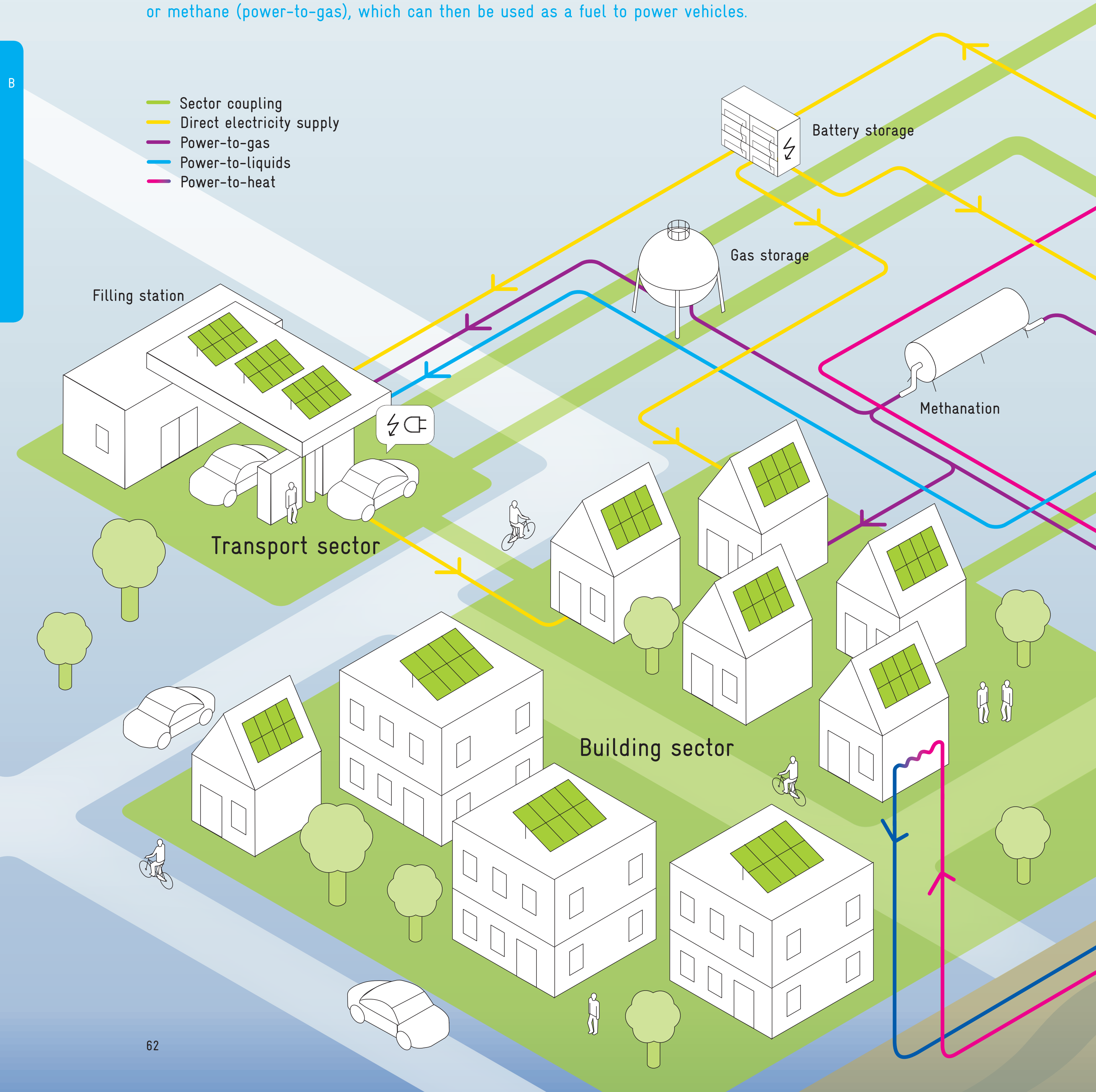
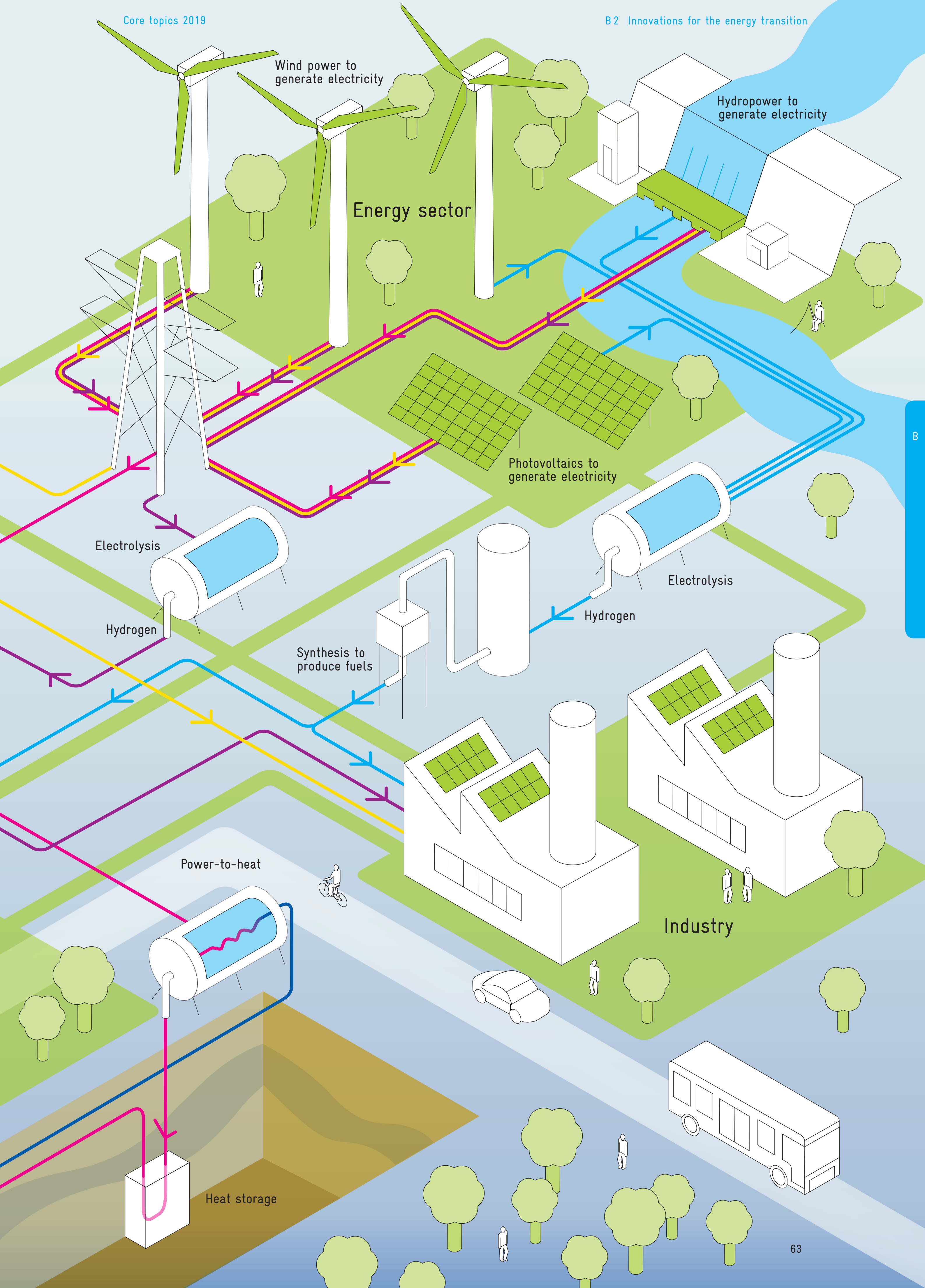
B 2 Innovations for the energy transition

Download data

Sector coupling will play a pivotal role in the energy transition. It is based on direct and indirect electrification. In the case of direct electrification, fossil energy sources are directly replaced by electricity – such as using electric cars rather than vehicles with a combustion engine. Indirect electrification involves converting electricity into other energy sources. Electrolysis, for example, is a process by which electricity can be used to produce hydrogen or methane (power-to-gas), which can then be used as a fuel to power vehicles.




Wind power to generate electricity
Hydropower to generate electricity
Energy sector
Photovoltaics to generate electricity
Electrolysis
Hydrogen
Electrolysis
Hydrogen
Synthesis to produce fuels
Power-to-heat
Industry
Heat storage

B 2 Innovations for the energy transition

B 2-1 The Federal Government's ambitious greenhouse gas emission targets

At the 2015 UN Climate Change Conference in Paris, Germany signed up to an international commitment to keep global warming below 2 degrees Celsius. This aims to curb the drastic damage caused by climate change. As a result of the Paris Agreement, the German energy system will have to become largely greenhouse gas-neutral by the year 2050.

Back in 2010, the German Federal Government committed to reduce greenhouse gas emissions[274] (GHG emissions) by 80-95 percent by the year 2050 compared to 1990 levels. In late 2016, the Federal Government adopted the Climate Action Plan 2050, which sets down specific GHG reduction targets for various sectors of the German economy.[275] Figure B 2-1 illustrates German GHG emissions by sector[276] for the reference year 1990 and for 2017 in millions of tonnes of CO_2 equivalents. These figures are accompanied by the Federal Government's GHG reduction targets for 2020, 2030 and 2050.[277]

Germany is, in all likelihood, set to miss the interim target of reducing GHG emissions by at least 40 percent by 2020 compared with 1990 levels.[278] In order to achieve the reduction target for 2030, GHG emissions will have to be 55 percent lower than in 1990.[279] However, reaching this target will only be possible if annual reductions in GHG emissions between 2017 to 2030 are around fourfold greater than annual reductions over the last ten years.

The drastic reductions in GHG emissions proposed by the Federal Government are to be achieved through an energy transition from fossil fuels to GHG-neutral, renewable forms of energy. At the same time, however, secure supplies must be guaranteed and the affordability of energy ensured.[280]

Over the last decade, high levels of state funding for renewable energy (RE) for electricity generation[281] have led to a situation in which more than one-third of electricity consumption is now covered by RE sources.[282] The energy sector, however, is only responsible for a little over one-third of climate-damaging GHG emissions produced in Germany. In addition to further efforts to replace fossil fuels with RE sources as a means of generating electricity[283] it is obvious that considerable effort is required to reduce GHG emissions in other sectors – in particular in buildings, industry and transport.[284] In this context, the use of renewable electricity across all sectors – known as sector coupling – will be of pivotal importance.

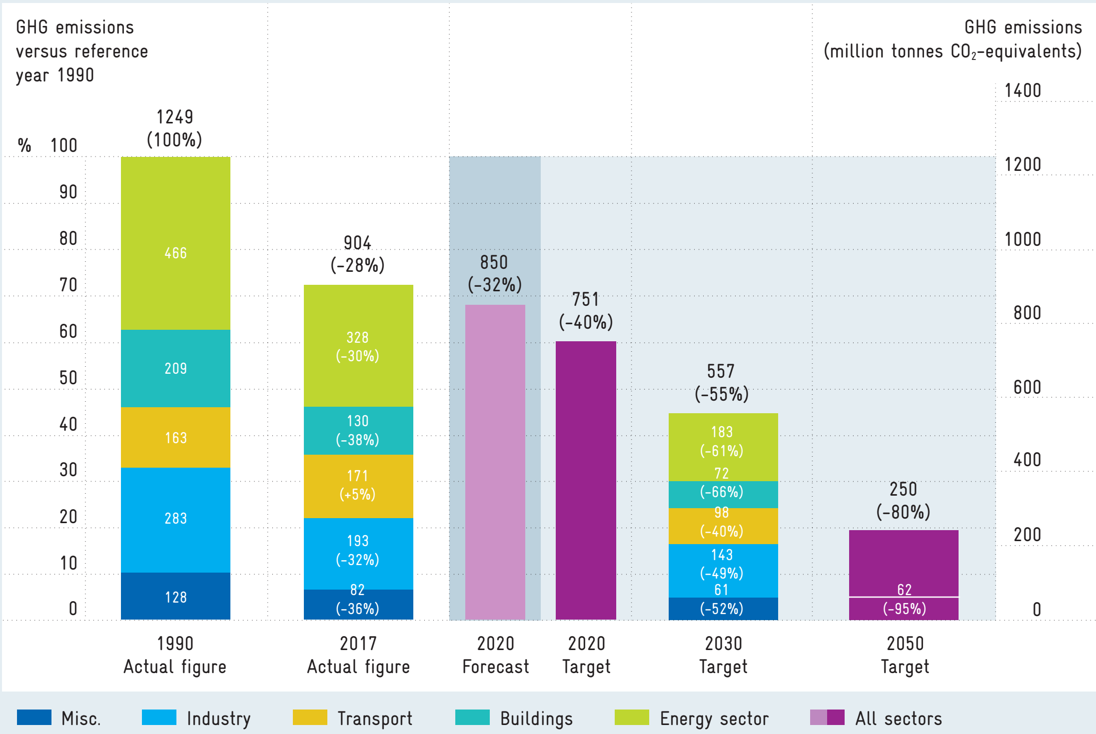
Sector coupling is based on direct and indirect electrification. In the case of direct electrification, fossil fuels are directly replaced by electricity. Examples of this include replacing an oil-fired heating system with an electrical heat pump (known as power-to-heat) or using electric motors in vehicles (power-to-mobility) in the place of petrol or diesel engines.[285] Indirect electrification is the conversion of electrical power into another energy carrier. Electrolysis, for example, is a process by which electricity can be used to produce hydrogen or methane (power-to-gas), which can then be used as fuels to power vehicles. Direct and indirect electrification both contribute to reducing GHG emissions when the electricity used is generated from GHG-neutral, renewable sources, such as wind or solar energy.

However, the energy transition must not simply be restricted to expanding the use of electricity from RE sources to electrify the energy system. A simple calculation makes this clear: in 2017, final energy consumption in Germany amounted to 2,591 TWh.[286] To cover the overall energy consumption for 2017

Fig. B 2-1

Download data

GHG emissions in Germany for 1990 and 2017, forecast of GHG emissions in Germany for 2020 and GHG emissions targets for Germany for 2020, 2030 and 2050



Absolute values in million tonnes of CO_2-equivalents. Figures in brackets show change versus reference year 1990.
Source: own diagram based on BMUB (2014), BMUB (2016), BMU (2018a) and BMU (2018b).

using only electricity from RE sources, Germany would require RE capacity of more than 1,400 GW[287] However, by the end of 2017 – following many years of sustained support for RE applications[288] the country had installed capacity of just 112 GW.[289] Not only is there too little time to expand the country's capacity to 1,400 GW, there is quite simply not enough land available upon which to build the required wind and solar installations. Specialists have therefore assumed that RE capacity will not exceed 500 GW in light of the spatial constraints.[290] Even for an expansion target of 500 GW, 12 GW would have to be added annually by 2050, while the average annual expansion of renewables in the period 2007 to 2017 was just 7.3 GW.[291] One thing is clear: even optimistic projections of RE expansion will not be enough to reach emission reduction targets on their own.Instead, the expansion of RE technologies must be combined with energy savings and energy efficiency improvements.

Innovative technologies and business models can help to force progress on the cost-effective generation of electricity from RE sources and encourage its use across sectors, while also realizing the potential for energy savings and energy efficiency improvements. Against this background, this chapter will examine three core issues:

i. Which innovative technologies and business models are of central importance for the energy transition in different sectors?
ii. What barriers to innovation do different sectors face?
iii. What reform options are available to policy-makers?

To answer these questions, a survey of domain experts has been carried out (cf. box B 2-3). The evaluation of its results shows that key innovative technologies and business models are, in principle, available today. However, their market diffusion is curbed by market externalities, regulatory requirements and lock-in effects. Box B 2-2 highlights the most significant externalities in the context of the energy transition: GHG externalities and network externalities.[292] Furthermore, existing regulatory requirements often heavily influence which technologies and business models succeed in the market. Moreover, switching to new technologies often entails significant costs – which can create situations in which the most economical technology over the longer term fails to gain acceptance (lock-in effect). Such issues present barriers to the use of innovative, climate-friendly technologies and business models as part of the energy transition.

In the following, the four core sectors in the energy transition – energy, buildings, transport and industry – will be examined in further detail. The section on each sector will illustrate the initial situation, followed by i) the central technologies and business models in use, ii) barriers to innovation and iii) potential routes for reform.

Box B 2-2

Market externalities in the context of the energy transition

Externalities are generally defined as the effects of economic activities on third parties for which no compensation is paid.[293]

GHG externalities:
GHGs are emitted when oil, coal and gas are burned. These emissions amplify the earth's natural greenhouse effect and lead to global warming and climate change. As a result, sea levels are rising and extreme weather events are becoming increasingly common. The negative consequences of climate change, such as floods and droughts, affect large numbers of people around the world. These damages are not considered by GHG emitters if they are not compelled to pay for them. In this case, more GHGs are emitted than is societally viable. Charging for GHG emissions[294] at a level corresponding to the damage caused would force each and every person to consider the harm they are causing to the environment. Doing so would internalize the negative externalities of GHGs. Such a system could be achieved, for instance, by taxing energy sources on the basis of their GHG content.[295] The German Environment Agency (Umweltbundesamt, UBA) calculates the societal costs of GHG externalities to be €180 per tonne of CO_2.[296]

At present, the level of taxes and charges on energy sources such as electricity, coal, oil and gas are not based on their respective negative GHG externalities; in comparative terms, energy sources with high GHG emissions are too cheap. This creates a particular competitive disadvantage for climate-friendly technologies based on renewable electricity, such as electric cars and heat pumps. This hampers the use of electricity from RE sources in the transport and building sectors and thereby also hinders sector coupling as a core element of the energy transition.

Network externalities:
The attraction of using a technology can depend on how many other actors already use it.[297] This is referred to as a network externality. The cost-effectiveness of developing infrastructure to use specific technologies is dependent on there being a critical mass of users. The market diffusion of electric and hydrogen-powered cars, for instance, is curbed by the lack of comprehensive charging and refuelling infrastructure. By contrast, the required refuelling infrastructure for existing technologies (combustion engines powered by fossil fuels) is already in place. This favours the continued use of existing technologies and hampers the transition to new, alternative drive systems – a so-called lock-in effect.

Box B 2-3

Survey of experts on technologies for the energy transition

On behalf of the Commission of Experts, a survey of renowned experts in the energy sector has been conducted to gather their views on technologies for the energy transition. The experts assessed the maturity level of these technologies and their significance for the energy transition. The survey concerned the energy sector, industry, transport and buildings. The experts assessed both the significance of technologies and their maturity level on a four-point scale, based on the target of full decarbonization of the German energy system by 2050. In addition, the experts had the opportunity to propose additional technologies and business models they consider important for the energy transition but which had not been included in the survey.

In total, 36 experts took part in the survey, resulting in a response rate of around 50 percent.

In the analysis, a technology is considered to have a high degree of maturity if the experts assign one of the two highest levels of maturity to it on average. A technology was identified as having a high degree of significance for the energy transition if at least 70 percent of the experts surveyed said they considered it important or very important for the energy transition.[298]

B 2-2 Energy sector

Initial situation

The energy sector has successfully reduced GHG emissions by 30 percent compared to 1990 levels (cf. figure B 2-1). However, this represents just half of the sector's target for 2030 – a reduction of 61 percent. Achieving this amount will require a massive increase in electricity generation from RE sources. Fossil fuel power stations and nuclear power stations made redundant by the nuclear phase-out will have to be replaced.[299] This migration poses considerable challenges for the energy sector due to the volatility and decentralized nature of renewable generation.

For many years, the energy industry was characterized by largely centralized power generation that could be effectively controlled, based on fossil fuels and nuclear energy. It was also possible to select power plant sites with proximity to major consumption centres, which made it comparably easy to coordinate the expansion of the power grid. The massive expansion of renewable energies is leading to a weather-dependent electricity generation system that is more varied in terms of location and generation time, which is very difficult to control, and which is spread across many decentralised plants.

The rise of geographically shifting electricity generation, at changing times and from decentralized systems, necessitates the expansion of power networks on a massive scale at all voltage levels.[300] Expanding and upgrading the power grid will place growing importance on efficient grid management – a field in which digitization of the energy industry will be key.[301]

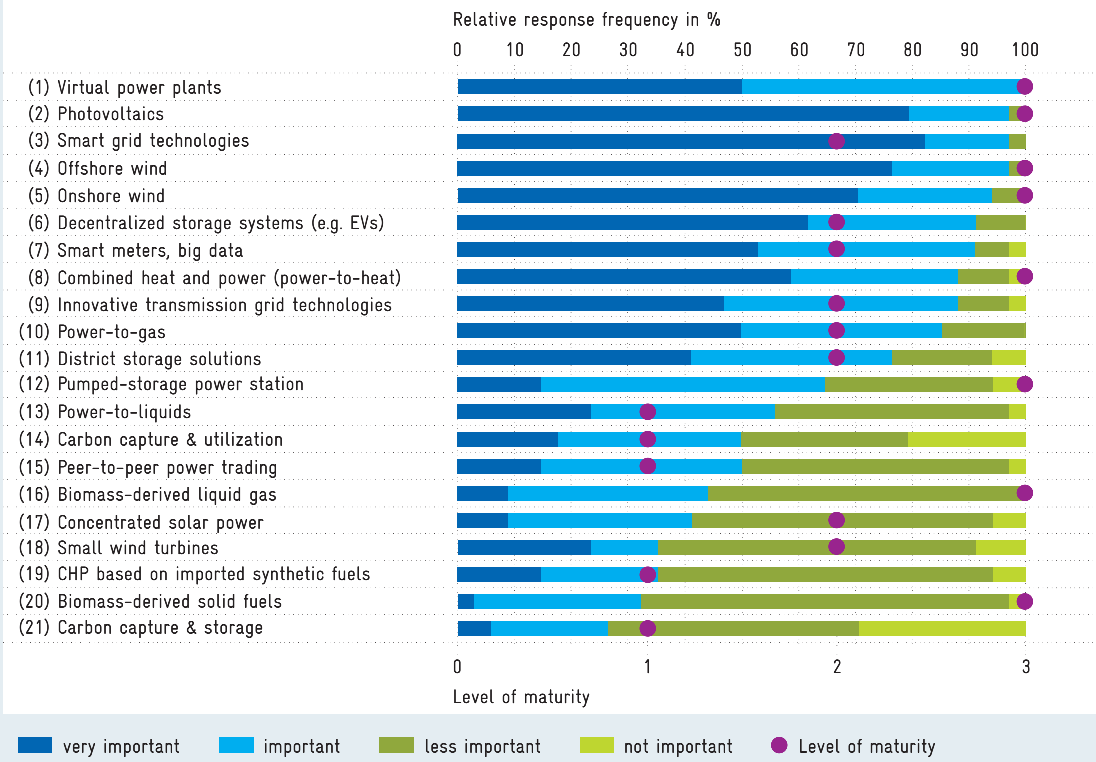
The ever-increasing proportion of electricity from RE sources, along with advancing direct and indirect electrification of the entire energy system, presents new challenges for supply reliability. To ensure a reliable supply of electricity, the generation and demand of electricity must be matched at all times. Flexibility options are therefore required in order to compensate for short-term peaks in generation and consumption. Such options include electricity storage systems and converting electricity into other energy carriers, such as gas, fluids or heat (power-to-X). It must also be ensured that the system is capable of covering longer periods with low levels of energy generation, gloomily referred to in German as "Dunkelflauten" – dark doldrums. Sufficient reserve capacities must be set up to safeguard against this. In future, supply reliability requirements will become increasingly important, particularly in light of the advancing electrification of further sectors such as transport and heating.

Increasing the capacity of electricity from RE sources must therefore be accompanied by further expansion of power grids and the use of innovative flexibility options and sector coupling technologies. Flexibility options and sector coupling technologies can make a decisive contribution to the economic viability of the energy transition by maintaining a very high level of supply security.

Fig B 2-4

Download data

Technologies in the energy sector – significance for the energy transition and level of technological maturity



In the first instance, the technologies are listed in descending order according to the absolute number of "very important" and "important" responses. If this total is shared by more than one technology, the technology with more "very important" responses is listed higher. The bars show the relative frequency of answers as a percentage. The level of maturity is classified as follows: 0=Initial research, 1=Technology under development, testing and piloting, 2=Product concept and business plan exist, 3=Market-ready product exists.
The values in the diagram represent the median value of the experts' assessments.
Source: Gatzen and Pietsch (2019).

B

Important technologies and business models for the energy transition

Figure B 2-4 presents how the surveyed experts assessed the significance of various technologies in the energy sector for the energy transition and their level of technological maturity (cf. box B 2-3). Listing the results in descending order, the experts consider the most significant technologies to be virtual power plants (1), photovoltaics (2), smart grid technologies (3), offshore and onshore wind (4 and 5), decentralized storage systems (6), smart meters and big data (7), combined heat and power (CHP) (8), innovative transmission grid technologies (9), power-to-gas (10) and district storage solutions (11). Most of the experts surveyed said that product concepts have at least been produced for these technologies, while some even feature market-ready products. However, the experts surveyed do not believe there are market-ready products to date in the areas of smart grid technologies (3), decentralized storage systems (6), smart meters and big data applications (7), innovative transmission grid technologies (9), power-to-gas or district storage solutions (11).[302]

A key requirement for the success of the energy transition is seen – in addition to generation technologies such as photovoltaics (2) and wind (4 and 5) – in virtual power plants (1), smart grid technologies (3), smart meters (7) and innovative transmission technologies (9) which make use of (intelligent) digital technologies to manage power grids, power generation and power consumption.

It is clear that the digitalization of the energy industry is a key requirement for (increased) use and implementation of innovative technologies and business models. In this way, digitization makes

Box B 2-5

The European Union Emissions Trading System

The European Union Emissions Trading System (EU ETS) has been a cornerstone of European efforts to combat climate change since its introduction by the EU in 2005. In addition to the 28 EU member states, the Emissions Trading System also includes Norway, Iceland and Liechtenstein. The EU ETS operates on what is known as the 'cap and trade' principle, which sets an upper emissions threshold for the energy sector and energy-intensive industries.[303] This covers around 12,000 installations around Europe which together produce around 45 percent of GHG emissions in Europe.

Within the emissions cap, companies receive or buy emission allowances which they can trade as required. Trading these allowances in the EU ETS makes it possible to reduce emissions where it costs least to do so.

The price of emission allowances is currently around €20 per tonne of CO_2, though this figure was for a long time less than €10 per tonne of CO_2. The previously low pricing in the EU ETS can be traced back to various factors–including the high initial quantity of emission allowances created by the EU ETS, reduced economic activity as a consequence of the 2008 economic crisis and the subsidization of renewable energies to generate electricity.

The latest reform of the EU ETS significantly reduced the permitted emission levels and removed excess certificates from the market.[304] Allowance trading prices have increased in its wake. Nevertheless, these prices remain far below the societal cost of pollution, which the German Environment Agency (UBA) states is €180 per tonne of CO_2.

B

Box B 2-6

Business model for distribution network monitoring

Brief description

Gridhound is an entrepreneurial company founded in 2015. It uses machine learning to monitor medium-voltage and low-voltage networks in real time. Such approaches allow distribution system operators to identify problematic network states and thereby optimize network operation.

Service offering and business model

A sensitivity analysis determines the optimal points at which to integrate measurement technology in the field. Based on that, an assessment of the network status and real-time monitoring of medium-voltage and low-voltage networks provide network data, such as forecasts of future network status. The software used to do this is based on machine learning methods.

Pilot projects to determine the optimal measuring points in the field and analyses of small parts of the network will be offered on a project-by-project basis. The assessment of the network status and real-time monitoring are offered in the form of software-as-a-service and can be charged based on the services used.

Relevance for the energy system

IThere are over 800 distribution system operators in Germany. In 2016, the compensation payments made by distribution system operators for power outages totalled over €370 million. Dynamic feed-in management could reduce compensation costs which would, in turn, lead to a reduction in electricity prices for end customers.

Regulatory barriers

Regulation currently in force makes it more appealing to invest in hardware such as power cables than to invest in digital solutions such as real-time monitoring.[305]

it possible, for instance, to collect consumption data and use it to identify potential savings, control power consumption or make consumption more flexible. Companies can implement smart grid technologies (3) to enable network operators to conduct real-time monitoring and supplement their operations with forecasts of future network status (cf. box B 2-6). This could significantly reduce costs for network operators. Digitalization and decentralization could also lead to the formation of new value-creation networks.[306] An example of this is business models based on blockchain technology (box B 2-7).

B

Barriers to innovation

In the energy sector, barriers to innovation primarily stem from the lack of internalization of GHG externalities (cf. box B 2-2) as well as regulatory barriers.

Until now, negative GHG externalities have not been sufficiently reflected in the price for emission allowances in the EU ETS. While the German Environment Agency (UBA) considers a price of €180 per tonne of CO_2 to be a reasonable guide for the cost of GHG emissions to the climate, the price for emission allowances fluctuated between €15 and €25 per tonne of CO_2 in Q4 2018.[307] As a result, there is relatively little financial incentive to invest in climate-friendly, low-carbon technologies.

To date, network charge regulation has created a situation in which the majority of customer groups are not subject to the actual, geographically different and time-dependent costs of power grid use.[308] Price signals required for the efficient flexibilization of power supply and demand are not currently in place. Consequently, innovative technologies – such as decentralized storage systems or power-to-X – cannot sufficiently monetarize their contribution to the flexibilization of the energy system and are impeded in their market diffusion.

By failing to sufficiently consider the scale of operating expenditure in relation to capital expenditure, the German Incentive Regulation Ordinance (Anreizregulierungsverordnung, ARegV) lacks incentives for network operators to invest in innovative concepts for power shortage management (cf. box B 2-6). From the perspective of network operators, investing in network expansion is generally more lucrative, even though power shortage management without network expansion may be more cost-efficient on a macroeconomic level.[309] As a result, the spread of technologies such as power-to-heat and storage systems[310] – as well as business models for innovative network management – is significantly curbed.

Options for reform

There are a range of options for reform to overcome barriers to innovation in the energy industry; due to the asymmetric nature of their distributive effects, some of these options will be controversial and require political assessment. Key options for reform include:

– reinforcing the price signals from the EU ETS by further reducing the number of emission allowances;
– adjusting network charges to integrate geographical and time-related shortages in the power network's price signal, and,
– revising the ARegV to increase the incentive for network operators and other market players to use systems that benefit grid stability.

Buildings B 2–3

Initial situation

GHG emissions from buildings in 2017 were 38 percent lower than in 1990. The sector is therefore well over halfway to achieving its target of a reduction of 66 percent by 2030 (cf. figure B 2-1).

The primary uses of energy in buildings are room heating and air conditioning (85 percent) as well as hot water generation (15 percent).[311] In 2017, some 75 percent of building heating was produced using fossil fuels in oil or gas heating systems.[312] Due to the long service life of heating systems, these figures remain fairly stable over time; migrations to other energy sources are therefore a slow process. As a result, measures involving low-CO_2 and CO_2-free heating technologies will not be sufficient to achieve the sector target for 2030 as they are generally limited to newly constructed buildings.[313]

Box B 2-7

Blockchain technologies in the energy industry[314]

Evolving the energy industry to organize small-scale, decentralized systems will require increased coordination of transactions, both physical (in terms of electricity generation, transport and consumption) and financial (in terms of electricity trading). On a fundamental level, blockchain technologies make it possible to coordinate an array of transactions in a safe and efficient manner (see chapter B 3). Such technologies therefore also have the potential to play a vital role in the energy transition with decentralized electricity generation and supply structures.[315]

The costs for network operation are passed on to consumers in the form of network charges. However, such charges are only transparent to a certain degree; this is because not enough network status data is available and can be distributed between various actors. One solution to this would be to combine sensors that indicate network status with blockchain technologies that automatically collect and store data without the risk of manipulation. On that basis, performance and cost indicators could then be determined in the network directly and communicated reliably via the blockchain. This would make it possible to set fair and transparent usage-based network charges.

Energy efficiency also has a decisive role to play in achieving sector targets. The Federal Government has formulated a long-term target of 40 kWh/m^2 for annual consumption in residential buildings.[316] In 2016, the final energy consumption in private households was 126.2 kWh/m^2.[317] It will therefore be necessary to promote the development and construction of buildings that produce more (CO_2-free) energy than they consume.

Important technologies and business models for the energy transition

Figure B 2-8 presents innovative technologies in the building sector and depicts the surveyed experts' assessments of them for the energy transition and their respective level of technological maturity (cf. box B 2-3). Listing the results in descending order, the experts consider the most significant technologies to be heating pump systems (1), energy-efficient construction and renovation (2), smart meters (3), renewable CHP and district heating (4), innovative heat and cold storage systems (5), district solutions and landlord-to-tenant electricity supplies (6), building automation technologies (7), technologies for energy-saving building use (8), solarthermics (9), heat recovery (10) and powertoheat (11). Most of the experts agreed that market-ready products – or at least product concepts – currently exist for these technologies. The majority of experts indicated that the step of producing market-ready products still had to be taken for smart meters (3), innovative heat and cold storage (5), district solutions and landlord-to-tenant electricity supplies (6), building automation technologies (7), energy-saving building use (8) and heat recovery (10).[318]

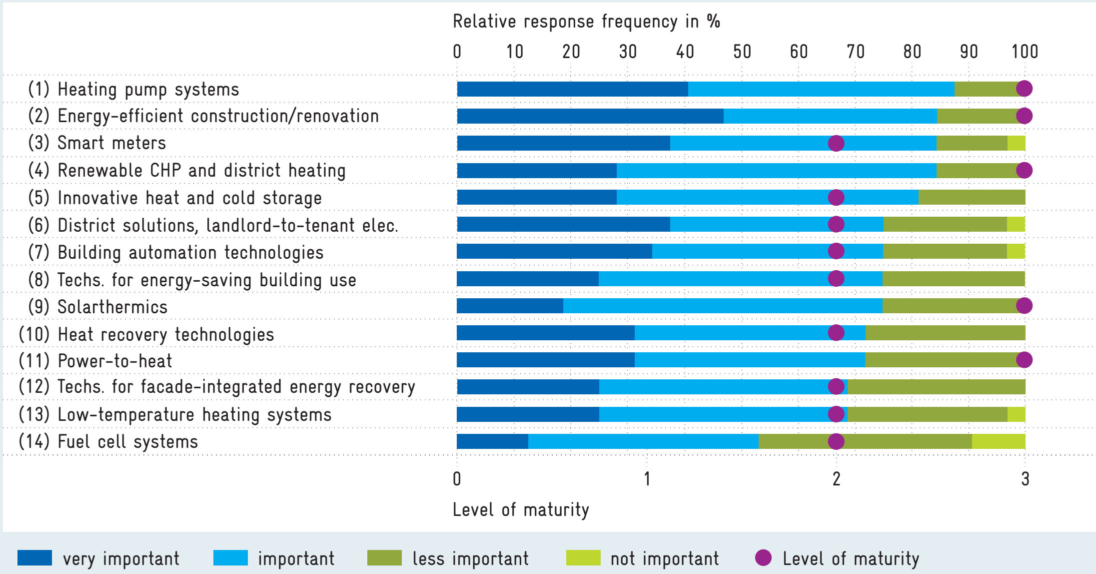
The technologies the experts consider to be significant can be divided into two categories: efficient and climate-friendly energy provision on the one hand, and technologies to reduce consumption on the other. The first category includes heating pumps (1) and other power-to-heat applications, renewable CHP and district heating (4), solarthermics (9), innovative heat and cold storage (5) as well as district solutions and landlord-to-tenant electricity supply models (6). Technologies to reduce energy consumption relate to energy-efficient construction and renovation (2), building automation (7) and energy-saving building use (8).

The building sector also features innovative services that can be offered in the form of digital business models (cf. box B 2-9). Companies offer green electricity in combination with domestic power optimization or landlord-to-tenant electricity supply models. Landlord-to-tenant electricity and district electricity systems denote electricity produced locally by a landlord and offered to tenants directly. Suppliers generate revenues from monthly charges for green electricity supplies or contributions to landlord-to-tenant supply associations.

Fig. B 2-8

Download data

Technologies in the building sector – significance for the energy transition and level of technological maturity



In the first instance, the technologies are listed in descending order according to the absolute number of "very important" and "important" responses. If this total is shared by more than one technology, the technology with more "very important" responses is listed higher. The bars show the relative frequency of answers as a percentage. The level of maturity is classified as follows: 0=Initial research, 1=Technology under development, testing and piloting, 2=Product concept and business plan exist, 3=Market-ready product exists.
The values in the diagram represent the median value of the experts' assessments.
Source: Gatzen and Pietsch (2019).

Box B 2-9

Business model for landlord-to-tenant electricity

Brief description
Polarstern GmbH was founded in Munich in 2011. The energy supplier offers energy products such as green electricity and eco-gas from 100 percent renewable sources. In addition, Polarstern offers special tariffs for heating pumps and electric cars as well as decentralized electricity supply products for private homes and apartment buildings, such as landlord-to-tenant supply models.

Service offering and business model
In its operations, Polarstern uses both the central, public power network and locally generated electricity to supply energy to buildings. Polarstern creates and organizes landlord-to-tenant and domestic electricity models to enable the use of locally generated electricity. Furthermore, it offers services to optimize domestic power consumption.
Polarstern generates revenues from monthly green energy supply charges as well as levies for the use of locally generated electricity.

Relevance for the energy transition
All of the company's products and services are based entirely on renewable energies. The integration of decentralized storage systems, such as electric cars, makes it easier to balance electricity supply and demand in the network.

Regulatory barriers
The German Landlord-to-Tenant Electricity Act (Gesetz zur Förderung von Mieterstrom) was adopted in 2017. To date, however, the law only permits the use of photovoltaic technology. Limiting the scheme to just one technology makes it impossible to exploit the full potential of landlord-to-tenant energy.

Barriers to innovation

Barriers to innovation in the building sector can be traced back to GHG externalities (cf. box B 2-2) and lock-in effects.

Energy sources used to power households vary significantly in terms of the taxes, charges and levies placed on them, sometimes referred to as state-imposed price components. Electricity is subject to significantly larger state-imposed price components than natural gas and fuel oil. Considering these energy sources in relation to the GHG emissions they produce shows major differences from uniform CO_2 pricing. The implicit CO_2 price for electricity is far higher than that of natural gas or light heating oil.[319] This results in significant competitive disadvantages for electricity-based sector coupling technologies in the building sector (incl. heating pumps).

Lock-in effects occur in the building sector because the costs of migrating from an established technology to a new one are too high (in part due to irreversible investments and sunk costs). This can curb the spread of innovative, climate-friendly heating systems that would be more cost-effective over the long term.[320]

Options for reform

There are a range of options for reform to overcome barriers to innovation in the building sector; due to the asymmetric nature of their distributive effects, some of these options will be controversial and require political assessment. Key options for reform include:

– revising taxes, charges and levies – so-called state-imposed price components – on energy sources and using the costs of the GHG externalities caused by respective energy sources to dictate these components in future;
– expanding fiscal incentives or depreciation schemes in addition to funding programmes in order to create further incentives to use innovative technologies,[321] and
– extending regulatory measures relating to existing buildings in order to overcome lock-in effects.[322]

Transport

B 2–4

Initial situation

Rather than falling, GHG emissions in the transport sector actually rose slightly between 1990 and 2017. As a result, the Federal Government's target of reducing GHG emissions in the transport sector by 40 percent compared with 1990 levels by the year 2030 remains distant.[323] This adverse development can primarily be ascribed to the rise in traffic volumes, which has more than negated energy efficiency increases of 25 percent in passenger transport and 12 percent in goods transport.[324, 325] Drastic measures are required if the sector is to meet its target for 2030.

At present, cars are responsible for 61 percent of GHG emissions in the transport sector, followed by goods vehicles on 35 percent, domestic flights on 1.4 percent and diesel engine trains on 0.6 percent.[326] The proportion of renewable energy used in the transport sector has been stagnant at around 5 percent since 2008.[327] Alternative drive systems[328] are yet to make an appreciable contribution to defusing the critical GHG situation in the transport sector. In 2018, they accounted for only 1.7 percent of the total vehicle stock in Germany.[329]

In addition to e-mobility, hydrogen and synthetic fuels can play an important role in the transport sector's future energy mix and help to achieve the strict GHG reduction requirements by 2030 and beyond. The use of different technologies would appear sensible, particularly in light of the differing mobility requirements (in terms of range) and vehicle dynamics in goods and passenger transport. Furthermore, concepts to avoid and shift traffic – such as expanding and developing local public transport networks, sharing models and traffic avoidance measures in traffic planning – are gaining in importance.[330]

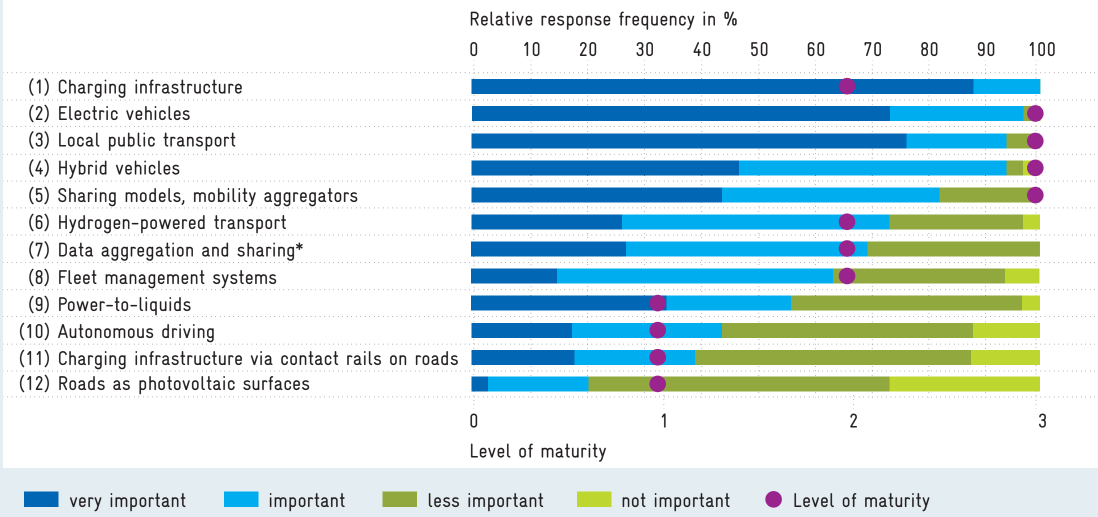
Important technologies and business models for the energy transition

Figure B 2-10 presents innovative technologies in the transport sector and depicts the surveyed experts' assessments of them for the energy transition and their respective level of technological maturity (cf. box B 2-3). Listing the results in descending order,

Fig. B 2-10

Download data

Technologies in the transport sector – significance for the energy transition and level of technological maturity



In the first instance, the technologies are listed in descending order according to the absolute number of "very important" and "important" responses. If this total is shared by more than one technology, the technology with more "very important" responses is listed higher. The bars show the relative frequency of answers as a percentage. The level of maturity is classified as follows: 0=Initial research, 1=Technology under development, testing and piloting, 2=Product concept and business plan exist, 3=Market-ready product exists.
The values in the diagram represent the median value of the experts' assessments.
* Aggregation and sharing of data for the purpose of traffic flow optimization
Source: Gatzen and Pietsch (2019).

B

the experts consider that the most significant technologies relate to charging infrastructure (1), electric vehicles (2), local public transport (3), hybrid vehicles (4), sharing models and mobility aggregators (5) and hydrogen-powered transport (6). Most of the experts surveyed stated that product concepts have at least been produced for these technologies, while some even feature market-ready products. The majority of experts believe that charging infrastructure (1) and hydrogen-powered mobility (6) are not yet market-ready solutions.[331]

Electric vehicles (2) will take on a key role in the transport sector of the future.[332] By enabling the direct use of electricity from renewable sources and with particularly high energy efficiency levels, electric vehicles can make a decisive contribution to the decarbonization of the transport sector.[333] To expand the operating ranges of electric vehicles, however, charging infrastructure must be further expanded.[334] Furthermore, battery systems need to be further developed in order to increase their power density and thereby extend their range and reduce their cost.[335]

Hybrid vehicles and plug-in hybrids[336] – which feature both an electric motor with a high-performance battery and a combustion engine – are expected to contribute to decarbonization of the transport sector in the transition phase.

In addition to electric battery-driven vehicles, hydrogen-powered vehicles (which use hydrogen that can be generated through electrolysis using renewable electricity) will become increasingly important. Hydrogen-powered vehicles benefit from a greater range as well as faster refuelling, though their energy efficiency is significantly lower than that of electric vehicles.[337] Significant investment in infrastructure will also be required to facilitate the fuelling of hydrogen-powered vehicles.[338]

Avoiding and shifting traffic can also contribute to reducing GHG emissions. Such measures include expanding local public transport to provide greater network coverage, increasing service frequency and promoting travel by foot and by bicycle. In addition, new business models (such as car-sharing services) can reduce the number of vehicles required and better

Box B 2-11

Business model for smart traffic management and sensor systems

Brief description
Sonah UG was founded in Aachen in 2016. Sonah develops flexible optical sensors for a range of applications relating to smart cities, such as in the fields of parking space monitoring, EV charging station monitoring and intelligent traffic management systems. Their sensors can be installed in existing infrastructure, such as streetlights and buildings.

Service offering and business model
Sonah is developing a decentralized sensor network to combat issues such as parking space issues, EV charging point monitoring and traffic management. To achieve this, the company is working to develop optical sensors. These optical sensors make it possible to analyse and interpret on-street situations in conformity with data protection regulations and send relevant metadata for various application cases. This data is evaluated using machine learning algorithms and processed in new business models.

Sonah generates revenue through the sale of these sensors and monthly charges for parking space monitoring. It can generate further income by supplying data on parking and traffic behaviour.

Relevance for the energy transition
Traffic made up on vehicles hunting for a parking space is today responsible for a significant proportion of urban air pollution. Monitoring parking space availability and making this data available in navigation applications will make it possible to reduce this traffic and, therefore, air pollution.

Regulatory barriers
Data-driven business models encounter difficulties when applied in the public realm, as it is not clear to whom the data actually belongs. This uncertainty hampers potential innovation projects.

use the capacity of vehicles on the road.[339] Moreover, mobility aggregators make it possible to combine a range of transport services in a single app. Intelligent transport optimization technologies can also play a role in making traffic flow management more efficient.

Cloud-based mobility platforms can make it possible, for instance, for companies to offer their employees so-called shared mobility services. Fleet vehicles can be digitized and used privately by employees after work. The transport platform therefore forms an interface between the suppliers and consumers of transport services. In this case, the business model is a software-as-a-service package, with usage charges payable per vehicle and unit of time.

Barriers to innovation

Barriers to innovation in the transport sector can be traced back to GHG externalities (cf. box B 2-2) and regulatory obstacles. Electric and hydrogen-powered vehicles require spatially inclusive and comprehensive charging and fuelling infrastructure respectively; due to network externalities, such infrastructure is yet to be established in Germany. These externalities are intensified because a comprehensive charging infrastructure has to be aligned with the expansion of the distribution network infrastructure.[340]

While car manufacturers are subject to CO_2 fleet targets for new vehicles, hardly any measures are in place that aim to change driving behaviour or transport usage and thereby realize effective reductions in GHG emissions from existing vehicles. This will cement the status quo for private car transport that discriminates against innovative technologies such as mobility aggregators, traffic avoidance or public transport.[341]

Support for alternative drive systems based on CO_2 fleet targets is not open to different technologies. If the proportion of electric vehicles in a manufacturer's fleet of new cars exceeds a certain threshold, this dilutes the CO_2 requirements for the fleet as a whole. This focus on electric vehicles is to the detriment of other alternative drive system concepts, such as hydrogen-powered vehicles. A critical appraisal of government activities in the transport sector must not ignore the fact that the Federal Government is pursuing industrial policy on the international stage that protects the German automotive industry. At the European level, for example, the German government has advocated for greater weakening of the reduction targets for new cars than a majority of EU member states would have supported.[342] Such policies inhibit innovations for alternative drive system concepts and could backfire in the long term and actually weaken Germany's position as a core location for the automotive industry.

Options for reform

There are a range of options for reform to overcome barriers to innovation in the transport sector; due to the asymmetric nature of their distributive effects, some of these options will be controversial and require political assessment. The options for reform comprise:

– increasing the price of GHG emissions by adjusting taxes on vehicles and fuel;
– promoting climate-friendly drive concepts and their charging/refuelling infrastructure through a technology-agnostic approach;
– implementing more coordinated expansion of traffic, charging and refuelling infrastructures, and
– charging private vehicles for road usage as a further incentive to transition from individual transport in cars to other modes of transport with lower GHG emissions.

B 2-5 Industry

Initial situation

The manufacturing industry is responsible for around 20 percent of GHG emissions in Germany. That being said, GHG emissions in this sector fell by 30 percent between 1990 and 2017 (cf. figure B 2-1). However, to achieve the sector's target for 2030, GHG emissions from the manufacturing industry must fall by 50 percent compared to 1990 levels.

In the manufacturing industry, reducing GHG emissions poses particular technical challenges where very high temperatures are involved, in basic industry (e.g. lime and cement production) and in the chemicals sector.[343] In such cases, fossil fuels are required in part due to the specific material properties of such fuels[344] and CO_2 is sometimes created as a direct by-product even when non-fossil materials are used.[345]

Important options for GHG reductions in the manufacturing industry include improving industrial processes' energy efficiency and migrating to renewable electrical power where possible, as well as the capture, use and storage of CO_2.[346] In addition, fossil resources can be replaced in applications that do not burn them but instead relate to their material use. Examples of this include the use and production of ethylene or ammonia using power-to-X technologies for the chemical industry or using hydrogen produced through renewable-powered hydrolysis in steel production.[347]

Important technologies and business models for the energy transition

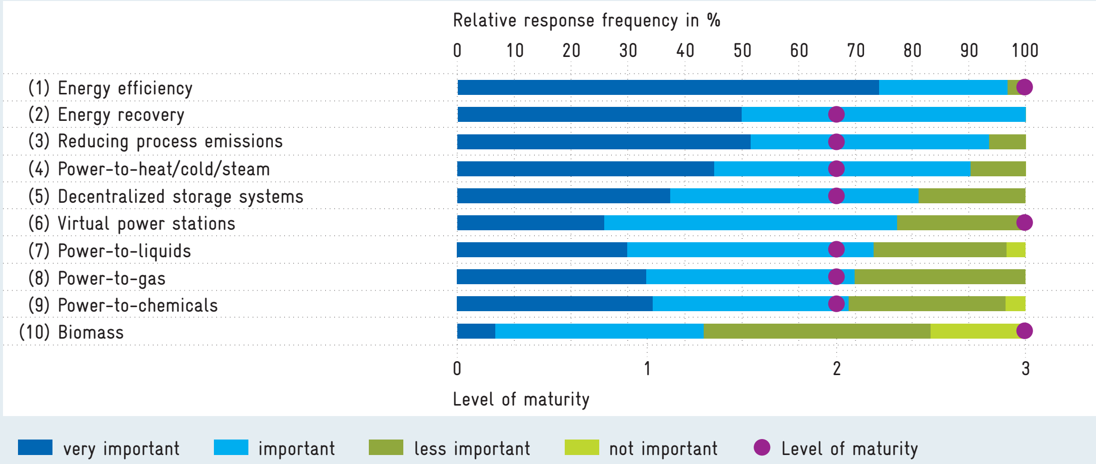
Figure B 2-12 presents innovative technologies in industry and indicates the surveyed experts' assessments of them for the energy transition and their respective level of technological maturity (cf. box B 2-3). Listing the results in descending order, the experts consider that the most significant technologies relate to increasing energy efficiency (1) and energy recovery (2), reducing process emissions (3), power-to-heat/cold/steam (4), decentralized storage systems (5), virtual power stations (6), power-to-liquids (7) and power-to-gas (8). Most of the experts surveyed stated that product concepts have at least been produced for these technologies, while some even feature market-ready products. However, they indicated that technologies relating to energy recovery (2), reducing process emissions (3), power-to-heat/cold/steam (4), decentralized storage systems (5), power-to-liquids (7) and power-to-gas (8) are not yet mature enough to be market-viable.[348]

In industry, innovative climate-friendly technologies are primarily aimed at increasing efficiency. Among other things, innovative business models for the analysis of energy data are used here (cf. box B 2-13). In addition to more economical use of resources, energy efficiency can also be increased through energy recovery.[349]

Fig. B 2-12

Download data

Technologies in the industry – significance for the energy transition and level of technological maturity



In the first instance, the technologies are listed in descending order according to the absolute number of "very important" and "important" responses. If this total is shared by more than one technology, the technology with more "very important" responses is listed higher. The bars show the relative frequency of answers as a percentage. The level of maturity is classified as follows: 0=Initial research, 1=Technology under development, testing and piloting, 2=Product concept and business plan exist, 3=Market-ready product exists. The values in the diagram represent the median value of the experts' assessments.
Source: Gatzen and Pietsch (2019).

Furthermore, migrating to low-carbon energy sources is a highly effective measure by which to reduce GHG emissions. In power-to-X processes, electricity (from renewable sources) is converted into new energy carriers such as gases, liquid fuels, chemicals or heat. This makes it possible to reduce the use of fossil fuels. For instance, hydrogen can be produced through electrolysis using water and (renewable) electricity instead of using natural gas.

Barriers to innovation

In the manufacturing industry, barriers to innovation are primarily caused by a lack of or insufficient internalization of GHG externalities (cf. box B 2-2). On the one hand, the CO_2 price for facilities covered by the EU ETS is too low; on the other hand, electricity use is disadvantaged compared to other energy sources in terms of taxes, charges and levies. This inhibits the introduction of innovative low-CO_2 or CO_2-free technologies in the manufacturing industry.

Options for reform

Options for reform to overcome the barriers to innovation in the manufacturing industry aim to internalize THG externalities. The options for reform include:

– reinforcing the EU ETS by further reducing the number of emission allowances, and
– revising taxes, charges and levies – so-called state-imposed price components – on energy sources and using the costs of the GHG externalities caused by respective energy sources to dictate these components in future.

B 2–6 Using the sector coupling principle to guide R&D funding

The energy transition must also be supported through R&D investments in innovative, climate-friendly technologies.[350] R&D not only contributes to the creation of new technologies but is also beneficial to

Box B 2-13

Business model for industrial electricity supply

Brief description
EnergyCortex was founded in Aachen in 2018 and works to develop a cloud-based, cross-sector energy data platform for industrial customers, municipal utilities and operators of decentralized systems (e.g. renewable energy and CHP systems).

Service offering and business model
EnergyCortex collects and visualizes data from sources such as smart meters and then processes and prepares this data on behalf of its customers. The prepared data makes it possible to offer services that reduce costs and improve performance.

EnergyCortex provides its services on the basis of fixed-tariff, pay-as-you-use and profit-sharing models.

Relevance for the energy transition
Visualizing and evaluating consumption data makes it possible to identify measures to reduce energy consumption.

technologies which, in the opinion of the surveyed experts, are ready for the market today. The aim in this regard is to increase their market potential and accelerate their market diffusion. In light of the outstanding potential sector coupling harbours for the energy transition, R&D programmes should not consider the innovation potential of technologies and business models for the energy transition in isolation but rather on a cross-sectoral basis.

Research efforts to support the energy transition are being funded by the Federal Government, in particular by the BMBF and BMWi.[351] In its 7th Energy Research Programme,[352] the Federal Government set down the basic approaches and focuses of its support for energy research; it also referenced these in its High-Tech Strategy 2025 (HTS 2025).[353]

The Commission of Experts welcomes the Federal Government's increasing consideration of the principle of sector coupling in R&D funding.[354] However, the coordination of funding across departments must be made more effective in order to tap further synergies. The Commission of Experts therefore suggests that in these research activities – as in the entire portfolio of funding measures and in the coordinating work of the HTS 2025 – the aspect of sector coupling should be further strengthened.

Recommendations B 2–7

The Federal Government has assigned the energy transition a prominent position in its policy goals. Innovative technologies and business models can make a decisive contribution to the success of the energy transition. Decarbonizing the German energy system in the most cost-effective manner possible is inconceivable without the use of innovative technologies and business models. The primary challenge ahead, however, is not to create new technologies – domain experts believe that key technologies and business models are ready for the market today. However, their market diffusion is curbed by insufficient internalization of externalities and existing regulatory requirements.

Removing these obstacles will lead to considerably higher CO_2 pricing and, therefore, higher prices for diesel, petrol, heating oil and natural gas. These price increases will be necessary to achieve the required steering effects. However, they also entail unfavourable distribution effects. The reforms must therefore be accompanied by socio-political measures such as income transfers.

The Commission of Experts recommends that the Federal Government implement the following measures:

- In order to help innovative, climate-friendly technologies to prevail in market competition, energy charges and levies should be determined by the damage caused to the environment by – and CO_2 content of – respective energy carriers across all sectors of the economy. As part of such CO_2-oriented fiscal reform, it is crucial that the state use tax revenues generated in this regard to compensate and support economically disadvantaged households most severely affected by energy price increases.
- The German Incentive Regulation Ordinance (ARegV) should be amended for power network operators to make operating innovative systems

and pursuing business models that stabilize and support the power network worthwhile.

- To ensure that the overall economic benefits of flexibilization options in the supply and demand of electricity also make commercial sense, network charges should be reformed in order to better represent the actual costs of power network use in terms of both geography and time.
- In order to encourage digital business models for the energy transition, legal issues relating to the collection and use of data should be clarified without delay.
- In light of the outstanding potential sector coupling harbours for the energy transition, R&D activities and their funding should be structured with a greater emphasis on the organizational principle of sector coupling.