and will present results by the end of 2018 if possible. It is tasked with the development of an instrument mix that brings together economic development, structural change, social compatibility and climate change mitigation.

- **Flexible CHP plants will play an important role as an interim technology (cf. Trend 7)**. Over the medium-term, fossil- and renewable-based CHP plants can replace non-combined fossil-based generators in a cost-effective manner. The CHP landscape will be modernised so that the medium-term expansion of combined heat and power (CHP) generation is consistent with Germany's long-term climate goals. In particular, this will mean that CHP plants respond flexibly to the feed-in of electricity and heat derived from renewable sources. In heating networks, CHP installations are combined with renewable energy sources – such as solar thermal and geothermal installations – or heat pumps, as well as heat storage systems and electric boilers, for instance. In the end, CHP plants become modern CHP systems.

- **The ETS is Europe's central instrument for climate change mitigation**. The ETS ensures that European climate targets are met. To this end, the functioning of the emissions trading system must be improved, the overabundance of allowances reduced and the pricing signals for carbon thereby strengthened. While the ETS is not designed to specifically reduce emissions in individual countries, it can influence the use of fossil fuels in the power plant fleet through stronger price incentives and thereby help us meet our national climate targets.

Selection of current studies

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Trend 4: 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.** On 30 November 2016, the European Commission presented suggestions for the continued development of the internal market for electricity in its “Clean Energy for all Europeans” package (known as the “winter package”). 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.

Outcome of the discussion on trend 4

- **The European internal market for electricity helps deliver a secure, low-cost energy transition.** Given its size, the internal market taps the potential of several million electricity producers, consumers and storage systems. The internal market creates competition and provides incentive for innovation. It makes it possible to export electricity when an abundance of wind and solar power is produced, and to use the resources of neighbouring countries when electricity is scarce. In a nutshell, the European electricity market creates flexibility, resulting in real cash savings.

- **In particular, intraday trading u*ntil shortly before real-time* can integrate wind and solar power into the European energy system.** Electricity generated from wind and solar power depends on the weather, and its supply can fluctuate within a very short space of time. To be able to respond to these short-term fluctuations, it must be possible to trade capacities *until shortly before real-time*. In addition, capacities should be available to all market players and across national borders. Therefore – alongside day-ahead trading – intraday trading, above all, should be strengthened as a lead market, as this is where there is most competition on the supply and demand side. Improvements in other areas, such as the area of balancing energy, are also important, but should not be implemented at the expense of intraday and day-ahead trading.

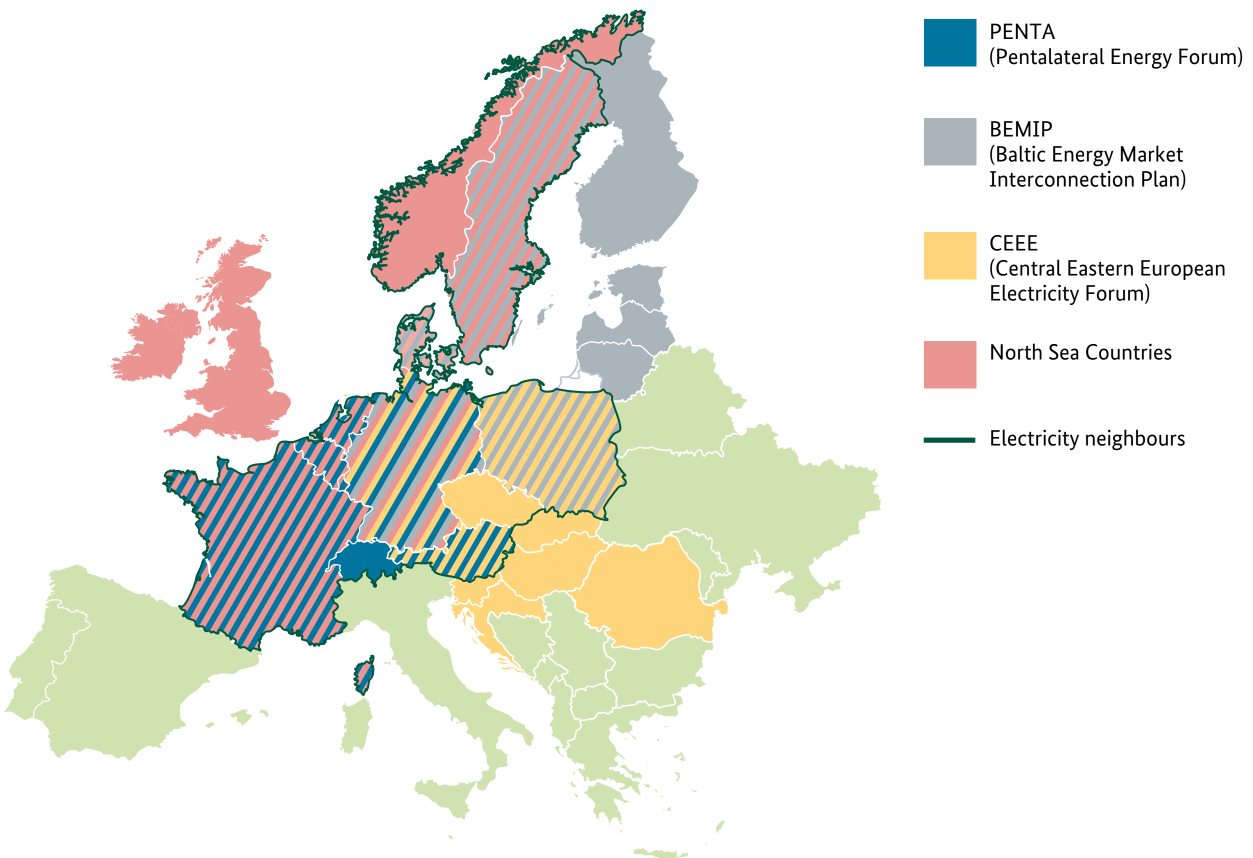
- **Additional market segments with short-term trading should be considered with caution, as they could weaken the intraday and day-ahead lead markets on a lasting basis.** Grid operators also need energy at short notice to balance congestion on the grid. Power stations on the oversupplied side of the congestion bottleneck are ramped down, while power stations on the other side of the bottleneck are ramped up. This is known as redispatch because the dispatch (deployment) of the power stations that was originally scheduled is readjusted. No price is formed on a market between multiple suppliers and consumers for redispatch measures. The power plant operators are simply reimbursed for the costs. Discussions are currently being held throughout Europe on whether these redispatch capacities should instead be procured in a market setting, i.e. power stations and other players would then offer a price for which they would be prepared to provide redispatch. Such a market for redispatch would be feasible from a technical perspective. However, it would have very distortive effects on the intraday and day-ahead lead markets, as power plants that are closer to a bottleneck have a bigger impact on the bottleneck. They could take advantage of this favourable proximity to a bottleneck in the grid and demand far higher prices than other power stations. This could significantly increase the costs of redispatch. In addition, the power stations would then strategically optimise their bidding behaviour in the electricity and redispatch market. This has been observed in other countries. Therefore a power plant's geographical location could become relevant for bidding behaviour patterns in all market segments, which could exacerbate existing grid congestion. In addition, the transmission system operators would be the only purchasers in such a market. Therefore individual submarkets with distortive effects and a single purchaser should be avoided if at all possible. Instead congestion on the grid should be remedied as quickly as possible by expanding the grid to meet demand.

- **Flexibility is a core component of future European electricity markets.** The greater the pan-European competition between different flexibility options, the lower the costs. To increase the numbers of flexible participants in the electricity markets, barriers to market access must first be removed. A 15-minute interval across Europe for balancing group account settlement is an important element in this context. This means that market players must balance and charge generation and consumption for every quarter hour. Many countries still balance and charge on an hourly basis. The shorter intervals help market players to respond precisely to the fluctuating generation of renewable energy, identify short-term demand peaks or gaps in supply and balance these via the electricity market. Further to this, *cross-border* intraday and day-ahead trading, in particular, should be improved and intraday trading should be brought closer to real-time. Here too, cross-border trading is currently only permitted up to one hour before real time and no trading takes place after this time. In addition, it is worth examining to what extent certain national specifications – for example those governing the structure of the grid charges or the management of balancing groups – complicate the cross-border exchange of flexibility.

- **Regional collaboration arrangements drive the integration of the European electricity markets forward, provided the Member States still have margin for**

manoeuvre. Not all measures for the stronger exchange of electricity can apply immediately to the whole of Europe. It can make sense to first trial solutions at a regional level, particularly if the topic addressed is new. For example, technical solutions to link national electricity markets more closely were first developed at the regional level in the Pentalateral Energy Forum. The transmission system operators of the BeNeLux countries, France, Germany, Austria and Switzerland developed approaches to strengthen the exchange of electricity in this forum, with the involvement of all stakeholder groups. Following a test phase, these will now be applied to additional regions of Europe. Many of these approaches are also included in the proposal for a new European electricity market design. This can serve as a blueprint for other regional collaborations. The Member States that work together in a regional collaboration will depend on the issue to be addressed and the parties affected. This is a key prerequisite for successful collaboration.

Figure 6: Political collaboration in the European electricity market (including observer status)



Source: Own graphic

Selection of current studies

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Trend 5: 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 should 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.

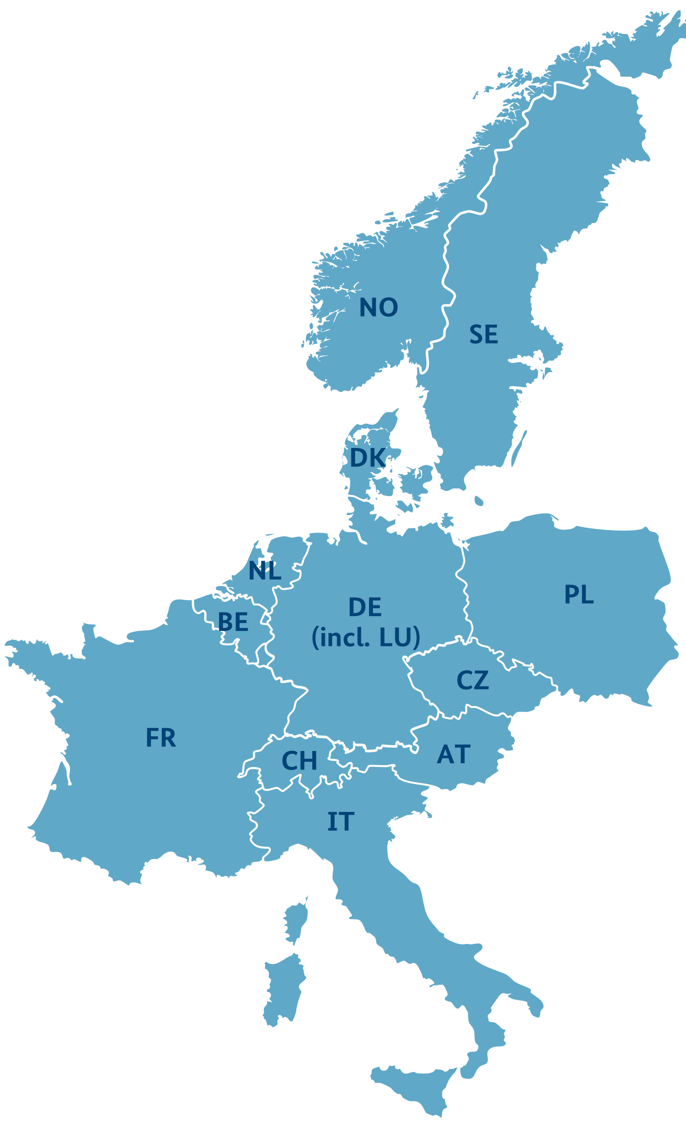
- **Guarantee security of supply with common instruments.** If an analysis from a European dimension reveals the need for additional measures, such measures could, potentially, be implemented where they are really needed or where they work best and are cost-effective. Measures such as reserves can be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

Outcome of the discussion on trend 5

- **Security of supply should be consistently considered in a European context.** A sound assessment of the security of supply in the electricity markets can only be made from a cross-border perspective in the European internal market for electricity, as the individual electricity market areas are interconnected by cross-border lines known as interconnectors. Approaches from a purely national perspective are no longer practical, as they no longer reflect the reality of a European internal market in which no one party can "keep" electricity just for themselves. Further to this, a regional approach also makes it possible to avoid overcapacity and therefore unnecessary costs for the consumer.

- **It is important to conduct a "state of the art" analysis of the security of supply.** We have made tremendous progress in the assessment of security of supply in the electricity markets in recent years. The 2015 Regional Generation Adequacy Assessment conducted on behalf of the Pentalateral Energy Forum 2015 (Pentalateral Energy Forum 2015) and another study, also from 2015, conducted by companies Consentec and r2b energy consulting on behalf of the Federal Ministry for Economic Affairs and Energy (Consentec, r2b 2015) take a probabilistic and cross-border approach for the first time. Here, "probabilistic" means a risk analysis based on probabilistic modelling with an hourly resolution. This approach

Figure 7: Relevant geographical scope for security of supply in the electricity market



Source: Consentec, r2b (2015)

should be continued on a systematic basis. When developing the complex methods further, it is important to consider the level of effort required in relation to the additional benefits achieved.

- **Defining a goal for security of supply is a central, yet complex, task.** Ultimately, the players in the electricity market determine the desired level of supply security. Consumers set the price they are prepared to pay to cover their demand and producers the price for which they want to offer their production of electricity. To be able to assess security of supply and identify necessary measures, if applicable, we need a "target" level of supply security which the actual security of supply can be measured against. German energy policy aims at a high level of security of supply, as could be guaranteed in the past. Identifying this optimum level of supply security for the economy is a challenging undertaking. For example, one needs to assess how many different groups of consumers would be prepared to pay for the supply of electricity, or estimate the costs of building new electricity production facilities. It is up to each Member State to specify their target security of supply level. A harmonised target level of security of supply across Europe would appear to make little sense.

- **Security of supply naturally also considers the grid situation and therefore actual capacity availability.** This trend in the "Electricity 2030" discussion paper deals with security of supply in the electricity markets, i.e. with the question of whether electricity supply matches electricity demand in the market at all times. However, for a full assessment of the security of supply, a host of other issues need to be considered, such as whether the lines can actually transport the electricity required. The technical challenges – security of supply in the electricity markets and the grid situation – are considered and resolved separately: when assessing the security of supply in the electricity markets, the assumption is that the power grids within the countries are free from restrictions. At the same time, existing interconnector capacities limit electricity trading between the countries. Grid restrictions in the countries are addressed separately. In Germany, for example, they are currently addressed by the grid reserve, inter alia.

Selection of current studies

Consentec, r2b (2015): System Adequacy for Germany and its Neighbouring Countries: Transnational Monitoring and Assessment; Consentec GmbH, r2b energy consulting commissioned by 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, available at: https://www.bmwi.de

Pentalateral Energy Forum (2015): Generation Adequacy Assessment; Pentalateral Energy Forum, Support Group 2

Trend 6: Electricity is used far more efficiently[5]

- **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.

5 The content of this trend has been discussed within the framework of the Green Paper on Energy Efficiency and the Platform on Energy Efficiency.

Outcome of the discussion on trend 6

- **Energy efficiency is central to the success of the energy transition.** The principle of "Efficiency First" applies: according to this principle, an energy system that is cost-effectively designed and sized consistently takes the potential for energy savings and the requirements of consumers into consideration. In this context, "Efficiency First" does *not* mean technical energy efficiency at any cost. Rather it means reducing our energy consumption – wherever economically viable – by investing in efficiency technologies first of all, and thereby helping to minimise the costs of the energy system.

- **The guiding principle of "Efficiency First" can be implemented in a variety of ways.** Here, it is important to consider the entire energy chain, from generation and distribution to the final use of energy. Incentives for the efficient use of energy are primarily found wherever a corresponding price signal influences such use. Stakeholders' opinions as to how "Efficiency First" can be implemented in the various areas of energy policy are presented in the Evaluation Report on the Consultation of the Green Paper on Energy Efficiency.[6]

- **With the growing use of electricity in the heating and transport sectors (sector coupling), incentives for electricity efficiency must be maintained and strengthened.** Sector coupling gives rise to new electricity consumers. For public acceptance of the energy transition, it is important to have framework conditions that are designed to keep this electricity consumption at an economically, ecologically and socially sustainable level (cf. Trend 2).

- **The energy system must become more efficient *and* more flexible.** The framework conditions for efficiency and flexibility should be developed together. The aim is for them to complement one another in a way that minimises the total costs of the energy system. Flexibility and electricity efficiency cannot always be implemented simultaneously, however. The degree of interaction between these two requirements – efficiency and flexibility – depends on the specific applications. This is also why a proper evaluation – where energy efficiency is weighed up against the provision of flexibility – can only be performed by the electricity users themselves in the various sectors. As a result of price incentives and the removal of regulatory barriers, the aim is to allow electricity consumers to reach decisions that are optimum for the system in the various applications.

Selection of current studies

Fraunhofer ISI, Consentec et al. (2017): Long-term Scenarios for the Transformation of the Energy System in Germany; Fraunhofer Institute for Systems and Innovation Research, Consentec GmbH, Institute for Energy and Environmental Research Heidelberg GmbH on behalf of the Federal Ministry for Economic Affairs and Energy (publication expected in the second quarter of 2017)

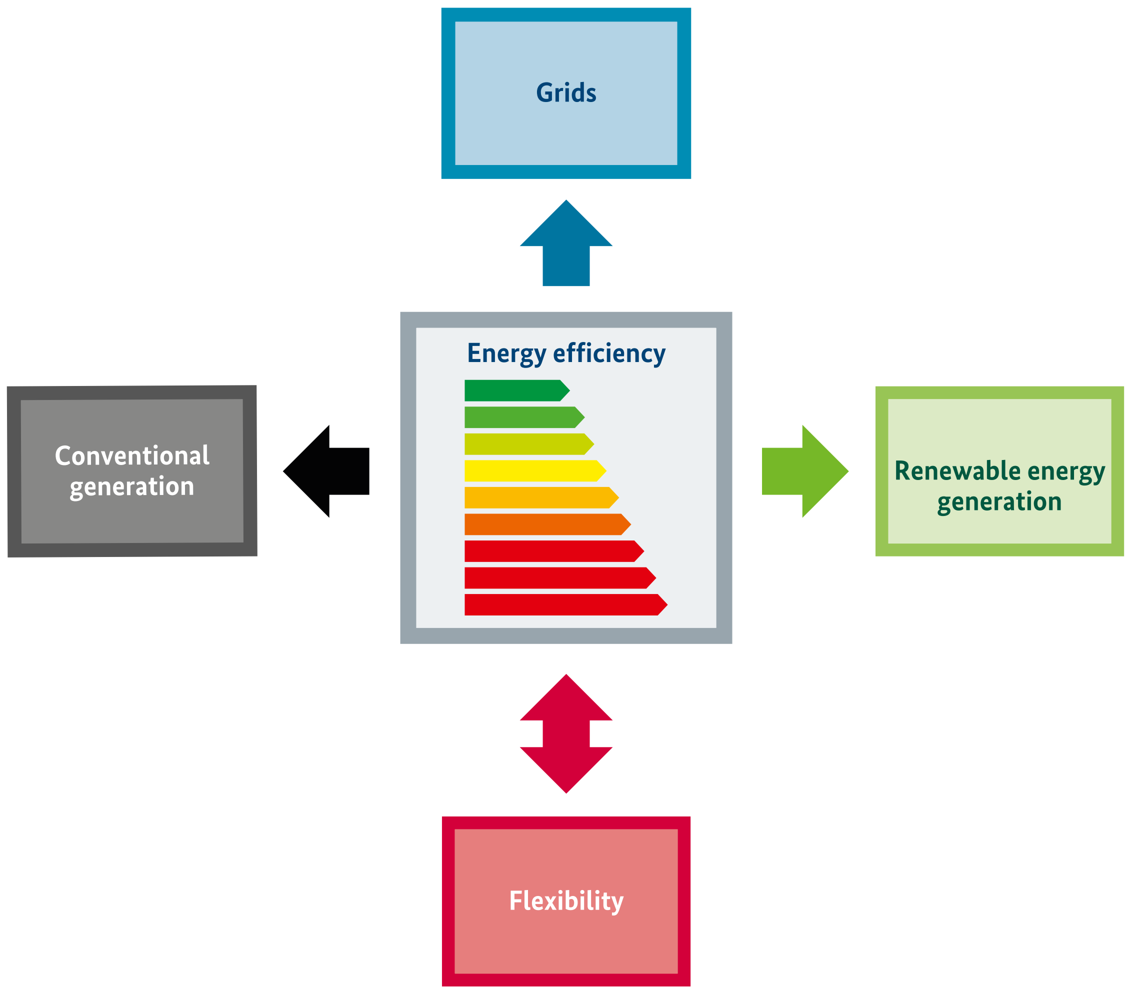
Ecofys (2016): Flex-Efficiency. A Strategy for the Integration of Efficiency and Flexibility among Industrial Consumers; Ecofys on behalf of Agora Energiewende

Federal Ministry for Economic Affairs and Energy (2015): Energy of the Future: Fourth Monitoring Report on the Energy Transition; Federal Ministry for Economic Affairs and Energy

Fraunhofer IWES et al. (2015): Interaction of Renewable Electricity, Heating and the Transport Sector; Fraunhofer Institute for Wind Energy and Energy System Technology, Fraunhofer Institute for Building Physics, Institute for Energy and Environmental Research Heidelberg, Foundation for Environmental Energy Law on behalf of the Federal Ministry for Economic Affairs and Energy

6 available at http://www.bmwi.de

Figure 8: The role of electricity efficiency in the electricity supply



Source: Own graphic

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 2). 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 Combined Heat and Power Act 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.

Outcome of the discussion on trend 7

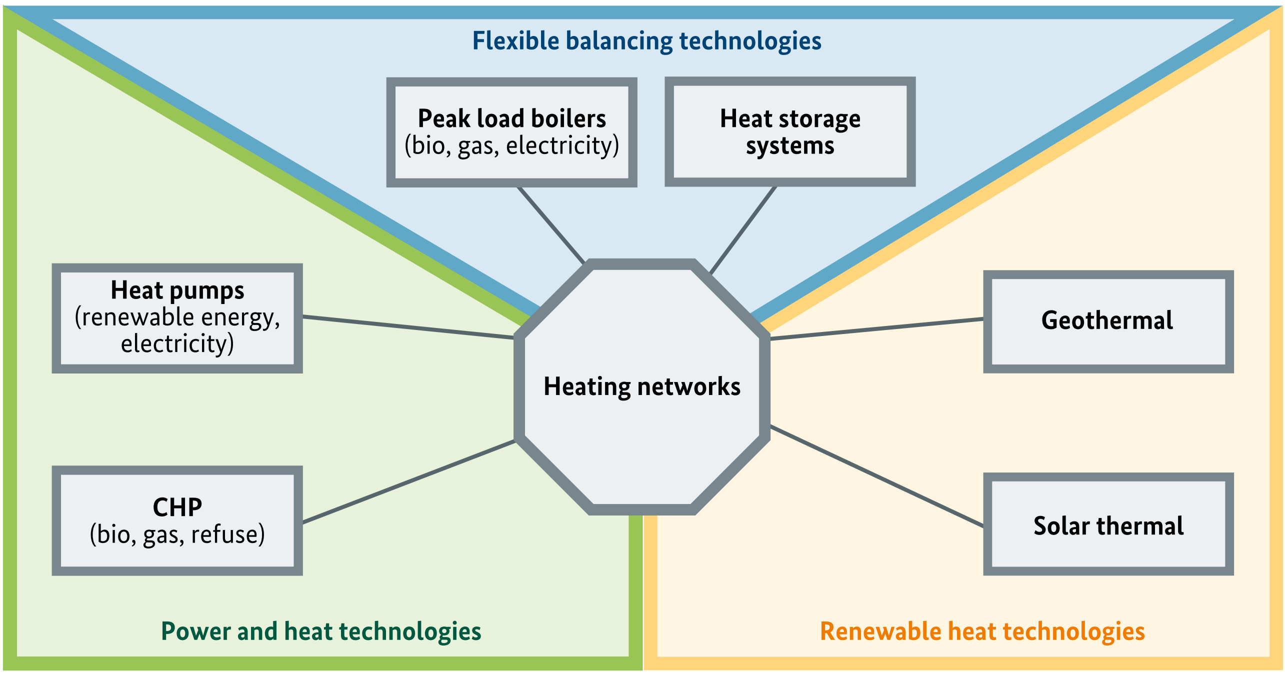
- **Heating networks are strategically important.** Heating networks offer many advantages. For one, they provide a central supply of heat to many buildings. Secondly, they can integrate different technologies, such as CHP plants, solar thermal, geothermal or heat pumps, and connect them to large-scale heat storage systems. This allows heating network operators to respond flexibly to unexpected developments, which is why heating networks are also referred to as “change enablers”.

- **Depending on the situation and geographical location, either heating networks or distributed producers are responsible for the supply of heating.** There is a clear tendency, however: in density populated areas, heating networks should be primarily responsible for the heating supply. Their role changes in this context: instead of “just” distributing heat over large areas, in future they will collect heat from various sources and distribute this heat to consumers – often at lower temperatures than today.

- **Fuel-powered CHP plants can still play an important role in the energy system for many years to come if they are modernised.** This applies to CHP plants that run on fossil fuels *and* renewable fuels, as the CHP plants will largely replace non-combined fossil generation in the coming years and thereby help cut CO_2 emissions.

- **From the present perspective, the importance of fuel-powered CHP plants will decline gradually after around 2030.** By 2050 there will hardly be any need to use fossil fuels for electricity and heat thanks to advances made in renewable energy and energy efficiency. For combined heat and power generation (CHP) this means that at the upper end of the climate goals, fuel-powered CHP plants will only have a future if they use *renewable* fuels. However, the use of renewable fuels is also limited, as – on the long term – the fuels themselves are only available in limited quantities or are expensive. Therefore, on the long term renewable fuels will primarily be used in areas where it is difficult to reduce greenhouse gas emissions with other renewable energy sources, such as the aviation sector, shipping or in the hard-to-insulate building stock. Therefore CHP support must give due consideration to competition for the use of renewable fuels across the various sectors.

Figure 9: Modern power and heat system based on heating network (schematic representation)



Source: Own graphic

- **There are indications that different technologies will dominate in some areas of industry and in the public supply system in the future.** Many industrial processes need very high temperatures, which only a few technologies can provide. This is why, above all, power-to-heat installations are likely to play an important role in industry in the medium to long term, in addition to CHP plants. On the other hand, in many cases it is possible to supply space heating and warm water to residential buildings with heat at lower temperatures than today. Therefore solar thermal, geothermal and waste heat can be responsible for a significant percentage of the heating supply in the public supply system.

- **To enable the desired development in the CHP landscape, the framework for CHP needs to be refocused.** Among other things, decisions concerning a key infrastructure like heating networks should be reached early on. To this end, we should already start identifying the local potential of renewable energy that could feed into heating networks. In addition, municipal heating plans should become standard to give municipal stakeholders more assistance in decision-making. In the industry sector, we should remove barriers to flexibility that prevent businesses from being affected by the electricity price signal. At the same time, businesses should have the opportunity to make more use of flexibility options.

Selection of current studies

Fraunhofer ISI, Consentec et al. (2017): Long-term Scenarios for the Transformation of the Energy System in Germany; Fraunhofer Institute for Systems and Innovation Research, Consentec GmbH, Institute for Energy and Environmental Research Heidelberg GmbH on behalf of the Federal Ministry for Economic Affairs and Energy (publication expected in the second quarter of 2017)

Fraunhofer IWES et al. (2015): Interaction of Renewable Electricity, Heating and the Transport Sector; Fraunhofer Institute for Wind Energy and Energy System Technology, Fraunhofer Institute for Building Physics, Institute for Energy and Environmental Research Heidelberg, Foundation for Environmental Energy Law on behalf of the Federal Ministry for Economic Affairs and Energy

Öko-Institut (2015): Method Paper to Assess CHP Plants from a Medium-term Perspective through to 2030; Öko-Institut on behalf of the Federal Ministry for Economic Affairs and Energy

Prognos et al. (2014): Potential and Cost-Benefit Analysis of the Possible Uses of Cogeneration (Implementation of the EU Energy Efficiency Directive) and Evaluation of the CHP Act in 2014; Fraunhofer Institute for Manufacturing Technology and Advanced Materials; Institute for Resource Efficiency and Energy Strategies, BHKW-Consult, Prognos AG on behalf of the Federal Ministry for Economic Affairs and Energy

Fraunhofer ISE et al. (2013): Development of an Integrated Heating and Cooling Strategy (Phase 2) – Target Systems for the Building Sector in 2050; Fraunhofer Institute for Solar Energy Systems, Fraunhofer Institute for Systems and Innovation Research, Fraunhofer Institute for Manufacturing Technology and Advanced Materials, Öko-Institut, TU Vienna on behalf of the Federal Ministry for the Environment, Nature Conservation, Building and Nuclear Safety

Ifeu et al. (2013): Strategies to Transform Fossil-based Central District Heating Systems to Networks with a Higher Share of Renewable Energy; Institute for Energy and Environmental Research Heidelberg, GEF Ingenieur AG, AGFW 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 carbon capture and storage (CCS) and carbon capture and utilization (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 in such a way that biomass is used on the long term wherever there are no cheaper alternatives 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.

Outcome of the discussion on trend 8

- **Bioenergy currently covers around one tenth of Germany's primary energy consumption. From today's vantage point, it can potentially increase its share to up to one quarter with primary energy consumption declining simultaneously.** This calls for the optimised use of residual and waste matter for energy purposes, increased yield per unit area of cultivated biomass, and increased sustainable imports to a certain extent. Some studies do not include the use of energy crops for energy purposes and the import of bioenergy. This reduces the potential of biomass for energy purposes to the potential for residual and waste matter. Most studies, however, assume a moderate share of energy crops and imports of bioenergy.

- **The available, sustainable potential of using biomass as an energy source in Germany is limited.** This potential comprises 1) **residual and waste material** generated in Germany, 2) the **domestic cultivation of energy crops** and 3) the **import of bioenergy sources** such as biofuels:

    1. **Residual and waste material account for a large percentage of the potential of biomass for energy purposes.** This potential can be determined comparatively well, and amounts to between 700 and 1000 petajoules a year in Germany according to most studies. Around two-thirds are already being used as a material or as an energy source.

    2. **The domestic cultivation of energy crops can only be increased to a limited extent.** Given the competition between the production of foodstuffs and the use of crops as a material, agricultural land for the cultivation of energy crops should not increase significantly any further. Today, roughly 2.2 million hectares of agricultural land in Germany is given over to the cultivation of energy crops. This is equivalent to more than 20 % of total arable land. Sustainability requirements must be met if land is used for the cultivation of energy crops. In this way, biomass actually contributes to climate mitigation. In addition, on the long term priority should be given to growing crops with a high biomass yield, such as fast-growing types of wood.

    3. **Imports of bioenergy sources should only increase to a limited extent and under clear, transparent conditions.** Biofuels or their feedstocks, such as vegetable oil and bioalcohol, account for the highest percentage of imported bioenergy sources. In this context, imports of bioenergy, particularly from the European Union, meet transparent sustainability requirements. By contrast, there is ongoing controversy on whether imports from a number of other countries are actually sustainable. This depends on the conditions for cultivation in these particular countries. In addition, direct and indirect changes to land use can impact sustainability. For example, the clearing of rain forest for the cultivation of palm oil gives cause for particular concern.

- **The production of food crops and use as a material have priority over use as an energy source.** Therefore the use of biomass for energy purposes should ideally take place at the end of the material use chain, e.g. *after* use in a chipboard panel or as a building material.

- **The higher the costs of preventing greenhouse gases the more valuable biomass will become.** It therefore follows that global demand for bioenergy will increase significantly on the long term, and can exceed the available sustainable potential of biomass several times over. To keep the costs of the energy transition to a minimum, it is therefore crucial to ensure efficient allocation to the various sectors. The central objective here is to keep the overall costs of the energy system down. Alongside this, there is, however, also the view that the economic costs of the maintenance of rural areas should also be considered in the context of bioenergy.

- **To keep the costs of the energy transition down, the limited potential of biomass should be employed wherever biomass cannot be replaced or can only be replaced at a high cost.** Following this approach, studies analysed how biomass can be put to optimum use in the individual sectors, based on the current state of knowledge.

    – **In the transport sector, biomass should be used on the long term in aviation, shipping and heavy-duty traffic**, as no cheap alternatives to biofuels will be available in these areas in the foreseeable future.

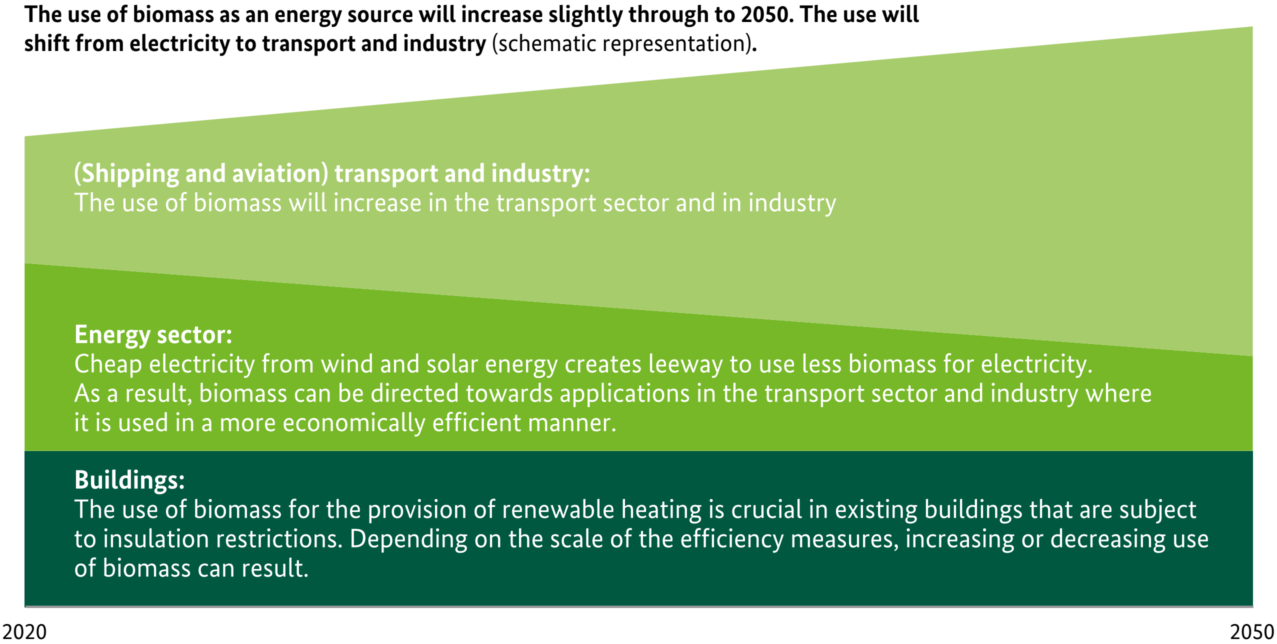
Other renewable fuels, such as power-to-X, require a comparatively large amount of renewable electricity. In addition, they are considerably more expensive from today's perspective. If the costs of preventing CO_2 emissions are very high, it may be necessary to fall back on other technologies, such as power-to-X, for instance. First generation biofuels can help climate change mitigation in the transport sector in the interim. In future, however, the priority should be to develop and promote second generation and third generation biofuels. These biofuels tap into a broad biomass base and their efficiency per unit area is high.

- **In industry, biomass should increasingly reduce the CO_2 emissions of processes with temperatures of over 100 to 500 °C on the long term.** Such processes are common in the chemical, pulp or food industry for example. As with the transport sector, no cheap renewable alternatives are currently available for these processes. Process heat and process steam should then be generated using combined heat and power technology wherever possible. A high fuel efficiency rate can be achieved in this way. Priority should be given to the use of biomass as a material, such as in the construction or chemical industry, as large amounts of CO_2 emissions can also be cut in these areas. In addition, the biomass can always be used for energy purposes after it has been used as a material.

- **In the buildings sector, biomass should primarily be used in buildings that are difficult to modernise.** Looking at the system as a whole, biomass can often be replaced by other renewable energy sources more cost-effectively in the buildings sector than in other sectors. This requires high-efficiency buildings and heat derived from renewable sources. For the grid-bound building heat supply system, biomass can facilitate the transformation of existing heating networks. Ideally high-efficiency and innovative CHP plants should be used here. CHP plants are innovative in conjunction with other renewable energy sources and heat storage systems, for example, if

Figure 10: The use of biomass as an energy source

The use of biomass as an energy source will increase slightly through to 2050. The use will shift from electricity to transport and industry (schematic representation)**.**



Source: Own graphic

they achieve a particularly high fuel efficiency rate and also offer additional flexibility for the electricity market.

– **In the electricity sector, biomass should only be used to provide flexibility with minimum full-load hours and additional heat extraction.** Electricity derived from wind and photovoltaics is cheaper than electricity from biomass. On the other hand, biomass power plants can generate electricity flexibly. However, other technologies, such as pumped storage and flexible consumers, can offer flexibility at a lower cost. Therefore it is still unclear to what extent biomass power plants will provide flexibility in future while competing with other flexibility options. Potentially, biomass power plants could, however, play a bigger role in providing seasonal flexibility.

- **The energy transition is a dynamic process, and technological progress its constant companion.** Given that biomass can basically be used universally as a material and for energy purposes, it is of strategic importance to the energy transition. New policy measures should therefore consider the biomass trends currently identified. Nevertheless, further research is needed in order to identify path dependencies in the future use of biomass.

Selection of current studies

Fraunhofer ISI, Consentec et al. (2017): Long-term Scenarios for the Transformation of the Energy System in Germany; Fraunhofer Institute for Systems and Innovation Research, Consentec GmbH, Institute for Energy and Environmental Research Heidelberg GmbH on behalf of the Federal Ministry for Economic Affairs and Energy (publication expected in the second quarter of 2017)

Fraunhofer IWES et al. (2015): Interaction of Renewable Electricity, Heating and the Transport Sector; Fraunhofer Institute for Wind Energy and Energy System Technology, Fraunhofer Institute for Building Physics, Institute for Energy and Environmental Research Heidelberg, Foundation for Environmental Energy Law on behalf of the Federal Ministry for Economic Affairs and Energy

Öko-Institut, Fraunhofer ISI (2015): Climate Protection Scenario 2050; Öko-Institut e.V., Fraunhofer Institute for Systems and Innovation Research on behalf of the Federal Ministry for the Environment, Nature Conservation, Building and Nuclear Safety

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 capitalise on 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 % of the capacity installed in renewable energy installations are connected to distribution grids. These grids account for roughly 98 % 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 the success of the transition of the energy system to one based on renewable energy.

Task: Expand the grid in a timely, needs-based and cost-effective 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 approved by law will be implemented in the transmission system 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.

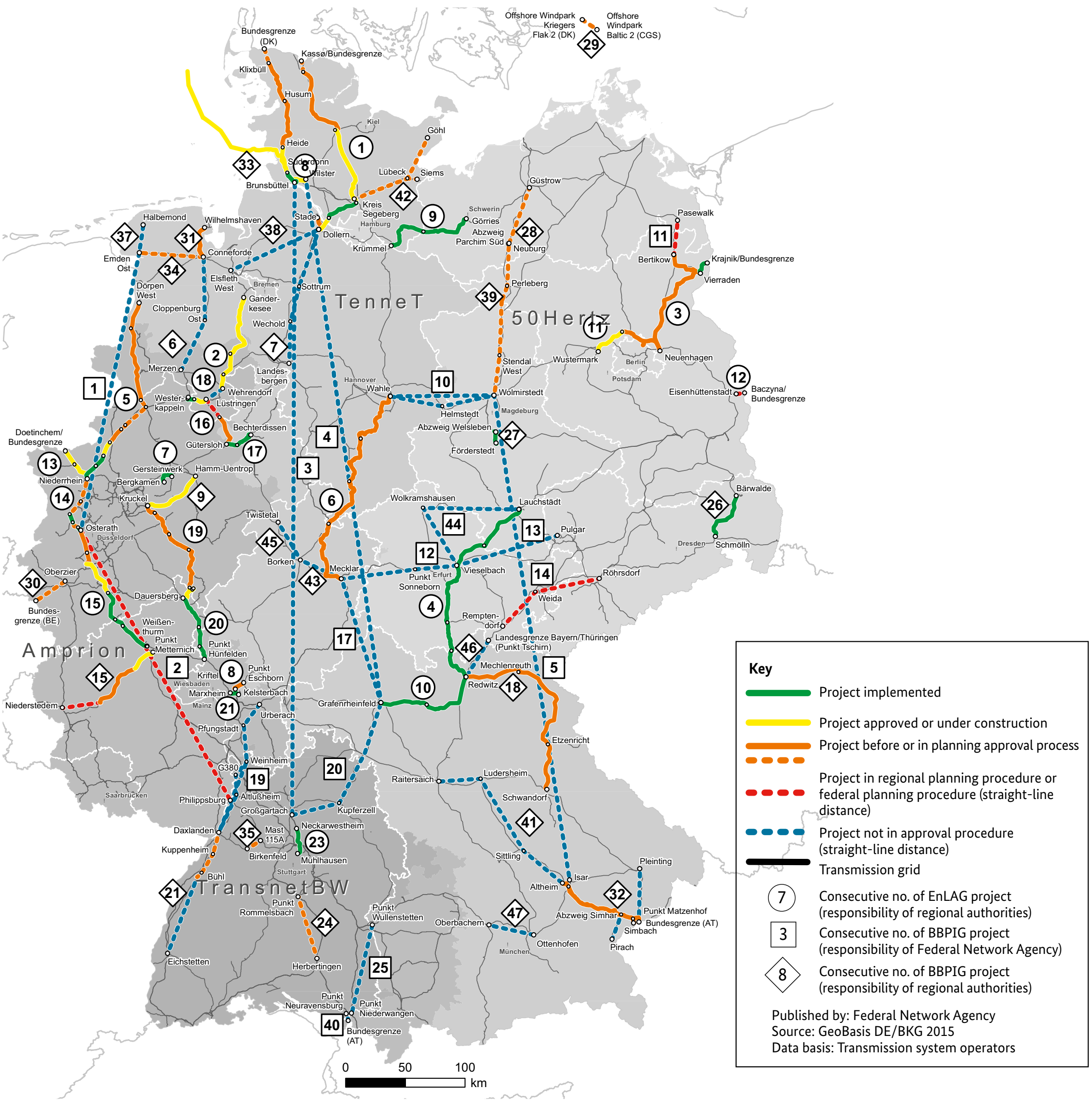
- **In the grid development plan, identify additional grid expansion projects beyond the current projects adopted through to 2030 and discuss these with the public.** Bringing the energy transition to fruition in a cost-efficient manner will likely require additional expansion of the transmission system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

- **Make the distribution grids ready for the challenges of the future.** With the reform of regulations governing incentives, the framework for ensuring that the distribution grids can reliably and innovatively perform their central role in the energy supply system will be created by the end of this legislative term. The framework conditions for decisions concerning grid expansion must also 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 also help to resolve problems.

Outcome of the discussion on trend 9

- **Grid expansion, which has been approved by law, enjoys broad support overall, despite local protests.** Well developed grids synchronise generation and consumption and eliminate bottlenecks for the transportation of electricity. Over the long term, other technologies will follow and act as an important support in balancing supply and demand. New storage technologies that would be able to store electricity for several days are very expensive and will only make sense when there is a far higher percentage of renewable energy in the electricity mix. In view of this, storage solutions cannot act as a substitute for the agreed grid expansion projects. Power grids and storage systems perform different functions in the energy system. While storage systems also offer the technology to flexibilise the power system, like all the other flexibility options they must hold their own in a competitive environment. Only a few stakeholders are critical of the planned grid expansion: in their opinion, the congestion in the grid is the result of simultaneous feed-in from conventional electricity producers rather than high feed-in levels of renewable energy.

Figure 11: Grid expansion projects according to the Power Grid Expansion Act (EnLAG) and the Federal Requirements Plan Act (BBPIG)



Source: Federal Network Agency

- **All participating stakeholders must pull together to ensure the on-schedule completion of the agreed grid expansion projects.** Swift grid expansion enables the continued supply of secure, low-cost electricity and is therefore of central importance for both the economy and the public. The Federal Government, the *Länder*, municipalities and policy-makers must be proactive in supporting grid expansion. Project developers and approval authorities should be appropriately staffed to ensure transparency in the planning and approval processes and seek early dialog with the public. An appropriate compensation framework, ideally standardised nationwide, also supports the swift expansion of the agreed grid expansion projects. Furthermore, additional measures that increase acceptance for grid expansion should be examined.

- **Approval authorities and project developers should draw more heavily on ways to simplify and accelerate planning and approval processes.** In planning and approval processes, it is necessary to concentrate on the individual examination steps that are required in the specific process, and to implement the processes rigorously. Duplicate inspections, for example, can be avoided in this way. Greater use should also already be made of simplification elements that are permitted by law. Professional process management is only possible, however, if approval authorities have adequate material and human resources.

- **There is a need to clarify additional grid expansion needs beyond the projects that have already been approved by law.** Further progress in the energy transition will likely require further expansion of the power grids. Additional grid expansion needs are identified as part of the grid development plan and discussed with the public. This will consider the development of the energy system in various scenarios.

- **Limiting the need for future grid expansion requires more attention to alternatives in grid planning and the energy policy debate.** The premise is still to limit future grid expansion in line with the "NOVA" principle, which prioritises grid optimisation ahead of grid reinforcement ahead of grid expansion. The efficient use of grid capacities at all levels is ensured with the optimisation and reinforcement of the grid. In any event, measures that prevent additional grid expansion should be discussed more than they have thus far, and be considered in grid planning where applicable. This applies both to grid-specific alternatives (such as DC transmission or system control) and to measures to limit supra-regional electricity transportation, such as the further development of congestion management.

- **Not least, the energy transition also requires the expansion of the distribution grids.** Smart equipment as well as measures for optimised system control can reduce the need to expand the distribution grids (< 220 kV). Innovative grid technologies ensure the best possible utilisation of the grid infrastructure at the distribution grid level. A key step towards improving investment conditions for distribution system operators was taken with the recent amendment to the incentive regulation.

Selection of current studies

Fraunhofer ISI, Consentec et al. (2017): Long-term Scenarios for the Transformation of the Energy System in Germany; Fraunhofer Institute for Systems and Innovation Research, Consentec GmbH, Institute for Energy and Environmental Research Heidelberg GmbH on behalf of the Federal Ministry for Economic Affairs and Energy (publication expected in the second quarter of 2017)

ENTSO-E (2016): Ten-Year Network Development Plan 2016

TSOs (2016): Scenario Framework for Grid Development Plans 2030; 50Hertz, Amprion, TenneT, TransnetBW

Federal Network Agency (2015): Grid Development Plan 2024

E-Bridge et al. (2014): Modern Distribution Grids for Germany (Distribution Grid Study); E-Bridge Consulting GmbH, Institute for Electrical Installations and the Energy Sector, Institute for Information Technology Oldenburg on behalf of the Federal Ministry for Economic Affairs and Energy

e-Highway2050 (o. J.): Modular Development Plan of the Pan-European Transmission System 2050

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-effective 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 system operators, distribution grid operators and 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 TSOs and distribution grid 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.

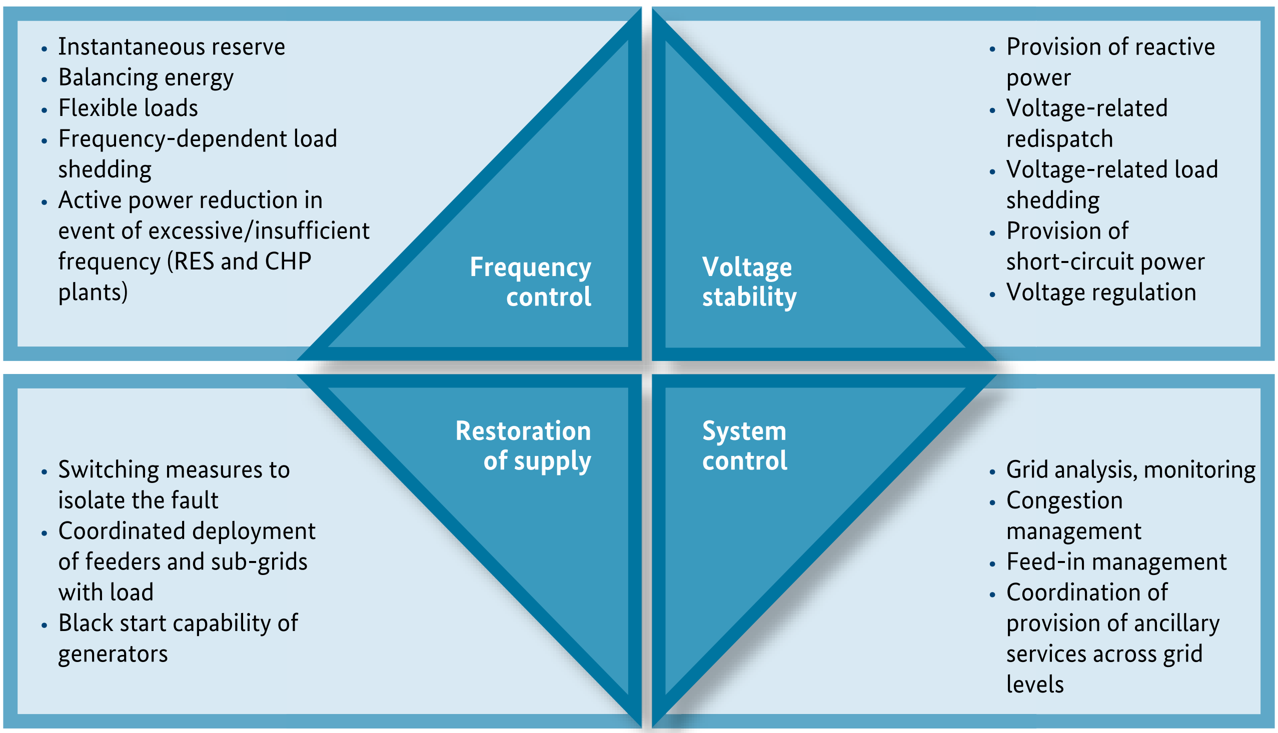
Outcome of the discussion on trend 10

- **With regard to the electricity system overall, ancillary services will be provided in a technically and economically efficient manner in the future.** The development of efficient solutions for the operation of the power grids increasingly calls for intensive coordination and collaboration among the transmission system operators, distribution system operators and market players. The grid operators should decide which ancillary services need to be provided at the various grid levels on the basis of a common cost/benefit analysis, as also defined in the European network code.

- **The responsibilities of the grid operators and market players are clearly defined.** The number of distributed consumers and generators whose behaviour patterns need to be coordinated across the various grid levels will increase steadily through to 2030. Therefore suitable interfaces are defined between the transmission system and distribution system operators and the market players to ensure they can communicate and exchange data efficiently. The responsibilities also need to be clearly defined and agreed by all parties involved. The necessary processes and the energy information network between grid operators and connected facilities will be improved upon accordingly. Data should be captured, processed and distributed as efficiently as possible, while taking data protection and data security requirements into account.

- **Distributed generation facilities and flexibilities become increasingly important.** Therefore, distributed players – renewable energy facilities, CHP plants, storage systems and demand side management – must increasingly assume system responsibility, provide ancillary services and help stabilise and relieve the strain on the power grids. If these distributed facilities are to be used efficiently and critical regional grid situations managed, this will require smart local control solutions, inter alia. Smart control strategies and concepts therefore need to be developed further.

Figure 12: Ancillary services for stable power grid operation in 2030



Source: Modelled after dena (2014a)

- **Requirements with regard to the technical characteristics of installations will undergo continuous further development.** Under the provisions of the Energy Industry Act, the industry develops the set of technical rules. This has proved successful and should be maintained. The European Network Codes are interpreted in Germany such that stable system operation is constantly guaranteed and implementation is as cost-effective as possible. Economic criteria should be applied to this end and the characteristics of the individual installations considered. In addition, local particularities in the grid regions (such as the power plant and consumption structure or differences in the grid landscape) should be taken into consideration when formulating the requirements. Furthermore, all alternatives should be examined in terms of their pros and cons and their technical and economic characteristics. This will also involve defining to what extent ancillary services are procured through mandatory grid connection codes and what contributions are made on a voluntary basis, and whether compensation for ancillary services is necessary within the minimum technical requirements. Technical specifications and test procedures used to verify the technical characteristics of the installations will undergo continuous further development, as will tendering and prequalification conditions.

- **Plants receive adequate compensation for voluntary contributions to system stability.** Grid operators should purchase such ancillary services in a competitive, market-driven process to the extent possible. There are some suggestions to procure ancillary services through regional platforms.

- **Major disturbances are also handled safely and reliably in an electricity system based on renewable energy.** The market share of conventional generation is falling steadily in Germany. As a result, a number of regions in Germany will only have a few conventional power stations to safeguard system stability in the post-2030 period. In this connection, pan-European approaches to manage major electricity disturbances (e.g. system splitting) will be developed further. Over the medium term, this particularly includes the availability of sufficient instantaneous reserve. The instantaneous reserve balances out very short-term fluctuations in the grid, and has been provided so far by the inertia of spinning masses in conventional power plants and some consumers. Alternatives to this will potentially be developed in the future.

- **Concepts for system control in critical grid situations and the restoration of the grid will undergo continued development.** Increasingly distributed generation and the European internal market for electricity call for greater coordination between the distribution system and transmission system operators. The European Emergency and Restoration Network Code serves as a basis for this. The established system analyses as defined in the Grid Reserve Ordinance will also be essential in the future. They are an instrument for predictive system planning and for the timely provision of reserves, also depending on the progress of grid expansion.

Selection of current studies

dena (2014a): Ancillary Services 2030. Security and reliability of a power supply with a high percentage of renewable energy; Deutsche Energie-Agentur GmbH

dena (2014b): Roadmap to Ancillary Services 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. The flexibility of connected grid users, on the generation side as well as the demand side and at a level that meets the needs of the system, contributes to the cost-effective 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 system of grid charges defines how the costs of the power grids are distributed to the grid users, namely private households, commercial and industrial customers, power stations and storage systems. The fair and transparent distribution of these costs among grid users is also 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 maintaining 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.

Outcome of the discussion on trend 11

- **The energy transition changes the framework for the financing of the power grids.** The regulatory framework for grid financing has evolved over time. In terms of its basic principles, the current system of grid charges stems from a time when large power plants fed in the electricity at the higher voltage levels and this electricity was then passed down to the lower grid levels and transported to the electricity consumers. This framework is gradually changing with the restructuring of the power supply system as part of the energy transition: the share of electricity generated by intermittent renewable sources is growing steadily and the share of decentralised feed-in into the distribution grids is increasing. This also causes a gradual change in the direction of electricity flow in the grids: increasingly, decentralised feed-in is no longer "consumed" locally but is also fed into upstream grid levels and traded nationwide via these upstream grids. Therefore it makes sense to gradually phase out payments for avoided grid use charges.

- **The regulatory framework for grid financing has two central objectives: to support grid user behaviour patterns that serve the grid and the market, and to ensure the fair and transparent distribution of the costs of the power grids.** Many contributions from the consultation agree with the tasks – as highlighted in this trend – regarding the further development of the system for regulating grid charges. For one, the importance of the system of grid charges for behaviour that serve the grid and the market in a cost-effective energy system is highlighted, also with regard to the use of electricity in the heating and transport sectors (cf. Trends 1 and 2). The fair distribution of the costs of the power grid among the grid users is cited as a second central action area, but opinions vary greatly as to what the fair distribution of costs actually entails. This is due, in particular, to the distribution effects that each change to the regulatory framework brings with it. Considerations on the continued development of the system of grid charges are an extension of the debate on a target model for levies, surcharges and fees that minimises the costs of the energy system overall (cf. Trends 1 and 2). For the system of charges, it is important to first define which costs are to be distributed as network costs among the grid users.

Ensure the distribution of network costs to grid users is fair and serves the system

- **The reduction of avoided grid charges as set down in the Draft Act to Modernise the Structure of Grid Charges reduces the difference in grid charges between regions.** The Federal Government proposed a Draft Act to Modernise the Structure of Grid Charges in January 2017 which seeks to establish a fairer system of cost allocation and distribution for grid charges. The planned reduction of avoided grid charges reduces regional differences between grid charges.

- **Costs are incurred in the power grid for the transportation of electricity and for the expansion and maintenance of the infrastructure required for electricity transportation.** The costs for expanding and maintaining the grid infrastructure and for reliable and secure grid operation are paid through the grid charges. The power grid 1) enables the purchase of electricity and 2) serves to maintain capacity for the transportation of electricity.

- **The Federal Ministry for Economic Affairs and Energy proposes to test an approach in pilot auctions under the Renewable Energy Sources Act (EEG) that factors in network costs deriving from the connection of generation facilities to the grid, in order to determine to what extent this can contribute to efficient interaction between grid expansion and renewable expansion.** The grid is currently being expanded in a way that takes advantage of the most cost-effective locations for wind and solar. This keeps the long-term costs for electricity supply to a minimum, also taking into consideration the costs for grid expansion. However, if new generation facilities are connected to the grid, this gives rise to regional concentrations of cost for grid expansion and operation. Factoring in network costs resulting from the connection of generation facilities to the grid can, in principle, provide incentive for the selection of the site or the design of the generation facilities. It is important to ensure, however, that this contributes to the efficient coordination of grid expansion and RES expansion overall, particularly in view of other regulatory instruments such as the EEG auction design or land use planning.
  In the pilot project focussing on joint auctions for PV plants and onshore wind under the Renewable Energy

Sources Act, the Federal Ministry for Economic Affairs and Energy has proposed to test an approach that factors in the costs of the expansion of the distribution grids deriving from the connection of new RES installations (distribution grid component).

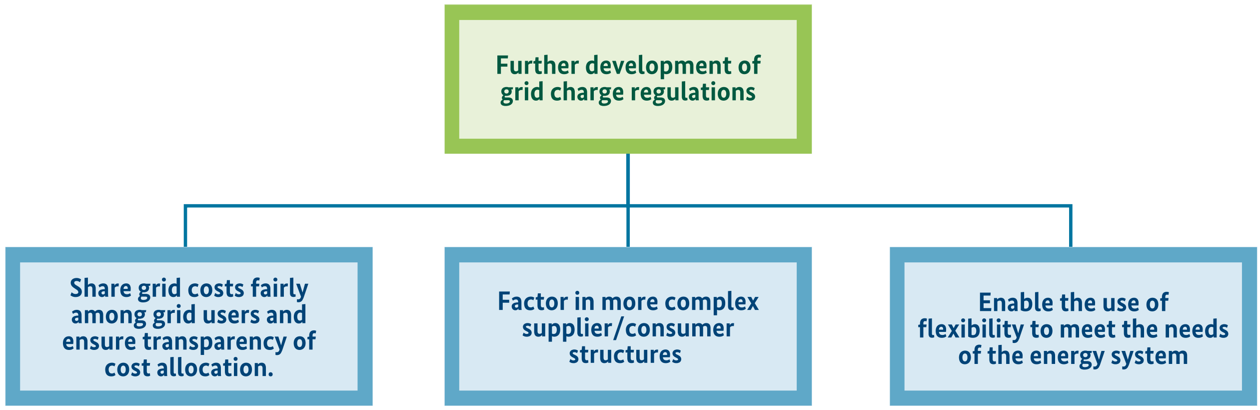
Importance of the cost-efficiency of the overall energy system and increasing sector coupling

- **Grid charges represent all the costs that the TSOs and DSOs incur for the operation, maintenance and expansion of the grids.** In the grid, costs are incurred on the short term as a result of electricity being drawn from the grid (e.g. costs to cover line loss or to balance grid congestion). In addition, long-term costs, such as costs for investment in the expansion of the grid, must also be refinanced. Consequently, the grid charges levied on purchases of electricity currently impose costs that go beyond the short-term costs incurred when a grid is already available and uncongested.

- **The price signals from the grid charges override the price signals from the electricity market.** In future, grid users will need to be able to adapt consumption and generation with increasing flexibility in order to balance the intermittent feed-in of electricity from wind and solar power. For consumers, grid charges currently act in combination with other price signals from the electricity market and also influence incentives for the provision of flexibility and the use of electricity in other sectors. For example, even when prices on the market are negative the use of electricity in the heating sector can prove to be uneconomical due to high energy charges for the use of the grid and high surcharges and levies that apply to the consumption of electricity. In addition, increased demand from industry consumers, for example, can drive up the capacity charge (for peak load obtained from the grid) even if this demand does not increase a grid's annual peak load, which is relevant for the dimensioning of the grid.

- **The interaction between the financing of the grids, the efficiency of the electricity market and sector coupling will be examined.** With the support of experts in the field, the Federal Ministry for Economic Affairs and Energy will examine whether network costs can be recovered in a way that adequately facilitates the market-driven use of flexibility and of electricity in other sectors. For example, contributions to the discussion include proposals to strengthen the fixed components of the grid charges and to align the charges more to the actual cost structure in the grid. In this context, it is essential to ensure that no incentives are given for the inefficient expansion of the grids and that stable and secure grid operation continues to be guaranteed. Further to this, in synergy with the electricity price and state-imposed price components the inefficient use of electricity should be avoided (cf. Trends 1 and 2).

Figure 13: Requirements concerning the further development of grid charge regulations



Source: Own graphic

Incentives for the integration of flexible generators, storage systems and consumers

- **Flexibility can serve several purposes in the electricity system.** The flexibility of producers and consumers in the electricity system will become more and more important in the face of an increasing share of intermittent electricity generation from wind and solar. For one, flexibility can "serve the market", i.e. consumers demand additional electricity when an abundant supply of electricity in Germany causes low electricity prices on the exchange, for example. Added to this, flexibility can also "serve the grid", i.e. the behaviour of producers, consumers or storage systems can help prevent temporary strain on the transmission or distribution grids.

- **The balancing of supply and demand in the electricity market and the stabilisation of the grids with flexible consumers and producers mutually influence one another.** The price of electricity on the exchange reflects the relationship between electricity generation and consumption among all the players in the German electricity market. For example, prices go down if electricity from wind and solar is in abundance. If this prompts a consumer to demand more electricity, this may impact stability in the local power grids. Conversely, it is important to ensure that when flexible producers and consumers are deployed "to serve the grid", this occurs in harmony with balancing responsibilities in the electricity market.

- **Grid charges can provide incentives for behaviour patterns that serve the grid.** Grid charges can reward grid users for flexible behaviour. For example, it is already possible to charge lower fees to controllable consumers at the low-voltage level (Section 14a of the Energy Industry Act). The Federal Ministry for Economic Affairs and Energy will examine how this mechanism can be further refined, particularly in light of new challenges presented, for example, by electric cars charging at the same time (cf. Trend 12).

Selection of current studies

Fraunhofer ISI et al. (2017): Future Workshop on Renewable Energy – Scenarios for the Development of Electricity Self-Supply; Fraunhofer Institute for Systems and Innovation Research, Consentec GmbH, Beiten Burkhardt Rechtsanwaltsgesellschaft mbH, Center for Solar Energy and Hydrogen Research Baden-Württemberg on behalf of the Federal Ministry for Economic Affairs and Energy

Expert Commission on Energy Transition Monitoring (2016): Statement on the Fifth Monitoring Report of the Federal Government for the 2015 Reporting Year; Expert Commission for the "Energy of the Future" monitoring process

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

Trend 12: The energy transition 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 areas 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 metering, build communication platforms, ensure system security

- **Use the technical potential afforded by digitisation to the full.** 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.

Outcome of the discussion on trend 12

- **The Act on the Digitisation of the Energy Transition signals the start of the smart grid, smart meter and smart home in Germany.** Electricity consumers and already over 1.5 million electricity producers are interconnected in a smart grid via smart meters. With this basis, Germany can become a leader in the field of smart grids, smart meters and smart home technology.

- **This infrastructure project can trigger investment of over €10 billion.** The Act on the Digitisation of the Energy Transition stipulates a binding standard for communication in the smart grid that uses technology to implement data privacy and data security ("Privacy & IT-Security by Design" approach). This strategy can become a "Made in Germany" brand as, ultimately, it serves as a perfect model for all areas of digitisation ranging from the smart home to Industry 4.0.

- **The "Smart Energy Showcases – Digital Agenda for the Energy Transit" funding programme, or SINTEG for short, opens large-scale practical trials for the energy supply system of the future.** Focussing on the smart interconnection of generation and consumption as well as the use of innovative grid technologies and operating concepts, the programme addresses the central challenges of the energy transition, such as system integration, flexibility, security of supply, system stability and energy efficiency as well as the development of smart energy networks and market structures. The solutions trialled in the SINTEG programme are then to serve as a model for widespread implementation in Germany.

Regulatory orientation under the Act on the Digitisation of the Energy Transition

- **Participants in the discussion see the Act on the Digitisation of the Energy Transition as a reliable basis for the next phase of the energy transition.** The potential of smart meter systems should be exploited further in the future. For example, conventional meters are not able to visualise exact consumption patterns on an hourly basis and have generally been associated with rigid tariffs. Smart meters make it possible to charge variable electricity tariffs and reward market-driven shifting of demand. In addition to regulatory coverage of variable tariffs, cross-segment metering and smart home applications are also future action areas.

- **Create more flexibility in the distribution grid.** As a building block for a cost-effective energy transition, the current mechanism for flexibility in the distribution grid is to be modernised and developed further on the basis of Section 14a of the Energy Industry Act. In this context, it is important to consider how the simultaneous response of producers and consumers (e.g. electric cars recharging simultaneously) affects the load on the power grids. The Federal Ministry for Economic Affairs and Energy is to develop a concept in 2017.

Scope and reliable standards for the digitisation of the energy sector

- **The potential of the digitisation of the energy sector has not yet been exploited to the full.** With regard to digitisation, the German energy industry was in the mid-range in 2015 compared with other sectors (source: DIGITAL Economy 2015 Monitoring Report). The study examined the usage intensity of digital technologies and services, the extent to which companies are geared towards digitisation and how digitisation affects business success.

- **Digitisation needs strategies for standardisation.** The Federal Office for Information Security (BSI) will publish a roadmap for a "Standardization Strategy for Cross-sectoral Digitisation under the Act on the Digitisation of the Energy Transition". Led by the Federal Ministry for Economic Affairs and Energy, the process will establish a standardisation strategy with the market players which facilitates innovation and which can help build a secure digital system architecture for the smart energy network. Further to this, the "Smart Energy" system committee of the German Commission for Electrical, Electronic and Information Technologies (DKE) serves as a platform for conceptual and strategic exchange in collaboration with other organisations active in the community at the national, European and international level.

- **The digitisation of the energy transition means being open to technical innovations and the further development of the legal framework.** The necessary scope of action for the digitisation of the energy transition is established within the framework of the SINTEG funding programme. To this end, the Federal Ministry for Economic Affairs and Energy will put forward an ordinance for the gathering of experience, also with a view to the implementation of any new legal measures.

New business models in a digital energy age

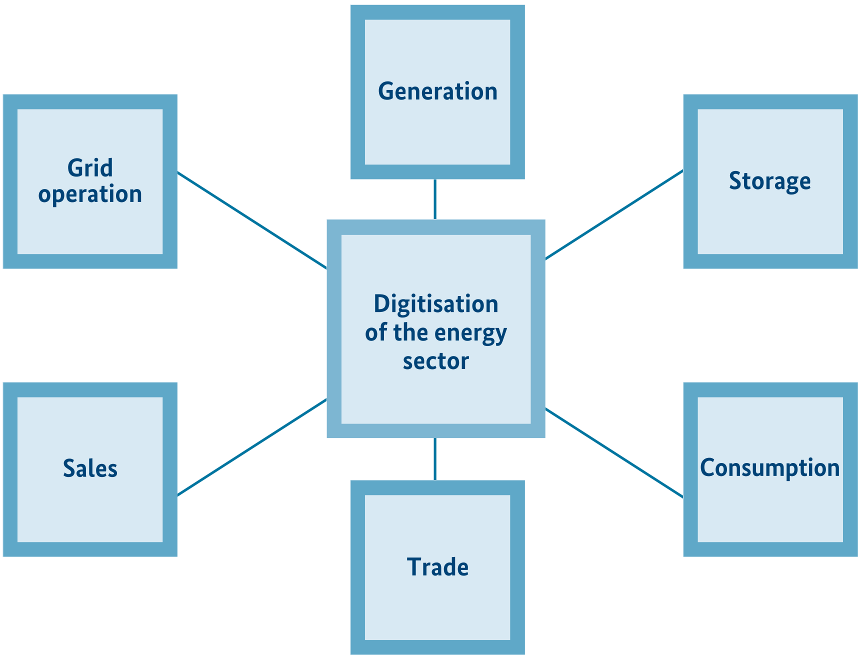
- **Digitisation affects all levels of the energy industry infrastructure and value chain.** This includes generation, grids, trade, supply, meter operation and consumption.

- **Digitisation and distributed energy supply give rise to new market players. Businesses and households will increasingly become active participants in the energy systems.** Data allow businesses to tap into new business field offering added value for customers, and enable system efficiency. As a non-discriminatory and secure communication platform for business models, the smart metering system offers "Digital sovereignty by design", giving users control over their personal data. Standardised meters that can be read remotely are already available for measuring energy consumption in households.

- **New business models are being tested in a real-life setting in the SINTEG funding programme.** Here, the programme will examine what effect these business models have on the energy sector and also how these models can benefit the energy transition.

- **A "BMWi barometer" for the digitisation of the energy transition will support the digitisation process.** It will support the further development of forward-looking topics such as "sector coupling with the heating and transport sector", "blockchain" and the "smart home".

Figure 14: Digitisation as an opportunity for the energy sector



Quelle: Eigene Darstellung

Selection of current studies

dena (2017): 15 hypotheses on the way to a digital energy world - conclusions of the dena dialogue "Digitisation in the energy market 2030", available at https://www.dena.de/newsroom/meldungen/2017/15-thesen-fuer-eine-digitale-energiewelt/

Federal Ministry for Economic Affairs and Energy (2016): Digital Strategy 2025; Federal Ministry for Economic Affairs and Energy

Forum for Future Energies (2016): Opportunities and Challenges Presented by the Digitisation of the Economy; series of publications of the board, volume 9

BDEW (2015): Digitisation in the Energy Sector; German Association of Energy and Water Industries (BDEW)

www.bmwi.de