ATLAS OF THE ENERGIEWENDE

THE ENERGY TRANSITION IN GERMANY

RENEWABLE ENERGIES AGENCY

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Version date: October 2017

Supported by:
Federal Ministry for Economic Affairs and Energy
on the basis of a decision by the German Bundestag

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Druck | ID: 11709-1503-1001

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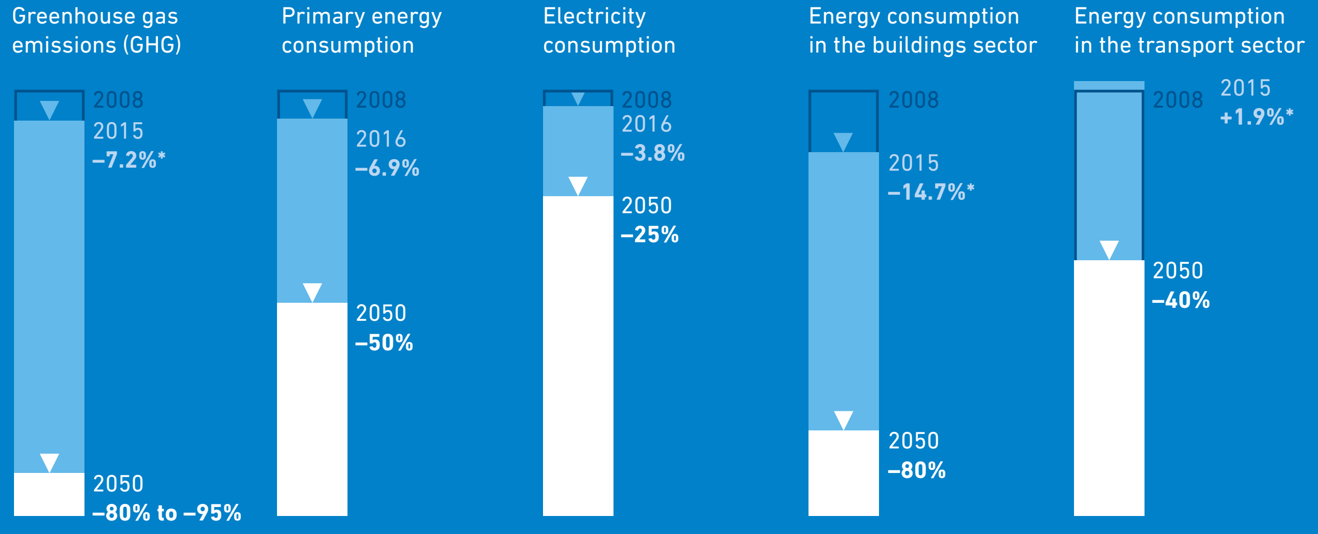
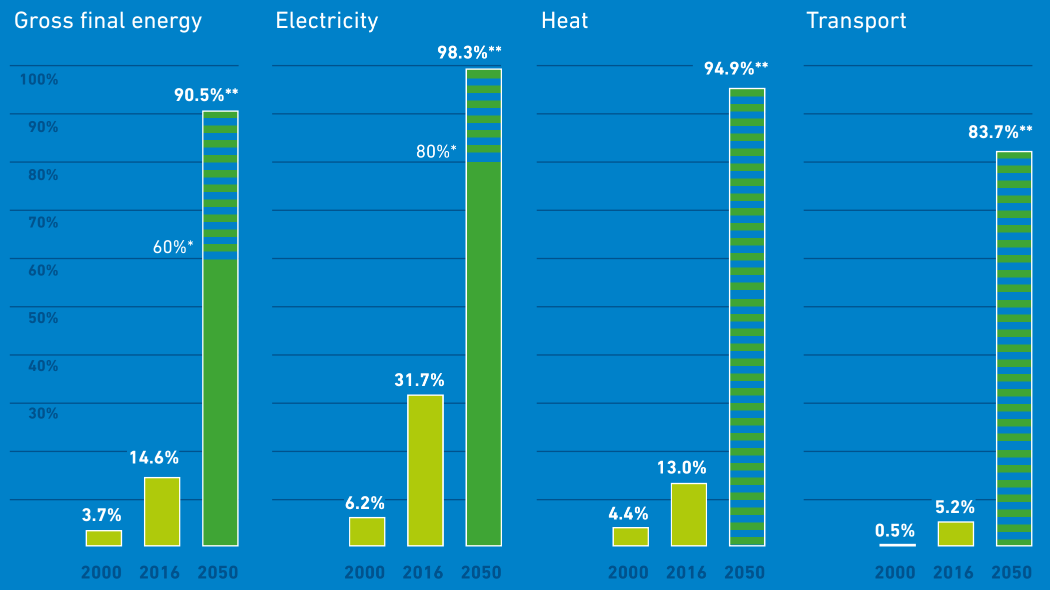
REDUCTION IN GREENHOUSE GAS EMISSIONS AND EFFICIENCY TARGETS FOR THE IMPLEMENTATION OF THE ENERGY TRANSITION
FEDERAL GOVERNMENT OBJECTIVES



* preliminary

Source: BMWi

SHARE OF RENEWABLES IN GERMANY'S ENERGY SUPPLY:



* Federal Government objective
** Nitsch (2016) (Climate protection scenario "Klima 2050")

Source: BMWi, Nitsch (2016) (Climate protection scenario "Klima 2050")

The growth forecasts for 2030 published in this Energy Transition Atlas are based on the brief study "Die Energiewende nach COP 21 – Aktuelle Szenarien der deutschen Energieversorgung" (The energy transition after COP 21 – current scenarios for the German energy supply), commissioned by the German Renewable Energy Federation (BEE) in March 2016. With the "Klima 2050" ("Climate 2050") scenario, the author, Dr Joachim Nitsch, outlines a series of objectives that will need to be pursued if the German Federal Government's targets for the energy transition (in particular, the GHG reduction target of –95 per cent by 2050) are to be met. The amount of space required for the expansion of renewables was calculated by Germany's Renewable Energies Agency (AEE) on the basis of industry data and forecasts and merely represents a guideline figure.

Dear readers,

In the Paris climate agreement adopted in December 2015, the international community resolved to limit global warming to well below two degrees Celsius by 2050. For this goal to be achieved, industrialised countries in particular will need to restructure their energy supply – away from fossil fuels such as coal and oil, and towards renewable energies. There is no one-size-fits-all, established approach. Rather, each country must seek out its own, workable set of solutions that is as efficient as possible and suited to its own particular challenges. The mammoth project that is the "Energiewende", or energy transition, will include some trial and error as well as imitators copying especially good ideas and plans.

Germany is regarded as a pioneer in terms of restructuring the electricity supply. Since the turn of the millennium, the share of renewables has evolved from about five per cent of the electricity supply into its largest component (2016: 31.7 per cent). This development has been – and continues to be – broadly supported by the German population. Almost every second renewable energy generation facility belongs to private individuals or farmers. More than 90 per cent of Germans are in favour of the further expansion of renewable energies. Ever since the Fukushima reactor catastrophe in 2011, there has been a consensus throughout society and across party lines on the abandonment of nuclear power. And the extensive decarbonisation of the country's remaining energy generation has also already been decided.

In Germany, the largest share of green electricity is supplied by wind and solar power. But since these sources produce varying amounts of electricity depending upon the weather and time of day, the energy transition involves more than just overhauling energy generation capacity. On the contrary, the entire energy infrastructure including power grids must be adapted to reap the wind and solar harvest. As a result, economic incentives will be needed in future to encourage consumers to purchase more of their power at times when there is a high level of supply in the market. Alongside this demand-side management, storage systems and an enhanced exchange of electricity within Europe must also provide a balance at moments when electricity supply and demand are not in alignment.

In contrast to power generation, renewable energies in the heat and transport sectors are still playing a minor role (2016: 13.0 and 5.2 per cent respectively). Great hopes are therefore being pinned on sector coupling – the name given to the principle of converting electricity into heat and operating power for transport. This has two major advantages: firstly, these two particularly energy-intensive and polluting sectors, heat and transport, will become more environmentally friendly. Secondly, the increasing number of heat pumps and car batteries can serve as valuable temporary storage for electricity generated by wind and solar. Further measures, such as the modal shift – away from motorised private transport to greater use of buses, rail and bicycles – will ultimately provide the necessary transformation in the transport system.

The key to the heat transition, however, lies primarily in renovating Germany's building stock to improve energy efficiency as well as in modernising heating technology. In the future, there will be an increasing number of houses and neighbourhoods in Germany that will be able to meet their energy requirements entirely from their own renewable energy systems. The importance of energy efficiency is common to all sectors. It is imperative that we reduce energy consumption and satisfy all of the remaining energy demand from renewable sources. Only with this combination will an almost completely climate-neutral, environmentally friendly energy supply become possible.

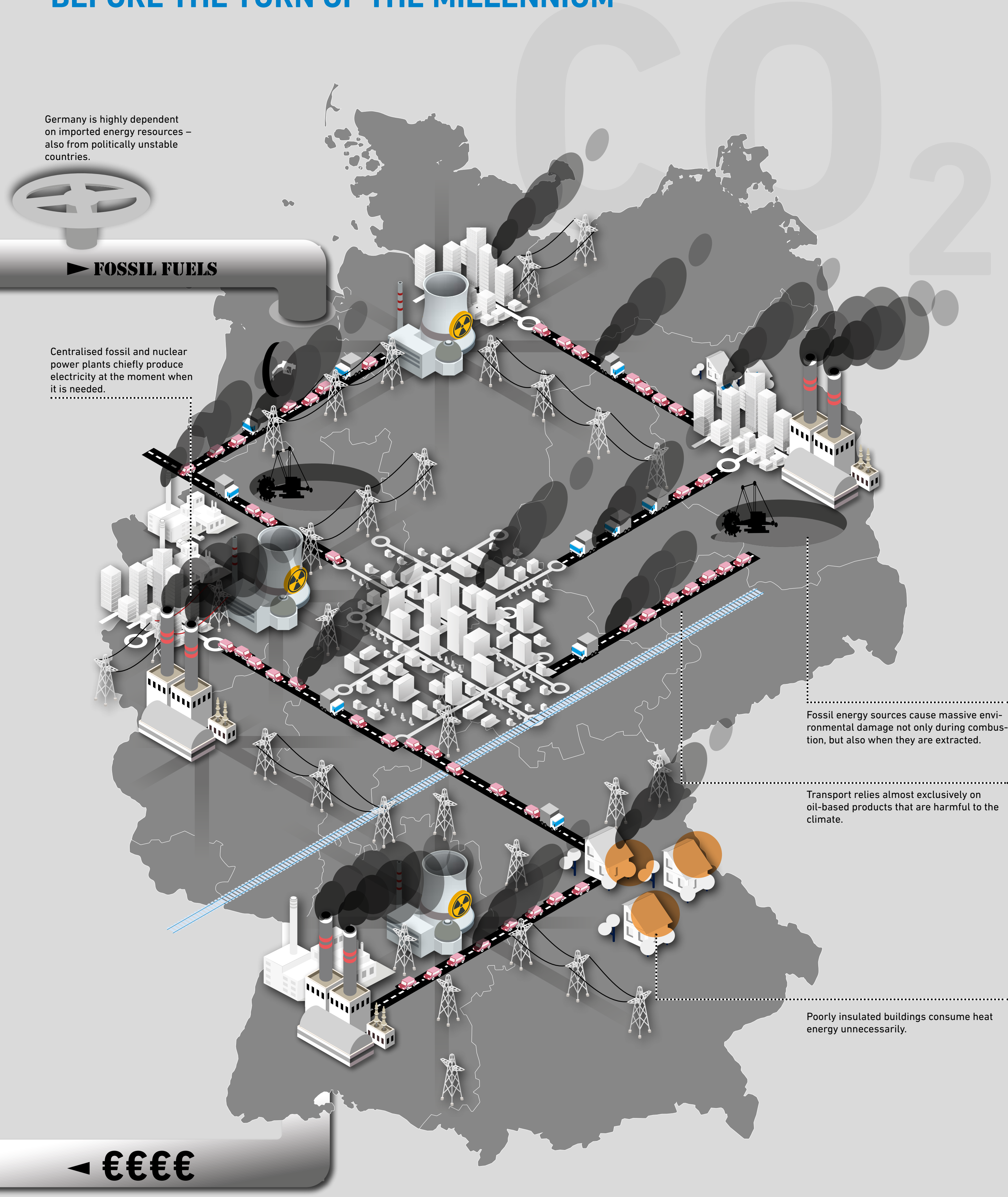
What may sound like a futuristic fantasy is already being put to the test in many research projects and in practice in Germany. With the Energy Transition Atlas, we want to show you some of these examples and whet your appetite for the energy system of the future. By taking a journey across our country, you will discover how Germany plans to implement its "Energiewende" – we encourage you to follow in our footsteps.

Philipp Vohrer,
Managing Director, Agentur für Erneuerbare Energien e. V.

LOOKING BACK: GERMANY'S ENERGY SUPPLY BEFORE THE TURN OF THE MILLENNIUM

Germany is highly dependent on imported energy resources – also from politically unstable countries.

Centralised fossil and nuclear power plants chiefly produce electricity at the moment when it is needed.



Fossil energy sources cause massive environmental damage not only during combustion, but also when they are extracted.

Transport relies almost exclusively on oil-based products that are harmful to the climate.

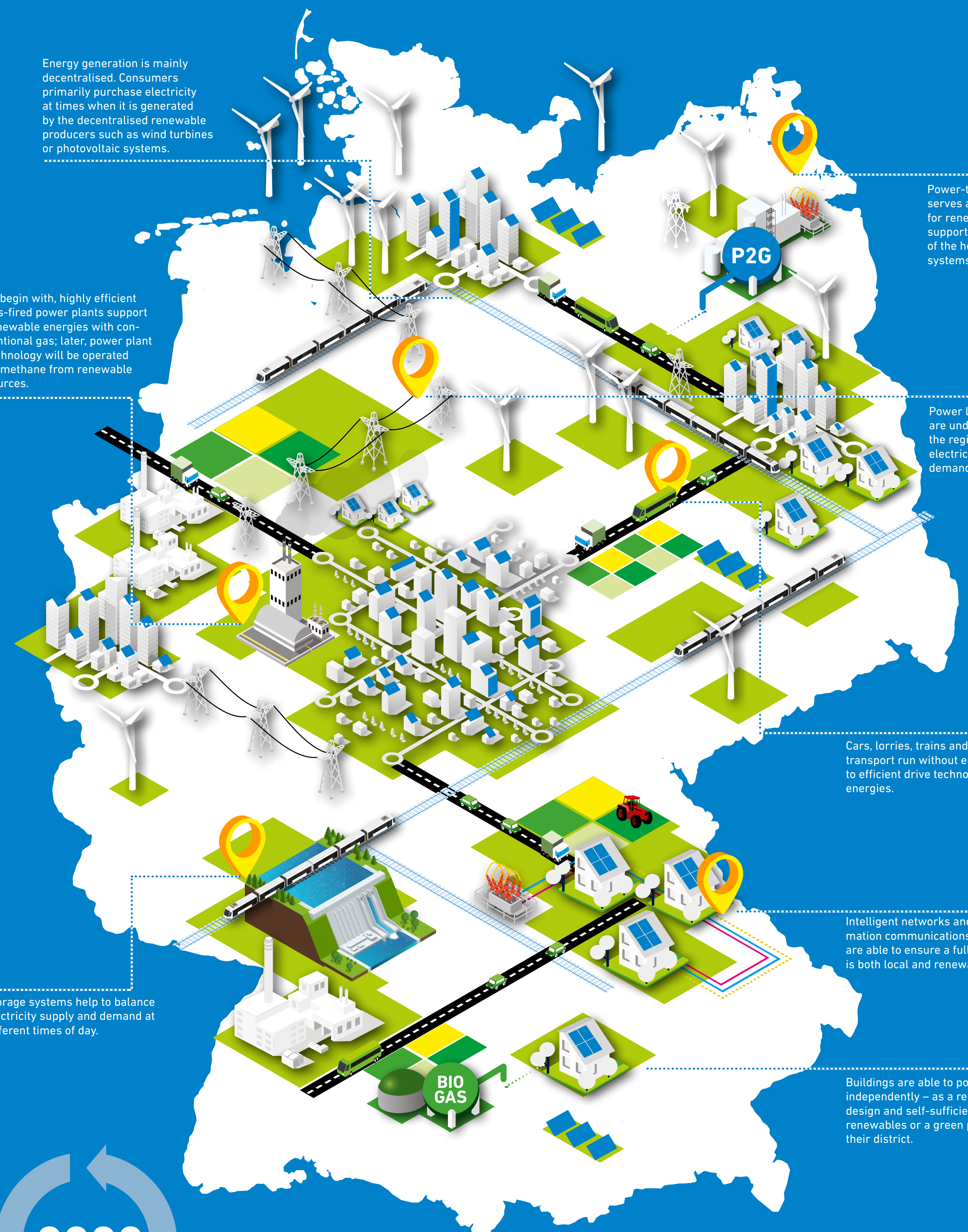
Poorly insulated buildings consume heat energy unnecessarily.

Germany spends several billion euros each year (2015: €66 billion) on energy imports.

LOOKING AHEAD: THE SUCCESSFUL ENERGY TRANSITION

Energy generation is mainly decentralised. Consumers primarily purchase electricity at times when it is generated by the decentralised renewable producers such as wind turbines or photovoltaic systems.

To begin with, highly efficient gas-fired power plants support renewable energies with conventional gas; later, power plant technology will be operated by methane from renewable sources.



Power-to-gas technology serves as long-term storage for renewable power and supports the transformation of the heat and transport systems via sector coupling.

Power lines, some of which are underground, ensure the regional balance of electricity supply and demand.

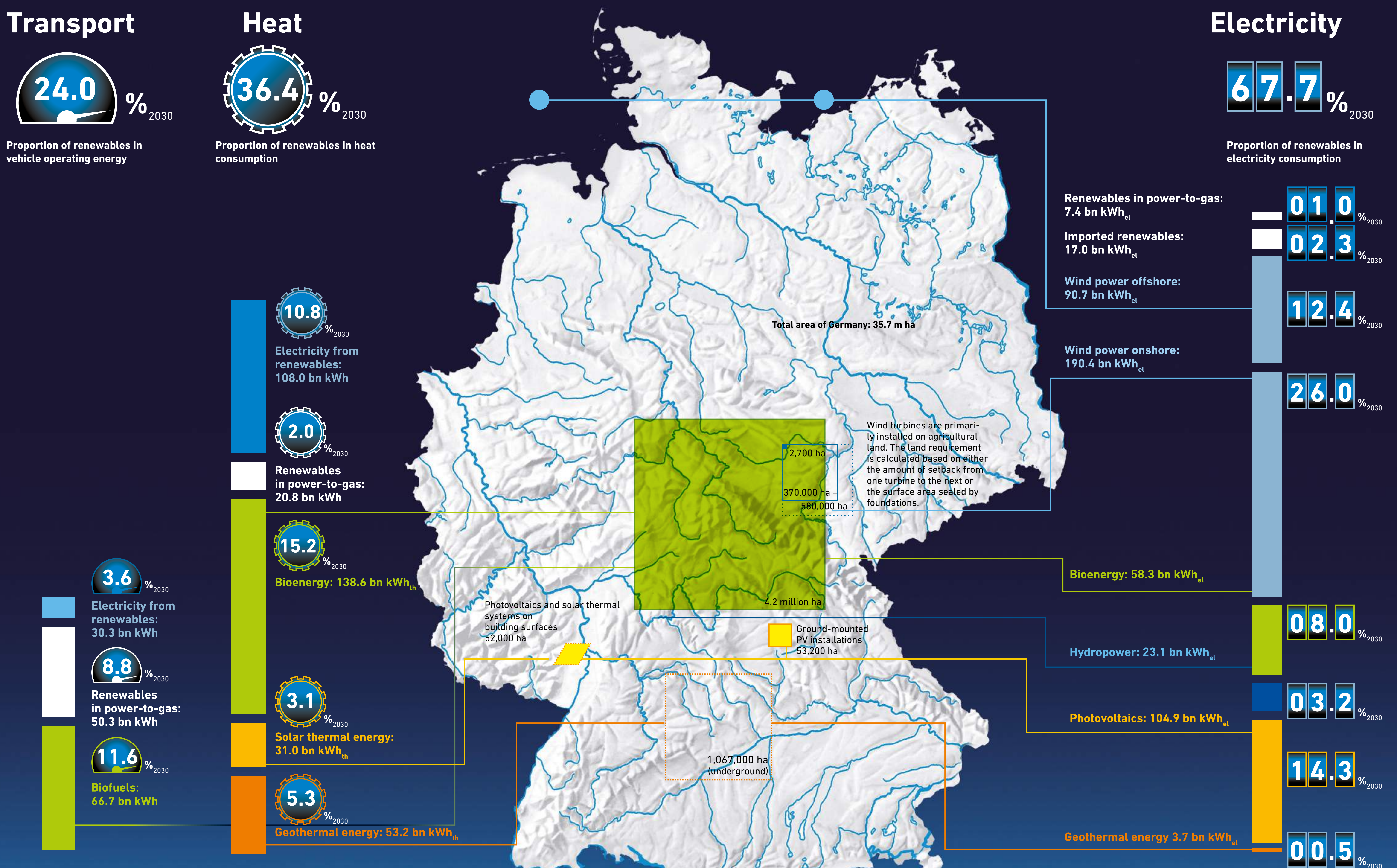
Cars, lorries, trains and other forms of transport run without emitting CO_2 thanks to efficient drive technology and renewable energies.

Intelligent networks and intelligent information communications mean smart grids are able to ensure a full energy supply that is both local and renewable.

Storage systems help to balance electricity supply and demand at different times of day.

Buildings are able to power themselves independently – as a result of efficient design and self-sufficiency from renewables or a green power supply in their district.

Renewable energies strengthen the domestic economy and local value creation.



The squares give a scale representation of the respective space requirements for renewables across the Federal Republic of Germany's total area and do not relate to specific locations.

Source: Nitsch (2016) (Climate protection scenario "Klima 2050"), own area calculations

Wind speeds at elevation of 120 m

Source: www.al-pro.de AL-PRO

FAIR WINDS FOR THE ELECTRICITY SUPPLY WIND POWER

At 120 m, the wind blows at an average speed of

- over 7 m/s
- 5 – 7 m/s
- 3 – 5 m/s
- under 3 m/s

It is no surprise that the wind is strongest on the coast. Nevertheless, it is also worth harnessing wind power in southern Germany, because there is a suitable turbine for each type of wind.

Wind power already supplies the largest portion of renewable electricity, however, its potential is far from exhausted. This is primarily due to the rapid improvement in the performance of the technology. The stronger wind at high altitudes can be used almost everywhere in Germany, and many old installations can be replaced by few, advanced, high-performance turbines. This means that fewer and more powerful wind turbines will generate increasingly more electricity.

Since August 2009, wind turbines have also been generating electricity off the coast of Germany (offshore wind power). These wind turbines will soon significantly contribute to the power supply.

Share in the energy supply in 2016 and 2030

(only onshore wind power)

26.0 %2030 Electricity

2016: 66.3 bn kWh p.a.

2030: 190.4 bn kWh p.a.

Land required in 2016 and 2030

including setback areas

2016 230,000 ha

2030: 370,000 ha – 580,000 ha

only foundations

2016: 2,300 ha

2030: 3,700 - 5,800 ha

Wind turbines must adhere to a minimum setback distance between units to minimise mutual interference. This is determined by the prevailing wind direction and the size of the turbines. In 2016, the setback area was an average of 5 hectares per MW. For 2030, a range was established from 3.8 hectares per MW (BWE 2012) to 6 hectares per MW (AEE 2015). This is a result of various assumptions regarding the size of the turbines and the required setback area, among others.

The foundation area of a wind turbine is a maximum of one per cent of the required setback area and seals the ground. The setback areas can be utilised for agriculture, for example.

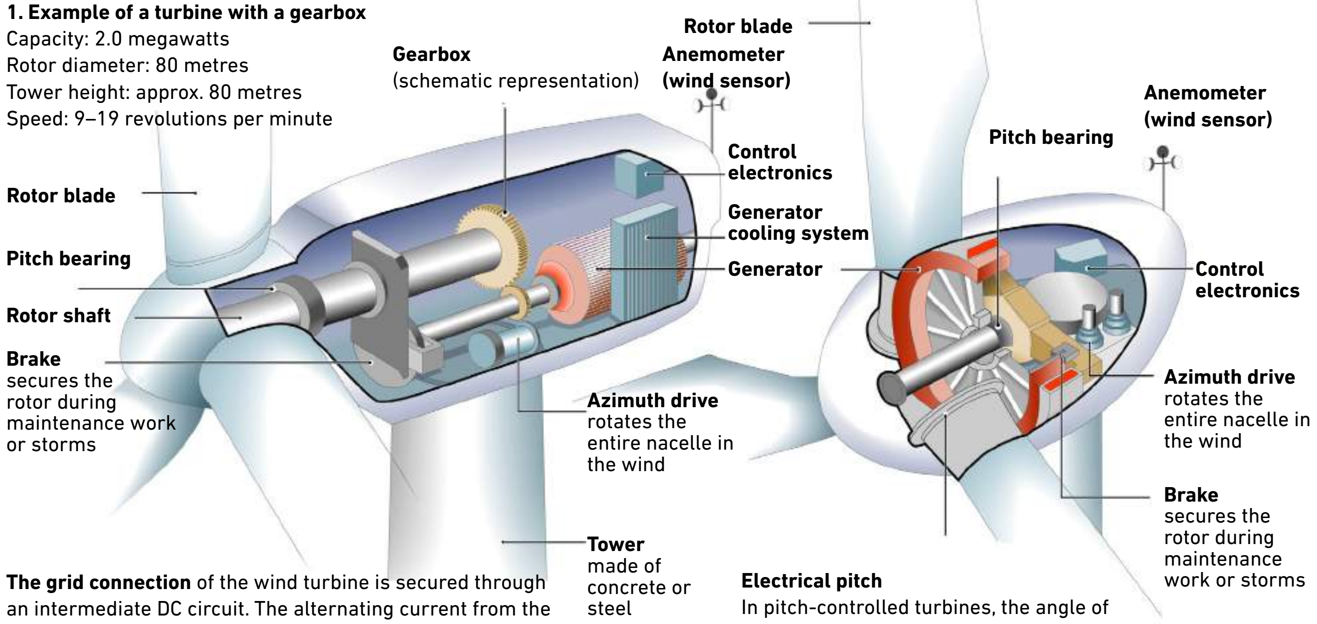
Source: BMWi, Nitsch (2016) (Climate protection scenario "Klima 2050"), own calculations

HOW A WIND TURBINE WORKS

Two different design principles are most prevalent in wind turbines: turbines with gearboxes (1) increase the low speed of the rotor shaft to a more favourable speed for the generator. In gearless turbines (2), the rotor of the generator is attached directly on the rotor shaft.

1. Example of a turbine with a gearbox
Capacity: 2.0 megawatts
Rotor diameter: 80 metres
Tower height: approx. 80 metres
Speed: 9–19 revolutions per minute

2. Example of a gearless turbine
Capacity: 5.0 megawatts
Rotor diameter: 114 metres
Tower height: approx. 124 metres
Speed: 8–13 revolutions per minute



The grid connection of the wind turbine is secured through an intermediate DC circuit. The alternating current from the generator is first converted to direct current and then back to alternating current with the correct frequency and voltage. This allows the wind turbine to operate at varied speeds and minimises the mechanical loads.

Electrical pitch
In pitch-controlled turbines, the angle of attack can be altered at different wind speeds to maintain a constant rotational speed.

THE ECONOMIC AND INFORMAL INVOLVEMENT OF THE PUBLIC CAN INCREASE THE ACCEPTANCE OF WIND FARMS.

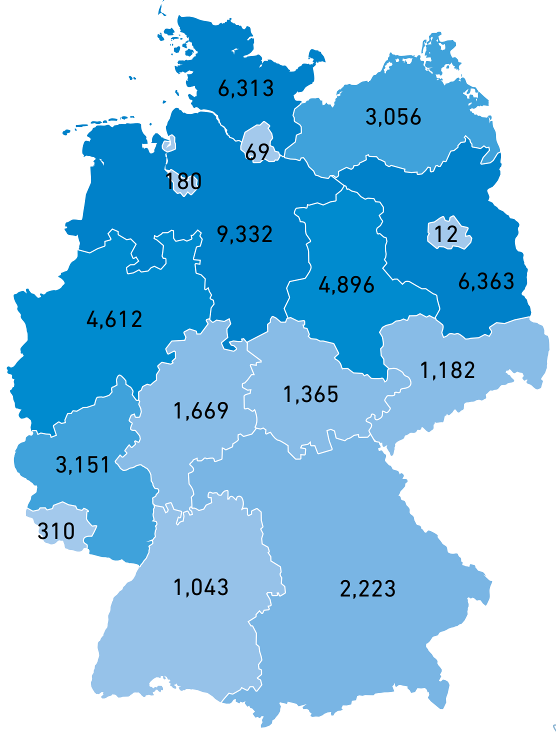
Almost all of the local residents are involved in the Reußenköge wind farm project near the German-Danish border.

GIVING WIND POWER MORE SPACE

93 per cent of Germans are in favour of expanding the use of renewable energies, according to the results from a TNS Emnid survey from 2016. However, whenever the energy transition reaches too close to home, the attitude of many residents becomes more critical. This is the case with wind power, just as with any other infrastructure project. The energy transition project can, therefore, be jeopardised by proverbially keeping wind turbines at a distance and establishing too restrictive regulations governing distances, as shown by the Bavarian example: there, wind turbines must be placed at a distance of ten times their height from the nearest residential area – for modern turbines this means a distance of 2,000 metres. The result for Bavaria equals a halt in development. Nevertheless, Germany's strictest setback regulation may be loosened to cater to disproportionately more energy transition sites.

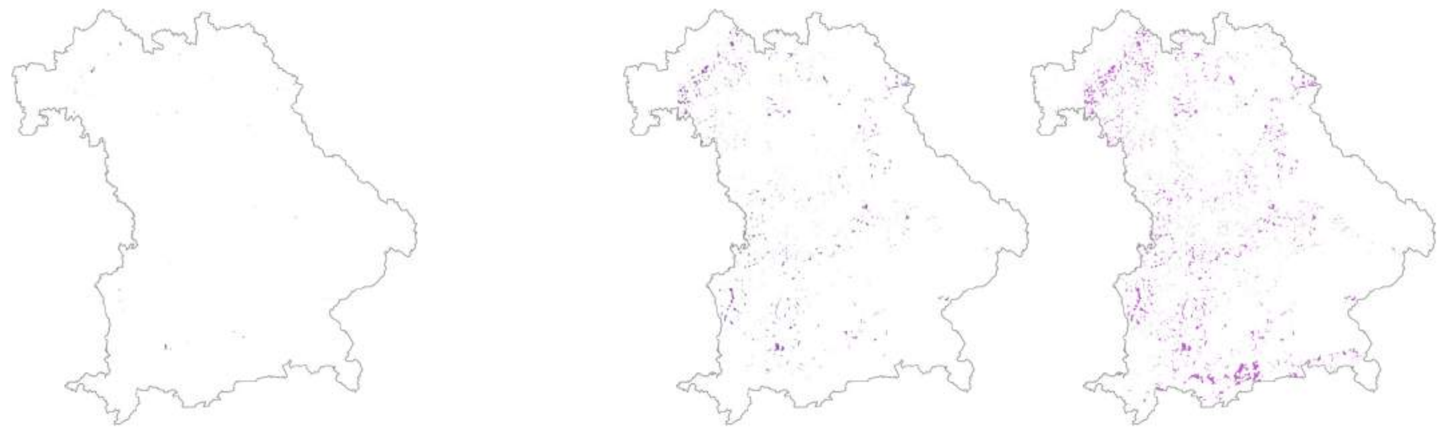
Transparent information and early involvement of local residents in project planning could ensure the necessary on-site acceptance for wind energy projects. The public could also benefit economically through profit-sharing schemes. Municipal tax revenue triggered from the energy transition projects flows, for example, into schools and kindergartens and thus benefits the entire population.

INSTALLED CAPACITY OF ONSHORE WIND ENERGY
2016, IN MW PER FEDERAL STATE



Source: DEWI (UL International GmbH) (2017)

BAVARIA CASE STUDY: RESTRICTIVE SETBACK REGULATIONS JEOPARDISE THE POTENTIAL OF THE ENERGY TRANSITION



Setback distance 2,000 m
(Bavaria status quo for advanced 200-m tall wind turbines)

By reducing the setback distance to:	1,200 m	1,000 m
Wind power capacity potential increases:	24-fold	61-fold

Areas that may be eligible for wind energy use according to the respective setback distances are depicted in purple. Further assessments must be conducted regarding, for example, nature conservation and wind forecasts. The calculated areas can therefore only be used as a rough guideline.

Source: Ostwind AG

WIND POWER CULTIVATES MORE ELECTRICITY PER AREA THAN LIGNITE

Lignite

The Garzweiler II Open-Cast Mine covers an area of 4,800 hectares and contains approximately 1.3 billion tonnes of lignite. An average of 32.5 million tonnes could be extracted per year. From this quantity, a modern lignite-fired power plant with an efficiency of 43 per cent can generate around 35 billion kWh of electricity per year. This results in an electricity yield of approx. 7.3 million kWh per hectare and year.

Comparing this value to the current electricity yield per hectare of the sealed area of the neighbouring wind farm Bergheim/Rheidt, it is clear that just one turbine with an installed capacity of 2 MW generates more energy per hectare than lignite.

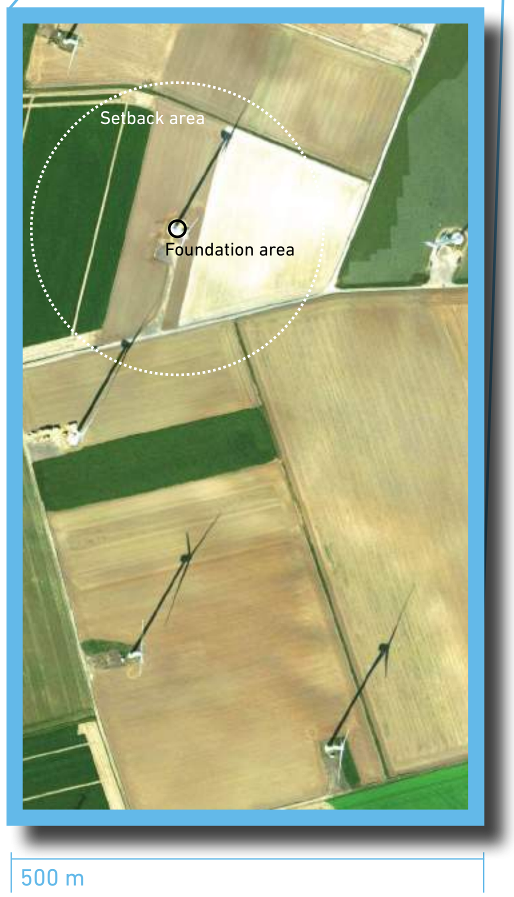
Lignite is a highly problematic energy source, as it emits particularly high levels of carbon dioxide compared to coal and natural gas, thus contributing significantly to climate change. In addition, the groundwater level is extensively lowered and entire villages have to be displaced in lignite mining – also in the case of the Garzweiler II Open-Cast Mine. Protests against the mines were answered in 2016: the red-green state government decided to decrease the mining area. Consequently, some 400 million fewer tonnes of lignite will be extracted over the next decade. 1,400 people may stay in their homes.

Wind power

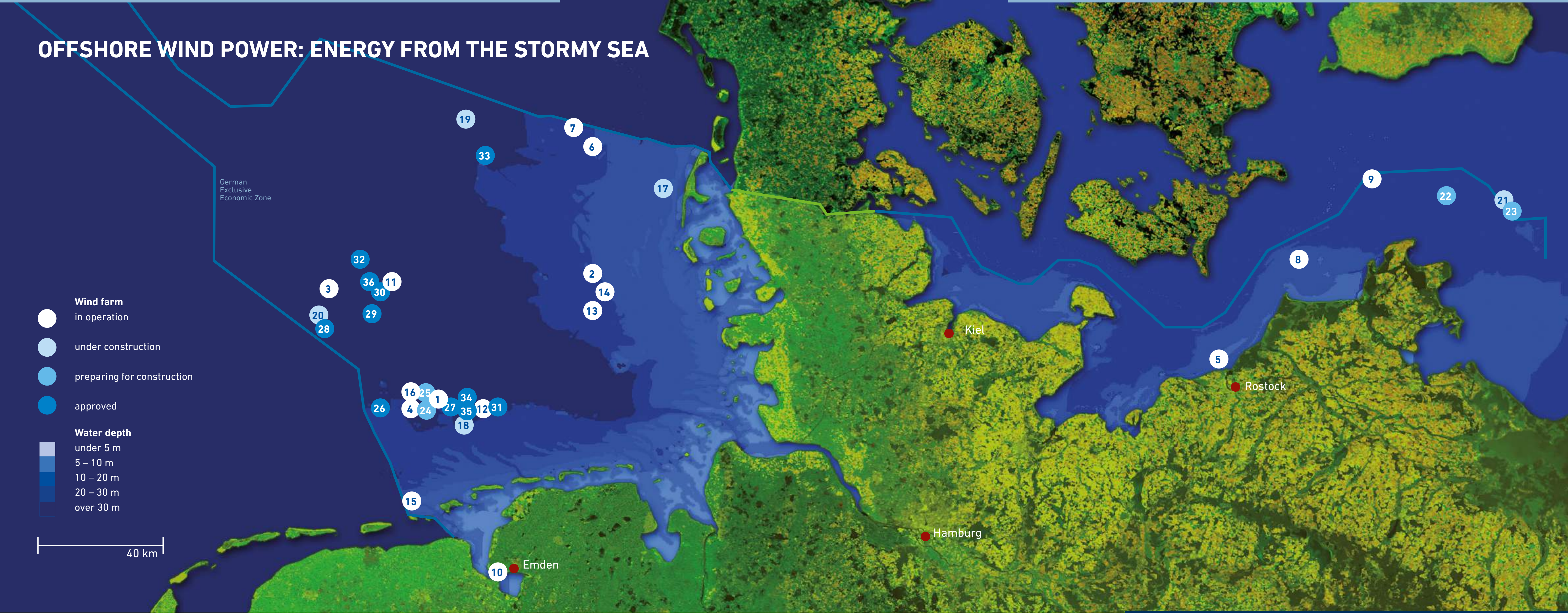
Garzweiler II Open-Cast Mine	2015	2015	Bergheim/Rheidt Wind Farm	
Annual potential yield per hectare	approx. 7.3 m kWh	approx. 22.5 m kWh	only foundation area	Annual yield per hectare
		approx. 225,000 kWh	including setback areas	

Germany	2015	2015	2030	Germany (only onshore wind power)	
Power generation	150 bn kWh	77.9 bn kWh	190.4 bn kWh		Power generation
Land requirement	48,300 ha	2,100 ha	3,700 ha – 5,800 ha	only foundation area	Land requirement
		210,000 ha	370,000 ha – 580,000 ha	including setback areas	
Annual yield per hectare	3.1 m kWh	37 m kWh	33 m kWh – 52 m kWh	only foundation area	Annual yield per hectare
		370,000 kWh	330,000 kWh – 520,000 kWh	including setback areas	

Source: DEBRIV (2015), Coal Industry Statistics (2015), own calculations



OFFSHORE WIND POWER: ENERGY FROM THE STORMY SEA



	Name	Commissioned	Number of turbines	Capacity in MW
in operation				
1	Alpha Ventus	2010	12	60
2	Amrumbank West	2015	80	302
3	BARD Offshore 1	2010	80	400
4	Borkum Riffgrund 1	2015	78	312
5	Breitling	2006	1	2.5
6	Butendiek	2015	80	288
7	DanTysk	2014	80	288
8	EnBW Baltic 1	2011	21	48.3
9	EnBW Baltic 2	2015	80	288
10	ENOVA Offshore Project Ems Emden	2004	1	4.5
11	Global Tech I	2015	80	400
12	Gode Wind	2016	97	582
13	Meerwind	2014	80	288
14	Nordsee Ost	2015	48	295.2
15	Riffgat	2014	30	108
16	Trianel Windpark Borkum I	2015	40	200

Source: BSH (as of: 01/2017)

	Name	Commissioning (scheduled)	Number of turbines	Capacity in MW
under construction				
17	Nordergründe	2017	18	110.7
18	Nordsee One	2017	54	332.1
19	Sandbank	2017	72	288
20	Veja Mate	2018	67	402
21	Wikinger	2017	70	350
preparing for construction				
22	Arcadis Ost 1	2018	58	348
23	Arkona	2019	60	385
24	Borkum Riffgrund 2	2019	56	450
25	Merkur	2019	66	396
in planning stage				
26	Borkum Riffgrund West I	not specified	45	270
27	Delta Nordsee I & II	2021	80	320
28	Deutsche Bucht	2019	30	252
29	EnBW He Dreiht	not specified	80	732
30	EnBW Hohe See	not specified	71	497
31	Gode Wind 04	not specified	42	252
32	Kaikas	not specified	83	581
33	Nördlicher Grund	not specified	64	384
34	Nordsee Three	not specified	60	369
35	Nordsee Two	not specified	48	295.2
36	OWP Albatros Phase 1	2019	19	116.8

Share in the energy supply in 2016 and 2030

(only offshore wind power)

12.4 %2030 **electricity**

2016: 12.3 bn kWh p.a.
2030: 90.7 bn kWh p.a.

Wind power on the high seas will soon supply a considerable amount of renewable energy. At the end of 2016, some 16 wind farms with a total installed capacity of around 4,100 MW were in operation. 20 additional wind farms with a total capacity of around 6,300 MW are under construction, in preparation for construction or in the planning phase.

Expansion potential

4,100 MW
Installed capacity
2016

22,100 MW
Installed capacity
2030

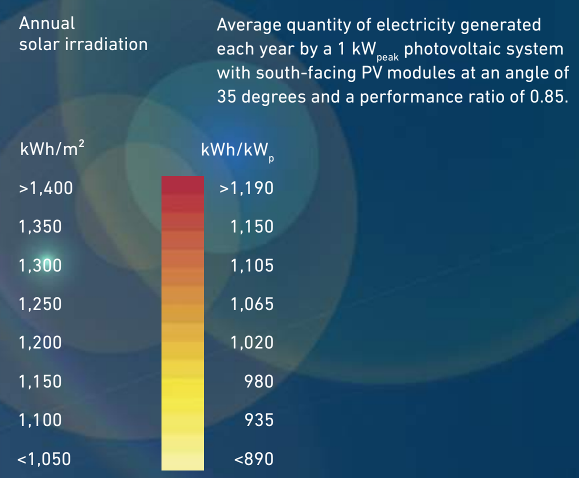
Sources: BMWi; Nitsch (2016) (Climate protection scenario "Klima 2050")

Source: GeoModel

SUNNY OUTLOOK FOR ELECTRICITY AND HEAT

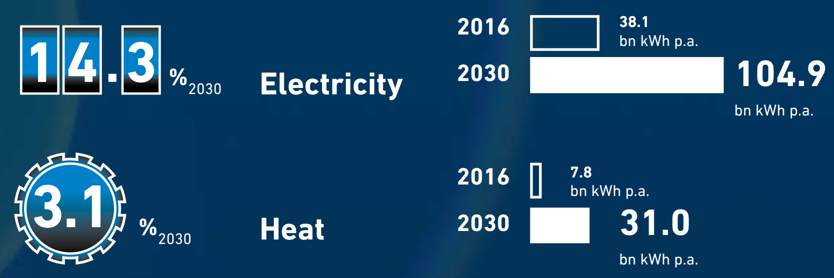
SOLAR ENERGY

In Germany, the annual solar irradiation per square metre is between 900 and 1,200 kWh. Although this is certainly lower than in southern Europe or Africa, it is still sufficient to make a significant contribution to Germany's heat and electricity supply. 234,400 hectares of building surfaces are suitable for solar installations. As yet, approximately 11 per cent of this space is being used, which indicates that there is still a great deal of potential to be tapped.



Calculation example:
The annual solar irradiation in Kiel is 1,100 kWh/m². A south-facing photovoltaic system with 1 kWp of installed capacity and angled at 35 degrees on an area of approx. 10 m² generates 935 kWh in a year. This corresponds to 27 per cent of the annual electricity consumption of an average household. In Munich, 1 kW_{peak} generates 1,170 kWh of electricity per year, thus covering 33 per cent of the electricity consumption.

Share in the energy supply in 2016 and 2030



Space requirements in 2016 and 2030

Land area for photovoltaics and solar thermal systems

2016: 26,200 ha (electricity only)

2030: 53,200 ha (electricity and heat)

Building surfaces for photovoltaics and solar thermal systems

2016: 25,800 ha

2030: 52,000 ha

Potentially suitable building surfaces: 234,400 ha

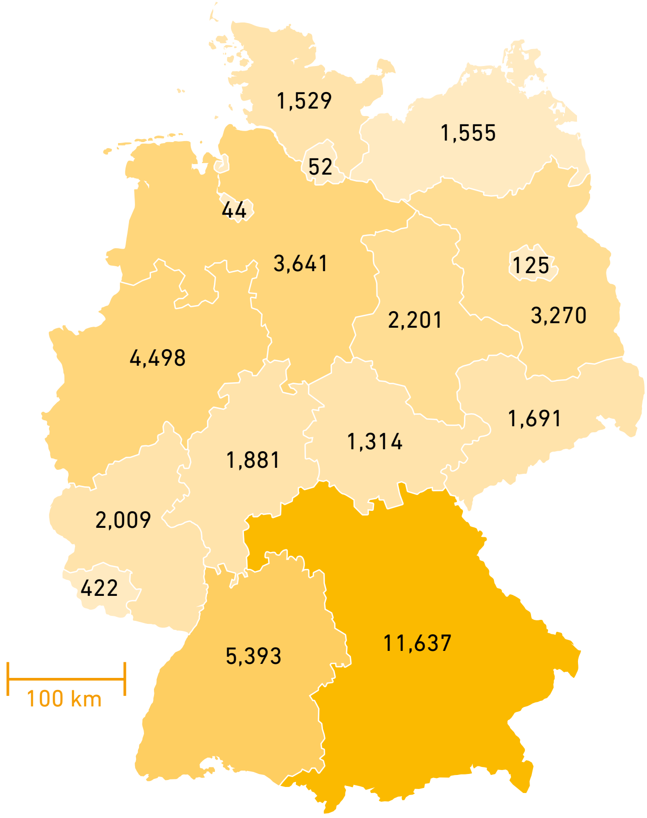
Source: German Federal Ministry for Economic Affairs and Energy (BMWi), Nitsch (2016) (Climate protection scenario "Klima 2050"), own calculations

GREAT POTENTIAL FOR DOMESTIC PV

In 2016, there was approximately 40,900 MW of photovoltaic capacity in Germany, more than a quarter of which was installed in Bavaria. Many households are taking advantage of the opportunity to produce electricity on their own roofs.

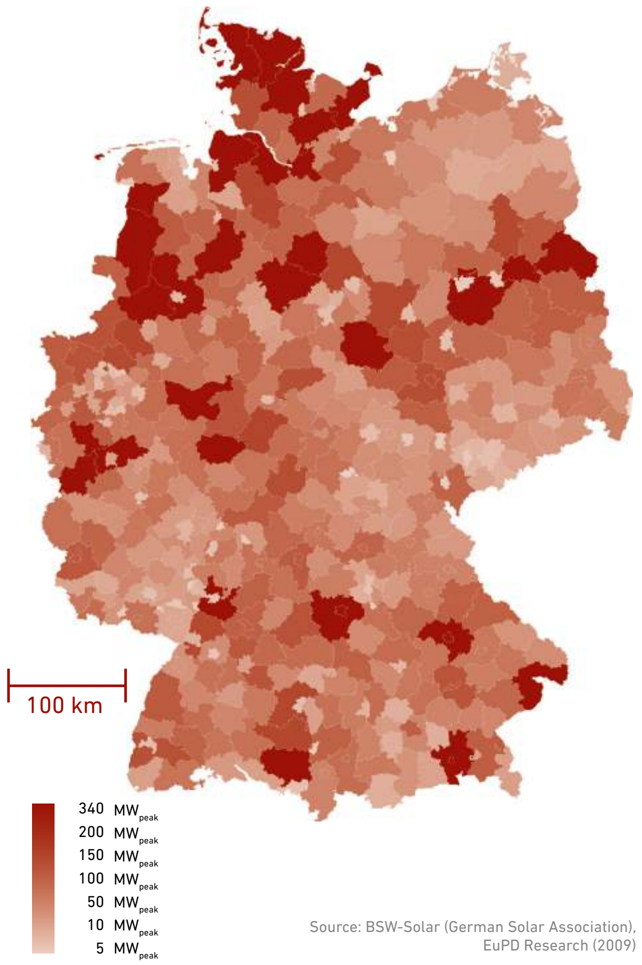
Just 7 m² of roof surface is enough to satisfy a quarter of the electricity needs of the average household. There is still great potential to generate electricity on the roofs of detached and semi-detached homes in Germany.

INSTALLED PHOTOVOLTAIC CAPACITY IN 2016 PER FEDERAL STATE IN MW_{PEAK}



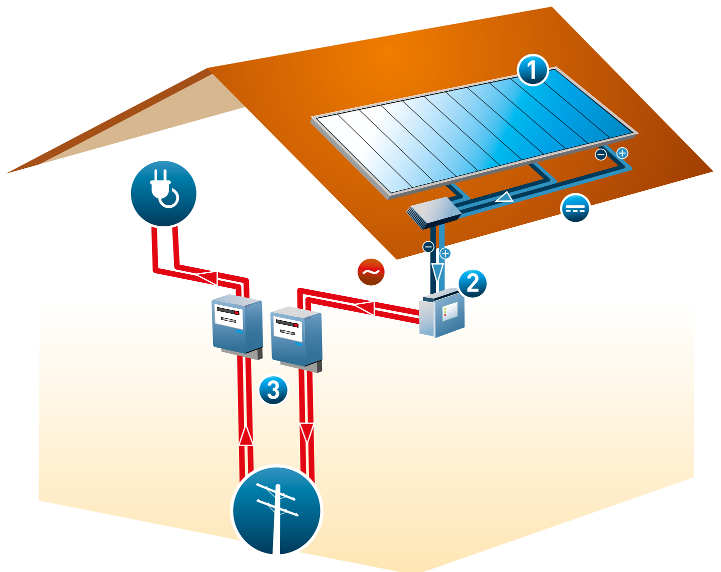
Source: BNetzA/BSW (2017), BNetzA (2017)

POTENTIAL FOR ROOF-MOUNTED PHOTOVOLTAICS PER ADMINISTRATIVE DISTRICT IN MW_{PEAK}



Source: BSW-Solar (German Solar Association), EuPD Research (2009)

HOW SOLAR IRRADIATION IS USED TO GENERATE ELECTRICITY:



1. The PV cells generate direct current from the energy from solar radiation.
2. The inverter converts the direct current into alternating current so that it can be fed into the power grid.
3. The electricity meters measure how much power is fed into the grid and how much power is drawn back out.

OSNABRÜCK CASE STUDY: USING SOLAR POWER, OSNABRÜCK'S ROOFS ARE CAPABLE OF COVERING MORE THAN 100 PER CENT OF THE ELECTRICITY DEMAND OF ALL ITS HOMES

In 2008, Osnabrück became the first city in Europe to create a register of solar roof potential. Residents can use this online tool to find out about the possible solar yield of their house roofs. This source of information makes it easier for them to decide whether or not to make the investment and supports the progress of the energy transition in the local area.

The City commissioned an aerial laser scan, which was then used to assess the suitability of Osnabrück's roofs for solar power. This process makes use of special aircraft whose fuselages are fitted with sensors, which scan the entire area in high resolution. The roof shape, pitch, orientation and level of shade of almost 70,000 buildings was determined, allowing the solar power potential of all of the roofs to be measured. Since then, more than 400 towns and municipalities have followed Osnabrück's example.

The results:

- Number of buildings measured: 69,759 out of 73,430 buildings
- Suitable and very suitable buildings: 27,500
- The calculation assumed a module efficiency of 15 per cent, as was being achieved at the time of the aerial laser scan by good-quality mono- and polycrystalline silicon PV cells.
- In Osnabrück, 1 kWp of rated power produces 650–900 kWh of electricity per year. This requires a PV installation with a module surface of 6.7 m².

The yield is dependent on the module's pitch, orientation and level of shade. The highest yields are obtained when the roof is pitched at 35 degrees and faces due south.

37% of Osnabrück's roof surfaces are very suitable or suitable for solar installations.

If all of the very suitable and suitable roofs in the city were fitted with photovoltaic systems, more electricity could be produced than is consumed by all of the private households put together.

Electricity consumption by private households in 2015 — **232 m kWh**

Electricity generation by all very suitable and suitable roof surfaces (37%) — **249 m kWh**

No. 20 Maschstraße
Max. installable module area: 13 m²
Electricity yield: 1,314 kWh p.a.
Limited suitability

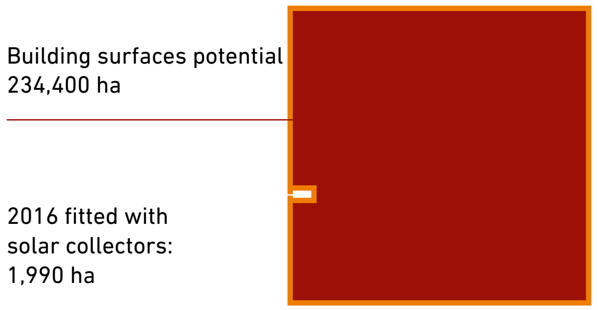
No. 32 Augustenburger Straße
Max. installable module area: 13 m²
Electricity yield: 1,681 kWh p.a.
Very suitable

Source: SUN-AREA (2008)

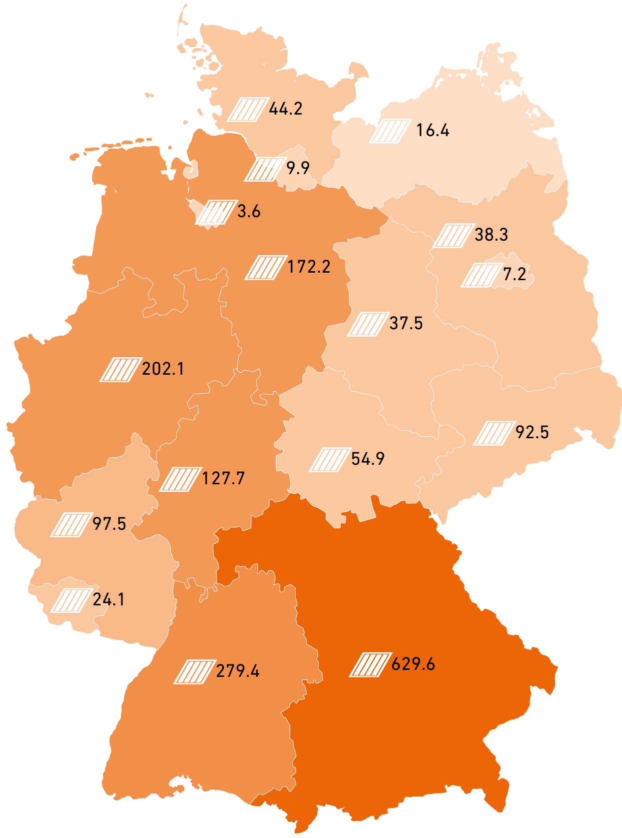
Solar thermal installations use collectors to convert energy from the sun into heat energy. In Germany, solar heat is mainly used to heat water for washing and showering, or for space heating.

It is, however, also possible to use solar heat for cooling. The use of solar thermal-driven chillers is a future-orientated option for reducing the electricity demand for air conditioning. The big advantage of this technology is the seasonal correlation between cooling requirements and solar irradiation. After all, the sunnier it is, the higher the demand for cooling is, too. There is, therefore, an opportunity to use the same system for cooling in the summer and heating in the winter.

Up to now, however, only a fraction of the building surfaces that are suitable for the use of solar energy is being used.

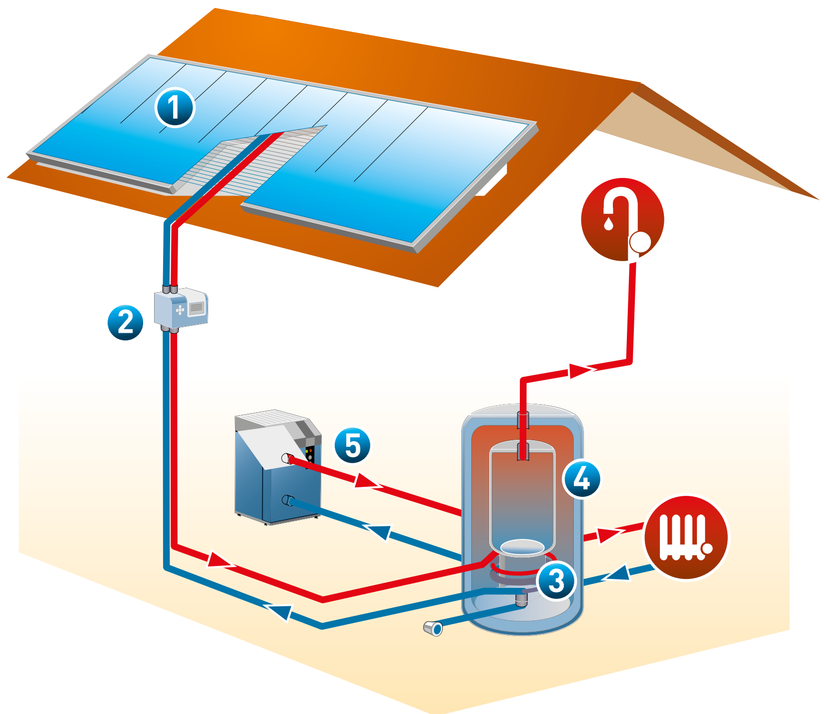


SOLAR COLLECTOR AREA BY FEDERAL STATE IN 2016 IN HECTARES



Source: BSW (2017)

HOW A SOLAR THERMAL INSTALLATION WORKS:



1. The sun's rays heat the heat transfer fluid in the collector.
2. When the temperature of the liquid is higher than the temperature in the tank, the solar controller starts the circulation process.
3. The heat exchanger transfers solar heat to the water in the buffer tank.
4. The buffer tank also makes the heat available at night and on cold days.
5. If the heat from the collector is not sufficient, an additional heating source (e.g. a wood pellet heating system) is activated.

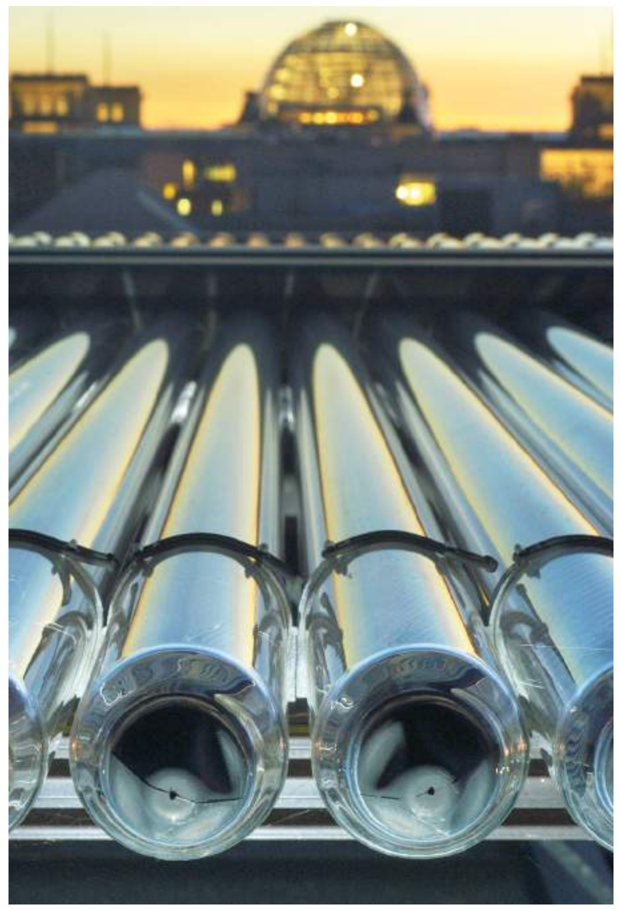
BERLIN CASE STUDY: SOLAR THERMAL POTENTIAL IN THE NATION'S CAPITAL

Berlin's roofs are bursting with energy. The potential for solar thermal installations is particularly great. So far, only 24.5 hectares of solar collectors have been installed in Germany's capital since 2001. Although the trend is growing – almost a quarter of the systems were installed in 2008 – the roof surface potential is far from being fully exploited yet. This has been demonstrated by the pilot project "Berlin Solar Atlas". The publicly accessible Internet portal informs users not only about a photovoltaic system's possible electricity generation, CO_2 savings and investment costs, but also about the solar thermal potential in the selected pilot regions. One such project area, "Friedrichstrasse", encompasses 5,837 buildings on an area of land covering 1,000 hectares. With a total roof area of 71 hectares, 3,926 buildings are suitable for the exploitation of solar thermal energy. Approximately 4,500 kWh of heat per year is produced by just 10 m^2 of solar collectors. This represents about one-fifth of the annual heating requirement of an average household.

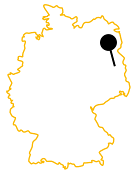
Usable area in m^2 per building
- 5,000
- 3,000–5,000
- 1,000–3,000
- 250–1,000
- up to 250
- 0

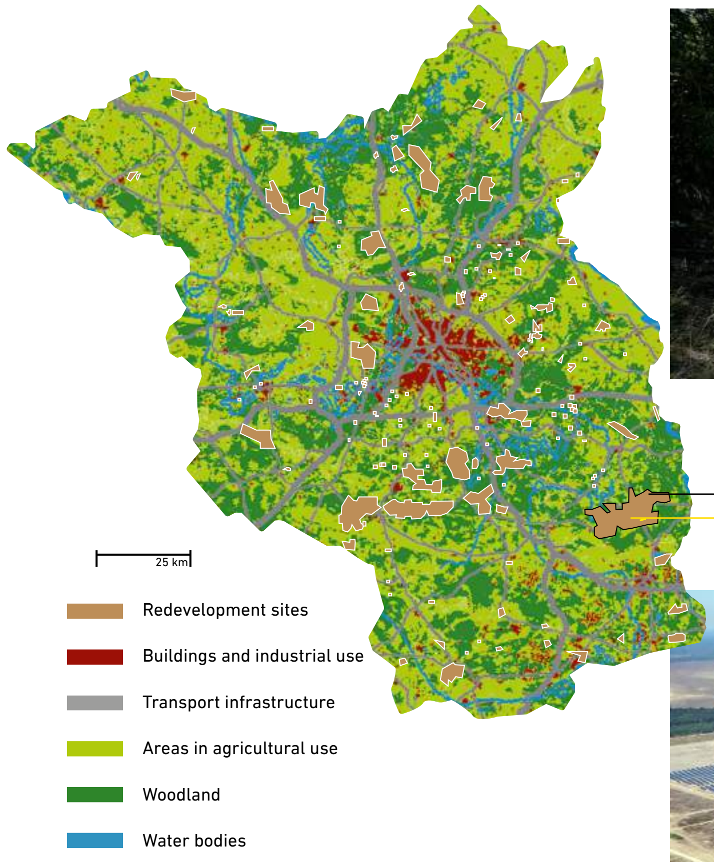
Source: Berlin Partner GmbH (2009)

FEDERAL PRESS OFFICE
The solar thermal installation on the roof of the Press and Information Office of the Federal Government (Federal Press Office for short) has a total area of 348 m^2 and is fitted with evacuated tubes. The solar heat is used in the summer to operate two absorption chillers, which partially cool the building. In the winter, the heat is needed to support the heating system.



LIEBEROSE CASE STUDY: PHOTOVOLTAICS PUT ABANDONED MILITARY SITES TO GOOD USE





Lieberose redevelopment site

Former chemical depot and testing centre – today, the site of the Lieberose solar farm

REDEVELOPMENT SITES

In Germany, there are around 350,000 hectares of former military land or military sites that will be decommissioned in the near future. Because redevelopment sites are often nature reserves, only part of this land can be used for photovoltaics. Nevertheless, there remains a large amount of potential space for ground-mounted (free-field) solar power plants. This is demonstrated by this real-life example from Brandenburg.

Covering an area of 27,000 hectares, the military training camp at Lieberose was the largest in the former GDR. After the withdrawal of the Soviet Army in 1992, the site passed into the ownership of the federal state of Brandenburg – including all of its residual pollution. Besides live ammunition, on an area of about 400 hectares, chemicals in particular constituted a hazard and contaminated the soil and ground water. Today, the site is being used to generate eco-friendly electricity.

LIEBEROSE SOLAR FARM

The Lieberose solar farm not only produces clean energy, but also ensures that dangerous ammunition is removed from the former military training area. The 5 million euros needed for this clean-up was financed by a one-off payment by the solar power plant's investors and the rental income for the site. This makes Lieberose a shining example of the successful combination of high-tech and active conservation.

Commissioning:	2009
Footprint:	162 ha (more than 210 football pitches)
Module area: approx. 700,000 thin-film modules	approx. 50 ha
Capacity:	**approx. 53 MW**
Annual yield:	**approx. 53 m kWh** (equivalent to the annual requirement of around 15,000 homes)

SENFTENBERG CASE STUDY: GERMANY'S LARGEST SOLAR THERMAL INSTALLATION

In September 2016, the largest thermal solar plant in Germany went into operation in Senftenberg, a town of 25,000 inhabitants. The plant was built by the municipal utilities company Stadtwerke Senftenberg on an area of about 2.2 hectares and is expected to produce around four million kilowatt-hours of heat per year. It is comprised of 1,680 tube collectors that generate heat during the average 1,700 hours of sunshine a year. In the summer months, the base load is almost completely covered. Demand above that level is met using natural gas-fired boilers. In combination, the systems have replaced the old pulverised lignite-fired boiler and supply heat to more than 10,000 inhabitants.

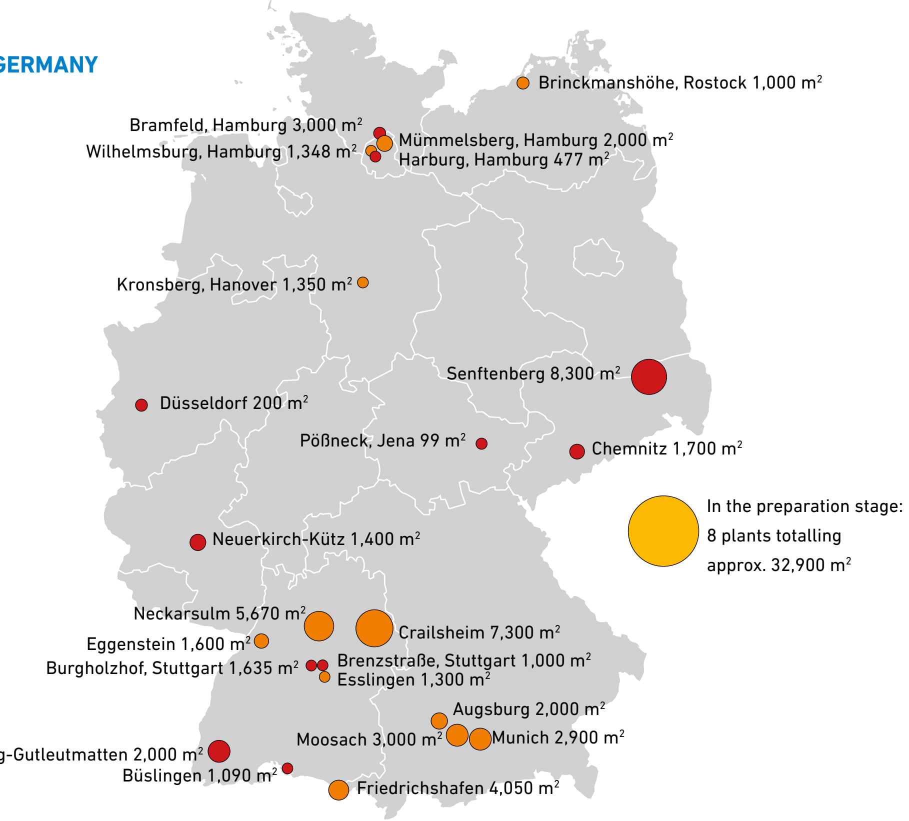
As a result of the plant's shrewd planning, there is no call for additional storage. Its short build time of just six months is also worthy of note. The availability of the restored former landfill site at Laugkfeld proved to be beneficial to those in charge of the project when planning the solar thermal installation. It provided an area of sufficient size on which to build the "solar power plant" and was ideally positioned to allow connection to the district heating network. The project is funded by an investment grant from the KfW development bank's "Renewable Energies Premium" programme.

SOLAR DISTRICT HEATING PROJECTS IN GERMANY

In operation: approx. 49,450 m²

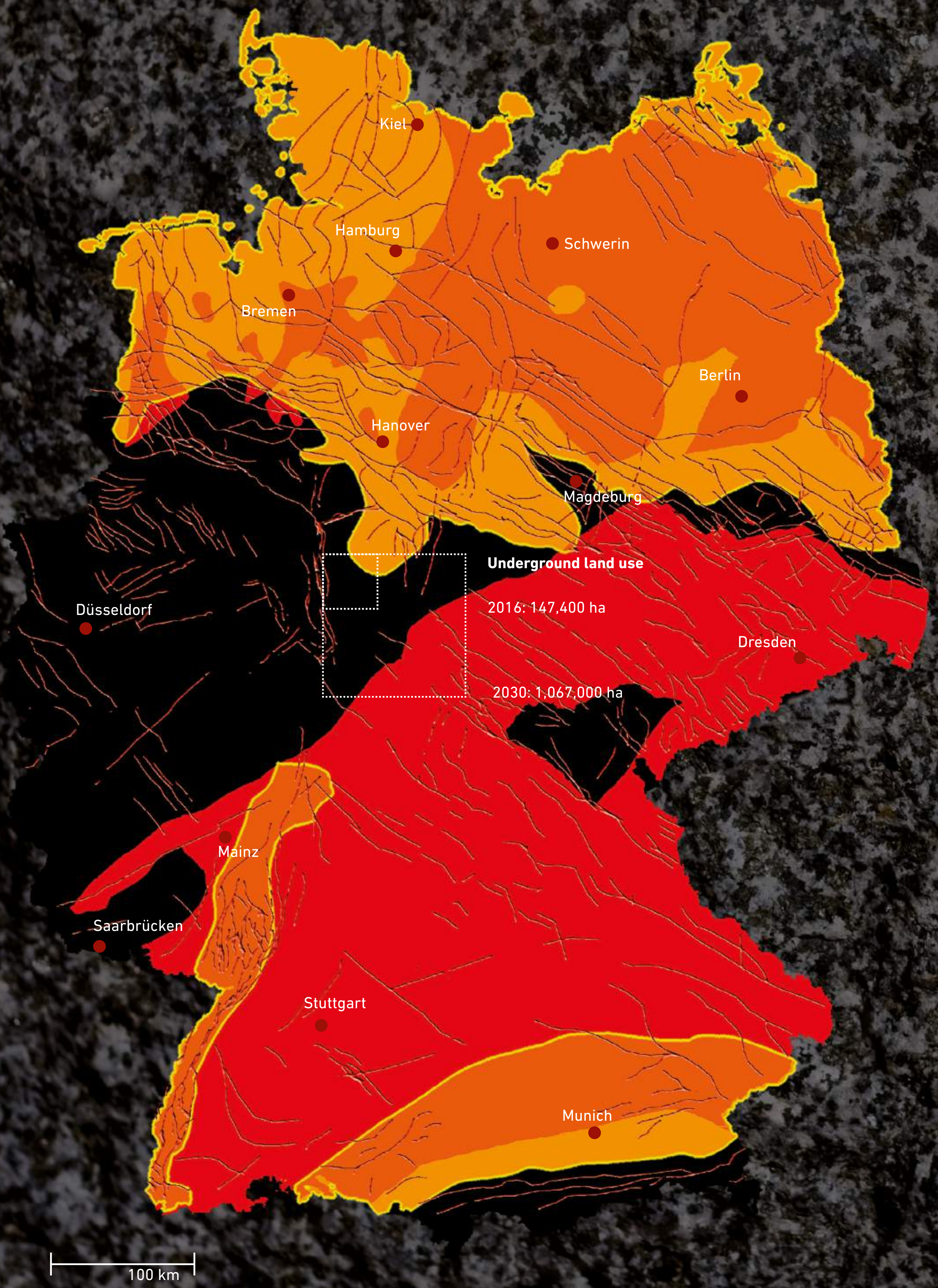
In the planning/implementation stage: approx. 5,000 m²

In the preparation stage: approx. 32,900 m²



Source: Soltes, E. Augsten (SW&W); version date: 2016

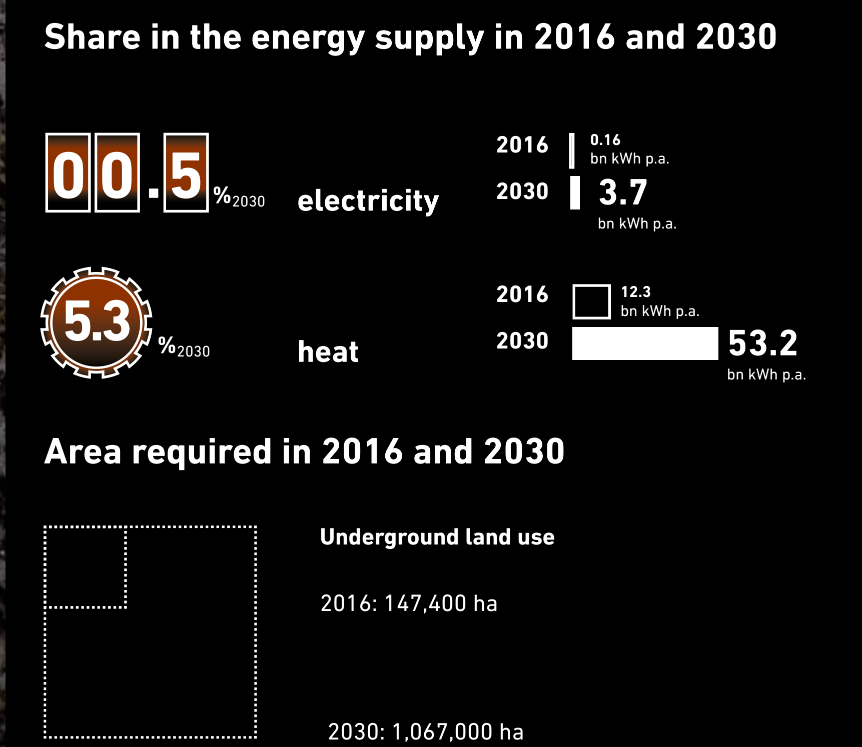
ENERGY FROM DEEP UNDERGROUND
GEOTHERMAL ENERGY



Source map: TAB (2003)

Geothermal energy is an inexhaustible energy reserve in terms of human use. It is a renewable energy source that can be harnessed virtually anywhere. There is also considerable geothermal potential in Germany and it contains significantly higher energy content than conventional energy sources.

In near-surface geothermal energy, heat from the ground is extracted for heat supply from depths of up to 400 metres using heat pumps. Deep geothermal energy (> 400 m) is used both for heating and for power generation. With regards to geothermal power generation, the regions of Germany featuring geological formations with layers containing hot water are of particular economic interest. These are mainly found in the Upper Rhine Valley and the North German Lowlands, as well as in the Molasse Basin in southern Germany. In addition to this so-called hydrothermal geothermal energy, there is petrothermal geothermal energy. This procedure allows heat and power to be generated even in areas without hot underground water. Water is injected into the dry rocks in order to utilise the high temperature.



Source: BMWi, Nitsch (2016) (Climate Scenario 2050), own calculations

POTENTIALS OF GEOLOGICAL FORMATIONS

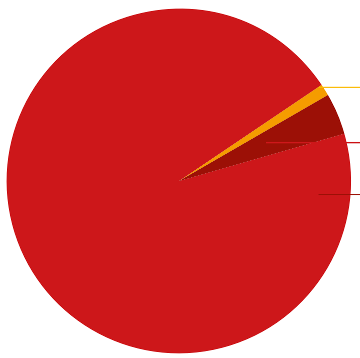
Near-surface geothermal energy
Near-surface geothermal energy utilises energy stored in groundwater or in the layers of the Earth at depths of up to 400 meters. The prevailing temperatures of 8 to 12°C at these depths can be harnessed to supply space and water heating through the use of heat pumps, horizontal geothermal heat exchangers or downhole heat exchangers. Heat pumps are also increasingly used to cool buildings and excess heat is stored in the soil for the winter.

Deep geothermal energy
The term "deep geothermal energy" refers to the use of heat from the ground at depths of between 400 and 6,000 metres. Temperatures are far higher than in near-surface geothermal systems. As a result, deep geothermal energy can also be used for power generation in addition to heat supply. Power generation is economically feasible starting at around 90 °C.

While **hydrothermal systems** utilise hot thermal water for electricity and heat generation, **petrothermal systems** are completely dry. That is why water is injected under high pressure into the dry rock at depths of approx. 2,000 to 6,000 m. This produces fissures less than one millimetre wide, which serve as paths used to heat cold liquids with the natural heat from the hot rocks. The high temperatures can then be used to generate electricity and heat.

Faults are natural cracks in the earth. These fracture zones conduct liquids at a higher rate than the surrounding rock. Rising thermal water therefore accumulates in these fracture zones, transporting heat towards the surface. This makes faults attractive for geothermal use. So far, fault zones have not been used for geothermal energy generation in Germany.

Geothermal resources for power generation
Even the capacity of the smallest geothermal resource (hydrothermal) corresponds to approximately five times the German annual electricity requirements.



Source: TAB (2003)

Near-surface geothermal energy

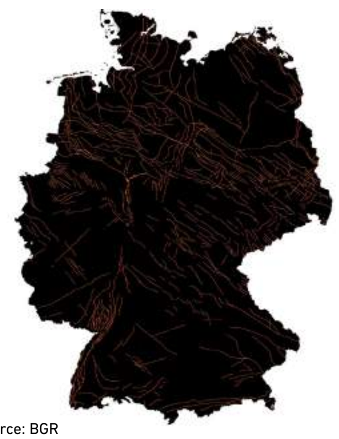
Hydrothermal systems

Source: TAB (2003)

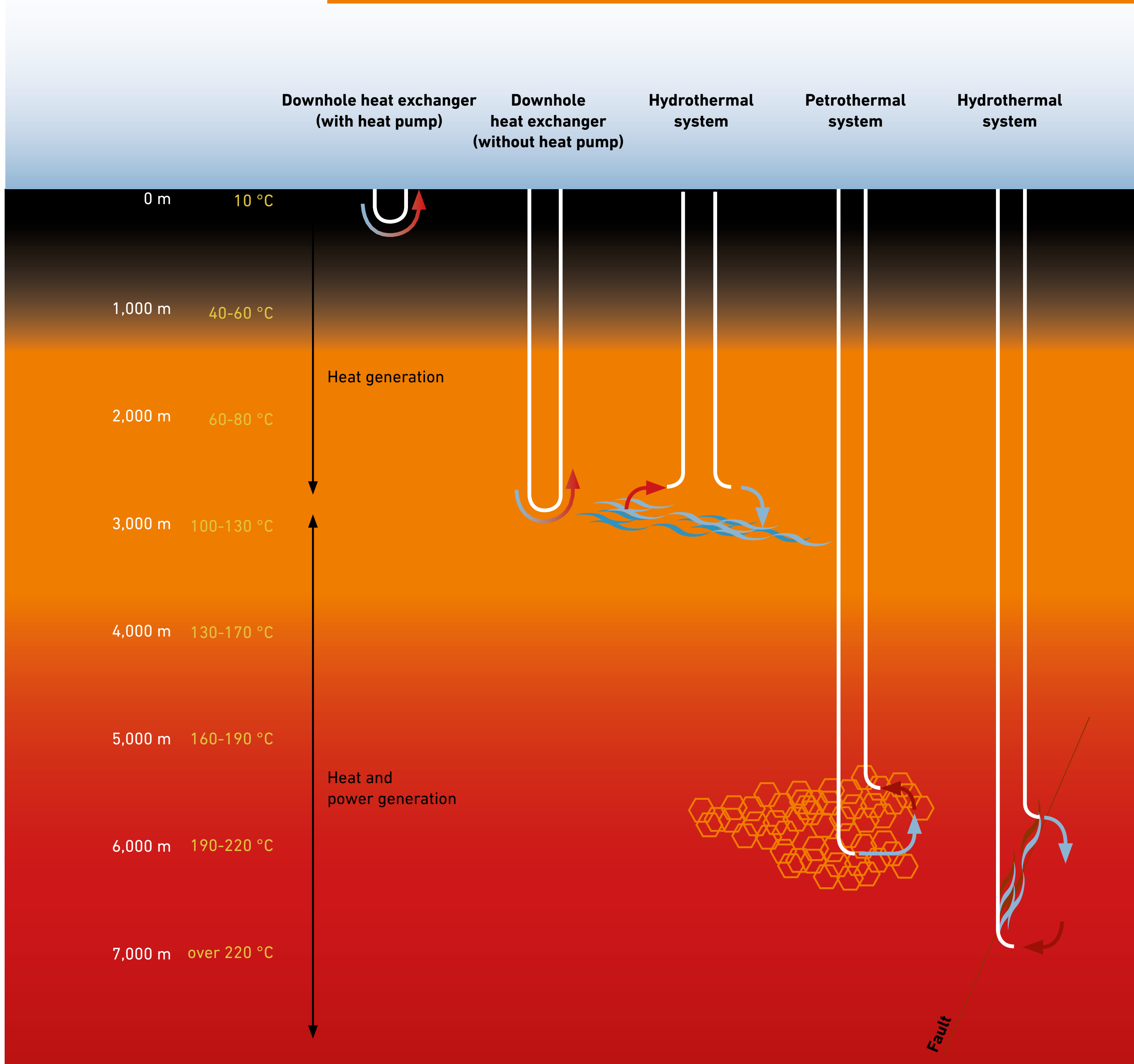
Petrothermal systems

Source: TAB (2003)

Faults (hydrothermal systems)



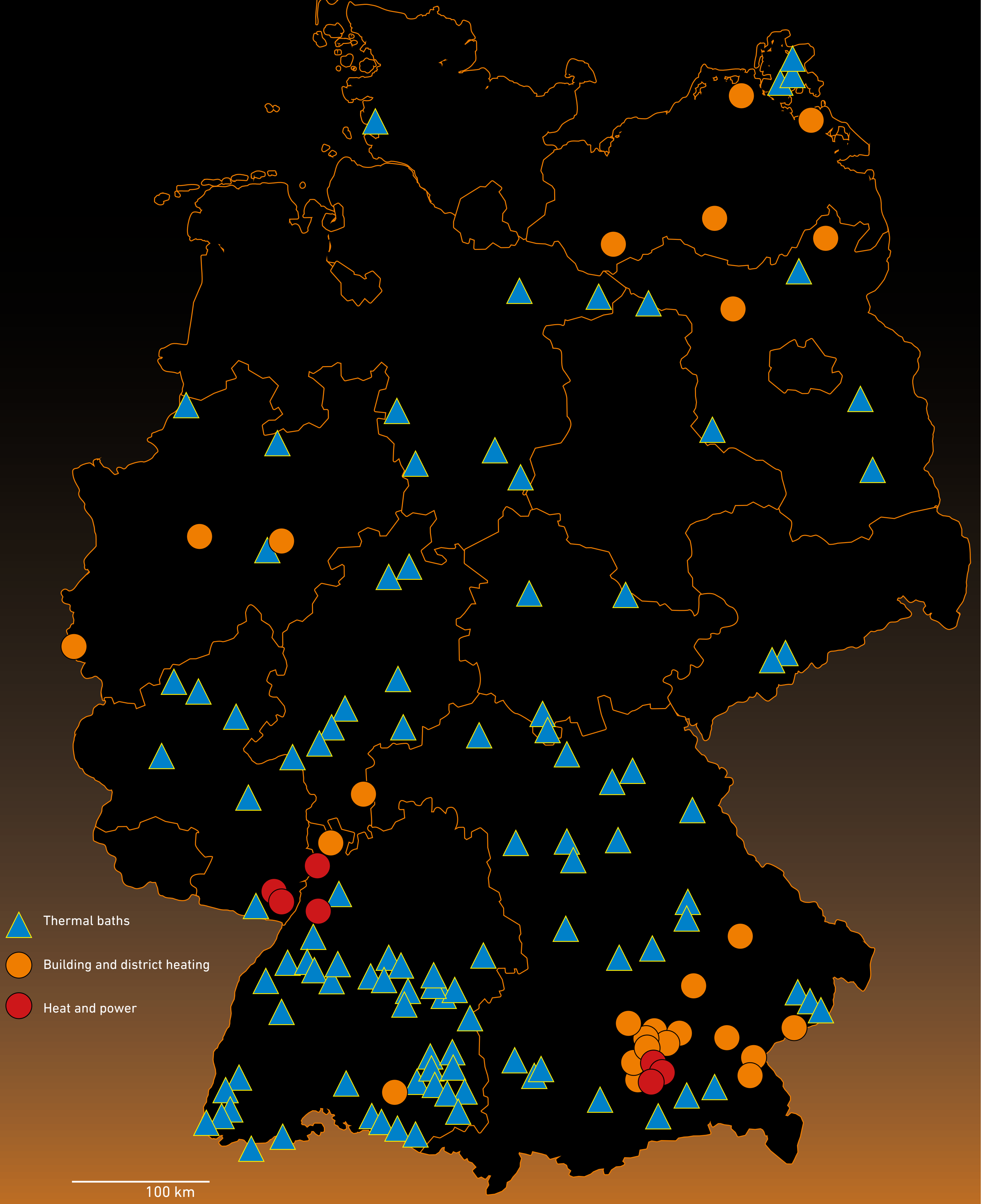
Source: BGR



The deeper we penetrate into the Earth's interior, the hotter it is. In Germany, temperatures increase on average by around 30 °C per kilometre. This means 40 °C is reached at a depth of 1,000 m, 70 °C at a depth of 2,000 m and 100 °C at a depth of 3,000 m. However, these values often vary greatly by region. Deviations from the standard are called heat anomalies. Areas with significantly higher temperatures are particularly attractive for energy generation, where temperature readings already rise to several hundred degrees Celsius at shallower depths.

In addition to temperature, geological conditions are also relevant for geothermal use. Depending on soil condition, various technical procedures are used to generate heat and power.

GEOTHERMAL HEATING STATIONS AND POWER PLANTS IN OPERATION AND UNDER CONSTRUCTION



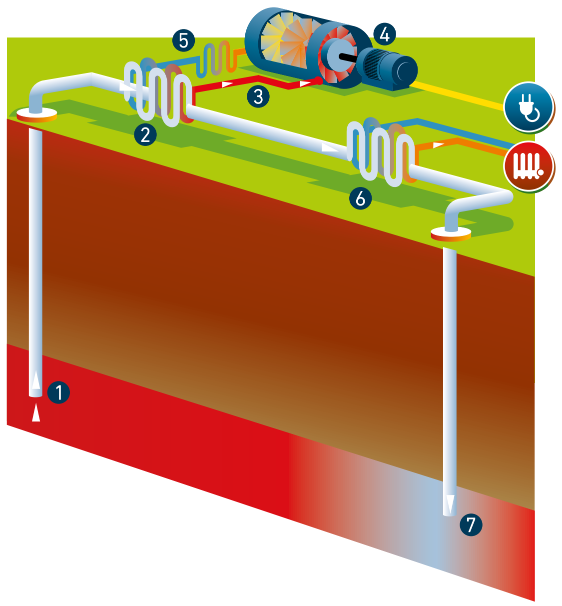
Source: GeotIS (2016)

Heat and, to some extent, electricity are produced at about 230 large geothermal plants in Germany. These plants have a total capacity of around 4,200 MW. Deep geothermal energy is especially used to heat thermal baths and building complexes. 21 geothermal combined heat and power plants feed heat into a local heat network, while 10 geothermal power plants generate electricity. An additional 11 plants are currently under construction. At the end of 2016, 30 deep geothermal plants were in the planning stage, according to figures from the German Geothermal Association (BVG).

UNTERHACHING CASE STUDY: HEAT AND POWER FROM THE GEOTHERMAL POWER PLANT

Commissioning	2008
Development concept	Hydrothermal
Method of power generation	Kalina cycle
Drilling depth	approx. 3,400 m
Pumping temperature of thermal water	122 °C
Aboveground drill hole spacing	3,500 m
Underground drill hole spacing	4,500 m
Electrical output	3.4 MW_{el}
Thermal output	38 MW_{th}

HOW HYDROTHERMAL GEOTHERMAL ENERGY WORKS:



From depths of 2,000 to 4,000 metres, ❶ thermal water at a temperature between 90 and 150 °C is pumped to the surface.

In the first heat exchanger ❷, the thermal water transfers its heat to a rapid evaporation heat transfer medium ❸. The steam powers the generator to produce electricity via a turbine ❹, before condensing and cooling back down ❺.

The thermal water is then still hot enough to transfer heat to a local heating network system in a second heat exchanger ❻. The cooled water is then pumped back into the Earth, where it is heated once again ❼.

With a thermal output of 38 MW, the Unterhaching plant near Munich is one of the largest geothermal power plants in Germany.

HEAT PUMPS CAN COVER THE ENTIRE HEATING REQUIREMENTS OF A HOME

The basic operation of a heat pump is principally identical to that of a well-known everyday device: the refrigerator. While the refrigerator extracts heat from its interior and releases it outside, a heat pump extracts heat from the outside environment and releases it as heat energy to the house. The process is thus the exact opposite. A heat pump generates heat from approximately 75 per cent naturally-occurring ambient heat and 25 per cent drive energy (i.e. electricity), which is needed for heating and hot water preparation. However, it can also be used very effectively for cooling.

Geothermal heat pumps are particularly efficient in meeting the heating needs of a household. The utilisation potential of near-surface geothermal energy depends on

- the thermal conductivity of the rock
- the specific abstraction capacity. This parameter indicates how much geothermal energy can be sustainably extracted from the ground without removing too much or too little heat to meet the current heat demand.

Ambient air can also be used as a heat source for a heat pump located in the garden.

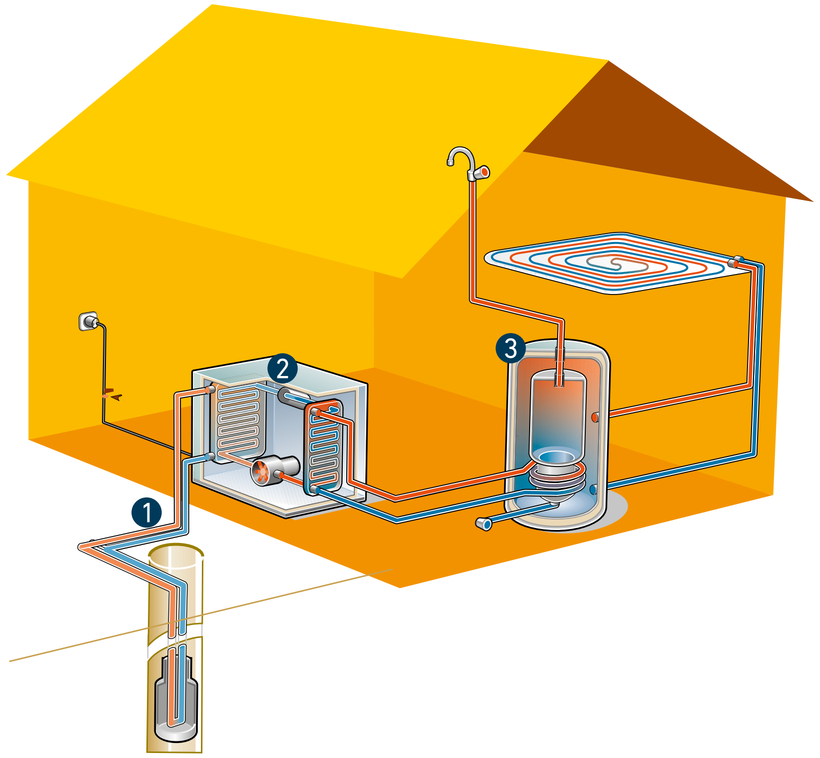
HOW NEAR-SURFACE GEOTHERMAL ENERGY WORKS:

A liquid (e.g. water) is heated to around 10 °C in a geothermal probe ❶ at a depth of approx. 10 metres.

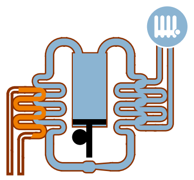
The geothermal heat pump ❷ transfers the geothermal heat from the geothermal probe to a heat transfer medium. This is heated by an increase in pressure – the geothermal heat pump is essentially a reversed refrigerator. It requires approx. 1 kilowatt-hour of electricity to provide a heat output of 3 – 5 kilowatt-hours of heat.

The buffer storage ❸ collects the geothermal energy to use it for space heating and water heating.

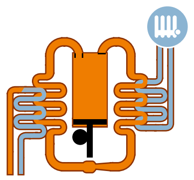
A geothermal heat pump can cover 100 per cent of the heat demand of a building.



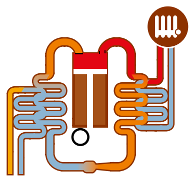
PRINCIPLE OF THE GEOTHERMAL HEAT PUMP



The ground warms the liquid in the probe to 10 °C.



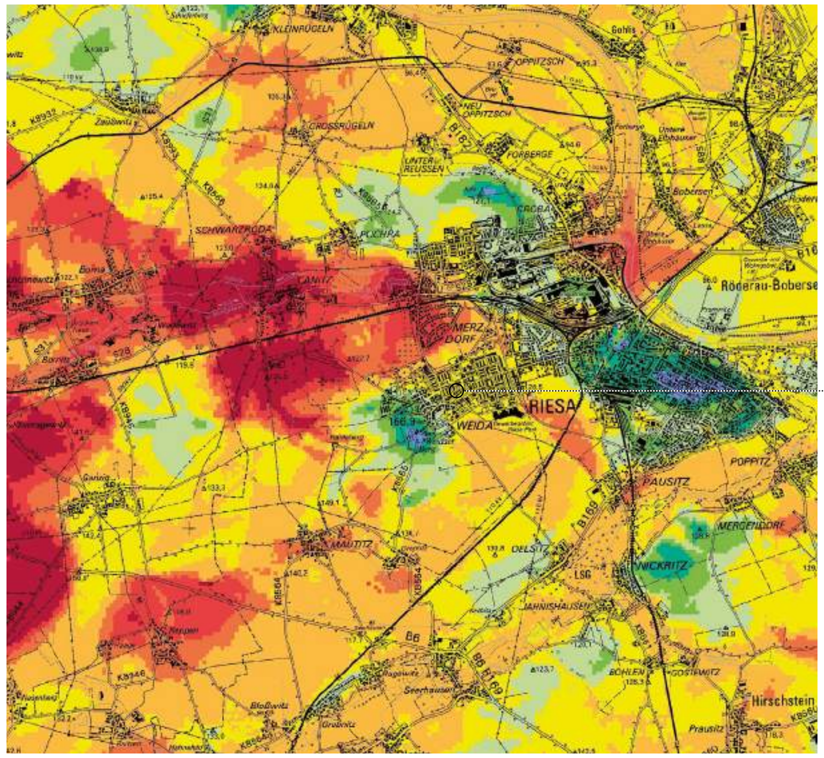
The heat transfer medium in the geothermal heat pump absorbs the heat and quickly evaporates.



The electric compressor in the heat pump compresses the vapour. This in turn increases its temperature. The heat can then be used for space and water heating.

RIESA CASE STUDY: GEOTHERMAL ENERGY MEETS THE HEAT REQUIREMENT OF A SINGLE FAMILY HOME

THERMAL ENERGY AVAILABLE AT A DEPTH OF 40 M



2 km

Source: LfULG (2009)

The heat required for an average single family home can be provided by a geothermal heat pump with a capacity of around 12 kW.

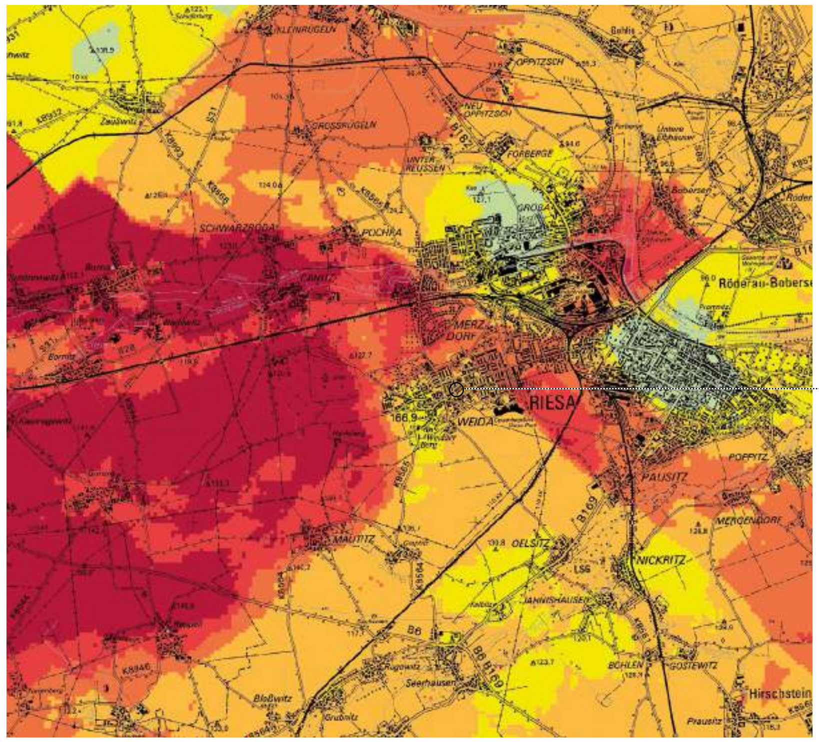
On-site geothermal energy at a depth of up to 40 m

50.1 – 52.5 W/m heat abstraction rate x 40 m

= 2,004 to 2,100 W
= 2.0 to 2.1 kW

The required heat output of 12 kW can be attained, for example, by six ground probe drills at a depth of 40 m each (6 x 2.0 kW = 12 kW).
In most cases, it is better to conduct just one or two deep ground probe drills instead of many smaller drill holes for the same heat source.

THERMAL ENERGY AVAILABLE AT A DEPTH OF 100 – 130 M



2 km

Source: LfULG (2009)

Heat abstraction rate in watts per metre at 1,800 annual operating hours

- under 40
- 40.1-42.5
- 42.6-45
- 45.1-47.5
- 47.6-50
- 50.1-52.5
- 52.6-55
- 55.1-57.5
- 57.5-60
- Over 60.1

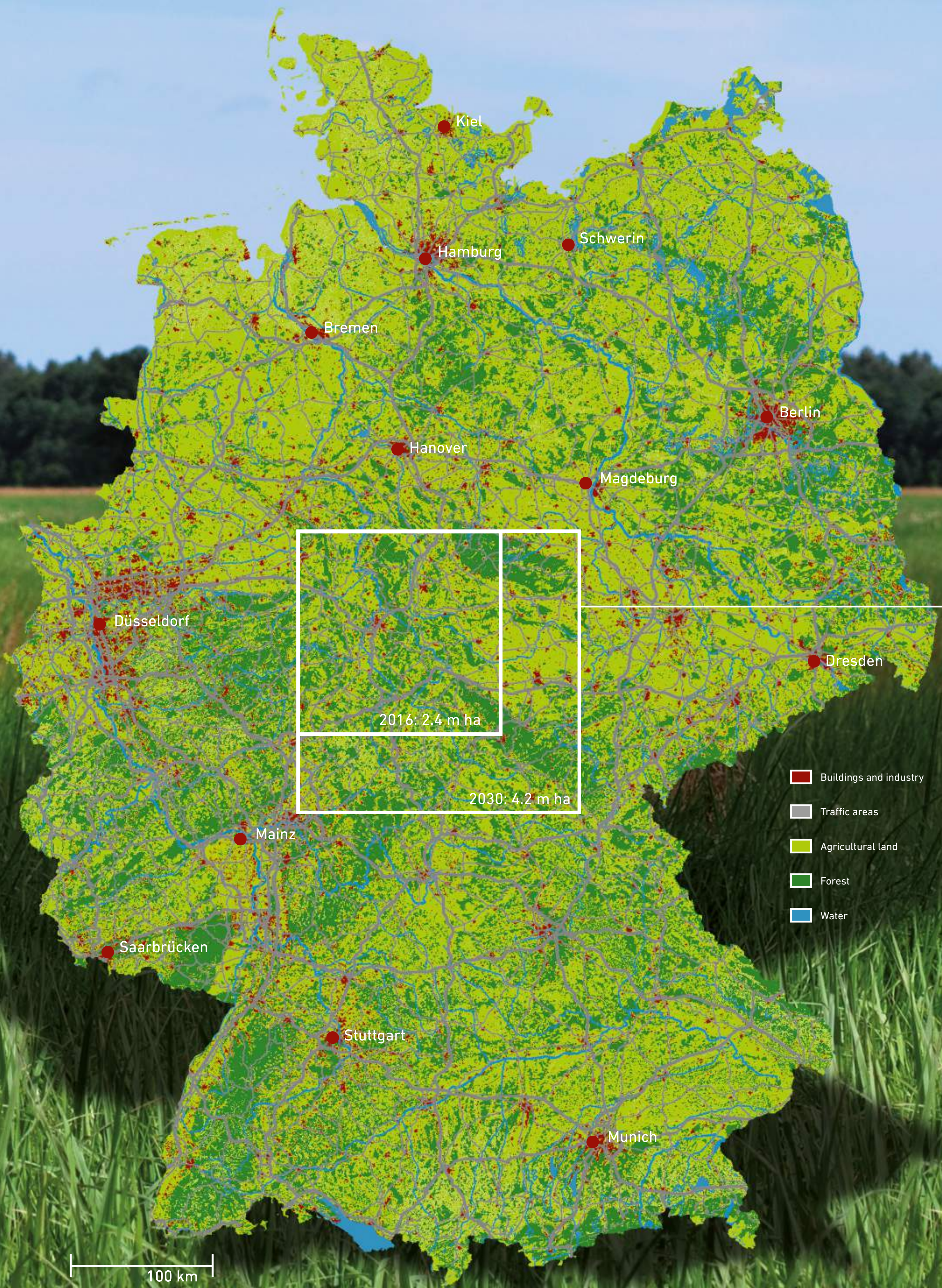
Geothermal energy at the same site at a depth of 100-130 m

52.6 – 55 W/m heat abstraction rate x 130 m

= 6,838 to 7,150 W
= 6.8 to 7.1 kW

Thus, two 130-m probes provide a heat output of 13.6 kW (2 x 6.8 kW = 13.6 kW).
Since a heat output of only 12 kW is typically needed, two probes at a depth of 115 m would suffice (52.6 W/m x 115 m = 6.05 kW; 2 x 6.05 kW = 12.1 kW).

HIGH YIELD FROM LITTLE LAND BIOENERGY

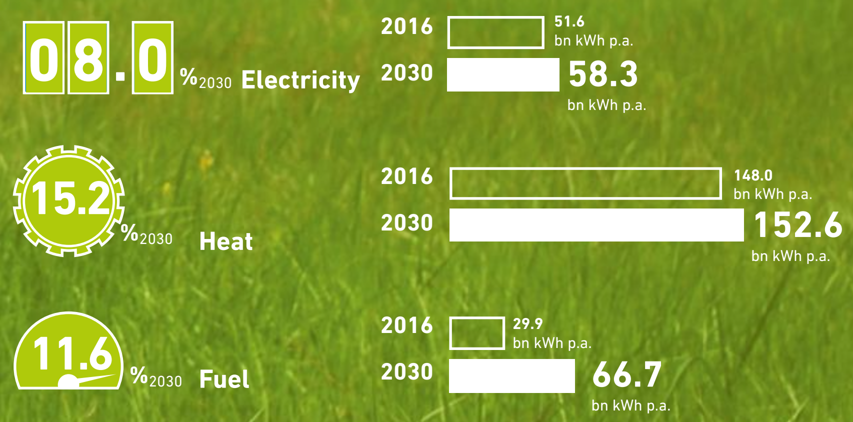


Sources: DLR 2004, Leibniz Institute

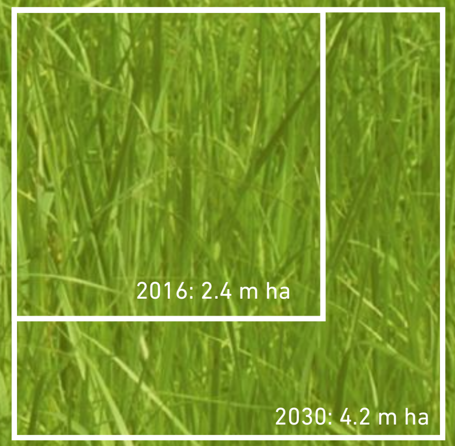
A wealth of space is available for the efficient use of bioenergy. Over the long term, Germany has an area of around 4 million hectares to cultivate renewable raw material. This corresponds to just over one-fifth of the land currently used for agriculture. In 2016, energy crops were grown on 2.4 million hectares across Germany. Traditional crops such as maize are increasingly found side by side with new energy crops such as millet or cup plant.

However, this area for cultivating energy crops provides just a portion of the bioenergy potential. To produce energy, heat and fuel, bioenergy technology can also use residual substances (such as slurry, scrap wood, biowaste) already produced in the agricultural and forestry sectors.

Share in the energy supply in 2016 and 2030



Utilised area in 2016 and 2030



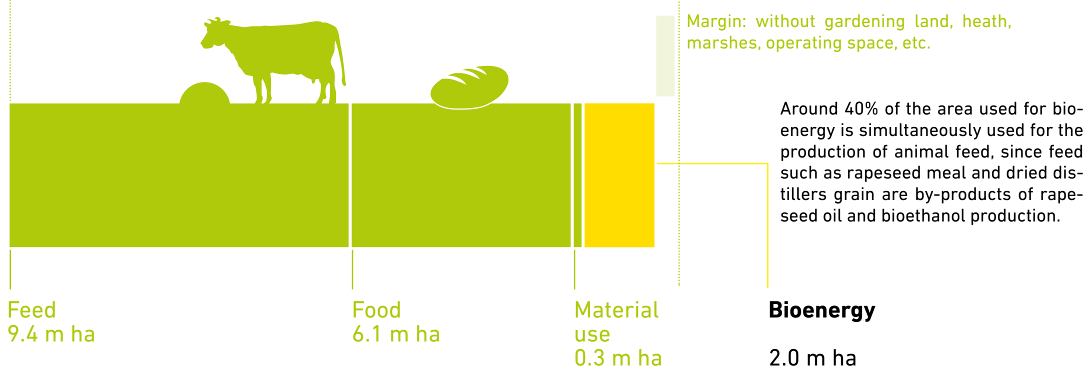
Sources: BMWi; Nitsch (2016) (Climate protection scenario "Klima 2050"); DLR et al. (2012)

THE GERMAN LANDSCAPE IS PRIMARILY COVERED BY FARMLAND, GRASSLAND AND FORESTS.

Total land area: 35.738 m ha

Source: German Federal Statistical Office, 2015

IN 2015, MORE THAN HALF OF THE AGRICULTURAL LAND WAS USED FOR ANIMAL FEED.



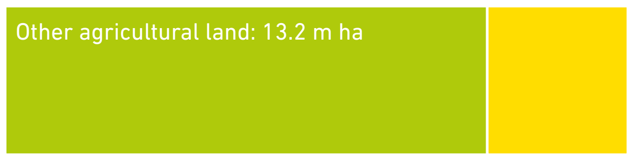
Agricultural lands: 17.8 m ha

Source: German Federal Statistical Office

PREPARING THE GROUND FOR THE ENERGY TRANSITION

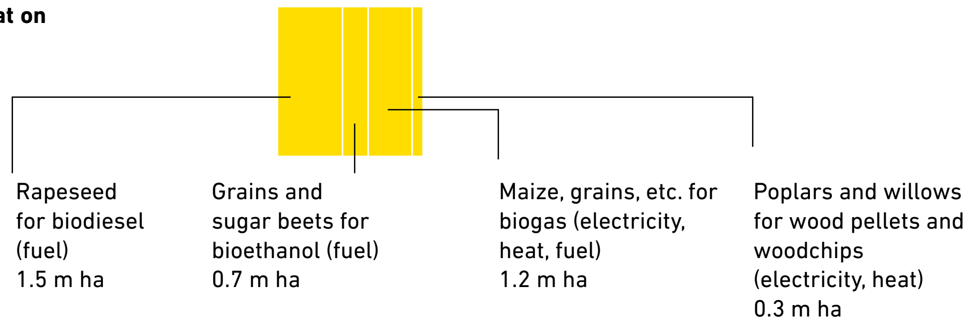
In 2015, German farmers utilised around 2.0 million hectares to cultivate energy crops such as rapeseed, maize and grass. They supplied reliable energy, heat and fuel using renewable resources, thereby ensuring the reduction of more than 61 million CO_2 equivalents. Bioenergy may soon see a moderate growth, facilitating climate protection from the countryside.

2030



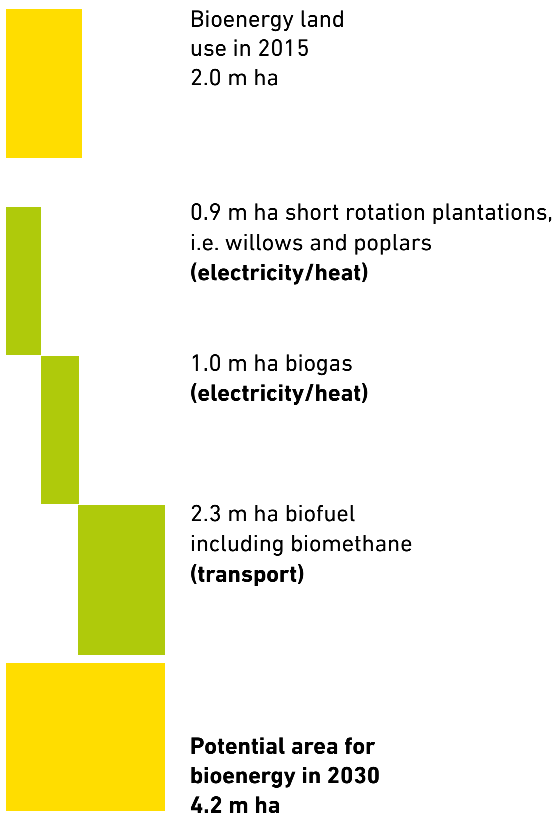
Bioenergy land use: 3.7 m ha
= approx. 22% of the agricultural land in Germany (16.7 m ha)

What will be grown to produce what on bioenergy land in 2030?



Source: AEE/BBFZ/AEE (calculation basis 2020)

WHAT WILL BIOENERGY BE USED FOR IN 2030?



Source: DBFZ; DLR et al. (2012)

WHERE DOES THE EXTRA LAND FOR BIOENERGY COME FROM?

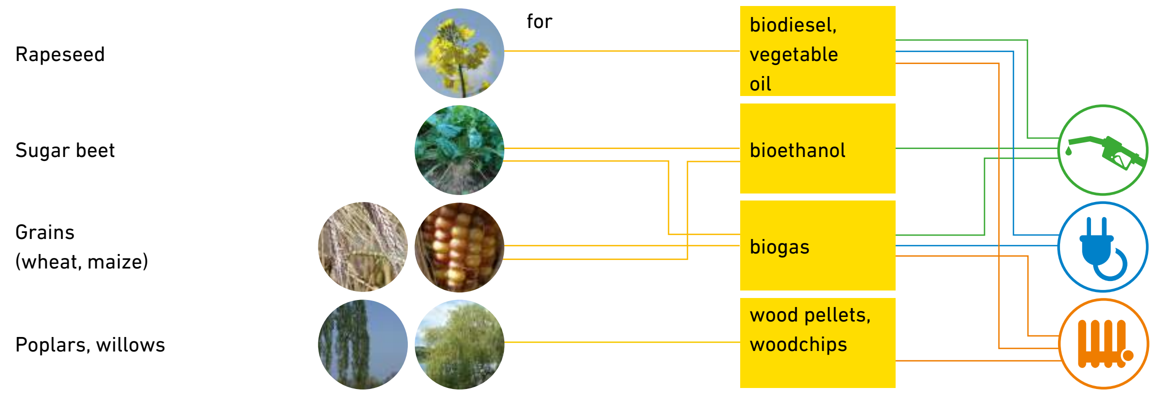
The demand for animal feed and food products, as well as for residential areas, will decrease as a result of the population decline in Germany. At the same time, crop yields continue to increase slightly. Consequently, additional land will be available for energy crop cultivation without jeopardising Germany's self-sufficient food production. Germany will continue to be a major agricultural exporter while bioenergy ensures greater national climate protection in agriculture. For example, Germany contributes around one-fifth to EU wheat exports.

HOW MUCH ENERGY COMES FROM ONE HECTARE:

1 ha of maize
= approx. 45 t of yields
= approx. 9,000 m^3 of biogas

= 18,000 kWh_{el} = **electricity for 5 households**
+ 12,000 kWh_{th} = **heat for 0.6 households**

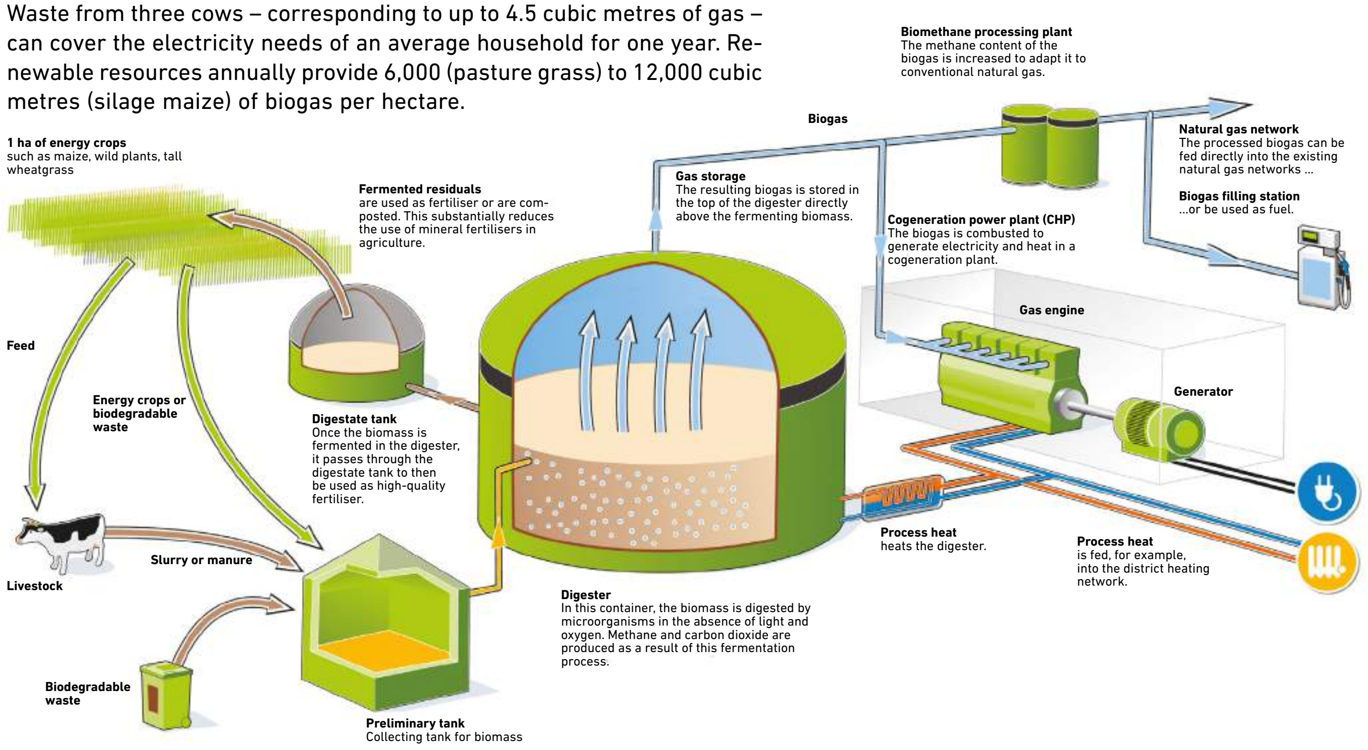
WHICH ENERGY CROPS WILL BE USED AND HOW?



Source: AEE/BEE/DBFZ

HOW A BIOGAS PLANT WORKS

Biogas can be produced from slurry, solid biomass and organic waste. Waste from three cows – corresponding to up to 4.5 cubic metres of gas – can cover the electricity needs of an average household for one year. Renewable resources annually provide 6,000 (pasture grass) to 12,000 cubic metres (silage maize) of biogas per hectare.



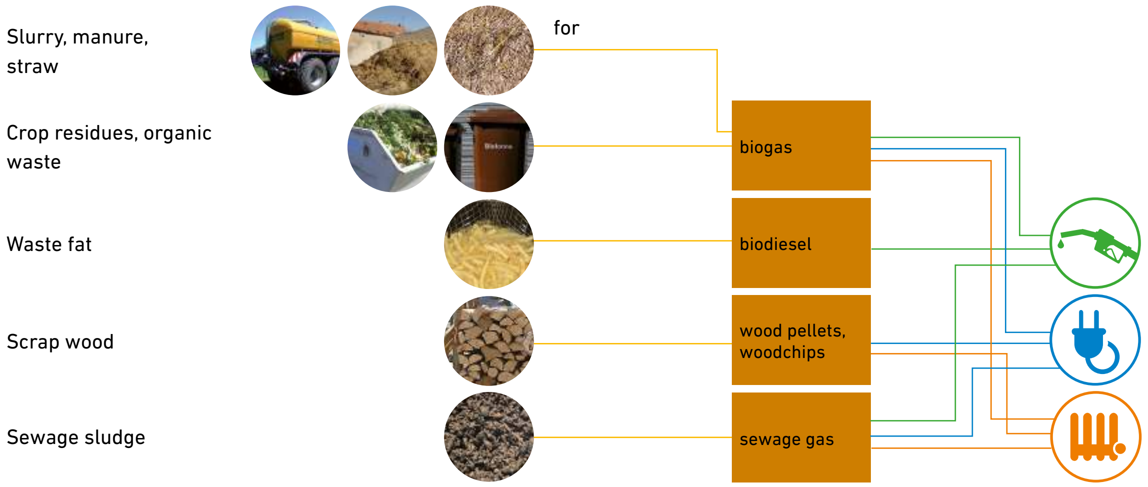
WHERE BIOENERGY COMES FROM: ENERGY CROPS AND RESIDUAL MATERIAL

If the residual materials had to be specifically produced for this process, the amount of biomass used in bioenergy production would today occupy an area of 2.6 million hectares. There is still an abundance of possibilities to use more residual material and waste for the energy transition. Germany must mobilise further potential if it wants to reach its energy and climate goals, as in the case of energy crops.

Residual material and waste (unexploited potential)	Residual material and waste (already in use)	Energy crops	Wood fuel from forests	Imports	Additionally required biomass
448 PJ	**541 PJ**	**247 PJ**	**131 PJ**	**66 PJ**	**482 PJ**

Source: FNR

WHICH RESIDUAL MATERIAL WILL BE USED AND HOW?



WHERE DO THE EXTRA RESIDUAL MATERIALS COME FROM?

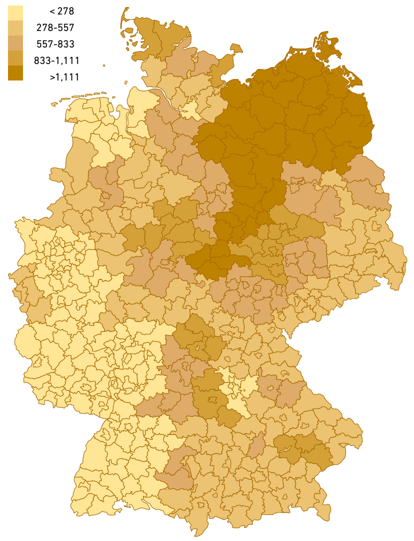
Potential for straw
The potential for utilising straw for energy generation is over 1,000 kWh per person in several regions in north-eastern and central Germany. If processed in biogas plants, this would be sufficient to cover one-third of the regions' annual energy consumption.

Potential for slurry
The potential for utilising slurry and other animal excrements for energy generation is over 1,000 kWh per person in several regions in northern Germany. If processed in biogas plants, this would be sufficient to cover one-third of the regions' annual energy consumption.

Potential for residual forest biomass
The potential for utilising residual forest biomass for energy generation is over 2,000 kWh per person in several regions in north-eastern and southern Germany. If processed in wood-fired power plants, this would be sufficient to cover two-thirds of the regions' annual energy consumption in addition to heat. This is without taking into account the potential of scrap wood and industrial wood waste.

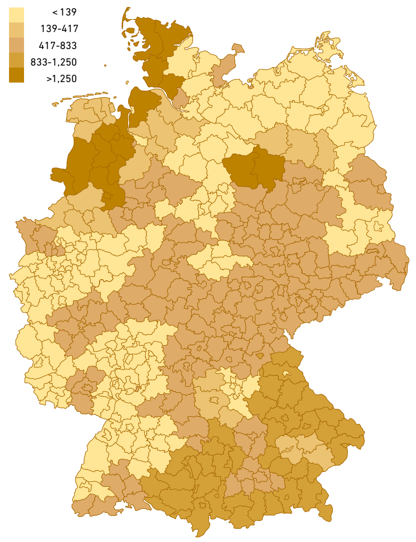
Residual straw

Annual potential/person in kWh



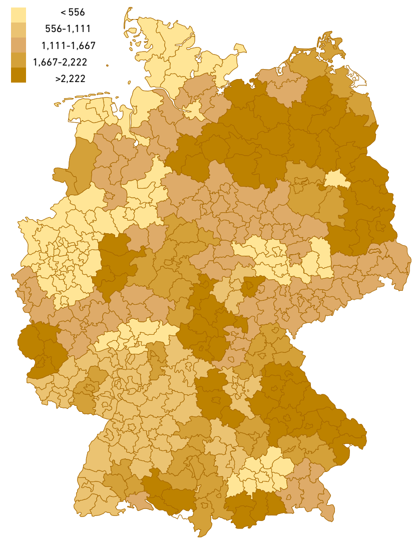
Animal excrements

Annual potential/person in kWh



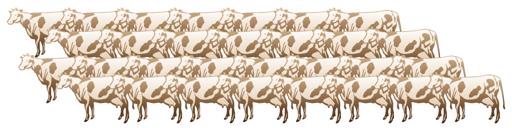
Weak and scrap wood

Annual potential/person in kWh



Source: BBSR

THIS MUCH ENERGY IS IN A COWSHED.



30 cows
= approx. 540 t of cattle slurry
= approx. 13,500 m³ of biogas

= 31,500 kWh_{el} = **electricity for 9 households**
+ 20,000 kWh_{th} = **heat for 1 household**

This much wood grows every second.

Around 122 million cubic metres of wood grow in Germany each year. This equals 4 cubic metres of wood per second, equivalent to a cube with a side length of 1.6 m.

WOOD ENERGY – ENOUGH SUPPLY FOR PLENTY OF HEAT

At 70 per cent, wood is by far the most extensively used renewable heat resource. The efficient, eco-friendly use of wood energy is essential in reducing greenhouse gas emissions and our dependence on fossil fuels. Standardised wood fuels like wood pellets are highly effective heat supplies for single and multi-family homes, as well as increasingly for local heat networks, as they have an efficiency rate of over 90 per cent. They will account for a significantly higher percentage of renewable heat on a medium-term basis.

Wood is a renewable resource, like biomass from energy crops. In terms of supply, Germany is far ahead of the rest of the European countries. Within the last ten years, the supply of wood has continued to rise by 7 per cent, according to the latest National Forest Inventory. Forests therefore offer further potential for sustainable use in many regions.

Source: www.bundeswaldinventur.de

NORDSTRAND CASE STUDY: BIOENERGY FROM NEIGHBOURS FOR NEIGHBOURS

Biogas is the most readily available form of energy on the North Sea coast in Nordstrand, Schleswig-Holstein. The movers and shakers at Nordstrander Inselenergie GmbH & Co. KG ensure that power and heat from their biogas plant benefit the residents of the municipality. Not only biomass, but also expertise, capital and personnel come predominantly from the municipality.

The biogas plant produces about one and a half times the energy consumed in Nordstrand per year and supplies roughly one-tenth of the residents with heat.

Karl-Volkert Meyer is a farmer. He grows potatoes and barley, among other things. The biogas plant digesters are located on his farm. He "feeds" the digesters with a multitude of residual materials, along with energy crops that he cultivates, to produce biogas. Amongst these are oats and beans that produce humus in the soil, as well as grasses that protect his land from erosion. He founded the energy company Nordstrander Inselenergie GmbH & Co. KG with his neighbour Thorben Holsteiner.

Dennis Delfs is a heating engineer at Maschinenringe Schleswig-Holstein Energie Pool. He connects the people of Nordstrand to the biogas plant's heat network. Over 100 houses and other buildings in Nordstrand are supplied by a total of more than 8 km of heat network piping.

Werner-Peter Paulsen is a sheep farmer and the mayor of Nordstrand. He brings the sheep manure from his flock to the biogas plant on Karl-Volkert Meyer's farmland. The sheep manure, along with the manure and slurry from neighbouring dairy farmers, is fermented in the digesters to produce biogas.

Dr Jenny Matthiesen is a member of the Registered Cooperative of German Green Energy Producers (GDGE). The association buys electricity produced by Nordstrander Inselenergie's cogeneration plants to sell it as needed. In the event of an energy surplus, energy generation is curbed and the biogas is stored. When demand increases, energy generation is then quickly elevated.

Around 6,400 hydroelectric power plants are compensated for their generated power in accordance with the Renewable Energy Sources Act (EEG). Around 6,000 of these hydroelectric plants have an installed capacity of under one megawatt.

However, approximately 170 hydroelectric plants with an installed capacity of over one megawatt market the electricity they produce outside of the EEG framework or are used to self-supply electricity.

- Hydroelectric plants with EEG remuneration (mostly < 1 MW capacity)
- Hydroelectric plants without EEG remuneration (mostly > 1 MW capacity)
- Pumped-storage power plants

Source: Ingenieurbüro Floecksmühle (2009), BKG (2007)

SOURCE OF CLEAN ENERGY HYDROPOWER

The use of hydropower is technically mature and has a long tradition. Nevertheless, there is still potential for expansion, because the majority of the hydroelectric power plants with an installed capacity of more than 1 MW were built before 1960. Growth is therefore especially feasible through the renovation of existing plants and their associated ability to attain higher outputs.

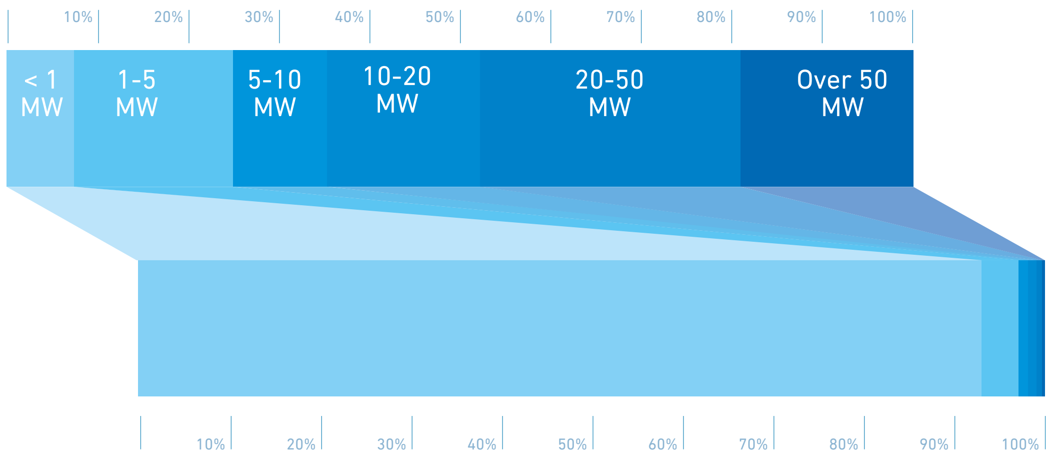
Potential can also be found in the reactivation of plants that were destroyed during the Second World War or that were shut down in the 1960s and 1970s. These plants can be re-commissioned using modern technology and at the same time offer enhanced nature and water protection.

Additional expansion potential of hydropower is estimated at around 1,000 MW or 3.0 billion kWh p.a. and is thus relatively small. A large percentage of this potential (around 80%) can be tapped by expanding and converting existing large-scale installations (≥ 1 MW).

Share in the energy supply in 2016 and 2030

Source: BMWi, Nitsch (2016) (Climate protection scenario "Klima 2050")

PERCENTAGE OF HYDROPOWER ELECTRICITY GENERATION IN GERMANY ACCORDING TO OUTPUT CLASS



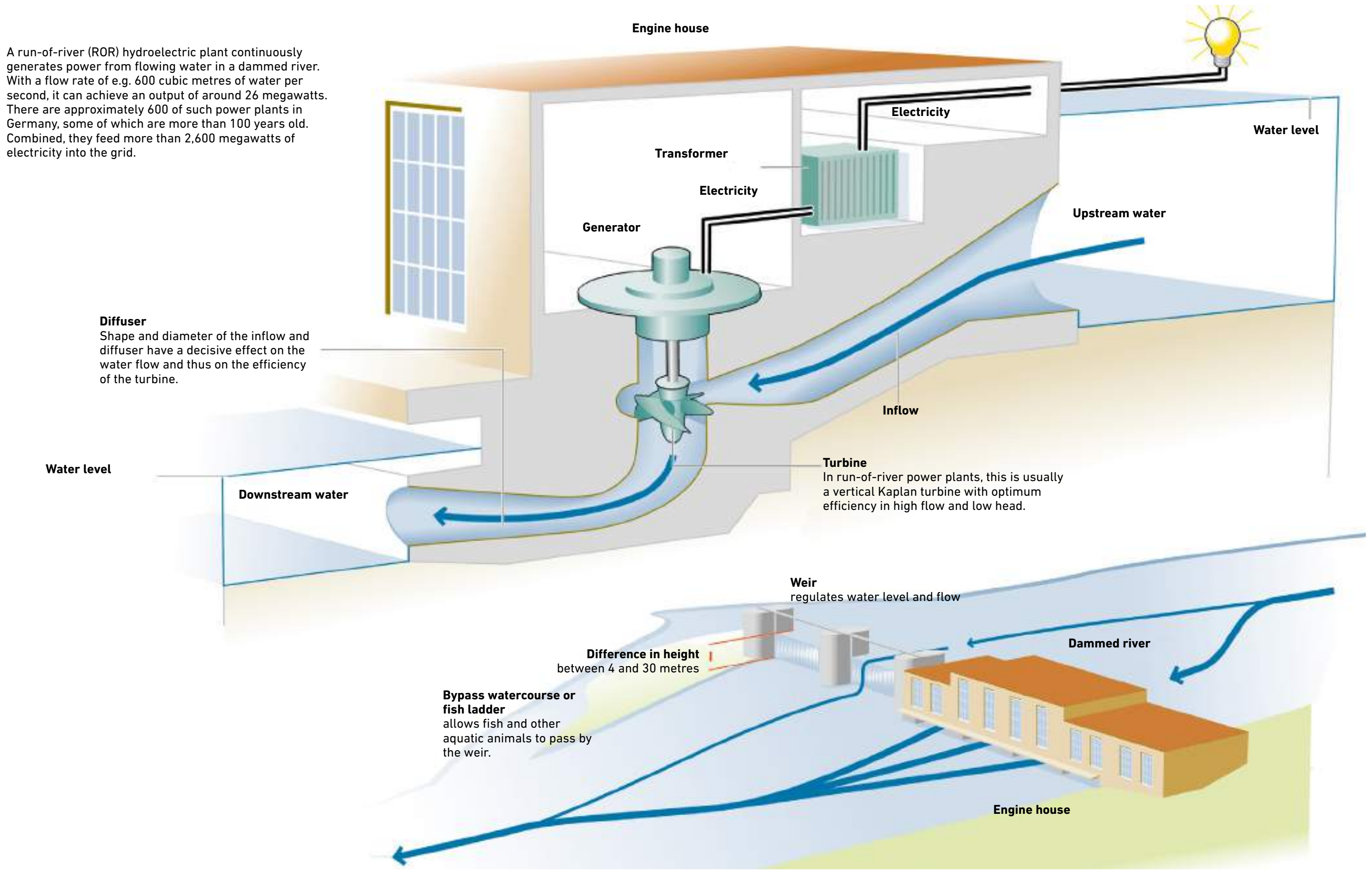
PERCENTAGE OF INSTALLED HYDROPOWER PLANTS IN GERMANY ACCORDING TO OUTPUT CLASS

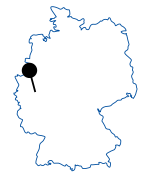
Source: Analysis from IBFM and Hydrotec, EEG data from the Federal Network Agency, BMWi (2015)

Small hydroelectric power plants with a capacity of up to 5 megawatts represent approximately one-third of all hydropower electricity production. Over 95 per cent of the hydroelectric plants in Germany were installed with this level of output (totalling 1,400 MW). From a climate protection perspective, it is still important to expand and renovate small hydroelectric plants. The goal must be to promote all possibilities for CO_2-free energy supply that are aligned with the concerns of water and nature protection.

The hydropower potential of a given location depends on geographic factors such as altitude difference and discharge quantity. Most hydroelectric plants, therefore, use lakes and rivers in the mountains and highlands. This is particularly evident in the regional distribution of ROR hydroelectric plants under 5 MW: these installations are primarily found in the states of Bavaria, Baden-Württemberg, Hesse, Rhineland-Palatinate and Thuringia.

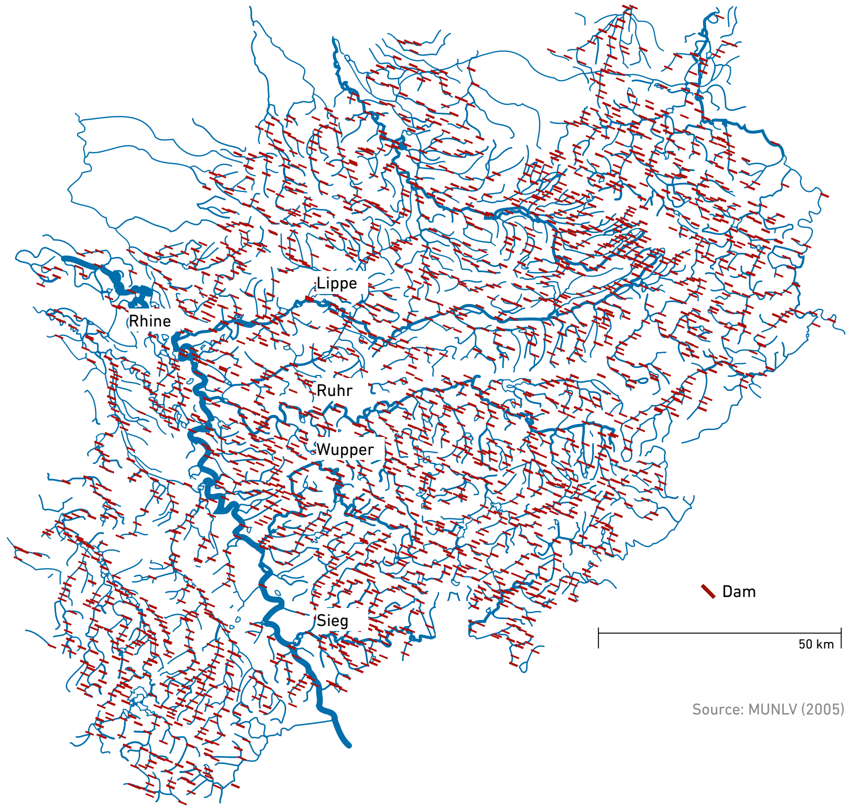
HOW A RUN-OF-RIVER HYDROELECTRIC PLANT WORKS





NORTH RHINE-WESTPHALIA CASE STUDY: EXISTING DAMS OFFER GREAT POTENTIAL FOR THE USE OF HYDROPOWER

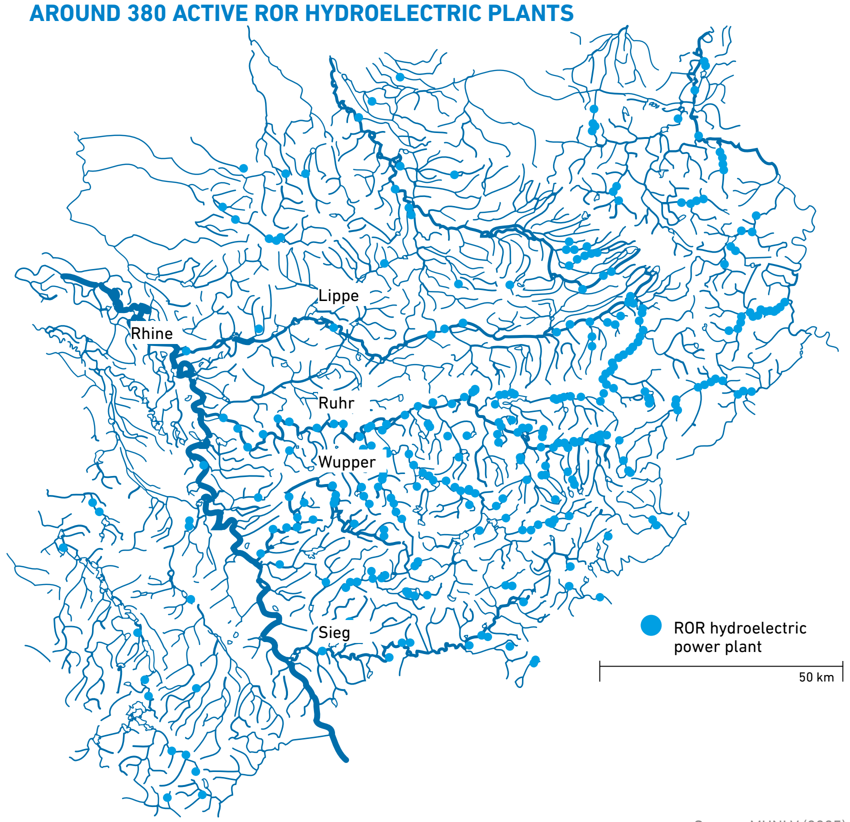
MORE THAN 14,000 EXISTING DAMS



Source: MUNLV (2005)

There are approximately 14,000 dams in North Rhine-Westphalia and 60,000 in all of Germany. The dams were built to retrieve drinking and service water, to irrigate adjacent lands, to benefit navigation or to utilise hydropower. The building structures that have been artificially introduced into the bodies of water can have a negative effect on the connectivity of the respective watercourses.

AROUND 380 ACTIVE ROR HYDROELECTRIC PLANTS

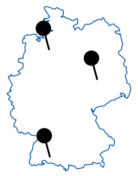


Source: MUNLV (2005)

Less than 15 per cent of the dams in Germany are utilised by hydroelectric plants. More than 85 per cent of the obstructions to the flow of water are therefore not a result of hydropower activity.

In North Rhine-Westphalia, just 3 per cent of the dams are utilised by active ROR hydroelectric plants.

In areas with existing dams, the use of power generation can provide new ecological benefits, for example fish ladders or fish passes that serve to restore the connectivity of dams. This connectivity is a crucial prerequisite for colonisation by migratory species of fish such as eel or salmon. The already limited potential for expansion of hydropower can be developed in harmony with nature using ecological monitoring of construction.



RADOLFZELLER AACH, WESER AND MULDE CASE STUDIES: EXPLOITING POTENTIAL THROUGH REACTIVATION, CONSTRUCTION AND INNOVATION

People have been using the force of streams and rivers to generate energy for centuries. Hydropower has also been used to generate electricity since the mid 19th century. However, many water wheels and mills were destroyed during the Second World War. Additionally, many installations were shut down in the 1960s and '70s. The reactivation and renovation of these facilities holds great potential.

The use of hydropower is partly criticised by fishermen and nature conservationists. The following case studies show that hydropower expansion and nature conservation are not mutually exclusive – on the contrary, nature protection and modern hydroelectric plants go hand in hand.

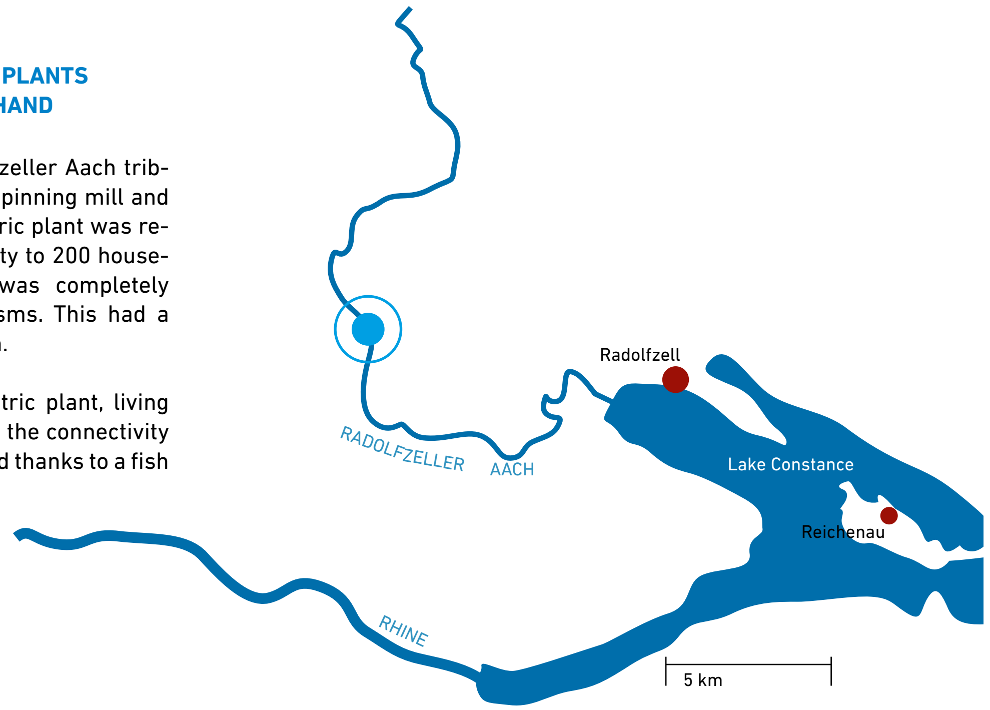
RADOLFZELLER AACH CASE STUDY: REACTIVATION OF SMALL HYDROELECTRIC PLANTS AND NATURE CONSERVATION GO HAND IN HAND

The hydroelectric power plant in the Radolfzeller Aach tributary had formerly been used by a nearby spinning mill and was shut down in the 1970s. The hydroelectric plant was reactivated in 2004 and now supplies electricity to 200 households. Before reactivation, the riverbed was completely obstructed for both fish and small organisms. This had a negative effect on the entire river ecosystem.

In the course of reactivating the hydroelectric plant, living conditions at the site could be improved and the connectivity of the water body was substantially increased thanks to a fish ladder, among other things.

Data and facts

Constructed	1896
Renovated	2004
Installed capacity	120 kW
Electricity production	0.7 m kWh p.a.



Source: DUH (2006)

Reactivated hydroelectric plant in the Radolfzeller Aach tributary

EXAMPLE OF BUILDING POTENTIAL: WESER POWER PLANT IN BREMEN

In the case of the hydroelectric plant in Bremen, a pre-existing weir was used instead of building a new one. The Weser Hydroelectric Plant is the largest hydropower construction project in northern Germany. The installation will also be the largest hydroelectric plant on the Weser River. The project sets ecological standards: it provides for an innovative fish protection concept that is unprecedented for a power plant of this size. It uses extensive ascending and descending ladders in addition to a system effectively protecting the fish from passing through the turbines.

Clean electricity from the Weser Weir

1906-12	Construction of a lock system, weir and hydropower station in Bremen-Hemelingen
1912	The only German hydroelectric power plant enters operation at the lower course of a river
1981	Severe flooding of Weser (approx. 25 m euros in damages)
1987-93	Demolition of old weir and construction of new one
2003-06	Planning for a new power plant
2007	Approval of plans
2008	Start of construction
2011	Commissioning of the new Weser Power Plant

Data and facts

Capacity	10 MW
Electricity production	42 m kWh p.a.
Commissioning	November 2011

EXAMPLE OF INNOVATION POTENTIAL: HYDROELECTRIC PLANT IN RAGUHN

Water wheels have been around for 2,500 years. Nevertheless, there is still room for technological development in hydropower. Latest example: the hydroelectric plant in Raguhn (Saxony-Anhalt) uses new turbines with a particularly high efficiency rate. In this case, hydropower benefited from the further technological development of wind turbines. These advances can be successfully transferred to the construction of turbines for hydroelectric power plants. This allows sites with low head to be developed as well. Moreover, the Raguhn Hydroelectric Plant has an extremely fish-friendly design. This is supplemented by a comprehensive fish monitoring system. The result: animals and plants welcome the hydroelectric plant as a part of their habitat since its installation in January.

Data and facts

Capacity	2.1 MW
Electricity production	9.3 m kWh p.a.
Commissioning	June 2009

RESEARCH FOR THE ENERGY TRANSITION

By 2050, Germany aims to reduce its greenhouse gas emissions by 80 to 95 per cent compared to 1990 levels. Within just three decades, the existing energy system must therefore be completely reconfigured: required are a dynamic expansion of the share of renewable energy, a rapid increase in energy efficiency and further development of the energy supply structure. Innovative technologies, products and concepts are necessary to meet these challenges and successfully implement the energy transition. The groundwork for this is provided by excellent energy research. Research funding is also an important instrument of economic policy. As a result, German companies are aided in further expanding their strong starting position in the field of modern energy technologies through innovation and research. These measures aimed at strengthening the economy also positively affect growth and employment in Germany. The domestic economy is not the only thing that profits from exporting green products and technologies. Likewise, climate protection efforts from other countries will be supported with "made in Germany" energy technology – an important German contribution to the implementation of international climate protection policy.

RESEARCH FUNDING FROM THE FEDERAL GOVERNMENT

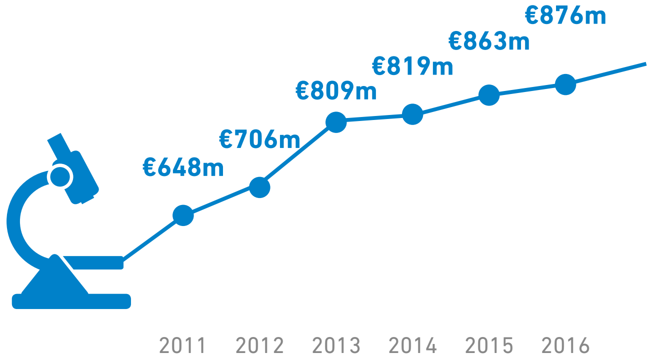
The first energy research programme, "Energy Research and Energy Technologies", was approved by the German Federal Government in 1977. Although this was the first programmatic foundation for research on non-nuclear energy technologies and energy efficiency, renewable energy was still considered a "niche technology". Since the 6th energy research programme (2011), energy research is now completely geared towards the energy transition. To accomplish this, large research communities such as the Helmholtz Association or the Fraunhofer Society are funded over longer periods, while, on the other hand, concrete and time-limited projects are also funded in companies, research institutions and universities. Thanks to this kind of project funding, it is possible to regularly adapt priorities to new findings. Furthermore, the cooperation between industry and science is supported through joint research projects. This helps to harness synergies and to more readily integrate research results into production technologies and processes.

The focus of energy research – renewable energy and energy efficiency – is also reflected in the available budget: the German Federal Government issued approximately 876 million euros in subsidies for research and innovation in the field of energy during 2016. In comparison: the budget in 1977 amounted to just 51 million Deutschmarks (134 million euros). In the past 40 years, around 17,300 projects were funded using a total of 12 billion euros.

The Federal Government's energy research strategy is essentially open to all types of technologies supporting the energy transition. This means that a wide range of technologies is funded in order to keep several options open. However, priorities and key areas of technology development are also determined in order to avoid ineffective across-the-board research funding. The Federal Government has defined the following as priority topics in the field of renewable energy and energy efficiency: wind and photovoltaic power generation, increase in the share of renewable energy in the heating sector, energy-optimising buildings and districts as well as promoting industrial energy efficiency. But even research into the systematic issues of the future energy supply structure is granted considerable importance. Here the focus is on the integration of new technologies in power supply, new grid technologies and energy storage as well as on sector coupling.

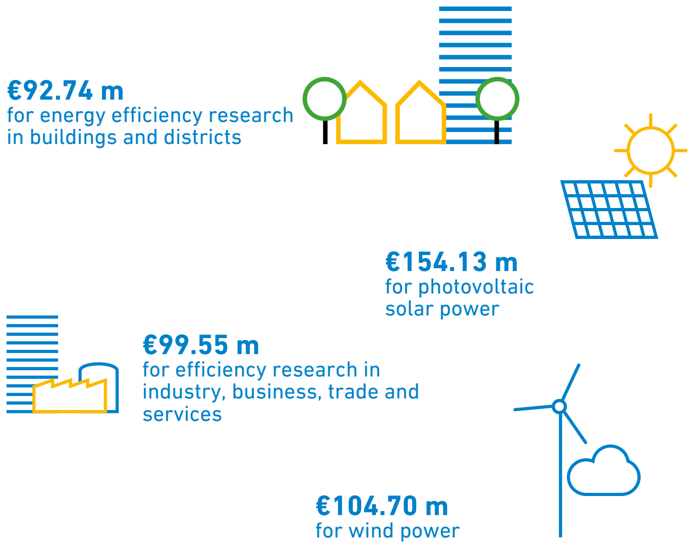
MORE MONEY
FOR RESEARCH AND INNOVATION

Energy-related research funding from the Federal Government is steadily expanding



Source: BMWi

THE MOST ACTIVE RESEARCH AREAS 2016*



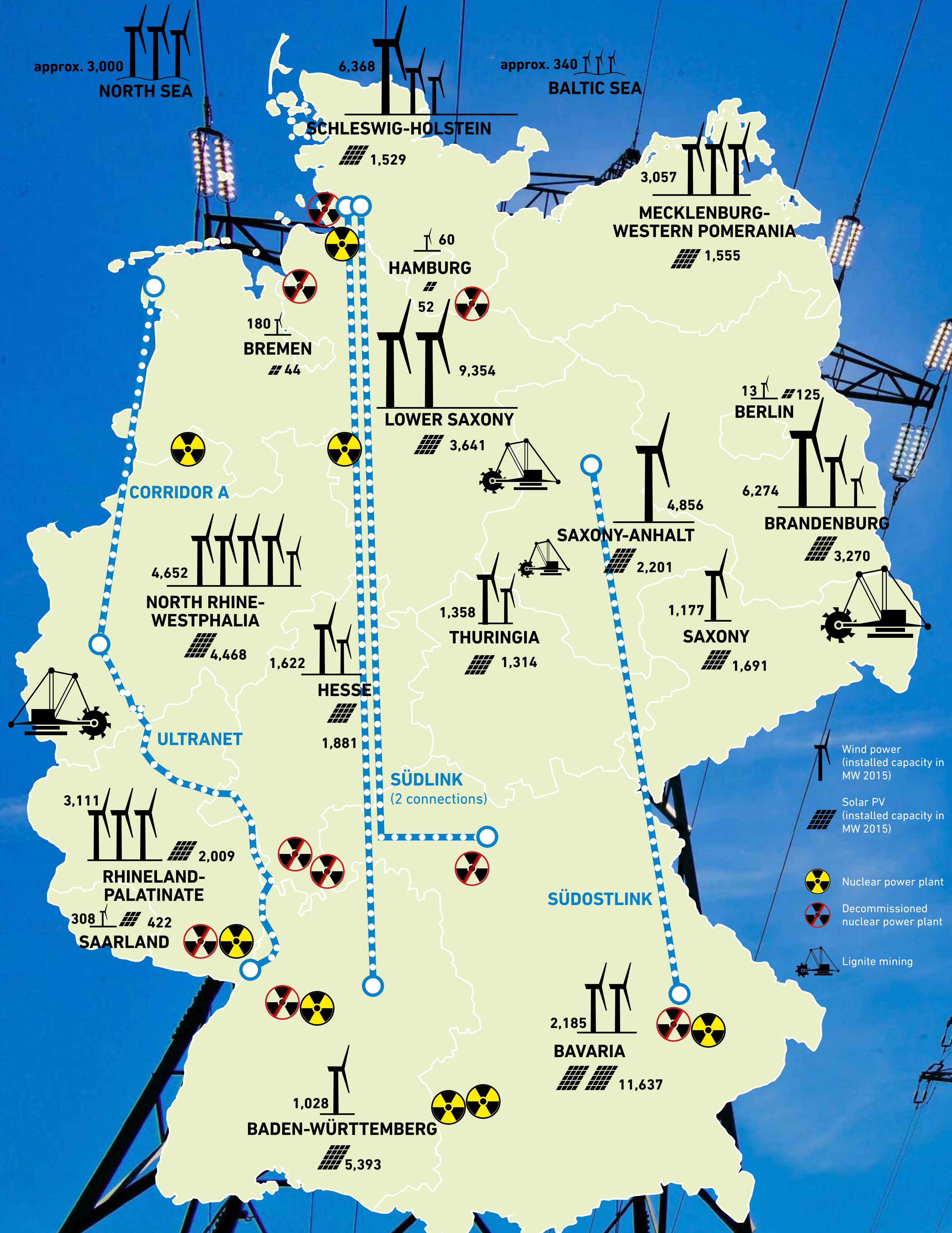
* Measured by the total cost of newly launched projects
Source: BMWi

SCIENCE AND ECONOMY WORKING TOGETHER

The 7th energy research programme is expected to be adopted in the summer of 2018. In autumn 2016, a broad participation process was started to spur communication among players in industry, science and from the federal states. The energy research networks play an important role within this process. Through active cooperation in these expert networks, representatives from industry and science can directly participate in the development of the new energy research programme. Up to now, energy research networks have been established for seven thematic focal points of energy research. Participants benefit from the exchange of experience and the possibility to get to know potential partners for research collaboration projects. Further objectives of the programme include accelerating results transfer and enhancing quality assurance in participants' research findings. The results of the work undertaken by the networks are included in the strategic considerations for the development of the energy research policy. A central aspect of the 7th energy research programme will be a stronger application orientation of energy research to promote the transfer of research findings into practice.

Full house: The in-person meeting of the research network Flexible Energy Conversion was met with great interest.

Through targeted research funding, the efficiency of photovoltaic solar cells has been steadily increased in recent years.



Source: BNetzA,
German Atomic Forum,
Deutsche WindGuard,
DEWI (2016)

A GOOD GRID IS HALF THE BATTLE POWER NETWORKS

Since its creation at the end of the 19th century, the German power grid has been designed to distribute electricity from central production plants (first coal-fired and hydropower plants, then also natural gas and nuclear power plants) to the centres of consumption. Around 100 years later, the energy transition process was heralded by the introduction of the Renewable Energy Sources Act (EEG) in the year 2000. The challenge associated with this process is nothing short of a complete conversion of the centralised production structure to a decentralised supply based on volatile energy, i.e. energy that fluctuates throughout the day and year. There is no course of action we can follow from a textbook for this process, instead we are treading uncharted territory.

Since Germany does not (yet) have any adequate means of storage, it was decided to significantly expand and reinforce the extra-high voltage grid by around 7,500 km, 2,300 km of which are planned to be high-voltage direct current (HVDC) transmission lines and laid primarily as underground cables. These measures aim to broadly compensate for the weather-related fluctuations in renewable energy generation until 2024. After all, wind power is produced most notably in northern Germany. The capacity of the onshore wind farms in northern Germany accounts for about 40 per cent of the total installed capacity in Germany. Furthermore, around 40 per cent of the German photovoltaic capacity is conversely installed in the high-consumption region of the South. When the last nuclear power plants in Bavaria and Baden-Württemberg are decommissioned in 2022 as a result of the nuclear phase-out decision of 2011, a major share of the local power supply will be cut off. Powerful “electricity highways” should be transporting wind power from the North to the centres of consumption in the South by this time.

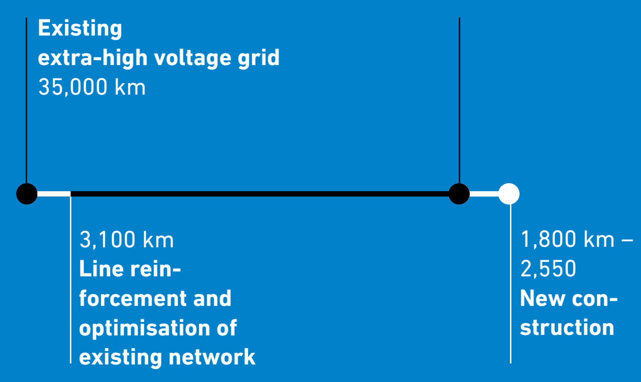
New routes are therefore urgently needed and long overdue. The German network infrastructure is substantially outdated: the transmission networks have been active for an average of 53 years (220 kV towers) and 37 years (380 kV towers). Some extra-high voltage towers have even been in use for 85 years. Investments in network maintenance and new construction declined from the beginning of the 1990s until 2003. Since then, they have been slightly increasing. In 2014, investments totalling four billion euros reached 1993 levels for the first time. For the German energy transition, this investment backlog now signifies the opportunity to establish the already necessary power grid expansion based on renewable energy.

The network expansion is progressing, albeit slowly, and lags behind the aggressive expansion of renewable energy production. According to a study from Prognos, this is, however, not an obstacle for continued ambitious capacity increases to renewable installations (Prognos et al 2016): in times of higher green energy production, the planned expansion of the HVDC transmission lines could be reduced by more than 40 per cent by withholding just five per cent of the electricity generated from renewable energy from being fed into the network.

The key to successfully converting the network infrastructure also lies in the distribution grid. More than 90 per cent of renewable electricity is fed into this network in Germany. For around one hundred years, the distribution network (230 V - 110 kV) was designed only to accept energy from the extra-high voltage network and to distribute it to the end consumer. Now it must also “collect” the electricity, namely from the millions of homes with PV solar panels or communal wind farms. The distribution grid is also in need of expansion and reinforcement. At the same time, the network must become smarter in order to automatically smooth out any fluctuations in production.

THE EXTRA-HIGH VOLTAGE GRID

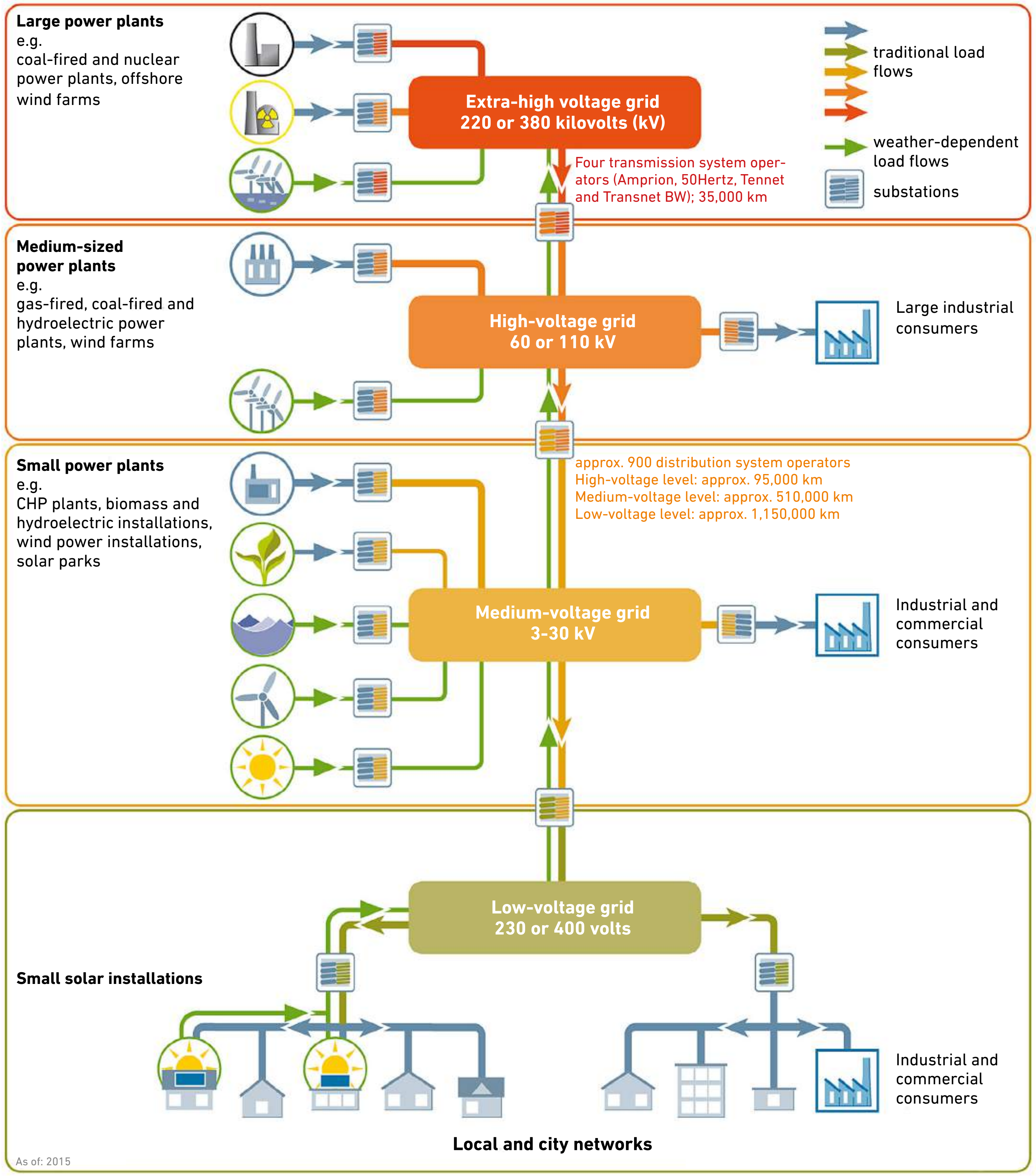
MODERNISATION REQUIREMENTS AND PLANNED EXPANSION



Source: Federal Network Agency (BNwtzA)

HOW GERMANY'S ELECTRICITY SUPPLY WORKS

The power grid in Germany was traditionally designed to work in one direction. The extra-high voltage grid or transmission grid transports the electricity from large-scale power plants over long distances to the consumption centres. The high-voltage networks distribute the electricity throughout a larger region to the medium-voltage networks. From there, it flows into the local low-voltage networks, to which small power consumers are connected. Thanks to the development of wind and solar energy, load flows are now periodically bi-directional. Then, electricity flows from the lower to the higher voltage levels.



GRID EXTENSION IN EUROPE: ELECTRICITY KNOWS NO BOUNDARIES

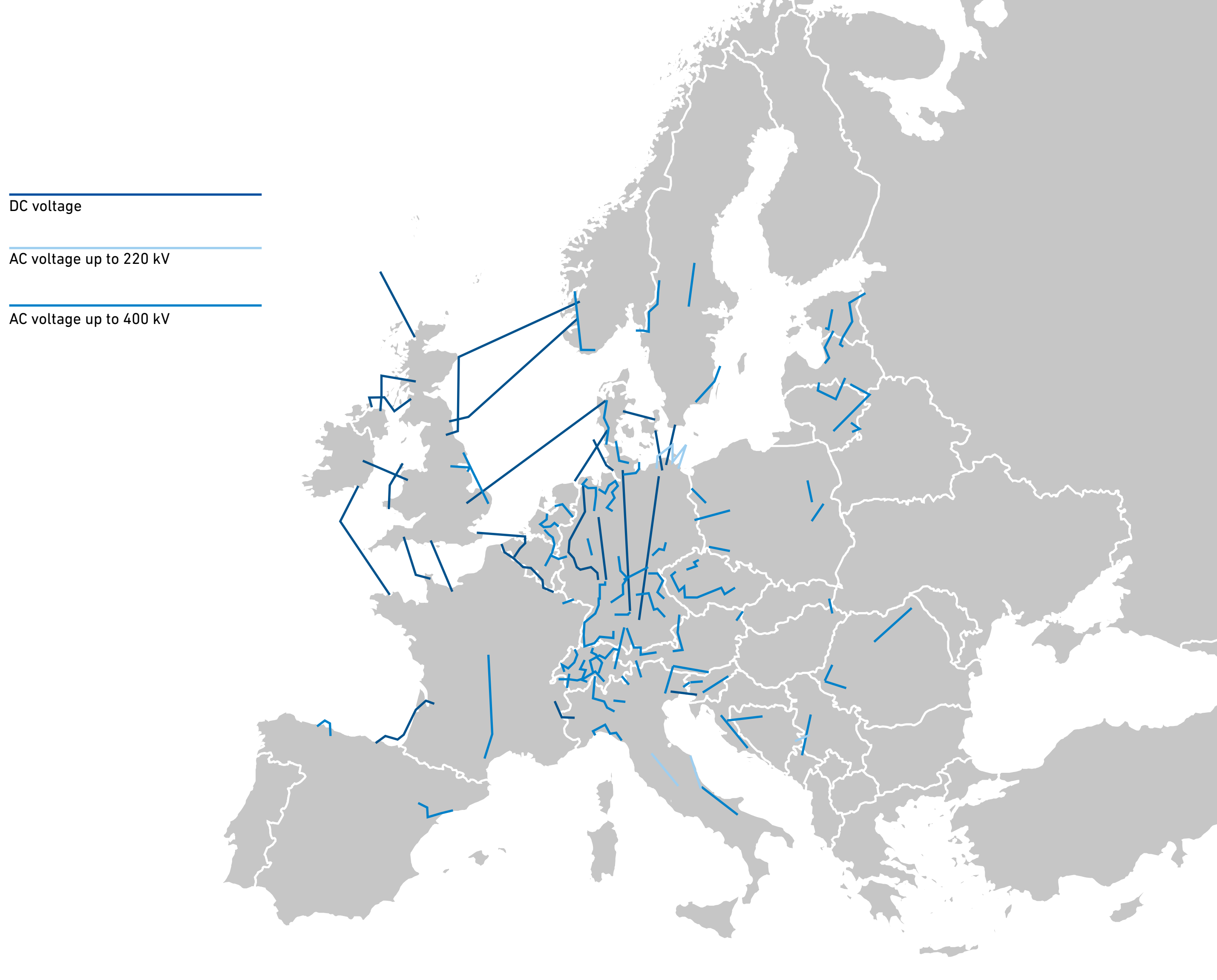
Since the mid 1990s, European energy policy has focused on achieving a European internal energy market. Investing in network infrastructure aims to increase competition and thus guarantee low-cost and secure energy supply for Europe. The European networks must also be modernised in order to absorb the increasing amount of renewable electricity. By 2020, renewable energy is expected to account for 20 per cent of Europe's final energy consumption. Individual member states contribute to this goal with defined national objectives according to their potential.

Germany has a designated national objective of 18 per cent of its total final energy consumption. A share of 38.6 per cent should be achieved in the power sector by 2020.

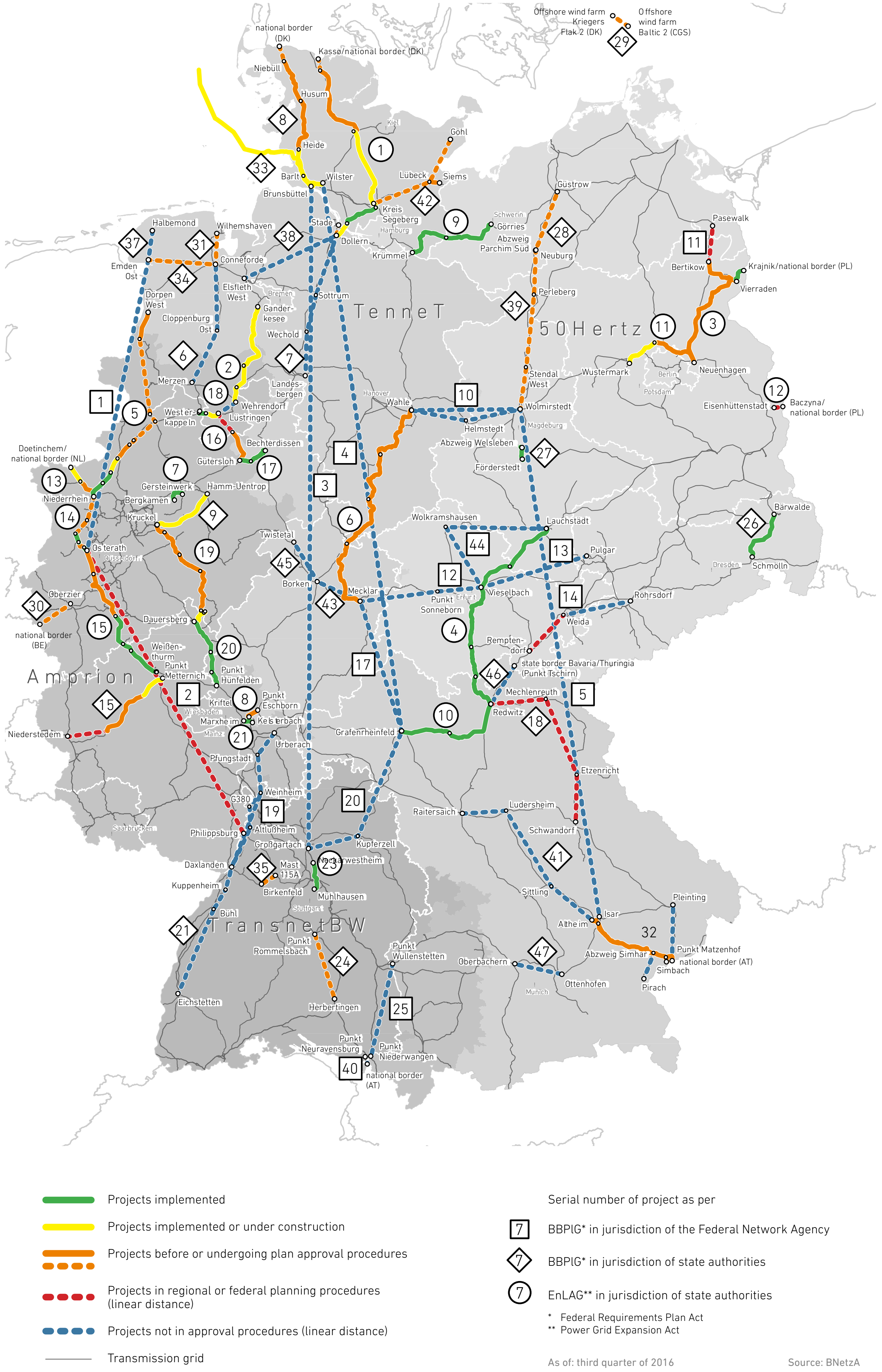
Every two years, the European Network of Transmission System Operators for Electricity (ENTSO-E) presents a European network development plan that determines the network expansion required to reach the fixed goals over the next ten years. The Projects of Common Interest (PCI) are also based on this plan and are implemented using EU funding.

Germany plays a special part due to its central geographic location and pioneering role in the area of renewable energy expansion. Connecting to Scandinavia and its large storage capacities is of great importance for the German energy transition. In this respect, there are also great expectations for the so-called NordLink. This is a subsea DC cable connecting Norway and Germany (start of construction: Sept. 2016). This first direct connection between the German and Norwegian energy markets is scheduled to be completed at the end of 2018 and will cover a distance of 623 kilometres with a capacity of 1,400 MW at 500 kV. In the future, wind power generated on the German coast will be temporarily stored in Norway's pumped-storage power plants using the NordLink.

NEW POWER GRIDS IN EUROPE



Source: ENTSO-E



THE EXTRA-HIGH VOLTAGE GRID – ELECTRICITY HIGHWAYS

New and up-to-date power grids are necessary for the energy transition. The urgent need for expansion in the extra-high voltage grid was defined in 2009 in the Power Grid Expansion Act (EnLAG), according to which some 1,800 km of additional power lines were meant to be implemented by 2015. The majority of the 22 (originally 23) EnLAG projects run from North to South.

Considerable delays were foreseeable after just two years, given substantial acceptance problems towards new overhead power lines and the slow approval process. Added to this was the 2011 renewed decision from the Federal Government to phase out nuclear power: the last nuclear reactors are scheduled to be disconnected from the grid by 2022. This eliminates the main energy producers in the South. For this reason, a new framework for the expansion of the network was decided in summer of 2011 based on the amended Energy Act (EnWG) and the Grid Expansion Acceleration Act (NABEG). The Federal Network Agency (Bundesnetzagentur) is now directly responsible for the approval of new networks that cross several federal states. Also, public participation in the planning phase has been increased.

Despite these amendments in energy law, network expansion lags considerably behind renewable energy development. The legislator once again responded and decided at the end of 2015 to prioritise underground cables for the three major DC lines. This is intended to ensure wider acceptance in order for wind power to reach the South by 2022.

The rapid implementation of the EnLAG projects is important for the German energy transition to be successful. However, the scope of building new lines beyond the start network is greatly disputed. The importance of public acceptance for the infrastructural measures is indisputable. The speed with which new construction measures can be completed depends on it.

STATUS OF NETWORK EXPANSION:

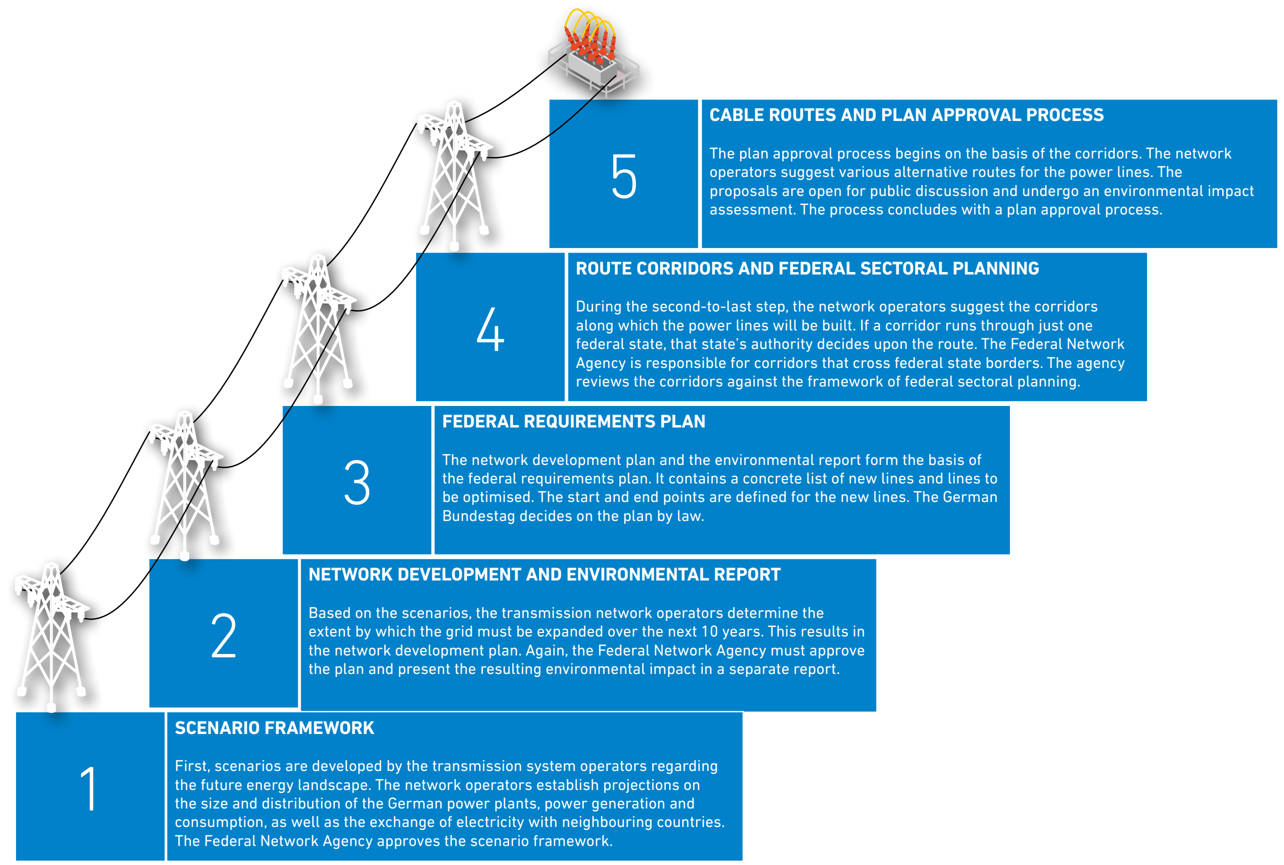
STARTING NETWORK (ENLAG PROJECTS):
22 projects over a total of 1,800 km
- approx. 950 km of which approved
- approx. 700 km of which implemented (approx. 40%)

ADDITIONAL NETWORK (ACCORDING TO THE FEDERAL REQUIREMENTS PLAN 2015):
43 projects with around 2,550 km of new cable routes and the optimisation and reinforcement of 3,100 km of existing lines in addition to the starting network
- 450 km of which approved
- 150 km of which implemented

As of: second quarter 2017 Source: Federal Network Agency (2017)

FIVE-STEP GRID EXPANSION PROCESS

The current energy grid must be developed and optimised to handle the increasing supply of electricity from renewable energy sources. The amount of new lines that will ultimately be needed and their location will be discussed and decided upon during a legally determined multistep process.



SCHLESWIG-HOLSTEIN CASE STUDY: WEST COAST POWER LINE – NEW ROUTES WITH THE SUPPORT OF THE PUBLIC

The energy transition is of particular importance in Schleswig-Holstein: This is the birthplace of wind power in Germany. Communal wind farms are widespread and onshore wind power enjoys high public acceptance. The state government has set a goal of increasing its onshore wind energy capacity to 10.5 GW by 2025 (2015: 5.8 GW) and its offshore wind energy capacity to 2.6 GW (2015: 1.5 GW).

The resulting green electricity will also supply the Hamburg metropolitan area and the federal states south of the River Elbe. The network expansion necessary to achieve this goal is crucial. The federal state government has therefore foregone a time-intensive regional planning procedure in favour of an innovative dialogue approach for the so-called West Coast line. The formal consideration of the area planning concerns, such as the environmental impact assessment for the priority corridor, was later considered in the framework of the plan approval process.

This approach aims to accelerate the implementation of the project with the greatest possible acceptance from the public. The affected population has been informed and involved since 2011. In 2013 alone, four large conferences, ten local events and six expert discussions were held with a total of more than 1,800 participants under the leadership of the federal state and with Environmental Action Germany (DUH) as the moderator.

CIVIL DIALOGUE GOALS:

- Information from the public: comments and suggestions for the network planning help to identify and resolve conflicts. This leads to fewer objections during the actual approval process.
- Information for the public: explanations of the planned project and its importance
- Transparent planning process

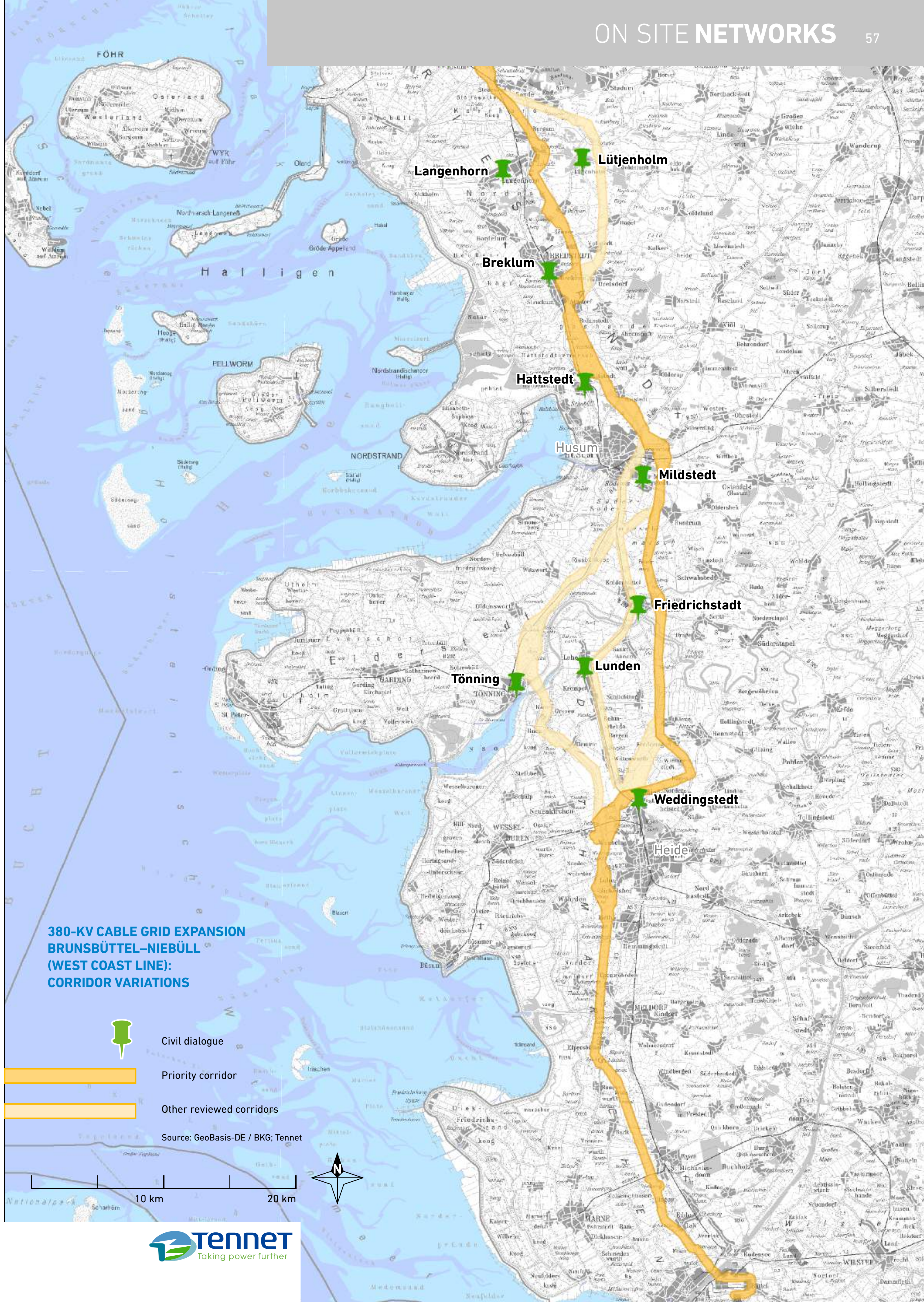
RESULT:

The fact that these communication strategies meant a dialogue on equal footing with the public is shown by concrete measures that were implemented by the responsible transmission system operator Tennet at the request of the public.

- "Bird markers" ("fluttering" ribbons) designed to deter birds from the cables will be attached to the power lines across large stretches.
- Improvements to the nature reserve Oldensworter Vorland outside Tönning: the new grid (380 kV) will run east of the protected area, the 110-kV line that crosses Eider River will be placed underground.
- Grouping routes: the new 380-kV lines will be placed along existing 110-kV power lines.

The nature conservation associations are also satisfied with the result. This is no small feat: German nature conservation groups BUND and NABU ultimately stopped other large projects in the North such as the deepening of the River Elbe for several years through complaints. Conversely, the West Coast power line is under construction and is expected to be completed in 2018.

The public learns about the West Coast power line grid expansion.



THE DISTRIBUTION GRID: GETTING THE BACKBONE OF THE ENERGY TRANSITION READY FOR THE FUTURE

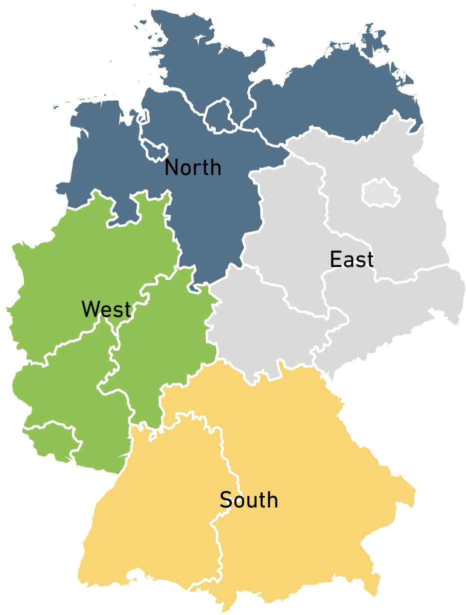
More than 90 per cent of renewable energy production is fed into the high, medium and low voltage networks (see Fig. on page 52). Thus, the distribution grids play a decisive role in the implementation of the energy transition. These grids are increasingly reaching their limit of capacity, as they were not designed to integrate such a large amount of decentralised production at the time of their construction. The challenge network operators face regarding voltage stability continually increases, particularly in rural distribution networks. The networks are utilised to maximum capacity. Network infrastructure, especially that of the distribution grids, must be prepared for the energy future to ensure that power supply remains secure and stable.

By 2032, the scope of the required distribution grids is estimated at 130,000 km to 380,000 km, with investments of 23.2 billion to 48.9 billion euros (BMWi 2014). The scope is calculated from different underlying renewable energy capacities during the period under consideration. The required development of the distribution grids varies by region due to different regional potentials for renewable power generation. Mainly low voltage networks are required for PV generation in southern Germany, while high voltage networks are needed for input from the wind farms in the North and East.

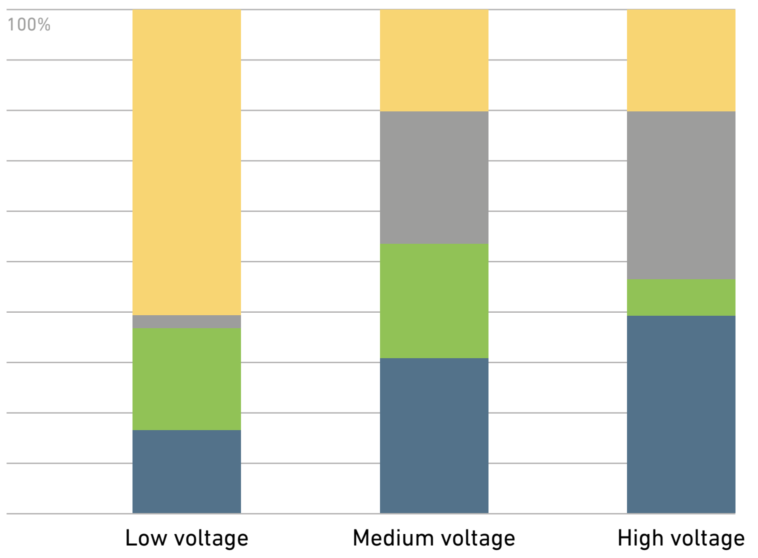
REDUCING THE NETWORK EXPANSION REQUIREMENT THROUGH INNOVATIVE PLANNING CONCEPTS AND SMART TECHNOLOGIES

Innovative planning concepts significantly reduce the network expansion requirement. Approximately 40 per cent of the network expansion can be axed by peak shaving in the feed-in management (curtailment of up to three per cent of the annual production of each renewable energy installation) in the network planning, according to the cited distribution grid study from the BMWi. An additional 20 per cent can be avoided through smart grid technology. In particular, voltage-regulated distribution transformers hold great potential. Through the widespread use of these transformers, required low voltage network expansion can be almost entirely avoided. While conventional network expansion is time consuming, a regulated distribution transformer can be easily integrated into existing local network stations.

REGIONAL DISTRIBUTION NETWORK EXPANSION REQUIREMENTS



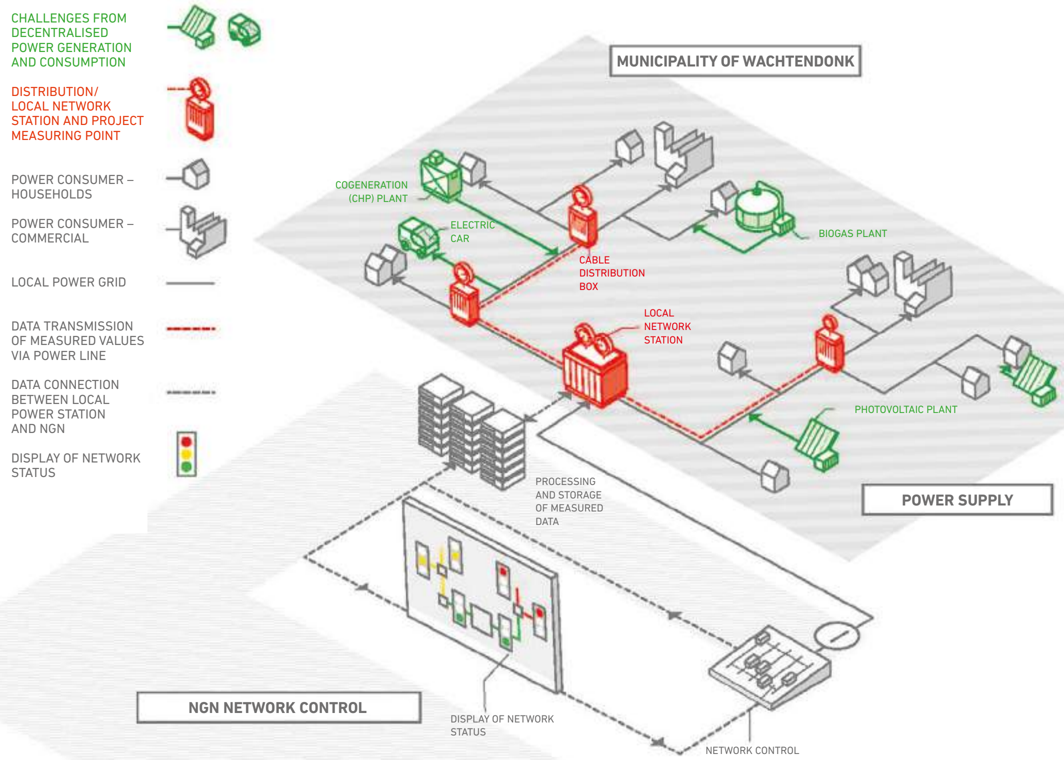
Regions' share of the total expansion requirement



Source: BMWi (2014)

WACHTENDONK CASE STUDY: LIGHT IN THE BLACK BOX – THE REGULATED DISTRIBUTION TRANSFORMER

Regulated distribution transformers can be easily integrated into local network stations and help to collect data regarding the state of the network. Two employees from Stadtwerke Krefeld municipal utilities are testing this in Wachtendonk.



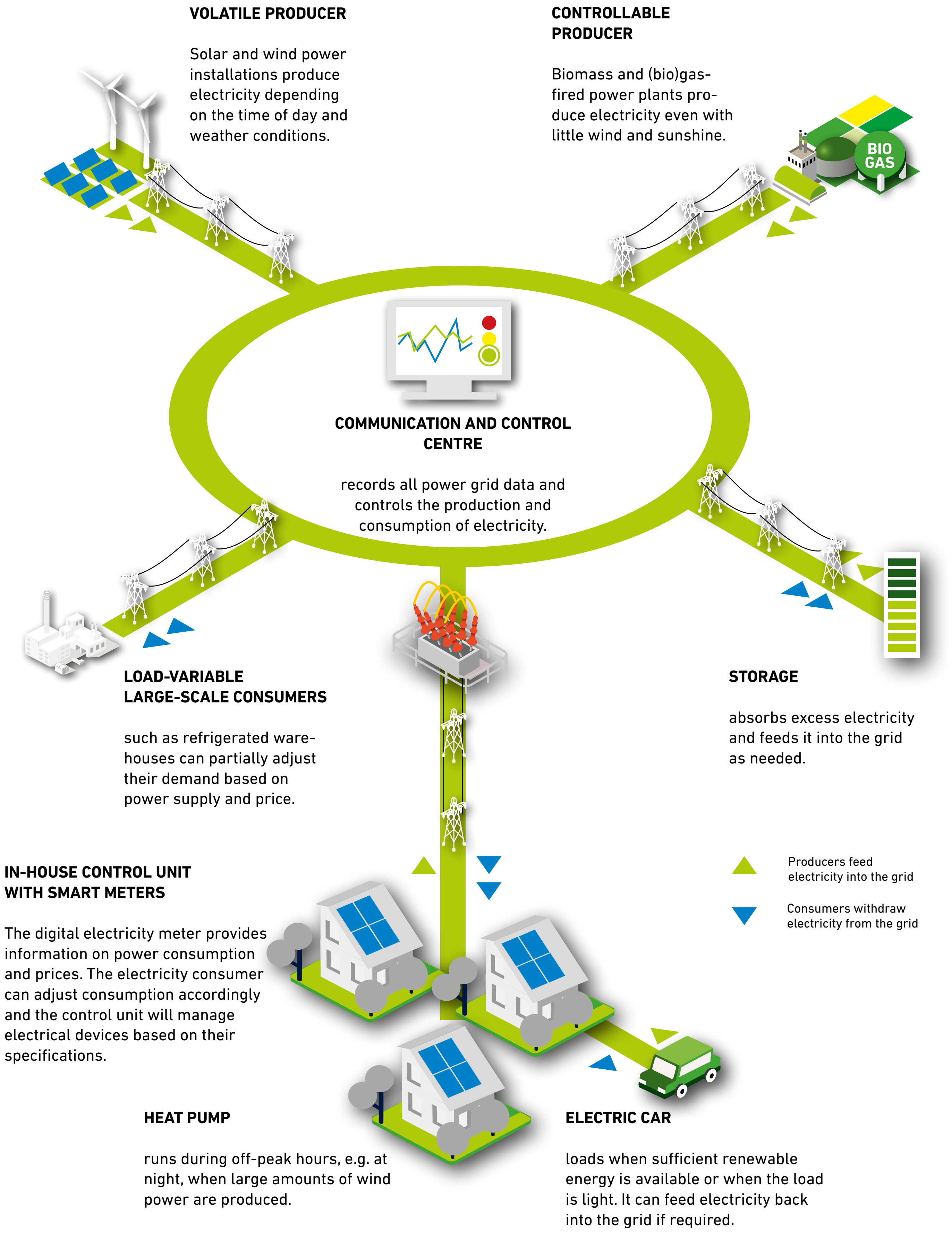
Source: SWK Stadtwerke Krefeld (2016)

As long as electricity was transported exclusively "top-down" from central power plants to end consumers, the parameters with which the transformers and low voltage networks had to be designed could be determined. The kilowatt-hours en route through the network could be almost exactly calculated. Since end consumers have now become electricity producers themselves, for example by means of photovoltaic installations, and since decentralised renewable energy installations send electricity "bottom-up", uncertainty prevails and the low voltage network resembles a black box. Inadmissible voltage fluctuations are discovered only through error messages.

The municipality of Wachtendonk in North Rhine-Westphalia near the Dutch border demonstrates how to remedy this. During a research project, the municipality, along with the regional electricity supplier, shed light on the low voltage network black box using voltage-regulated distribution transformer technology. The municipality of 8,000 inhabitants is characterised by a rural landscape and a high degree of enthusiasm for renewable energy: 80 per cent of the electricity comes from renewable energy sources like rooftop PV systems on homes and stables. The result: significant voltage fluctuations and peaks in the low voltage network. Under the project name „Wachtendonk macht mit - Forschung im Netz" ("Wachtendonk joins in - grid research"), 100 homes and many cable distribution boxes were first equipped with smart meters. The meters remotely record consumption data and measure the network status parameters of the low voltage network with a snapshot. The data is then analysed by the regulated distribution transformer. If there is an issue with the voltage, it is reported to the network operator, who can then respond accordingly and anticipate a failure. Concurrently, regulated distribution transformers increase the absorption capacity for other renewable installations or additional energy consumers, such as electric cars, without having to further expand the network. This technology is also an integral part of a smart grid, which in turn is necessary for the energy transition (see Fig. on page 60).

The 2016 follow-up project funded by the BMWi called ENERGIE (Capturing Network Status of Low Voltage Grid in Real Time) will investigate how this data can be reliably transmitted. Smart grids, with their wealth of information, require a different frequency range for data transfer than the one typically used until now. In order to maintain data volume as low as possible, the information will be grouped in advance on site so as to ensure that it remains within manageable limits in the case of widespread use of smart meters. The long-term goal of the research project is to ensure a self-sufficient and independent evaluation of the network status of the respective service area of a local power station.

HOW A SMART GRID WORKS:

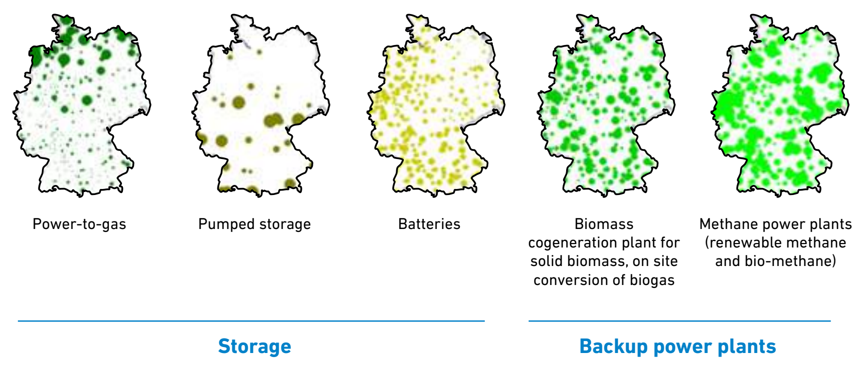


THE COMBINED RENEWABLE ENERGY POWER PLANT: 100 PER CENT RENEWABLE ENERGY = 100 PER CENT RELIABLE POWER SUPPLY

As early as in 2009, the "Kombikraftwerk 1" (Combined Power Plant 1) research project led by Fraunhofer IWES demonstrated that various decentralised electricity producers could be combined to balance out volatile renewable energy production, making full supply from renewable sources possible. To ensure a reliable power supply, the grids must also operate securely and certain parameters must be met with respect to voltage and frequency. The focus of an additional research project in 2015 "Kombikraftwerk 2" (Combined Power Plant 2), therefore, concentrated on which challenges regarding network stability are involved in such a system and how much the system must be serviced to maintain stable frequency and voltage with a large proportion of volatile producers.

The result of the simulation: a stable power supply from 100 per cent renewable energy is technically possible. This is ensured firstly by energy storage (power-to-gas, pumped storage and batteries) and secondly by backup power plants (methane power plants and adjustable biomass).

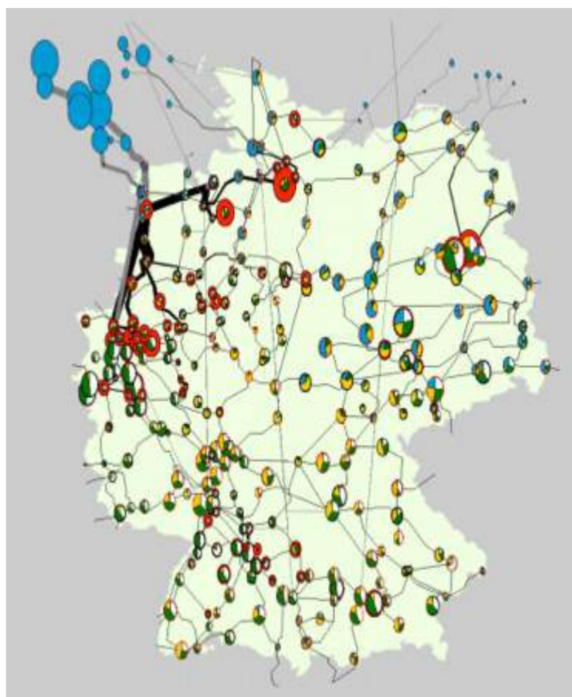
Technology	Installed capacity (in GW)	Energy generation (in TWh)
Onshore wind power	87.0	213.9 (without surplus)
Offshore wind power	40.0	108.7 (without surplus)
Photovoltaic	133.7	119.7 (Without surplus)
Hydropower	4.8	25
Geothermal energy	4.7	41
Bioenergy	17.3	34.5
Pumped storage	12.6	11.1
Methane power plants	53.8	18.5
Batteries	55	2.7
Surplus		58.8
Total		601



THE COMBINED RENEWABLE POWER PLANT SIMULATES FULL SUPPLY FROM RENEWABLE ENERGY SOURCES

The combined power plant's 100 per cent scenario models the possible regional distribution of renewable installations as well as storage options while taking potential surfaces, weather data and existing locations into consideration. Political objectives were also factored in. The model's power grid is based on the network expansion plan.

Source: IWES/Kombikraftwerk



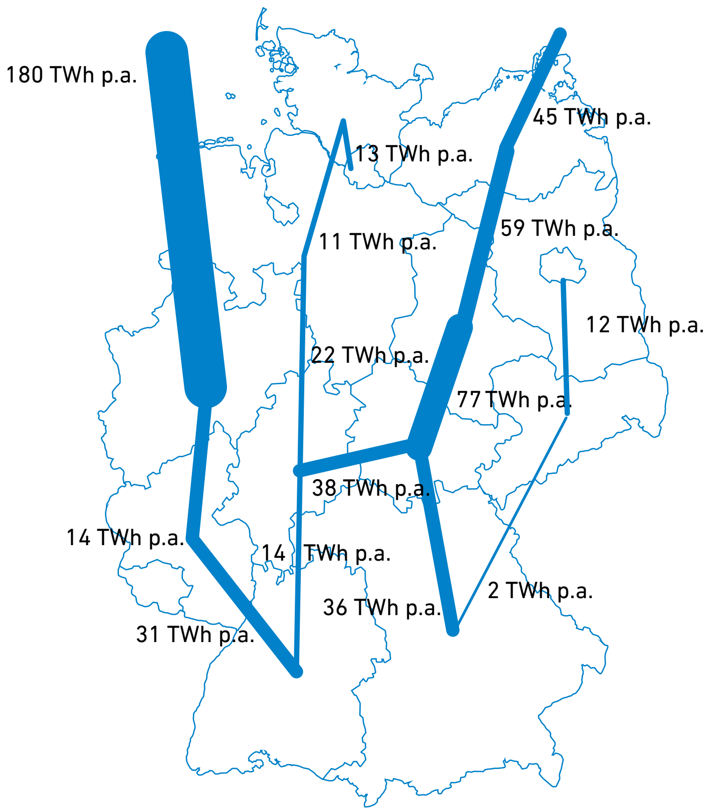
DISCHARGING POWER GRIDS THROUGH GRASS ROOTS INITIATIVES

Consuming energy where it is produced, i.e. on the local supply level, is the idea behind a study carried out by the German Electrotechnical Association (VDE) titled "The Cellular Approach".

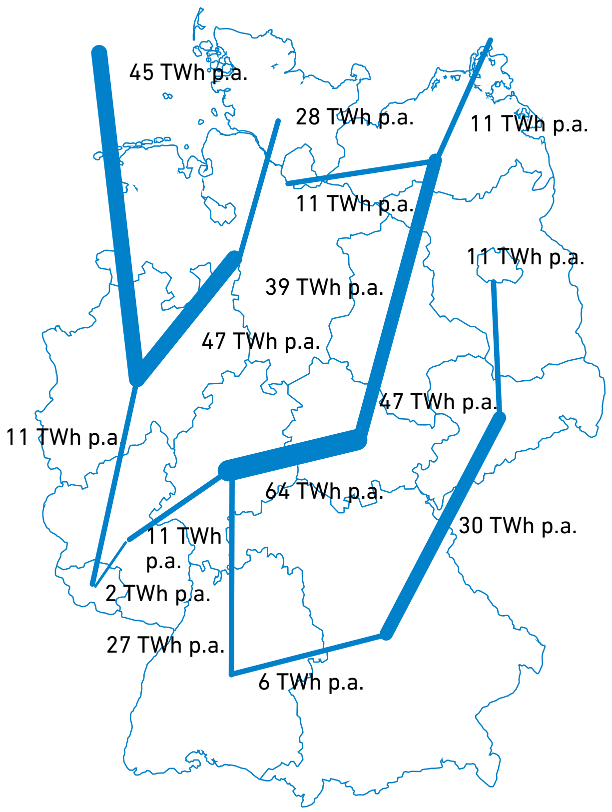
The study assumes the existence of local energy cells, within which energy supply, use, distribution, storage and other infrastructure services can be optimised largely independently. Thus, both heat and power demand can be met locally and mobility can be provided. In the ideal case, the energy cell is balanced out and on-site production meets the demand. This requires the energy compensation between the cells to be as low as possible. To that end, the energy cells remain interconnected and cumulated over multiple levels.

An important result of the study: consuming the generated energy on site results in a discharge for the overlying power grid. Network expansion will not become superfluous through the use of the cellular approach. However, experts predict that it will minimise the need to expand the grid. Two scenarios are compared; one with strong offshore expansion, the other with decentralised expansion ("cellular approach"). In both scenarios, energy must be transported from North to South and from East to West. In the "strong offshore expansion" scenario, 602 billion kWh of electricity is transferred annually to balance out the flow. In the "cellular approach" scenario, only 394 billion kWh must be distributed throughout the networks, placing considerably less load on these grids. However, the cellular approach requires heavy expansion of wind power in southern Germany, especially in Bavaria, as well as moderate offshore expansion.

APPROACH A WITH MASSIVE EXPANSION OF OFFSHORE WIND POWER



APPROACH B WITH VERY CONSUMER-ORIENTED EXPANSION OF RENEWABLE ENERGY



Source: VDI news, VDE (2015)

WIND POWER SUPPLY IN FUTURE SCENARIOS

(bn kWh)

	2015	Offshore scenario	Cellular approach scenario
North Sea	6.9	180	45
Baltic Sea	1.4	45	11.3
Bavaria	2.8	4.4	34.7
Baden-Württemberg	0.8	3.6	15.3

UM.BaWü (2016), VDE (2015), AGEE-Stat

SHOWCASES GIVE INSIGHT INTO THE FUTURE OF ENERGY

In February 2015, the Federal Ministry for Economic Affairs and Energy (BMWi) launched the funding programme "Smart Energy Showcases – Digital Agenda for the Energy Transition" ("Schaufenster intelligente Energie – Digitale Agenda für die Energiewende", or SINTEG for short).

Its focus is to intelligently link energy production with consumption, along with the use of innovative grid technologies and operating concepts. Six showcase regions address key challenges of the energy transition, such as the integration of renewable energy into the system, flexibility, security of supply, system stability, energy efficiency and the establishment of smart grids and market structures, with the aim of finding sample solutions for wide implementation.

THE SINTEG PROJECT

ENERA – THE NEXT BIG STEP IN THE ENERGY TRANSITION

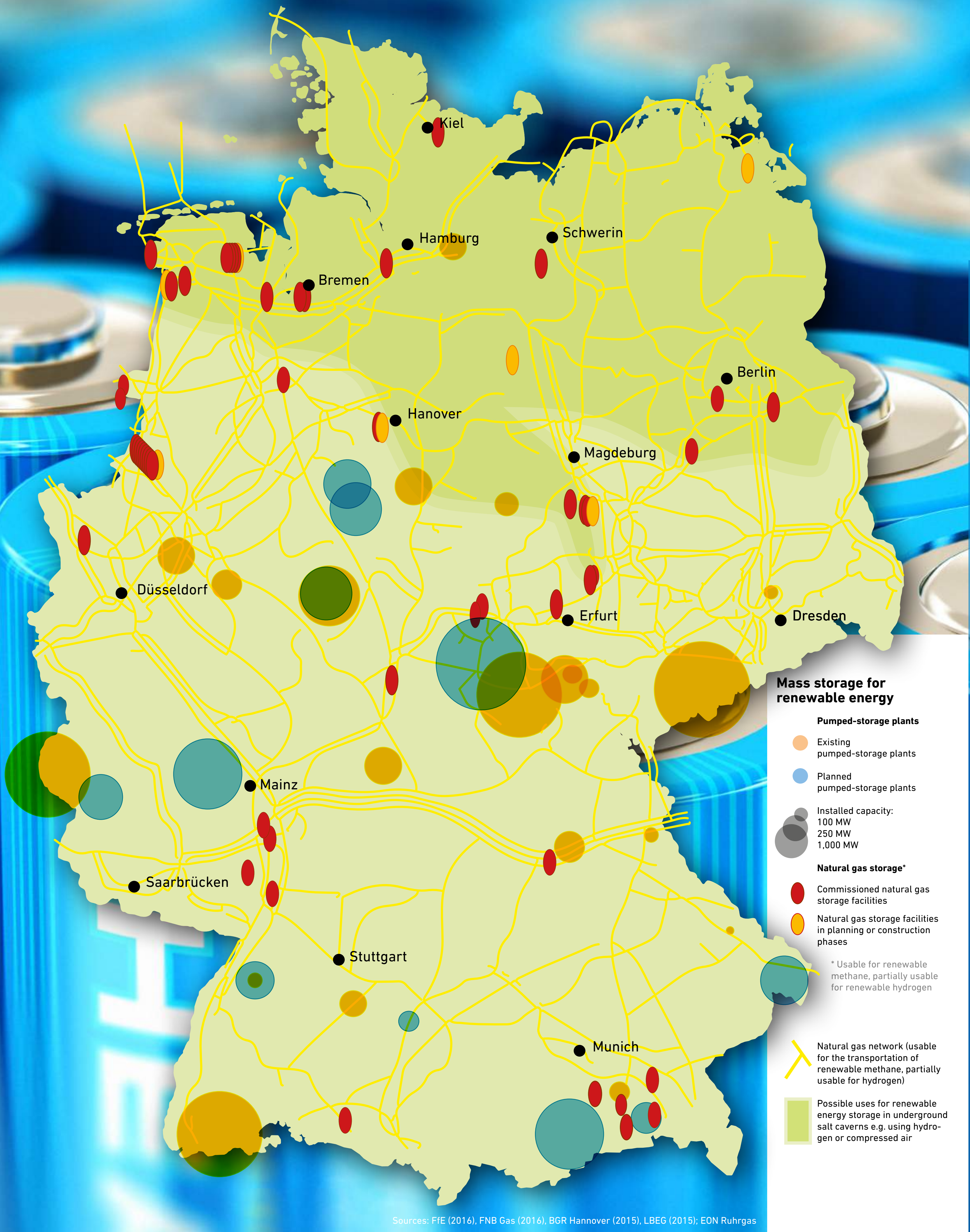
The SINTEG project from **enera** aims to demonstrate that the energy system can be made more flexible through technical upgrades for producers, consumers and storage devices and by strengthening the grid. Decentralised renewable installations are expected to yield system services to ensure voltage stability in the future and thus locally stabilise the grid. This aims to further increase the reliability of power supply based on renewable energy. Additionally, solutions as to how these regional system services will be traded on the electricity markets are being worked on.

FROM THE LAB TO PRACTICAL APPLICATION: C/SELLS TESTS THE CELLULAR APPROACH IN THE GERMAN SUN BELT

The SINTEG project by **C/Sells** includes the "solar arc" of southern Germany: 60 affiliates from industry, energy and science sectors want to make a cellular energy system a reality in Baden-Württemberg, Bavaria and Hesse. With almost half of Germany's photovoltaic output, southern Germany is predestined for this initiative. Over 760,000 producer-consumers already generate electricity in this region and partially use it themselves. The project also focuses on finding technical solutions for the practical implementation of the cellular approach ("cells"). The involvement of the public is a priority, however, both in the energy transition itself as well as in economic opportunities ("sells"). An adapted user behaviour could ultimately be financially beneficial to these. An example: in the household of the future, consumers will set a limit for the latest time of day they want their washing machine to run. The automatic control will determine exactly when the washing machine will be running, and can conform to the most economical electricity price while taking the ending time into account. Electricity demand can be made more flexible through monetary incentive. This flexibility increase makes an important further contribution to compensating for the fluctuating supply from renewable energy sources.

The project holders expect higher acceptance for the energy transition and its associated changes to the production structure by incorporating the public. By 2020, C/Sells aims to demonstrate how supply from renewable energy sources can be realised in a cost-effective and secure manner that also includes the general public.

At the 2016 C/Sells-Partner & Friends kick-off meeting, the cooperation partners are exchanging views.



Sources: FfE (2016), FNB Gas (2016), BGR Hannover (2015), LBEG (2015); EON Ruhrgas

STORING ENERGY

Germany wants its power supply to be 80 to 95 per cent renewable by 2050. This requires greatly increased contributions from weather-dependent wind and solar power. However, the balance between electricity supply and demand, necessary for the stability of the grid, will become more difficult to maintain as we see more participation from these energy sources. Increasingly, power production will exceed demand and vice versa. For the energy transition to be a success, it is necessary for the power plants, consumers and energy storage facilities to adjust to the fluctuating generation, or in other words, become more flexible. For example, biomass power generation can be controlled more flexibly in the future. In future homes, household appliances such as washing machines and even electric cars will automatically draw electricity at times when it is most economical. To achieve this, the devices must first be more intelligent and externally controllable. Consumer incentives through suitable power tariffs are also required. But household power demand is not the only thing that can be made more flexible. The industry sector can also shift its energy demand, for example temporally. This load transfer can contribute to offsetting the fluctuating electricity generation from wind and solar power.

Electricity storage similarly plays an important role for the energy transition. A number of technologies can be considered for this, including batteries, pumped-storage power plants or the use of electricity for hydrogen production (power-to-gas) or heat production (power-to-heat). They differ in terms of storage capacity, efficiency, cost and scope of application, ranging from short-term system service measures (balancing energy) to load balancing for days or weeks. Most storage technologies are already available today, but few are economically feasible as yet. Technological development must advance even further. Although the important role of storage technologies for the German energy transition is evident, the market currently offers little incentive to invest in the technologies. The price difference between peak and base load electricity on the electricity exchange is simply too low.

In addition to economic factors, to what extent and when certain storage technologies can and must be used depends on power generation developments, network expansion and access to further flexibility options. Despite this uncertainty, there is widespread consensus among researchers in Germany that long-term storage will only be relevant once renewable energy represents at least 60 to 80 per cent of power consumption. Most scientists consider the power-to-gas technology (P2G) to be the best option. Flexibility options, such as industrial and domestic load management, are generally significantly less expensive and should be developed before P2G.

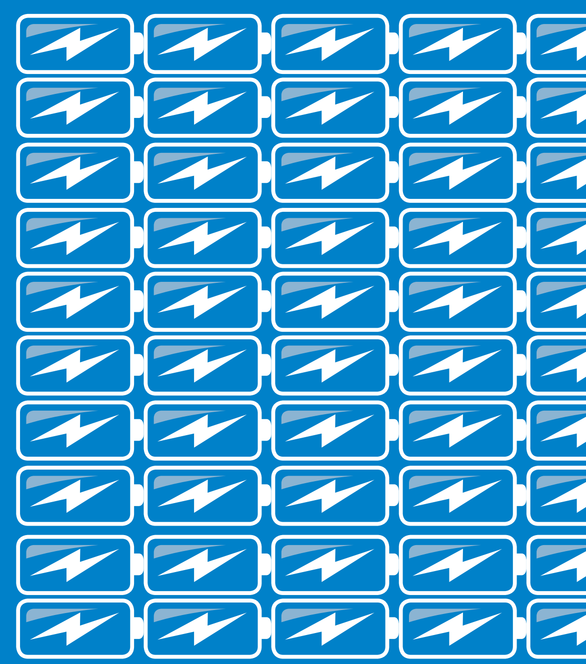
National and federal state governments are fostering the further development of the flexibility and storage options through dozens of research projects. Some of them are presented in this chapter.

Germany's 31 pumped-storage power plants provide a storage capacity of around 37 million kWh. Additional foreign storage capacities can also be used after NordLink is complete. But there is also still significant potential for storage in Germany: salt caverns in the North German Basin offer the possibility of storing hydrogen, methane or compressed air underground during electricity surplus. Former natural gas storage caverns can also be filled with climate-neutral gases in the future. The German gas network, with its approximately 440,000 km of lines, offers excellent storage and transportation conditions for the P2G technology.

Storage volume: 2016 and potential

2016: **37 m kWh**

Potential*: **337 bn kWh**



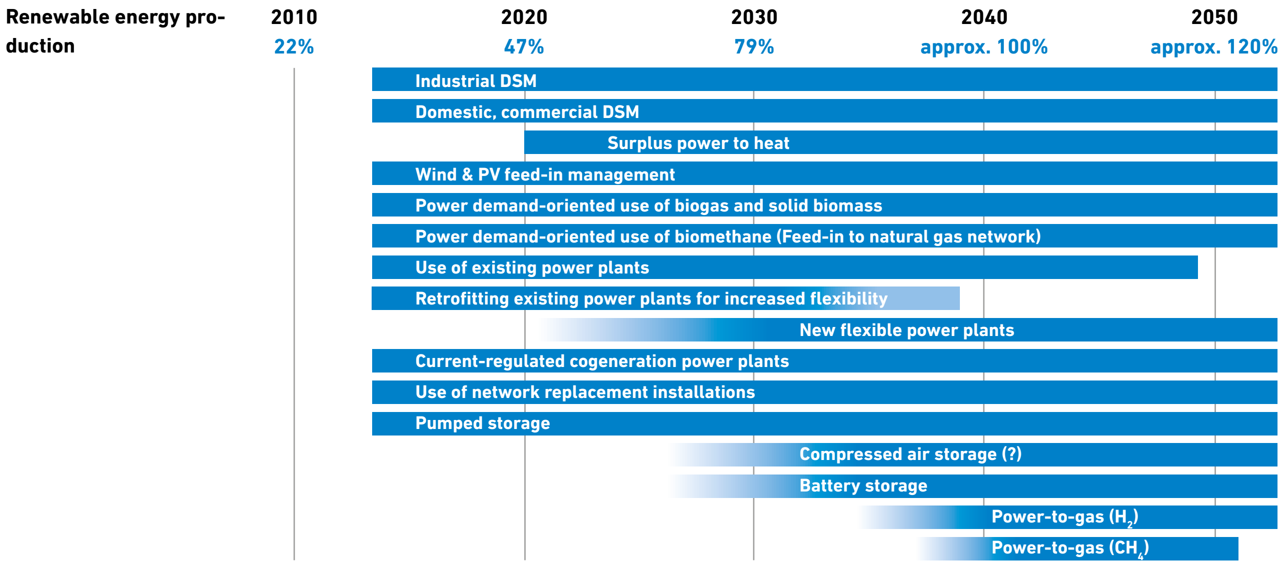
*Gas Storage

Source: Sterner (2016)

FLEXIBILITY OPTIONS AS A SOLUTION TO DECENTRALISED VOLATILE RENEWABLE ENERGY

The system transformation necessary for the energy transition to succeed can be achieved using various flexibility options, this means out with the static production structure and in with a dynamic energy system. A study by the German Renewable Energy Federation (BEE/BET 2013) analysed which flexibility options can be used and when by 2050. The result: a share of up to 47 per cent of renewable electricity can first be readily integrated into the existing German energy system. It is estimated that starting in 2020, larger power surpluses from renewable systems technology will occur and require the retrieval of various flexibility options. The surpluses can be partially offset through load management, partially removed by (new) grids or even curtailed if necessary. A colourful bouquet of storage technologies can enable the storage of electricity for up to several weeks and months. The use of long-term storage will not be necessary until the percentage of renewable electricity in Germany reaches an amount of 60 to 80 per cent.

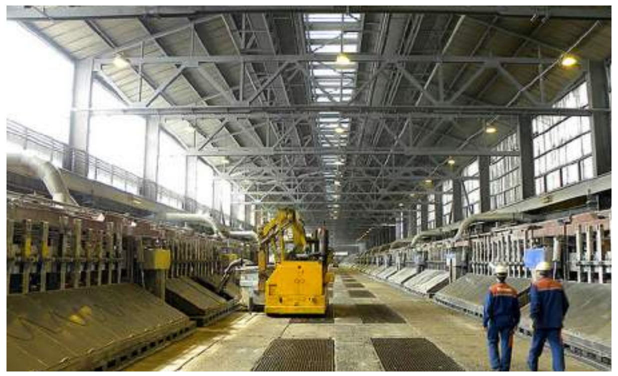
USE OF FLEXIBILITY OPTIONS



ESSEN CASE STUDY: ALUMINIUM PRODUCTION BASED ON WEATHER CONDITIONS – AN INDUSTRIAL GROUP SETS COURSE FOR THE ENERGY TRANSITION

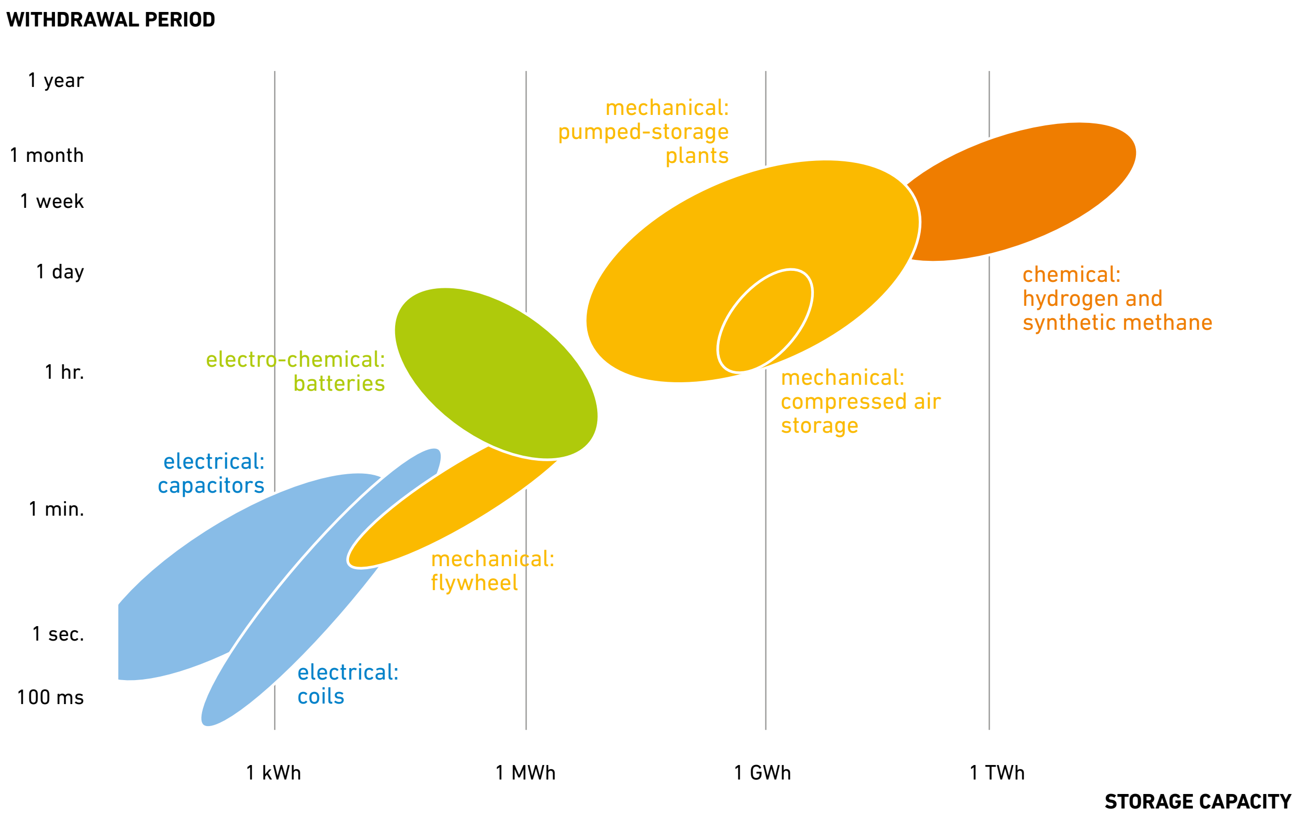
Essen-based aluminium producer Trimet demonstrates how industrial power demand can successfully be made more flexible. Producing the metal is very energy intensive. The power consumption of the group's aluminium mills is as high as the consumption of the Ruhr cities of Essen, Bochum and Dortmund combined. Since the invention of the electrolysis process to produce aluminium in 1886, constant energy supply has been required for a successful production process – until the German energy transition. Now the power-intensive company has made the process flexible: at strong winds, power consumption is increased by up to 25 per cent and is curbed by 25 per cent during lulls. The "sea of aluminium" within the melting furnace thus falls and rises according to weather conditions, without affecting the quality of metal production.

Therefore in the future, not only will the mill produce aluminium, but also the kilns will function as storage, buffering fluctuations in the grid. This makes Trimet partially independent of expensive electricity prices and allows it to offer balancing power by offsetting its load. Following a successful test phase, a total of 120 electrolytic furnaces in the aluminium mill in Essen are scheduled to be converted by the end of 2017.



120 electrolytic furnaces of aluminium producer Trimet will be converted into a "virtual battery".

A COMPARISON OF STORAGE TECHNOLOGIES



Source: Sterner (2016)

CAPACITIES OF DIFFERENT POWER STORAGE SYSTEMS

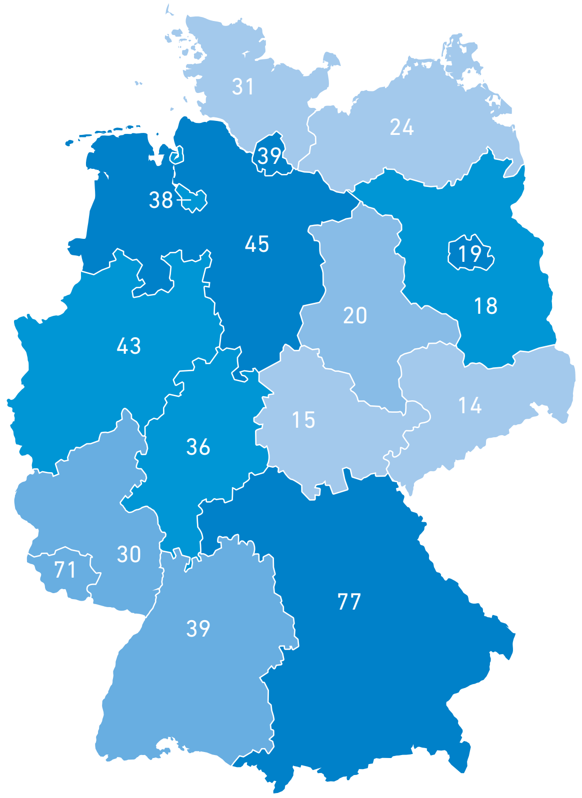
STORAGE TYPE/USE	DISCHARGE TIME	STORAGE TYPE	MAXIMUM STORAGE CAPACITY OF TYPICAL INSTALLATIONS AND TECHNOLOGIES
Short-term storage: Grid stabilisation, grid maintenance	less than 1 second to a few minutes	**SMES coils**	5.6 kWh
		capacitors/super caps	52 kWh
		flywheel storage	5 MWh
Long-term storage: Peak demand coverage	1 hour up to approx. 1 week	**compressed air storage**	2.86 GWh
		pumped storage	8.48 GWh
Electro-chemical storage: Reserve storage electromobility	1 hour to several days	**lithium-ion batteries**	85 kWh
		redox-flow batteries	12 MWh
		lead-acid batteries	40 MWh
Chemical storage	days to 1 year	**hydrogen**	several TWh
		synthetic methane	several TWh

Scale: 1, 10, 100 kWh; 1, 10, 100 MWh; 1, 10, 100 GWh; 1, 10 TWh

Source: Renewable Energies Agency (2014)

SMALL THINGS WITH BIG RESULTS: BATTERY STORAGE IN USE FOR THE ENERGY TRANSITION

NUMBER OF NEW PV INSTALLATIONS UNDER 30 KW WITH BATTERY STORAGE SYSTEMS (2016, IN PER CENT)



PV storage systems are especially used in the populated and sunny West and South of Germany.

Source: ISEA (2017)

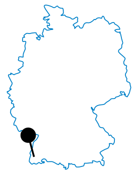
NUMBER OF INSTALLED PV STORAGE SYSTEMS IN GERMANY IN 2016

Source: ISEA (2017)

Wolfram Walter is often on the go to promote his solar storage system – and he does so using his electric car that he refuels with solar power.

Although the first multi-megawatt large batteries are already in commission to relieve the network and provide a balance of power (e.g. Feldheim in Brandenburg, 10 MW output, 10 MWh capacity), the large-scale use of batteries is not anticipated until the end of the 2020s. Meanwhile, until the fluctuating power supply reaches the projected quantities, centralised and decentralised battery storage systems can effectively supplement pumped-storage plants. Devices such as battery storage systems in private homes and in electric vehicles can become active in load management through intelligent communication technology and, in combination with PV installations, make a major contribution towards the energy transition. These decentralised storage systems are also being rapidly expanded, as the following example from Umkirch (Baden-Württemberg) demonstrates.

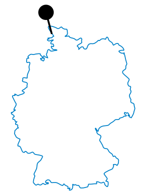
UMKIRCH CASE STUDY: STORING THE SUN THANKS TO GERMAN PIONEERING SPIRIT

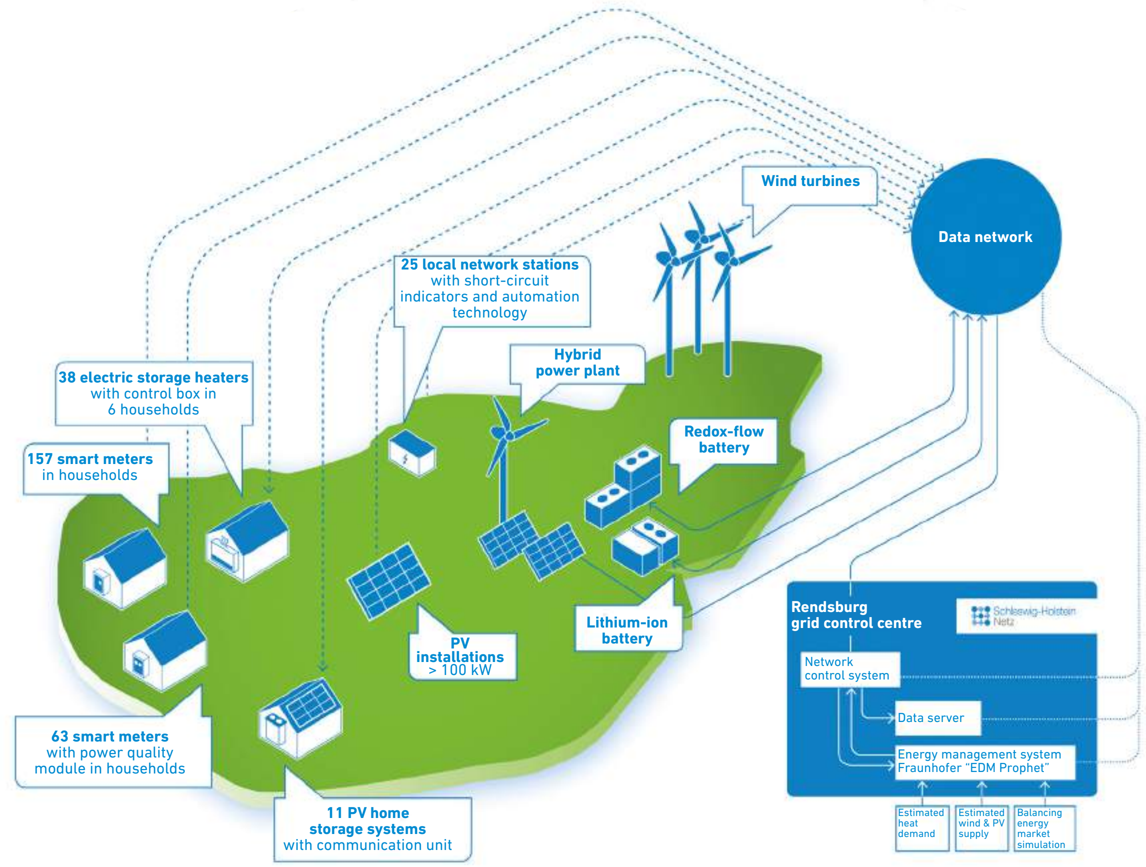


Wolfram Walter had a sudden inspiration a few years ago – at the very moment that he became annoyed with his photovoltaic installation. It was running perfectly smoothly, but Walter had to feed too much solar power into the grid for a small amount of feed-in remuneration during the day and then buy additional power from his energy supplier at night. So he devised a solution to store his electricity. The result: a solar storage device that charges a lithium battery with solar power from the roof during the day. This can be reused with nearly no loss (efficiency: 95 per cent) if the output from the PV installation is not sufficient to supply Walter's home. But he didn't stop there: through an intelligent power management of the solar storage device, individual consumption is maximised and the public power grid is ultimately unburdened.
In 2013, Walter received the German Renewables Award in the category of product innovation for his invention. Since then, there has been a very dynamic development in this area, almost every other PV installation under 30 kW is now bought with a storage battery. Politics stimulates this (e.g. through storage funding) and consumers wish for more independence.

Walter has a lot to do now and leads a successful start-up with more than a dozen employees – thanks to a sudden inspiration.

PELLWORM CASE STUDY: VIRTUAL MASS STORAGE SUPPLIES PRO-ENERGY TRANSITION ISLAND INHABITANTS





The island of Pellworm located in the North Sea belongs to the most sunny and windy regions in Germany. Wind power installations and continuously improving solar panels have been used here since the 1980s. Now they produce a total of 20 million kWh of electricity per year. This is far more than the 1,000 island residents consume. Nevertheless, electricity is also imported from the mainland at times.

As Pellworm already demonstrated some 35 years ago, now the "Smart Region Pellworm" project funded by the Federal Ministry for Economy Affairs and Energy (BMWi) points out innovative methods that can be used for the energy transition: a combination of various storage types, or hybrid energy storage systems (HESS), linked to a smart grid serves to increase compatibility between power generation and consumption. If the grid becomes overburdened, for instance in the case of strong winds, the peak production can be stored and thus unburden the network. An advantage of the hybrid storage concept is that the various storage technologies complement each other usefully. A lithium-ion battery, with its high output to capacity ratio, is especially suitable for providing balancing energy and is supplemented by a redox-flow battery. In addition to nearly wear-free operation, redox-flow batteries offer the advantage of virtually not discharging and therefore serve as excellent long-term storage systems. There are also 38 electric storage heaters that have already been used in households. Likewise, PV home storage systems (lithium-ion batteries) were installed in eleven households to increase load flexibility. All components are equipped with intelligent communication technology to optimise energy flows and to better coordinate production and consumption. Results from Smart Region Pellworm show: the technology of the energy future is already operational and market-ready, even though it is not yet economically viable.

The goal of the project was not to reach complete energy self-sufficiency for the island. This would have required roughly twice the storage capacity to even be able to cover the last load peak of 2.5 per cent at any given time. Rather, the idea of the intelligent hybrid storage concept is now expected to be exported to the mainland.

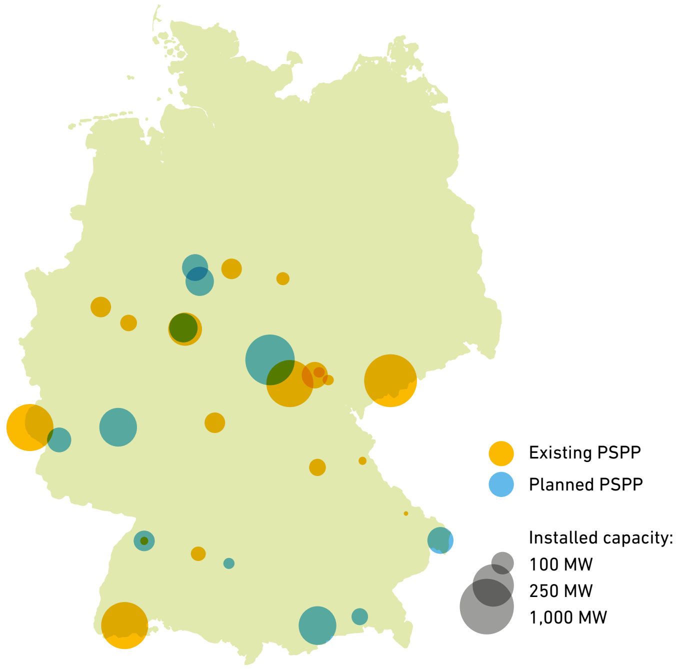
Power grid on Pellworm	
Network connection	two 20-kV submarine cables
Local network stations	over 50
Power consumption	about 7 GWh p.a.
Power generation	about 20 GWh p.a.

Geography of Pellworm	
Area	37.44 km^2
Inhabitants	approx. 1,000
Households	approx. 560
Economy	tourism, agriculture

PUMPED-STORAGE PLANTS
ESTABLISHED TECHNOLOGY OFFERS NEW ENERGY STORAGE SPACE

The technology of pumped-storage power plants has been in use for more than 100 years. It is technically sophisticated and relatively low-cost and efficient. New pumped-storage plants have an efficiency of 75 to 80 per cent. Its self-discharge rate (evaporation or leaching of water) is very low. Additionally, the technology has an unlimited number of cycles and a long service life spanning several decades. Pumped-storage plants supply peak load power (load smoothing), provide for the balancing of unexpected fluctuations in power consumption, provide system services and thus reduce the demand for fossil fuel power plant capacities. There are 31 pumped-storage power plants in Germany (as of: 2013) with a total installed capacity of 9,240 MW. The potential for expansion however remains limited in Germany because of geographical conditions and nature conservation restrictions. In many research studies, the (further) development of Scandinavian and Alpine storage capacities is therefore considered an option to offset this and to successfully implement the energy transition in Germany.

PUMPED-STORAGE POWER PLANTS (PSPP) IN GERMANY



Source: FfE (2016; as of: 2013)

GOLDISTHAL CASE STUDY:
THE LARGEST PUMPED-STORAGE POWER PLANT IN GERMANY

One of the most powerful pumped-storage power plants in Europe is located in Goldisthal (Thuringia). It was commissioned in 2003. Its output of around one gigawatt corresponds to that of a typical nuclear power plant. This output can be retrieved over the course of eight hours, thanks to the 12 million cubic metres of water in the upper basin. This would be enough to completely supply the entire federal state of Thuringia with electricity for eight hours.

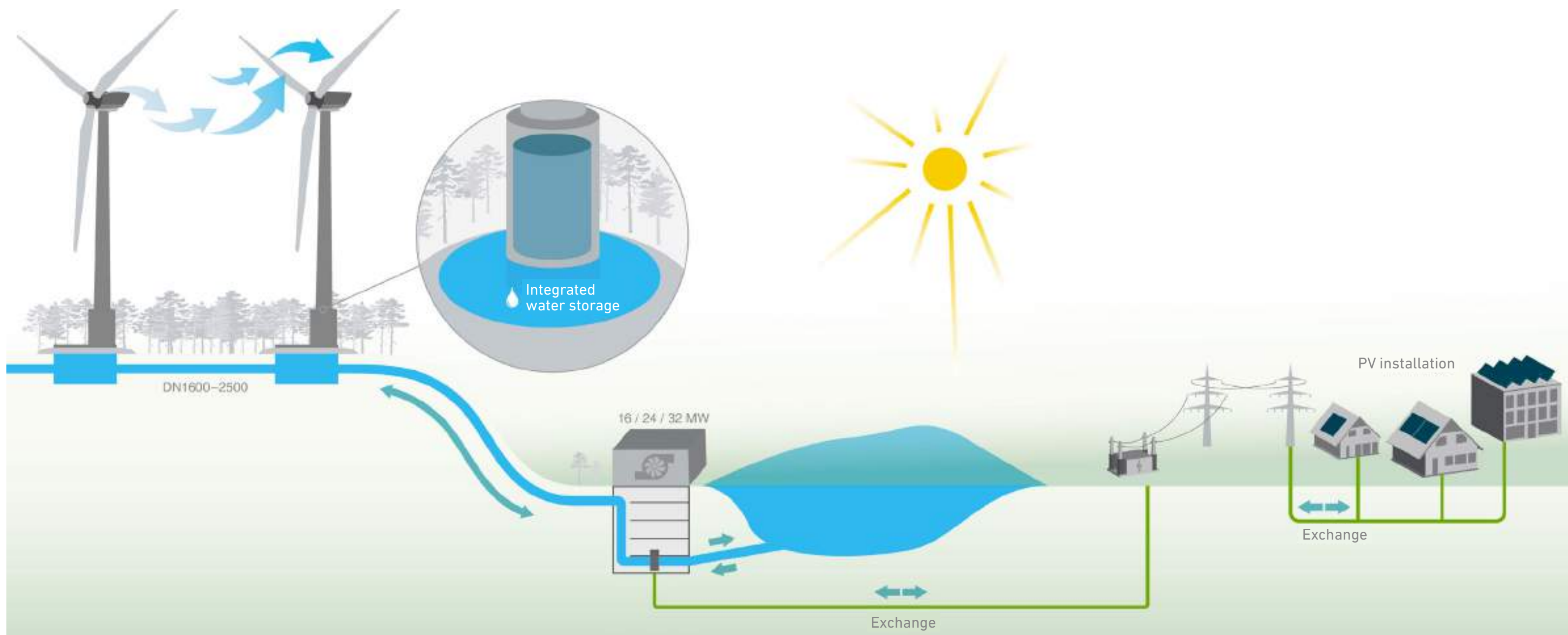
GAILDORF CASE STUDY:
PUMPED-STORAGE TECHNOLOGY 2.0 -
INTEGRATING THE UPPER BASIN WITH THE WINDMILL FOUNDATIONS

A photomontage shows what the Gaildorf pilot project will look like after completion.

The pilot project Naturstromspeicher (natural power storage) in Gaildorf (Baden-Württemberg) shows that even a 100-year-old technology still holds innovation potential. Four wind turbines each with an output of 3.4 MW will be built on the Limburg mountain range. What makes it special: situated on their foundations are water tanks connected to a pumped-storage power plant (16 MW) placed 200 metres below and a lower reservoir that is yet to be created. During low electricity prices and power demand, the waterworks pumps water into the foundations of the wind power plant, where it is stored for later use. In the case of high electricity prices and peak demand, the water flows downwards, thereby driving the turbines, which in turn provide power.

With the maximum amount of stored water, 70,000 kWh of electricity can be generated and supplied within four hours. It only takes 30 seconds to start up the power plant. The integrated water tanks therefore offer excellent conditions for the wind power operators to both balance fluctuating wind power production and to participate in the balancing energy market. These economic advantages go hand in hand with reducing the load on the power grid. Construction on this energy transition project funded by the Federal Environment Ministry began in October 2016. The wind power plants are expected to be finished in 2017 and the pumped-storage plant by the end of 2018.

HOW THE "NATURSTROMSPEICHER" WORKS



Source: Naturspeicher GmbH

RENEWABLE POWER AIDS THE ENERGY TRANSITION IN THE HEAT AND TRANSPORT SECTORS WITH "POWER-TO-X"

The so-called "power-to-gas" technology is a comparatively new energy storage concept involving the conversion of electricity to hydrogen (H_2) or methane (CH_4). The resulting gases can either be used directly (e.g. for applications in the chemical industry) or stored in the gas network for future energy use. The electricity ideally comes from renewable energy sources.

The P2G technology is particularly interesting because of the wide range of possible applications. This way, an energy source can be used not only in the electricity sector, but also in the heating (power-to-heat) and transport (power-to-fuel) sectors, which are still heavily dependent on fossil fuels. Because of the wide range of possible applications of renewable electricity, the terms "power-to-x" or sector coupling are also used in this context. These promising technologies will be essential starting in 2030/40, especially for seasonal storage of renewable power.

The fields of both industry and research, as well as politics, see the great potential of the P2G technology for implementing the energy transition. Some car manufacturers have already launched pilot projects. The national and federal state governments subsidise various research and development projects.

In Germany, there are currently more than 20 research, demonstration and pilot projects for the P2G technology, which have differing focuses but the same goal: to test the technology, achieve standardisation, cost reductions and to identify future challenges.

Source: greenfacts/DVGW; as of: October 2015

HOW POWER-TO-GAS WORKS

ELECTRICITY SURPLUS

OVERSUPPLY

Due to the increasing expansion of wind and photovoltaic power, flexibility options such as smart grids or interregional electricity exchange will not be sufficient to compensate for the oversupply of solar and wind power on very windy and sunny days in the future.

ELECTRICITY

POWER TO GAS

ELECTROLYSIS

The excess electricity from renewable energy sources is used for electrolysis, where **water is spit into hydrogen and oxygen using electrical energy**. Through this process, a part of the **electrical energy is chemically stored in hydrogen gas**.

HYDROGEN

METHANATION

During methanation, the **hydrogen produced from electrolysis is further "refined". Here it is mixed with carbon dioxide (CO_2)** to produce methane: the primary component of fossil natural gas. Methane is, **in comparison to hydrogen, easier to store** and transport.

HYDROGEN **METHANE**

STORAGE

HYDROGEN STORAGE

Hydrogen gas must be stored under high pressure and liquid hydrogen at very low temperatures (–253 °C), requiring a relatively high material and energy expenditure.

GAS NETWORK

Hydrogen can be injected into the existing natural gas network up to a certain percentage (approx. 5 per cent), while methane is unrestricted. This provides a connection to the largest energy store available today. The storage capacity of the German natural gas network with its pipes, tanks and subterranean caverns is estimated at 200 billion kilowatt-hours, which roughly corresponds to Germany's nationwide power consumption for four months.

HYDROGEN/METHANE

GAS UTILISATION

ELECTRICITY AND HEAT

Both hydrogen and methane can be used in **cogeneration or combined heat and power (CHP) plants.** Highly flexible gas-fired (thermal) power plants are also connected to the gas network. This allows the stored electricity to be both converted back into power and to be used to supply heat as necessary.

FUEL

Hydrogen and methane can be distributed in **hydrogen or gas fuel stations** and used as fuel for the corresponding internal combustion engines in vehicles. Furthermore, hydrogen serves as a source of energy for electric cars with **fuel cells.**

ELECTRICITY **HEAT** **MOBILITY**

INDUSTRY

The industrial sector is the largest CO_2 emitter in Germany, with 33 per cent (2015). In the production of crude steel alone, around 50 million tonnes of CO_2 are emitted. The EU-funded project Green Industrial Hydrogen, with eight collaborating partners from Germany, Italy, Spain, Finland and the Czech Republic, aims to design more climate-friendly industrial processes. The key: a high-temperature electrolysis process from project partner sunfire GmbH (see page 77). Firstly, industrial companies can increase their efficiency through heat recovery by using this procedure. Secondly, hydrogen, an important raw material for industrial processes, can be supplied in a more climate-friendly manner with renewable energy, for example for the:

- **Chemical sector**: hydrogen is the most important molecule in the production of ammonia, methanol and products based on paraffin
- **Steel sector**: hydrogen provides a safe atmosphere, eliminating oxygen and thus preventing the oxidation of steel during the annealing process.
- **Electricity sector**: hydrogen is used to cool large generators

FUEL OF THE FUTURE
TRANSFORMING TRANSPORT

The transport sector plays an important role in the energy mix. In Germany, mobility accounts for around 30 per cent of the final energy requirement. However, renewables are trailing behind, contributing only around 5 per cent towards the energy consumed in the transport sector in Germany and the EU.

A modal shift to rail transport – the most efficient form of electric mobility – is also lacking. Germany's motorway network has grown by more than 10 per cent over the past fifteen years to just under 13,000 km. Conversely, the rail network has been extended by only 6 per cent, with a length of just under 39,000 km.

The road-traffic dominated transport sector is therefore one of the largest sources of greenhouse gas emissions. There are solutions available, but they face challenges. When it comes to the use of biofuels from cultivated biomass, the EU applies an upper limit of seven per cent in the fuel mix, which there are plans to reduce yet further, according to the intentions of the EU Commission. Alternatives in road-based passenger transport, such as e-mobility using renewable energies, are only gaining ground slowly. But car manufacturers have intensified their activities. New electric production models such as the Opel Ampera-e are achieving greater cruising range. A buyer's bonus for electric vehicles on the road is providing an added incentive. And the infrastructure with charging posts is being rapidly developed, also by means of state funding.

With the expansion of e-mobility and the increasing demand for power by electric fleets, sector coupling is gaining importance. Linking the electricity and transport sectors will create increased demand for power for the foreseeable future and offers opportunities for the improved coordination of supply and demand in the electricity markets.

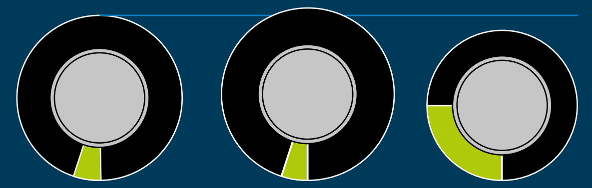
The same applies to hydrogen-fuelled transport, which is still in its infancy. In future, this technology should also be able to access particularly low-cost electricity from renewables, as is being made available at high wind speeds, for example. Of course, hydrogen mobility needs its own infrastructure as well. Nevertheless, two passenger cars – the Toyota Mirai and the Hyundai ix35 Fuel Cell – were available in series production in Germany at the end of 2016. More than 30 hydrogen filling stations are in operation. By the end of 2018, it is intended that a basic infrastructure of around 100 hydrogen filling stations will be available in major cities and on the motorway network. Work is also in progress in other Central European countries to develop a viable infrastructure for hydrogen-fuelled transport.

This technological progress is supported by research-funding initiatives from the German Federal Government. Both in the funding priority "Electric Mobility in Model Regions" and in the National Innovation Programme for Hydrogen and Fuel Cell Technology (NIP), stakeholders from science and industry are working to develop commercially viable products and test them in practice. More than 300 projects scattered across the whole country have received and continue to receive support through research funding.

While the technical options continue to be refined, the majority of the electricity mix – despite all of the advances – is still based on conventional energy sources. It is the German Federal Government's aim to put one million electric vehicles on the roads by 2020. Taking Germany's current electricity mix as a basis, with its average CO_2 emission factor in domestic consumption of around 600 g per kilowatt-hour, an electric car emits approximately 120 g CO_2 per kilometre – about the same as a small car powered by fossil fuel. If the demand for electric vehicles and hydrogen-fuelled cars grows as much as is hoped, the growth in renewables in the electricity market must also gather pace. If not, the roads will be increasingly filled with electric cars fuelled by coal- and nuclear-based power. This indicates the urgent need to further decarbonise the electricity mix – otherwise, the commitment to e-mobility from the perspective of climate protection will evaporate.

ENERGY CONSUMPTION IN THE TRANSPORT SECTOR

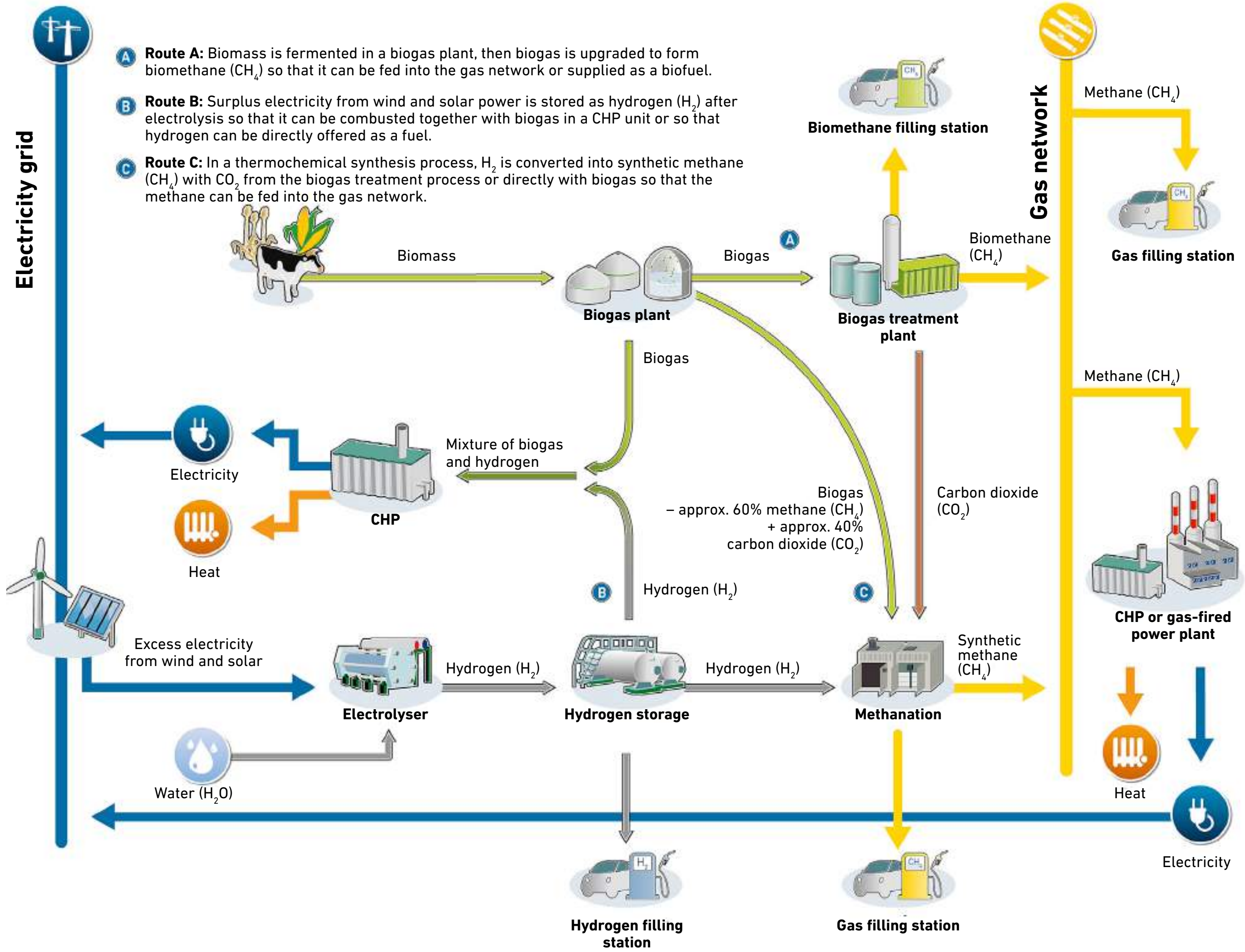
2008	2016	2030
619 bn kWh	650 bn kWh (+5.0%)	573 bn kWh (–7.4%)



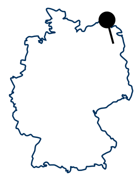
SHARE OF RENEWABLES IN THE TRANSPORT SECTOR

Source: Nitsch (2016) (Climate protection scenario "Klima 2050"); BMWi

LINKING THE RENEWABLE ELECTRICITY SECTOR AND THE TRANSPORT SECTOR



PRENZLAU CASE STUDY: PUTTING CLIMATE NEUTRAL CARS ON THE ROAD – WITH INNOVATIONS "MADE IN GERMANY"



In 2011, the world's first hybrid power plant went into operation near Prenzlau in the federal state of Brandenburg. Since then, the "Uckermark Power Plant", constructed by the company Enertrag, has been producing climate neutral hydrogen with the help of wind power. At the heart of the installation is a 50-kW pressure electrolyser, which is directly connected to three 2-MW wind turbines via a medium voltage cable. Here, the electrolyser acts almost like an energy regulator: when there is a surplus of wind power in the region, it is used for the electrolysis process. The resulting hydrogen is then stored in three pressurised tanks with a total capacity of 1,350 kg before being delivered as fuel to hydrogen filling stations.

If the wind turbines do not generate enough electricity, however, the stored hydrogen can be mixed with biogas and used in a combined heat and power plant. This way, heat is produced as well as electricity. This heat is then fed into the local heating grid for the town of Prenzlau, where it supplies around 80 single-family homes.

DRESDEN CASE STUDY: POWER-TO-LIQUID – THE FUEL PRODUCTION REVOLUTION

In March 2015, the Dresden-based energy technology company sunfire GmbH produced synthetic fuel made from water and CO_2 in its power-to-liquid (PtL) pilot plant for the first time.

For the production of the liquid energy source, sunfire uses green electricity, water and carbon dioxide obtained directly from the ambient air. The centrepiece of the pilot plant is its high-temperature electrolysis process, in which the water heated to form steam is split into its constituent parts: oxygen and hydrogen. The latter then reacts with CO_2 to form a synthetic gas, which is converted into hydrocarbons. Kerosene, diesel, petrol and other petrochemical products can be obtained from the resulting raw product (known as "blue crude") by means of a standard refining process.

Engineers from sunfire GmbH draw off the first, crystal-clear litres of "blue crude".

Since waste heat from the process is used to generate steam, with a system efficiency of 70 per cent, production is particularly streamlined.

The so-called PtL fuels are climate-friendly and resource-conserving and have the potential to make a significant contribution to reducing greenhouse gas emissions in the transport sector in the future. But the innovative process has yet another advantage: it can be used to generate hydrogen (see info box), but also the other way around ("reversible"), using a fuel cell to produce electricity and heat. This way, renewable fuels, for example, can be utilised to supply electricity flexibly to the public power grid.

The research project is being supported with funding of 6.4 million euros from Germany's Federal Ministry of Education and Research.

ALLENDORF CASE STUDY: MILLIONS OF LITTLE HELPERS WORKING TO TRANSFORM TRANSPORT

Three containers and one biomethane plant make up the power-to-gas installation in Allendorf (Hesse), which has been feeding gas into the network since 2015. Whereas in previous power-to-gas projects (see page 72) methanation took place in a chemical-catalytic process, MicrobEnergy, a company in the Viessmann Group, has developed a biological technique. Here, the CO_2 produced in a biogas plant and externally added hydrogen are converted into methane, which is chemically identical to natural gas. This methanation work is "carried out" by millions of highly specialised microorganisms. These take up the hydrogen, which has been dissolved in liquid, and the CO_2 through their cell walls and "digest" the two ingredients to form methane. The only residual product of this process is water.

The millions of little helpers get the energy they need to survive through the process of converting hydrogen and CO_2. By coupling the process with existing biogas and sewage gas plants as the CO_2 source, the investment costs for power-to-gas installations can be reduced significantly, because there are often already transformers in place as well as connections to the electricity and gas grids. As a result, the innovative and multi-award winning biological conversion process is able to contribute to the decarbonisation of the existing natural gas network, as well as supporting the energy transition in the transport sector.

The biomethane plant in Allendorf sets innovative standards.

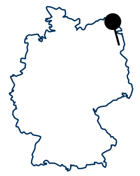
KIRCHAMPER CASE STUDY: SUSTAINABLE AGRICULTURE USING SUSTAINABLE FUEL

With financial support from Bavaria's RapsTrak200 funding programme, farmer Johann Felsl bought a new tractor that can run on vegetable oil, which he fuels with rapeseed biodiesel produced in the region. The aim of the funding programme is to increase the use of domestic rapeseed- and vegetable oil-based fuels in modern agricultural tractors, thereby supporting the rollout of these climate-friendly technologies on the market.

On his 92-hectare farm in Kirchamper, Bavaria, which he runs together with his daughter Theresia, Felsl uses the vegetable oil-compatible tractor for various tasks, including sowing wheat, barley, rape and maize, tilling the land, cutting grass, harvesting, haymaking, baling straw and transportation. The John Deere tractor has already given 915 hours of service powered with rapeseed oil fuel – to the full satisfaction of the 60-year-old farmer.

With his own rapeseed oil filling station, a solar power installation on the roof and products marketed directly from the farm, Felsl is a living model of sustainability and is therefore setting a good example with great potential for replication across the whole of Germany.

Sustainable agriculture: farmer Johann Felsl's tractor runs on rapeseed oil.



EASTERN GERMANY CASE STUDY: BIOREFINERIES – INNOVATIVE TECHNOLOGIES FOR CUTTING-EDGE MOBILITY

State-of-the-art biofuel production is based on several key areas. In the manufacture of biodiesel, valuable rapeseed meal as protein feed and glycerine for the pharmaceutical industry are also produced in the oil press alongside vegetable oil. Additional innovations have been developed: for instance, VERBIO AG offers a plant-based product for reducing cholesterol – another co-product of biodiesel production. At locations in Brandenburg and Saxony-Anhalt, the company produces further high-quality products: it makes bioethanol for petrol engines from energy crops – mostly rye grown in the region. After the fermentation and distillation of the energy crop to make fuel, digestates remain, the so-called distillers' grains. VERBIO uses these to produce animal feed or biogas. As biomethane this gas is then used as fuel – as, for instance, in Augsburg municipal utilities company's (Stadtwerke Augsburg) fleet of more than 100 buses. Finally, the fermentation residues (digestates) from the biogas plant are used as fertiliser on the fields.

But that's not all. In addition to the cereal grain, VERBIO also uses the straw. Since October 2014, biomethane has been produced entirely from straw in Schwedt/Oder. This innovative EU-funded project in Schwedt is now intended to show how the whole process can work on a large scale. The capacity of the existing plant will be increased to 16.5 megawatts by 2019, which corresponds to an annual production of approximately 136 million kilowatt-hours. There is great potential throughout Germany for straw to be used to generate energy.

The examples of rapeseed meal, ethanol distillers' grains and straw illustrate that, as part of a practical circular economy, biodiesel, bioethanol and biogas plants acting as biorefineries can meet the challenge of providing climate-friendly, domestic energy and other valuable products on a sustainable basis.

Staff check the esterification reactors, which are used for the production of biodiesel.

PROGRESS THROUGH EFFICIENCY

The decarbonisation of the transport sector requires, on the one hand, new drive technologies that use renewables as fuel. On the other hand, it is important to tap into existing efficiency potential wherever possible. For example, lightweight construction in the automotive sector not only saves resources and energy in production, it also lowers fuel consumption in use and thus reduces CO_2 emissions.

Improved aerodynamics also help to increase the efficiency of road transport. Trucks offer great potential in this regard: when all of the opportunities for the aerodynamic optimisation of the tractor unit and semi-trailer are exploited, the air resistance when driving is reduced by around 20 per cent. As a consequence, the vehicle's fuel consumption can be reduced by about three litres per 100 km. Another innovation in terms of design is the "longer heavier vehicle" (LHV), known as a super lorry. Field trials have shown that two super lorries can carry the load of three conventional trucks. The result: 15 to 30 per cent less fuel is consumed per transported tonne. At the same time, the volume of traffic is reduced. However, these LHVs are not without controversy. One criticism is that road construction is inadequate for these heavy transport vehicles.

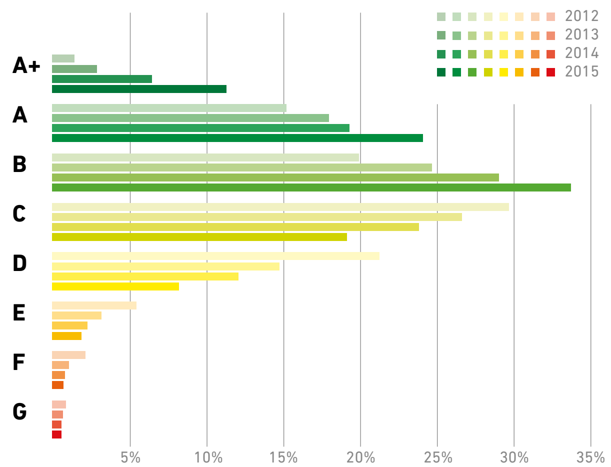
The savings potentials resulting from improved driving style are easy to realise: after all, a lorry's fuel consumption can be cut by around five per cent when the driver has completed a driver training course. To transform the transport sector, it is imperative that all of these efficiency potentials are exploited – and that the unavoidable residual demand for fuels is met from renewable sources.

An aerodynamically optimised design unlocks efficiency potentials for transforming the transport system.

HIGHLIGHTING EFFICIENCY

When buying a new car, alongside model, price and fuel consumption, the vehicle's emissions have also long been a point of interest. After all, in addition to consumer awareness of the issue of climate protection, road tax is also dependent on a vehicle's CO_2 emissions. In accordance with a directive from the EU, manufacturers and dealers have had to provide details about the fuel consumption and CO_2 emissions of new cars since 2004, both in their advertising and on the vehicle. Germany's Federal Government went a step further at the end of 2011 by introducing regulations for the energy consumption labelling of passenger cars, according to which new cars being sold or leased must be given a standardised CO_2 label. This label for cars is similar to the familiar efficiency labels on household appliances, for example. The vehicles are thus categorised into efficiency classes from A+ to G, allowing consumers to better compare them. It is hoped that this transparency measure will encourage the purchase and production of energy-efficient cars.

PASSENGER CAR REGISTRATION TRENDS BY CO_2 EFFICIENCY CLASS



Source: Federal Motor Transport Authority (KBA), new registrations (motor vehicles): Neuzulassungen von Fahrzeugen nach Umweltmerkmalen, Jahr 2012–2015 (FZ 14) (New vehicle registrations according to environmental performance, 2012–2015), Flensburg; illustration by the German Energy Agency (dena).

GOOD ALTERNATIVES FOR GOODS TRANSPORT

The electric truck providing zero-emission goods transport in Germany's capital city.

ELECTRIC TRUCKS IN BERLIN: NO MORE DRONING DIESELS

Since 2000, freight traffic on Germany's roads has risen by around 31 per cent. Almost all of the goods that are purchased in shops or on the Internet, are transported by lorry. In 2013, this goods transport gave rise to around 38.7 million tonnes of CO_2 emissions. The company E-Force has been developing a concept to reduce the environmental pollution caused by freight transport on the roads, fitting electric drives in conventional 18-tonne HGVs. In Berlin, two of these electric trucks have been used successfully in urban logistics operations since 2014. Although they have a shorter range when compared with conventional models, this is not particularly significant in urban use, where the electric motor can demonstrate its strengths to the fullest. These include decreased noise pollution as well as reduced operating costs.

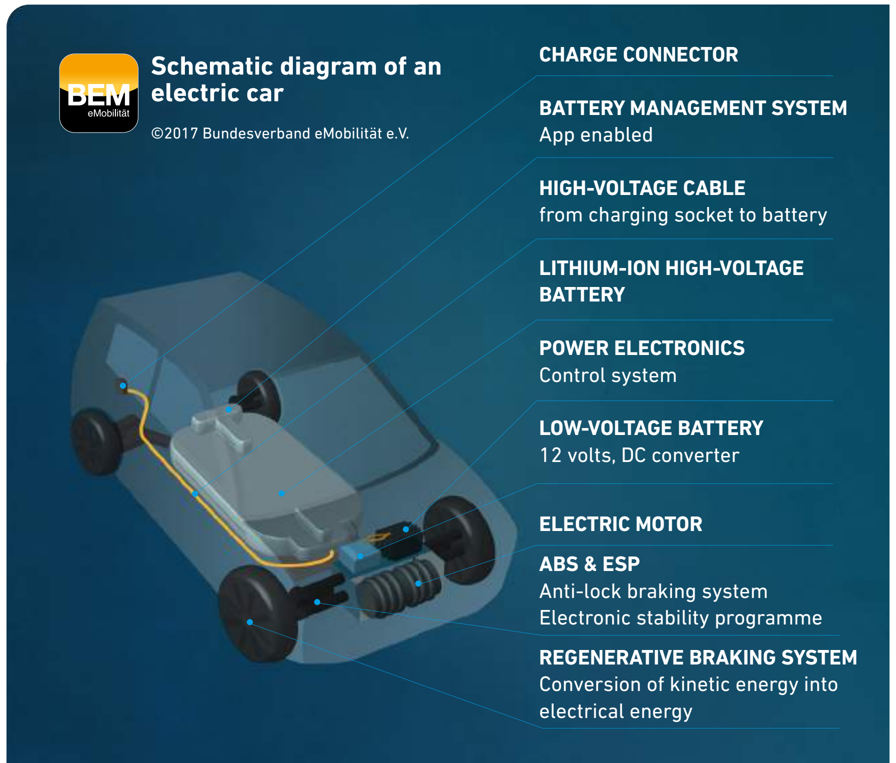
Enercon GmbH's E-Ship 1 transports wind turbines with the assistance of the wind on the high seas.

WIND POWER ON THE HIGH SEAS FOR THE WORLD

Since its completion in 2010, "E-Ship 1" has been transporting wind turbines around the globe for Enercon GmbH. Alongside a diesel propulsion system, the cargo ship also uses so-called Flettner rotors. This system features four cylinders, each 27 metres tall, mounted on the ship's deck, which are caused to rotate by electric motors. The air flowing past the sides of the cylinder is either accelerated or slowed down, creating a difference in pressure (the Magnus effect), which is used to drive the Flettner rotors. Thus, the renewable energy of the wind is harnessed even on the water.

In addition to its drive concept, "E-Ship 1" features an optimised rudder and propeller concept that uses know-how from wind turbine manufacturing. The underside of the hull was built with optimised flow characteristics. Using this technology, Enercon is able to achieve fuel savings of around 25 per cent. This equates to annual savings of about 1,700 tonnes of marine diesel or up to 5,100 tonnes of CO_2.

HOW AN ELECTRIC CAR WORKS



MODAL SHIFT 2.0: LEAVE THE CAR AT HOME AND HOP ABOARD THE FUTURE WITH ...

The e-bus in Bonn has successfully passed field testing.

... 100 PER CENT RENEWABLE ELECTRIC BUSES

The greatest potential for CO_2 savings in the transport sector lies in the transition from so-called motorised private transport, i.e. the use of cars, to local public transport. And further reductions in CO_2 emissions are possible when the operation of the public transport vehicle fleet is climate neutral. This also allows municipalities and cities to fulfil their function as role models. Take, for instance, the city of Bonn, where the practicality and operating efficiency of electric buses is being tested against conventional drive technologies. The result: six buses have since been successfully deployed on almost all of the network's routes. The batteries are recharged at night – using electricity from 100 per cent renewable energy sources. In addition to their zero-emission drive systems, the low level of noise pollution from the buses has also proved attractive. Other innovations are also being implemented. For example, USB ports for charging mobile devices are fitted as standard.

The trial is part of the ZeEUS (Zero Emission Urban Bus System) project, funded by the European Union. Alongside Bonn, Stockholm, London, Paris, Münster, Pilsen, Warsaw, Barcelona, Randstad and Cagliari are also taking part in the project, which has received funding of 13.5 million euros.

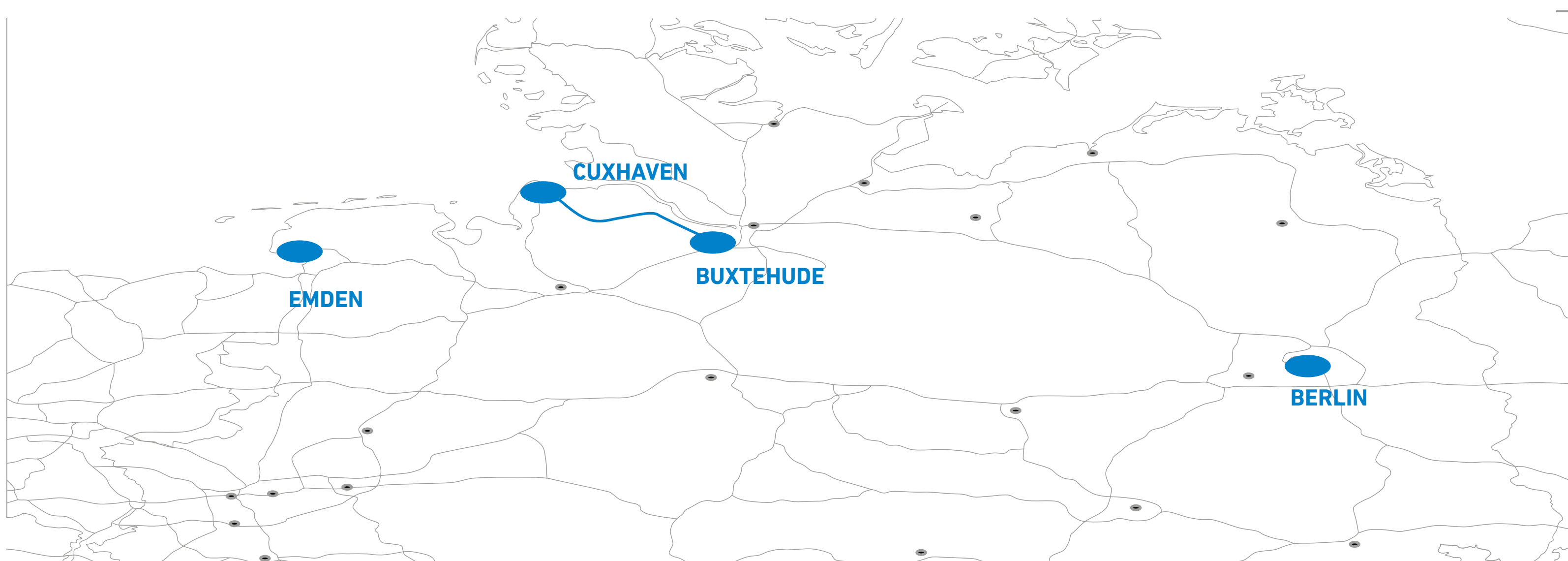
The first hydrogen train on German tracks is waiting in the wings.

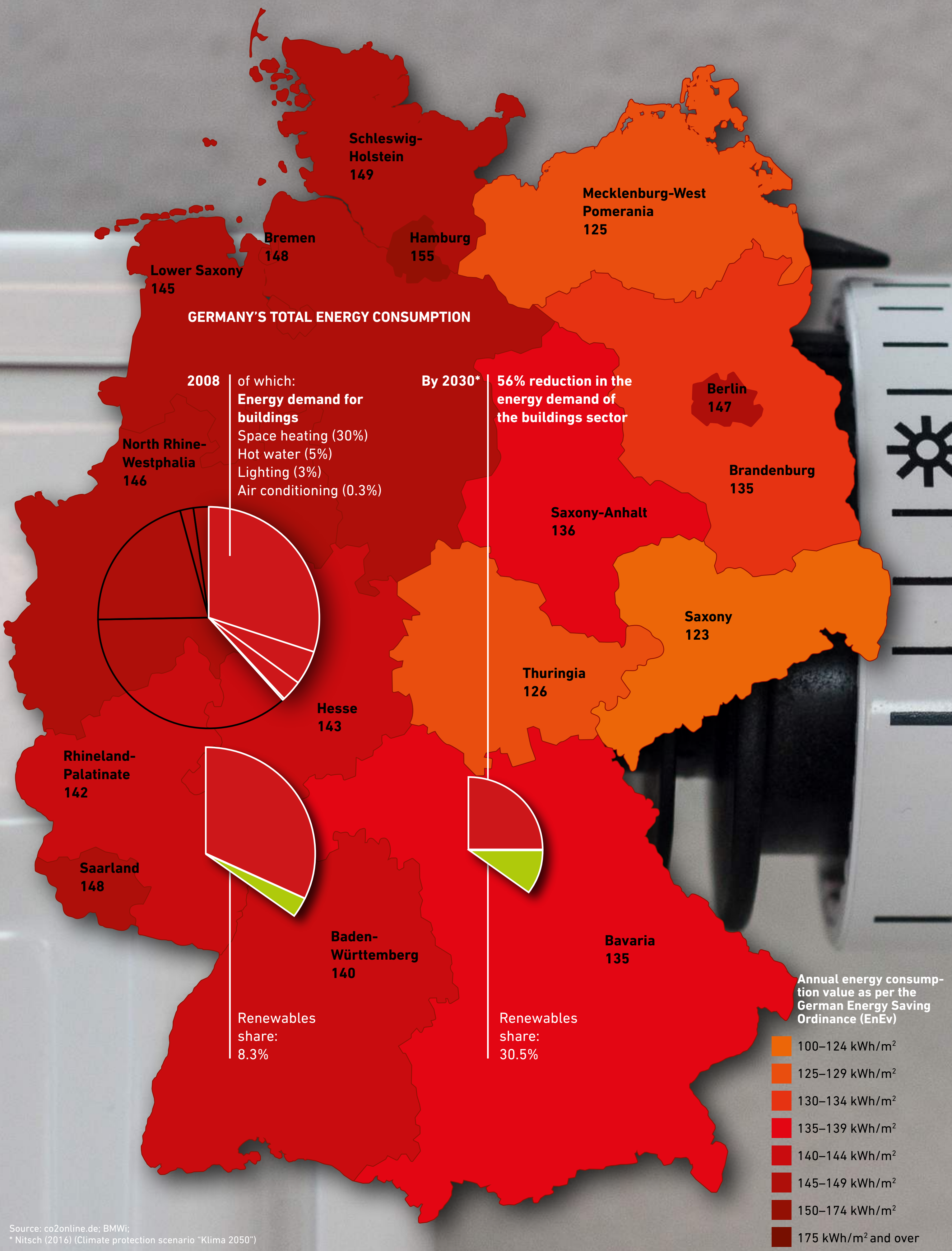
... HYDROGEN-POWERED TRAINS

Electrically driven trains have long been considered state of the art and, with the use of renewable electricity, can be deployed without any impact on the climate. However, only 60 per cent of Germany's rail routes are equipped with overhead lines, meaning a large portion of the rail service is operated by highly polluting diesel locomotives.

One alternative to this conventional energy source may be found in hydrogen propulsion. In Northern Germany, on a route in the Hamburg area, Germany's first hydrogen-powered train – the "iLint" from Alstom – will enter regular service from 2017. A hydrogen tank and a fuel cell, which supplies electrical energy, are located on the roof of the train. The advantages are plain to see: the drive technology is virtually noiseless, it is climate neutral when using electricity from renewables and has a range of up to 800 kilometres. It can reach a maximum speed of 140 km/h.

Fourteen orders have already been placed by Lower Saxony's public transport authority and Baden-Württemberg, Hesse and North Rhine-Westphalia are amongst the other states taking a keen interest in the "iLint".





Source: co2online.de; BMWi;
* Nitsch (2016) (Climate protection scenario "Klima 2050")

UNLEASHING ENORMOUS POTENTIAL EFFICIENCY AND RENEWABLES

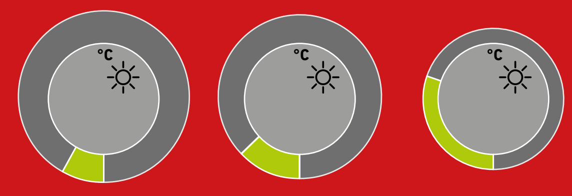
There is a mixed picture in German boiler rooms. Whether central or district heating, using fossil fuels or renewables, modern or long since out of date: the so-called "sleeping giant" – i.e. the immense potential for saving fossil fuels and greenhouse gases in the heating sector – is not clearly identifiable. Nevertheless, it is especially important that rapid and dynamic changes are made in the heating sector, which is responsible for about half of Germany's energy consumption, if Germany is to achieve its climate targets: the Federal Government aims to achieve an "almost climate neutral buildings sector" by 2050.

So far, the energy transition in Germany has, however, been taking place chiefly in the electricity sector, where renewables have achieved a market share of just under one third. Conversely, at around 13 per cent (2016), the share of renewable energies in the heating sector has barely grown for years. And that is despite the fact that, with heat pumps, solar thermal energy and bioenergy, there are advanced renewable technologies available for every application, which can make a highly significant contribution to climate protection efforts.

To achieve the climate protection goals in the future, a shift is needed from decentralised individual heating systems based on biomass to a networked supply or to industrial biomass plants. If a climate-friendly heating supply is to be developed, it will also be necessary in the long term to tap into the existing potential of solar thermal energy and deep geothermal energy much more dynamically than previously.

FINAL ENERGY CONSUMPTION ACROSS THE WHOLE HEATING SECTOR

2008	2016	2030
1,322 bn kWh	1,251 bn kWh	844 bn kWh



SHARE OF RENEWABLES IN THE HEATING SECTOR

Source: Nitsch (2016) (Climate protection scenario "Klima 2050"), BMWi

ENERGY EFFICIENCY AND THE HEAT TRANSITION GO HAND IN HAND

The energy transition also means putting a stop to the wasteful use of energy and favouring a climate-friendly and resource-efficient energy supply. Energy conservation and energy efficiency are important pillars of the energy transition, in addition to the generation of renewable energy.

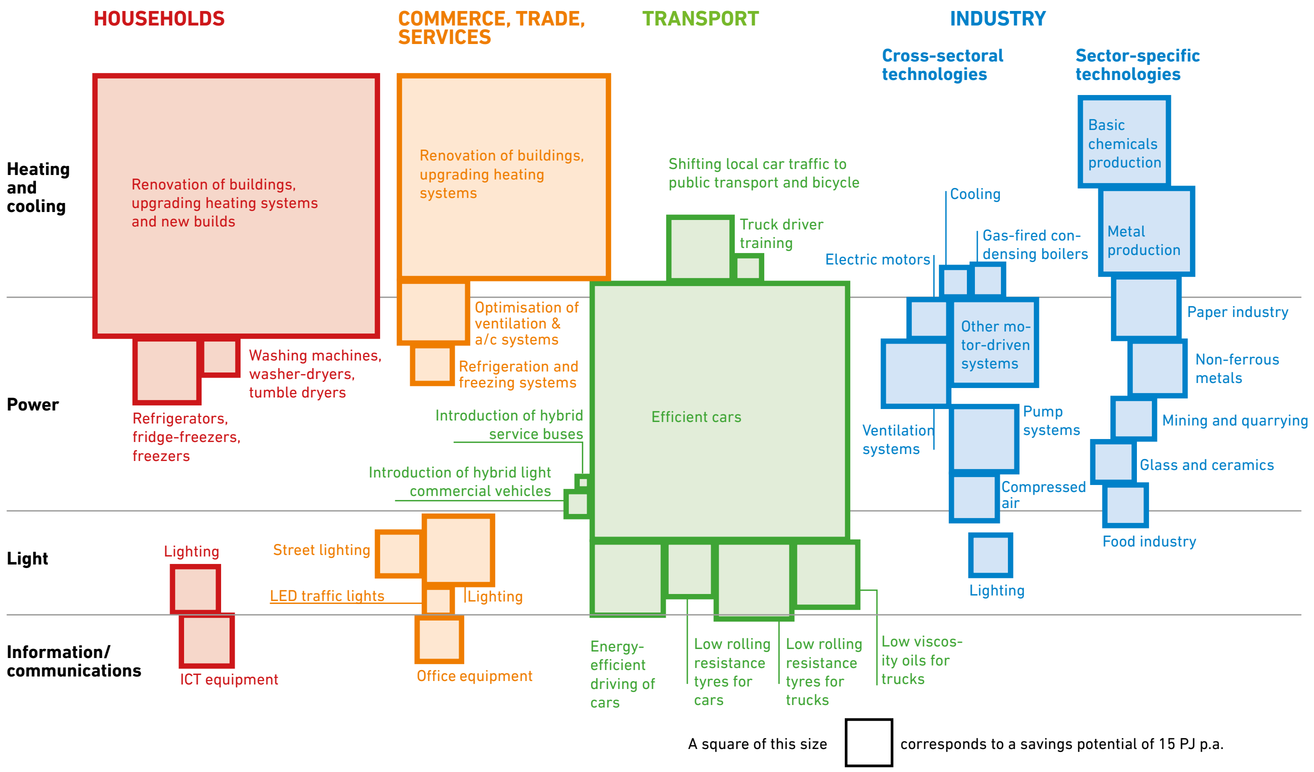
The opportunities for making energy savings are significant, as the “Efficiency map” shows. Energy consumption can be reduced considerably, especially through the rapid introduction of fuel-efficient vehicles and the renovation of old buildings with a focus on energy efficiency, as well as by upgrading heating systems. Further savings are possible in other areas such as electrical household appliances and the industrial sector. The “Efficiency map” also illustrates that the potential for savings is spread across many individual measures and different consumers. Therefore, a variety of instruments are required if these savings are to be realised.

In the buildings sector, which accounts for about 40 per cent of Germany’s final energy consumption, existing measures include minimum standards relating to the energy demand of new buildings, which are steadily becoming stricter. However, three-quarters of the building stock was built before the country’s first Thermal Insulation Ordinance – a law governing energy-saving construction – came into effect in 1977. These buildings are still largely unrenovated and consequently in a poor condition as regards energy efficiency. Up to 80 per cent of energy demand can be saved through professional refurbishment and the installation of modern building and heating technology. Financial incentives, such as low-interest loans from the KfW development bank, are therefore intended to encourage homeowners, for example, to renovate their buildings for energy efficiency. This benefits not only the climate, but also the residents of the house thanks to lower energy bills.

From 2021, newly built private residential buildings must have an annual energy consumption of almost zero, according to the European Union’s Energy Performance of Buildings Directive.

The concept of so-called “energy plus” houses, which produce more energy than they consume, goes one step further. This excess energy can be used for the family’s electric car, for example. The Federal Ministry for Building is funding around 200 model homes that are testing out this construction method in practice.

EFFICIENCY MAP: SAVINGS POTENTIAL BY CONSUMER



In 2010, Germany consumed around 9,000 PJ of final energy.

Technical savings potentials in Germany by 2030, broken down by sector and application. The larger a square, the larger the savings potential. Total potential by 2030: around 25 per cent of today’s energy demand.

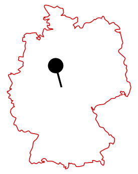
Source: Institute for Energy and Environmental Research Heidelberg (ifeu). Licence: Creative Commons by-nc-nd/3.0/de; Federal Agency for Civic Education (bpb), 2013, www.bpb.de

ENERGY-EFFICIENCY RENOVATION PAYS OFF

In old buildings, energy is quite literally thrown out of the window. But it is not just through outdated windows, but also through poorly insulated exterior walls, roofs and cellars that precious heat escapes, especially in winter. These heat losses can be minimised and energy costs drastically reduced by installing insulated glazing or by insulating the building envelope. What’s more, this increases both the comfort level and the value of the property. When modernisation is professionally carried out and an efficient heating system is installed, ideally using renewable energies, a building’s energy requirements can even be reduced to the level of a new build.

Areas of heat loss are easily identifiable in the thermal image: the uninsulated left half of the house is losing a lot of energy through the facade. The thermal image also clearly shows the weak spots at the windows.

KASSEL CASE STUDY: AN “ENERGY PLUS” HOUSE AS A BEACON PROJECT FOR ENERGY-EFFICIENT CONSTRUCTION



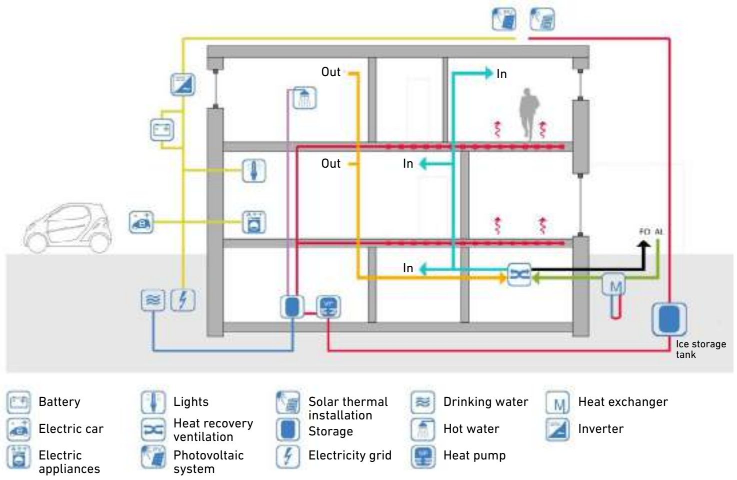
KEY FIGURES:
Year of construction: 2012/2013
Gross external area: 453 m^2
Heated net internal area: 280 m^2
Heated building volume: 1,510 m^3

BUILDERS’ OBJECTIVES:
- An architecturally state-of-the-art building
- Low energy consumption and efficient use of resources without sacrificing comfort
- Low energy costs in the long term

HOW IT WAS ACHIEVED:
- High-quality, air-tight building envelope; south-facing, extensive glass facade
- A PV installation on the roof and the facade (15.75 kWp) supplies green electricity. Intelligent building management and battery storage mean that the excess power produced can be stored and, for example, made available for e-mobility via a charging station.
- The building is heated by solar thermal energy and via a heat pump. The water from an ice storage system (for operating principles see Glossary, page 102) serves as a heat source, which in turn is supplied by the solar collector area of about 17 m^2.
- Heat is distributed through the building via underfloor, low-temperature panel heating systems.
- To reduce the heat losses of manual window ventilation, the entire residential property is mechanically aired and ventilated using a ventilation unit that includes heat recovery.
- To reduce water consumption, rainwater is collected in a 10 m^3 rainwater tank and used primarily to supply the washing machine, flush toilets and irrigate the garden.

THE RESULT:
The house produces an electricity surplus of around 3,100 kWh p.a. This corresponds to an annual mileage of an average electric car of about 18,000 km (17 kWh/100 km).

The “Energieeffizienzhaus Plus” (Energy-efficiency House Plus) in Kassel makes use of solar energy.



Source: Fraunhofer IBP

MIETRACHING CASE STUDY: TRANSITIONING FROM MILITARY WASTELAND TO ZERO-ENERGY AND ZERO-EMISSIONS TOWN

The Mietraching district of Bad Aibling (Bavaria) is a flagship project for the "Energiewende" on the ground: an entire neighbourhood is being transformed into a "zero-energy town" by means of sustainable construction and a decentralised renewable energy supply.

The former US military base was acquired in 2005 by the B&O Group. This private service provider to the housing sector aims to develop an energy-efficient model community with mixed use, featuring both housing and employment, and thereby intends to gain experience for other projects.

The majority of the 52 existing buildings on the site of approximately 70 hectares were built in the 1930s and have been extensively renovated and modernised. For instance, the facades were thermally insulated using wooden prefabricated elements, including pre-installed windows. Internal disruption was thus kept to a minimum during the renovation period. The new buildings in Mietraching, also known as "city of woods", were each built according to low-energy construction standards as wooden structures of high architectural quality. The high degree of prefabrication is considered particularly innovative and promises short construction times and low building costs for the future.

At the heart of the district's renewable energy supply is the so-called "heating icon", which was even blessed by a priest. It is a wood-chip power plant, which outwardly resembles a wood-panelled church and is therefore visually in keeping with the architecture of the district. Inside, there is a 500-kW boiler, which uses residual wood from the region's forests to supply heat to the individual buildings via a local heating network (see diagram for operation). In addition to the "heating icon", approx. 2,000 m^2 of solar collectors provide renewable heat. By contrast, a ground-mounted photovoltaic system (2.3 MW) and a PV installation on the roofs of the former aircraft hangars (400 kW) use the sun to generate electricity. The renewable energy supply is completed by the use of heat pumps.

The district achieves an annual positive energy balance of approx. 290 kWh/m^2 thanks to its high energy building standards, renewable heat supply and large PV system.

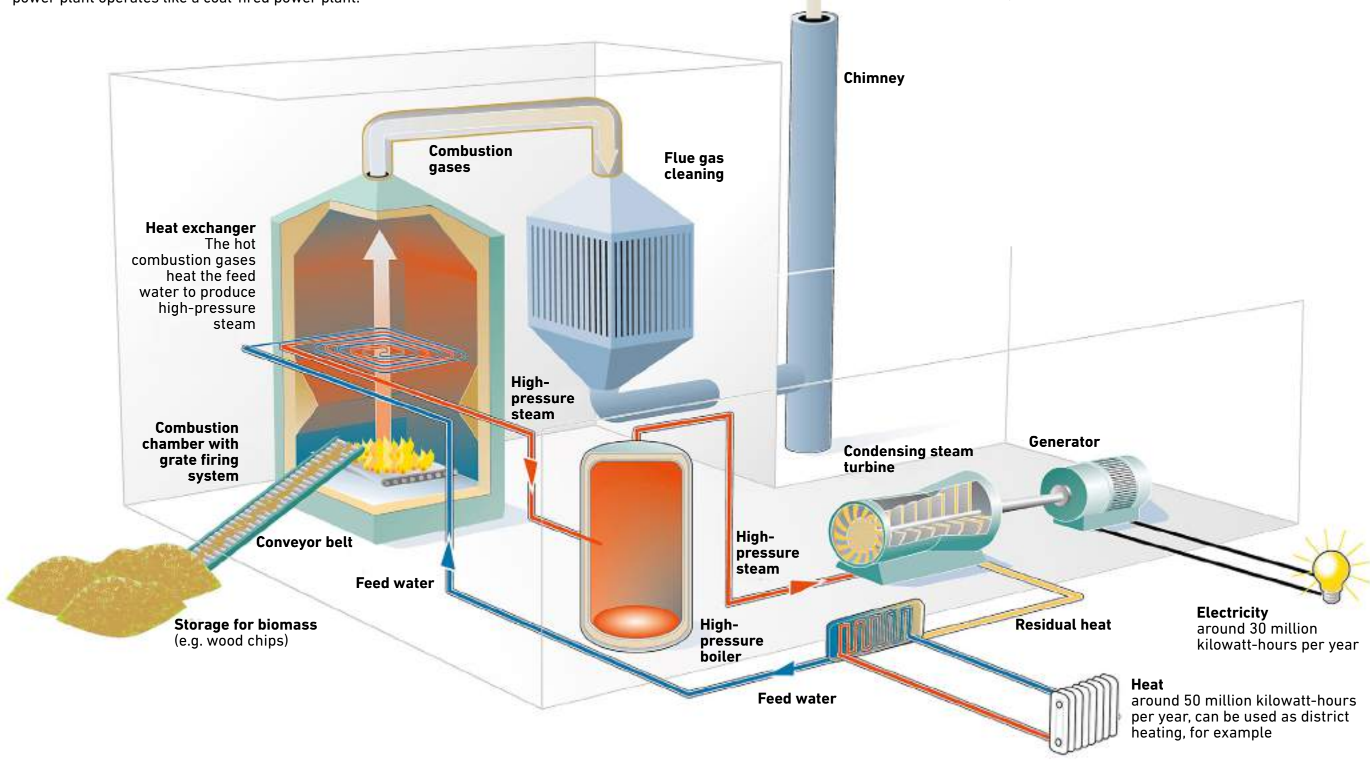
This beacon project, funded by the German Federal Ministry for Economic Affairs and Energy (BMWi) as part of the research initiative "EnEff:Stadt" (energy-efficiency town), demonstrates a high potential as a multiplier, given Germany's many military brownfield sites.

Heating icon: from the outside, designed to look like a chapel and, on the inside, a modern wood-chip heating system.

The newly built multi-family houses are fitted with a wooden facade and PV systems.

HOW A BIOMASS COMBINED HEAT AND POWER PLANT WORKS

With a consumption of 40,000 tonnes of wood or other biomass, a 5-MW combined heat and power (CHP) plant generates around 30 million kilowatt-hours of electricity and 50 million kilowatt-hours of heat each year. In principle, this kind of power plant operates like a coal-fired power plant.



RENEWABLE ENERGY FOR INDUSTRIAL USE

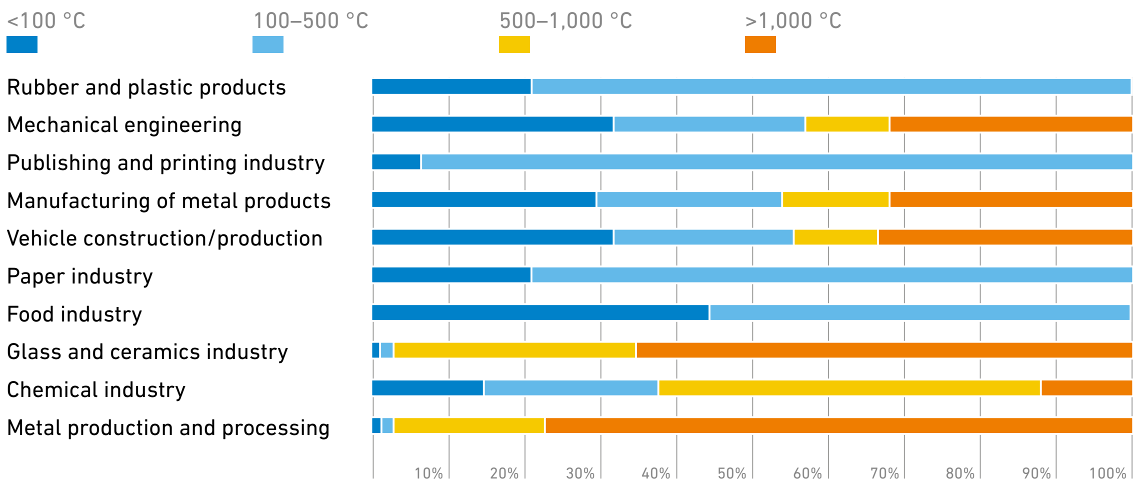
The biggest lever for industrial energy savings is in industrial process heat, which accounts for two thirds of industrial final energy consumption but just 5 per cent of which is covered by renewable energy. In addition to low oil and gas prices, both the relatively long payback periods as well as structural and technical conditions inhibit investment in renewable energies in the industry sector. Process heat is necessary for the manufacturing, processing and refining of products. Depending on the sector of the economy, varying temperature levels are needed for the production process. For example, temperatures used in the food industry reach only up to 100 degrees – which involves cooking. Solar thermal energy, deep geothermal energy and heat pumps can be utilised very well for production processes at this low range of temperature.

However, the bulk of the process heat demand in the industrial sector occurs at temperatures above 500 degrees Celsius. This is a temperature range that can be sustained particularly by means of bioenergy, which is why bioenergy is greatly important for the energy transition in the industrial sector. 500 degrees Celsius can be easily reached through the combustion of solid biomass and biogas. Biomethane (treated and purified biogas) inserted, for example, into a cogeneration plant can also obtain temperatures well over 500 degrees Celsius. But the use of other renewable energy gas technologies (power-to-gas, wind gas) provides relevant options, too.

Direct electrical heat generation (power-to-heat) in the industrial sector is especially useful for the energy transition in Germany if it is used as a flexibility option for the power sector. Electricity from renewable energy sources that is not directly consumed due to bottlenecks can be used in industrial companies to produce process heat. This form of sector coupling can lead to considerable reductions in economic costs.

INDUSTRIAL HEAT DEMAND BY SECTOR

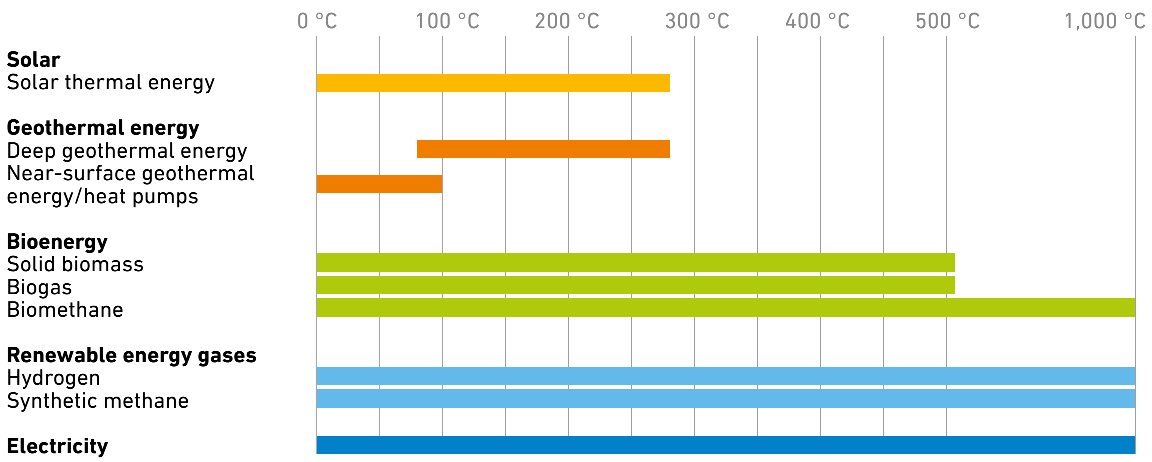
By temperature level in degrees Celsius (°C)



Source: Ifeu/DLR/ZSW 2010; As of: 6/2017

TEMPERATURES ACHIEVED FROM RENEWABLE HEAT SOURCES

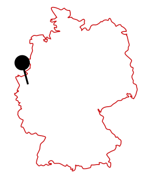
By temperature level in degrees Celsius (°C)



Source: DLR 2016; As of: 6/2017

Electrochemical process development in the laboratory.

OBERHAUSEN CASE STUDY: GREEN ELECTRICITY INSTEAD OF FOSSIL PROCESS HEAT IN THE CHEMICAL INDUSTRY

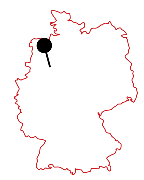


Elevated temperatures are often required to produce chemicals: a process heat demand of over 500 degrees Celsius often prevails in the chemical industry. The resulting energy-intensive production comes with high costs and high CO_2 emissions. Today, cheaper electricity, produced on low CO_2 emission levels, is already available as a result of the energy transition. According to science, the amount of renewable electricity will increase considerably within the next 15 years. This should make it possible to produce chemical products for which oil is still used today. The Fraunhofer Institute UMSICHT is working on just that objective. In the lighthouse project "Electricity as a Resource", electricity that was generated on low CO_2 emission levels is used in a process to synthesise important basic chemicals. There are two approaches: the first, in which the prototype in Oberhausen easily and reliably produces hydrogen peroxide (H_2O_2) using electricity. Hydrogen peroxide is a disinfectant and bleach and is used, for instance, in the production of paper. In the other approach, researchers aim to create valuable basic chemicals – ethene as well as various alcohols – out of electricity and CO_2.

If they succeed, the researchers' vision will soon be a reality: on the premises of a pulp manufacturer, electrochemical reactors – powered by neighbouring wind farms when possible – always produce just as much bleach as the paper manufacturer requires: on-demand hydrogen peroxide production.

The galvanic plunge basin is heated by solar energy at the company Hustert Galvanik.

RAHDEN CASE STUDY: SOLAR PROCESS HEAT IN THE AUTOMOTIVE INDUSTRY

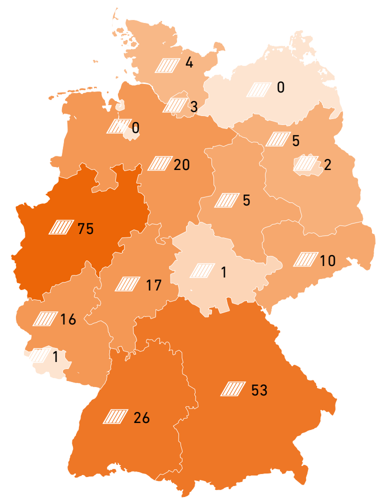


Parts for the automotive industry are galvanised at Hustert Galvanik, a medium-sized family business in the Westphalian town of Rahden. This electrochemical process allows for base materials for parts to be coated with a thickness of only a few micrometres. In the automotive industry, this process is used primarily for protection against corrosion and wear.

A plunge basin at a set temperature of 80 degrees Celsius is required for the galvanising process. Since 2011, this process heat is partially generated through a solar thermal plant at Hustert Galvanik. 45 vacuum tube collectors occupying a total gross area of 221 m^2 support the existing oil-fired boiler plant. This saves 12,500 litres of oil per year. The annual yield of the solar plant is around 95,000 kWh and thus lies below the overall demand of the production process. Peak yields during the summer are buffered using the plunge basins. The family-run business was not only motivated by the profitability of the solar system, but also by the effect it has on climate protection. Now Hustert Galvanik saves around 35 tonnes of CO_2 emissions per year.

USE OF SOLAR PROCESS HEAT

Distribution of approved installations and collector surfaces according to plant location in the respective federal states
(Sample of 205 out of 263 installations)



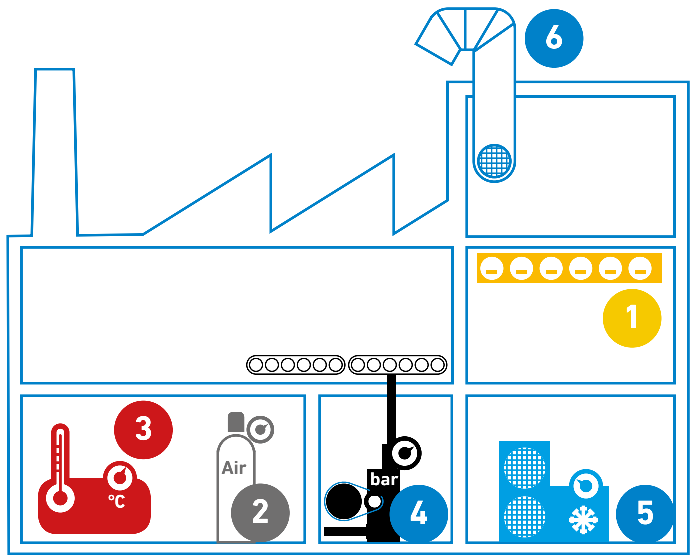
LESS IS MORE: INTRODUCING ENERGY SAVINGS AND EFFICIENCY MEASURES INTO THE ECONOMY

The industrial sector is the second largest greenhouse gas emitter in Germany behind the energy sector (2016: 188 million tonnes of CO_2 equivalents). It is therefore an important prerequisite for the success of the energy transition to introduce it into the economy. This means that energy must be used and saved efficiently during production and that the rest of the energy demand will increasingly be met using renewable energy.

Whether it be a family-owned business or a large corporation, a butcher or metal production facility – no company can run without energy. Raw material energy is the elementary lubricant in operating a business, though it can also often run perfectly smoothly with less energy consumption. Energy savings and efficiency measures are well worth the effort: less energy consumption means lower costs and reduced dependence on price increases, strengthening the company's competitiveness.

At the same time, lower emission levels help to mitigate climate change. Corporate image is also improved by sustainable production, resulting in the acquisition of new clients. However, savings options are often still not utilised. Cited reasons for this are insufficient time, low budget or lack of knowledge, especially in the case of small and medium-sized businesses. This is where a development programme for high-efficient interdisciplinary technologies from the German Federal Ministry for Economic Affairs and Energy (BMWi) comes into play. This term is used to describe the basic technologies utilised in all sectors. These technologies drive production processes with special forms of energy such as compressed air, process heat or cooling energy and are also a company's largest power consumers. The greatest energy savings solutions can therefore often be found in these interdisciplinary technologies.

The BMWi development programme subsidises the replacement of standard technologies for more energy efficient technology. The Ministry also funds energy consulting for small and medium-sized businesses. These support measures for increased efficiency and energy savings in companies, along with others, are expected to contribute to a 20 per cent decrease of the primary energy consumption by 2020 compared to 2008 levels (as of 2015: -8.3 per cent) and a 50 per cent decrease by 2050. The result is a win-win situation: the climate is protected and the German business location is bolstered.



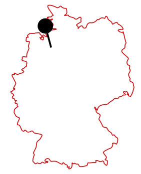
COMPETITIVE ADVANTAGE OF ENERGY EFFICIENCY

Companies can reduce energy consumption by investing in energy-efficient technologies and process optimisation.

1	Lighting	–70%
2	Compressed air	–50%
3	Process heat	–30%
4	Pump systems	–30%
5	Cooling & cooling water system	–30%
6	Ventilation systems	–25%

Each company is unique and contains a different savings potential. During the search for efficiency measures, the company should always be considered as a whole. Energy consulting is funded by the government, and federal state energy agencies support the regional economy in the application of energy efficiency.

1 STUHR CASE STUDY: TECHNOLOGY: LIGHTING SYSTEM

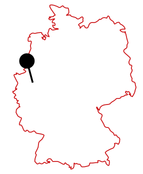


Sector: Printing industry
Company: August Koopmann GmbH

The medium-sized printing company August Koopmann GmbH from Stuhr (Lower Saxony) had the lighting of its 3,500-m^2 production hall converted entirely to LED: 800 existing systems with fluorescent tubes were replaced with 350 new systems using highly efficient LED technology to now efficiently and economically illuminate machines, work stations and storage facilities.

Energy savings:	75,000 kWh per year
Cost savings:	10,500 euros per year
CO_2 savings*:	approx. 39.5 tonnes per year

2 MÜLHEIM CASE STUDY: TECHNOLOGY: COMPRESSED AIR SYSTEM

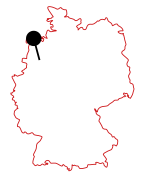


Sector: Metal production and processing, metal products manufacturing
Company: MÜLHEIM PIPECOATINGS GmbH

MÜLHEIM PIPECOATINGS GmbH coats longitudinal and spiral-welded large-diameter pipes such as oil and gas piping as well as drinking water and wastewater pipes. The internal and external coating of the pipes varies depending on the usage type. Compressed air is always used for drying during the production process, which naturally must also be dry itself. The ideal drying level of compressed air could be reached using a new combined cold and adsorption drying method. First, approximately 85 per cent the moisture content of the compressed air is isolated through cold drying. The remaining moisture is then removed using an adsorption dryer in the subsequent drying phase. Finally, the compressed air is used in the refrigeration dryer where it cools the new incoming warm compressed air in an air/air heat exchanger. One quarter of the energy required for the compressed air can be saved using this procedure.

Energy savings:	806,000 kWh per year
Cost savings:	112,900 euros per year
CO_2 savings*:	424.8 tonnes per year

3 GEORGSMARIENHÜTTE CASE STUDY: TECHNOLOGY: PROCESS HEAT

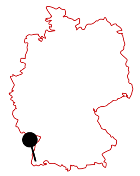


Sector: Steel production
Company: Georgsmarienhütte GmbH

Georgsmarienhütte GmbH has been manufacturing steel since 1856. Its customers are predominately from the automotive industry. Scrap steel is melted by an electric arc furnace in the steelworks. The electric arc transfers the electricity into heat of fusion during this step of production. Thanks to an energy management system, the electric arc furnace was discovered to contain an enormous waste heat potential. Steam extraction and storage was therefore performed for the first time at Georgsmarienhütte. This steam generated from waste heat is used for process heat and space heat supply and thus saves a significant amount of energy.

Energy savings:	62,892,800 kWh per year (corresponds to 79 per cent of the previous power consumption)
Cost savings:	around 14.4 m euros per year
CO_2 savings*:	33,144 tonnes per year

*Calculation is based on a CO_2 emission factor of the 2016 German electricity mix of 527 grams per kWh (UBA, March 2017); Source: dena



FREIBURG CASE STUDY: SUSTAINABLE CORPORATE STRATEGY: GREEN PRODUCTION IS INVALUABLE

The advantages of the energy transition in the factory are obvious: independence from imported raw materials and rising prices is improved, the climate assessment of the company is enhanced and a positive public image for marketing purposes is achieved.

The US pharmaceutical company Pfizer has been pursuing a "green strategy" for many years. With its own climate goals – 20 per cent greenhouse gas reductions by 2020 – as well as numerous large and small steps, the company works hard to achieve sustainable and resource-saving business. The pharmaceutical production site in Freiburg is considered a pioneer, producing over 230 million medication packages annually. It has drastically reduced its CO_2 emissions and now covers more than 90 per cent of its energy demand using renewable sources.

A flagship project and guarantor for low-emission production is one of the largest pellet-fired boilers (3.8 MW) in Europe, which saves around 5,500 tonnes of CO_2 per year and provides 95 per cent of the required process heat.

The modern wood-pellet fired steam-boiler plant is fed with ecologically produced wooden pellets from the nearby Black Forest. This saves on long transport routes.

In the summer, the steam from the pellet boiler is also used for cooling: an absorption refrigeration unit is used to obtain cooling from the steam, as in the case of a refrigerator. This cold energy is used for air conditioning, among other things. The all-rounder bioenergy thereby supplies the industrial plant with heat and cooling.

Hamburg's Environmental Senator Kerstan at the inauguration of the Industrial Energy Efficiency Network in Hamburg. The network aims to save a total of 60,000 tonnes of CO_2 by 2018.

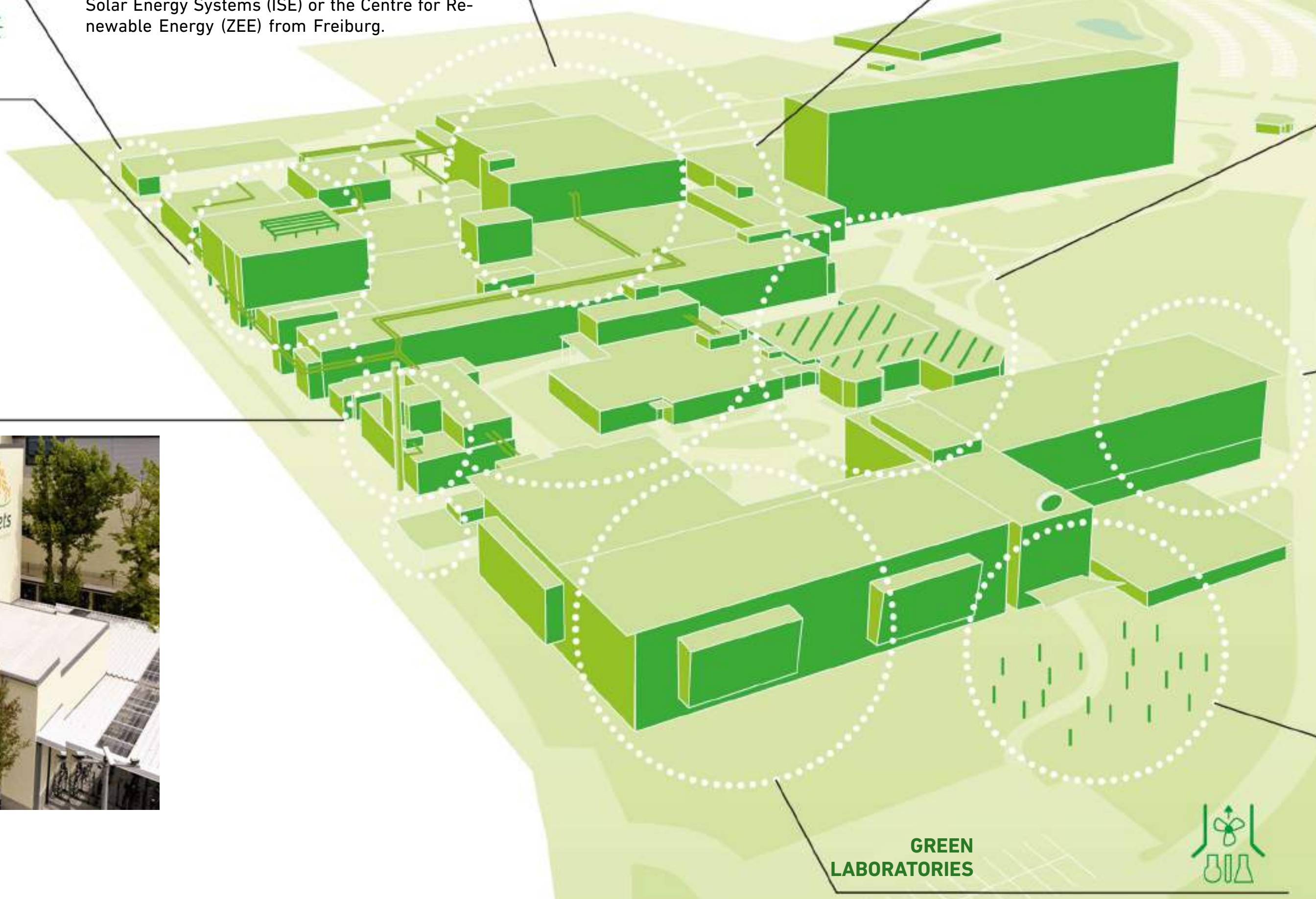
ENERGY EFFICIENCY NETWORKS: GIVE AND TAKE FOR THE CLIMATE AND THE COMPANY

The Federal Government and 22 associations and professional organisations founded the Energy Efficiency Networks Initiative with the goal of launching 500 networks by 2020. The purpose of this network is the exchange of experiences on topics such as energy management, efficiency technologies and implementation. The exchange is structured and moderated by skilled experts. The companies set individual efficiency targets as well as targets for their respective network as a whole and implement appropriate measures. This makes it possible for companies in energy efficiency networks to increase their energy efficiency twice as fast as the average firm. Networks also offer the opportunity to find new business partners.

More than 130 new networks with a total of over 1,300 participating companies already joined forces as of August 2017.

- Network being set up
- Network commissioned
- Contact (trade associations)

Source: www.effizienznetzwerke.org



RECYCLING STATION

The sustainable use of resources means to prevent waste where possible and to find a sensible way of dealing with it when not. Pfizer Freiburg makes further use of residual materials.

GREEN PRODUCT AND PROCESS DEVELOPMENT

Starting in the early phase of medication development and their manufacturing processes, Pfizer relies on eco-friendly and energy efficient solutions. In order to find cutting-edge procedures, the development department also works with external experts, like the Fraunhofer Institute for Solar Energy Systems (ISE) or the Centre for Renewable Energy (ZEE) from Freiburg.

STAR* – SOLAR AIR DRYING

Pharmaceutical production requires very dry air. But dehumidification systems are large energy consumers, and not only in Freiburg, but in industry as a whole. Pfizer Freiburg is testing the first solar air drying system jointly with the University of Applied Sciences Offenburg. Solar heat is used instead of electrical power. The solar air collectors in the pilot installation enable energy savings of up to 50 per cent.

WOOD-PELLET FIRED STEAM-BOILER

GREEN PRODUCTION

The Pfizer plant in Freiburg has its focus on the entire lifecycle of a medication – from the raw materials to manufacturing and packaging all the way to transport routes and logistics. The company is committed to sustainable development and resource conservation at all hours of the day.

SOLAR ROOFS

The plant supplies solar power to the public grids from its own 105-square metre photovoltaic installation. With an annual yield of 24,500 kilowatt-hours, the environment is spared 16.5 tonnes of carbon dioxide per year.

CLEVER ARCHITECTURE

The buildings of the plant contribute to energy efficiency. A geothermal energy plant heats and cools the administration building in a highly efficient manner. Room partitions made of glass let light pass, saving energy for lighting and facilitating communication. Special window panes ensure better heating in the winter and protection against overheating in the summer. The building's insulation has been optimised according to the latest standard.

GEOTHERMAL FIELD

Pfizer Freiburg extracts heat or cooling from depths of 130 metres, depending on how things look above ground. Heat is absorbed from the Earth or emitted back into the ground through 19 U-shaped tubes, which are driven deep into the ground on the premises and circulate a water-glycol mixture. The geothermal energy plant removes heat from the Earth during winter, warm water comes to the Earth's surface and must be heated only slightly to be used for space heating. In the summer, the water is sometimes below 12 degrees Celsius. In these cases, it can be directly used for cooling. It is passed through the ceilings in radiant panels also known as heating and cooling ceiling panels.

GREEN LABORATORIES

The cutting-edge technology in pharmaceutical laboratories is energy intensive. The annual consumption of a standard ventilation system during day-to-day laboratory operations is about as much energy as a three-person household. Pfizer Freiburg invested in special vents which significantly reduce energy consumption. These need just 33 per cent of the air volume of a conventional ventilation system. Since less air is moved, less energy is needed.

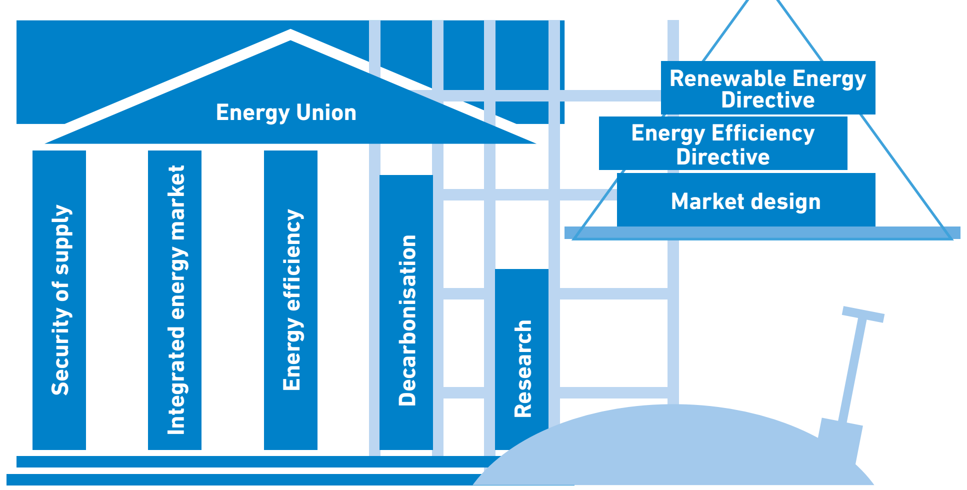
* Solar technologies applied to absorption wheels regeneration

Source: Pfizer

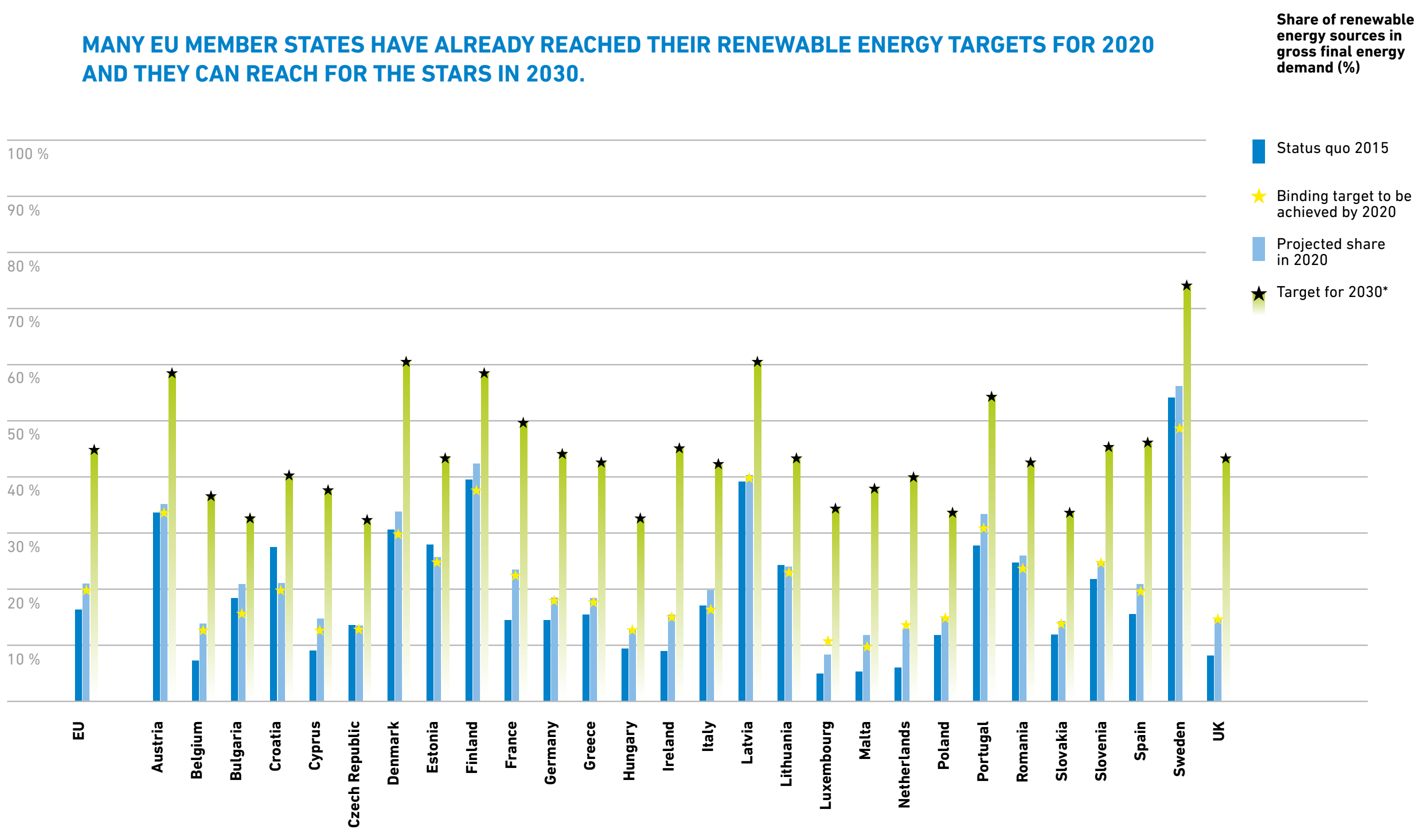
THE EU IS RENEWABLE

The energy transition is not just a German endeavour. All Member States of the European Union have established mandatory national targets for a minimum share of renewable energy in 2020. The combined efforts of the individual countries, in parallel with increasing energy efficiency, complement one another in their joint pursuit of renewable energy expansion. Thus, the EU is on its way to fulfilling its global commitments to climate protection. However, it is important to establish an even more ambitious framework for the upcoming decisions regarding further steps until 2030. Europe must act as a pioneer for the Paris climate agreement to be a success.

The Energy Union project can provide new impetus to European collaboration. Since 2015, it has been pooling measures that the EU Commission and the Member States use to advance the energy transition. It is intended to make Europe less dependent on energy imports. EU citizens are expected to benefit from lower energy costs as a result of better involvement in the internal energy market. The "Clean Energy for All Europeans" legislative package proposed by the EU Commission in November 2016 is a central component to this.



MANY EU MEMBER STATES HAVE ALREADY REACHED THEIR RENEWABLE ENERGY TARGETS FOR 2020 AND THEY CAN REACH FOR THE STARS IN 2030.



*Target 2030: An overall EU 2030 target of a 45% renewable energy share would allow continued dynamic expansion to reach the objectives of the Paris climate agreement.
The methodology used for the target sharing amongst Member States is similar to that chosen for 2020, which takes into account the countries' national gross domestic products.
Sources: European Commission: Renewable Energy Progress Report, February 2017; Ecofys/TU Wien: National benchmarks for a more ambitious EU 2030 renewables target, June 2017.

GERMANY IN THE EUROPEAN ENERGY TRANSITION

By implementing the Energy Union, the EU is developing the framework for secure and clean power supply over the long term. A functioning internal energy market is crucial for progress in the European energy transition. However, renewable energy is still at a disadvantage to fossil fuels: fossil fuels are often subsidised. Additionally, society as a whole assumes the environmental and health costs from the combustion of coal and the like. Renewable energy sources still struggle to establish themselves in this unfair competition.

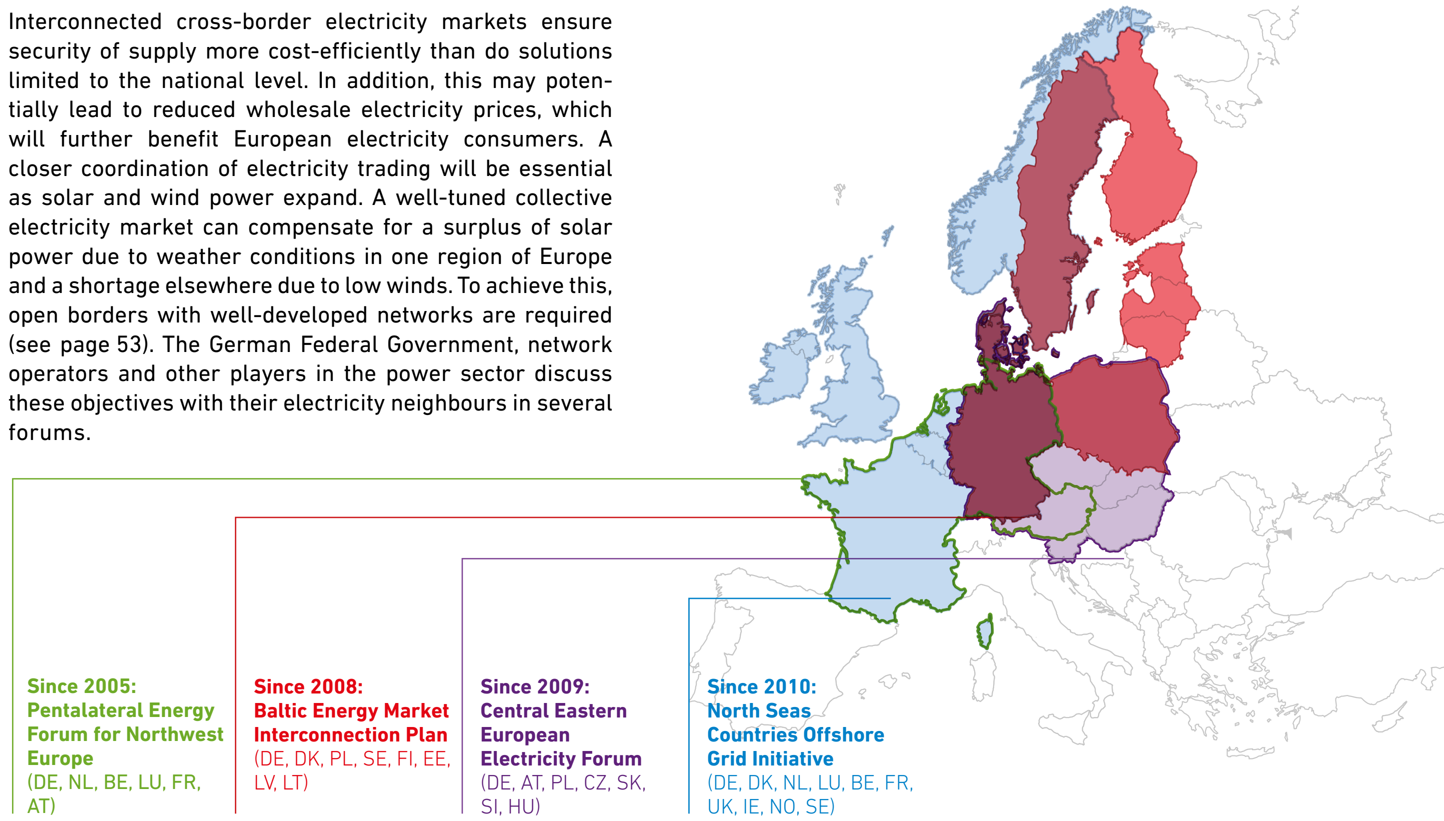
PROMOTING DECENTRALISATION, INTERCONNECTING EUROPE

With the promotion of renewable energy, Germany is contributing within the framework of the European targets. Together with the other EU members, it bears responsibility for the success of the European energy transition. Each Member State first adopts a customised development strategy, which is based on its potential and level of technological development, to reach its national renewable energy target.

To pool forces, Member States can also establish common support schemes or finance cross-border renewable energy projects, which are then credited towards the national renewable energy targets. For example, in 2016 Denmark and Germany organised pilot auctions for solar power plants for the first time. The two mutually opened cross-border auctions allowed to explore synergies and cost reduction potentials. Germany will continue to cooperate with other Member States to advance the objectives of the Energy Union.

GERMANY AND ITS ELECTRICITY NEIGHBOURS

Interconnected cross-border electricity markets ensure security of supply more cost-efficiently than do solutions limited to the national level. In addition, this may potentially lead to reduced wholesale electricity prices, which will further benefit European electricity consumers. A closer coordination of electricity trading will be essential as solar and wind power expand. A well-tuned collective electricity market can compensate for a surplus of solar power due to weather conditions in one region of Europe and a shortage elsewhere due to low winds. To achieve this, open borders with well-developed networks are required (see page 53). The German Federal Government, network operators and other players in the power sector discuss these objectives with their electricity neighbours in several forums.



"I want Europe's Energy Union to become the world number one in renewable energies."

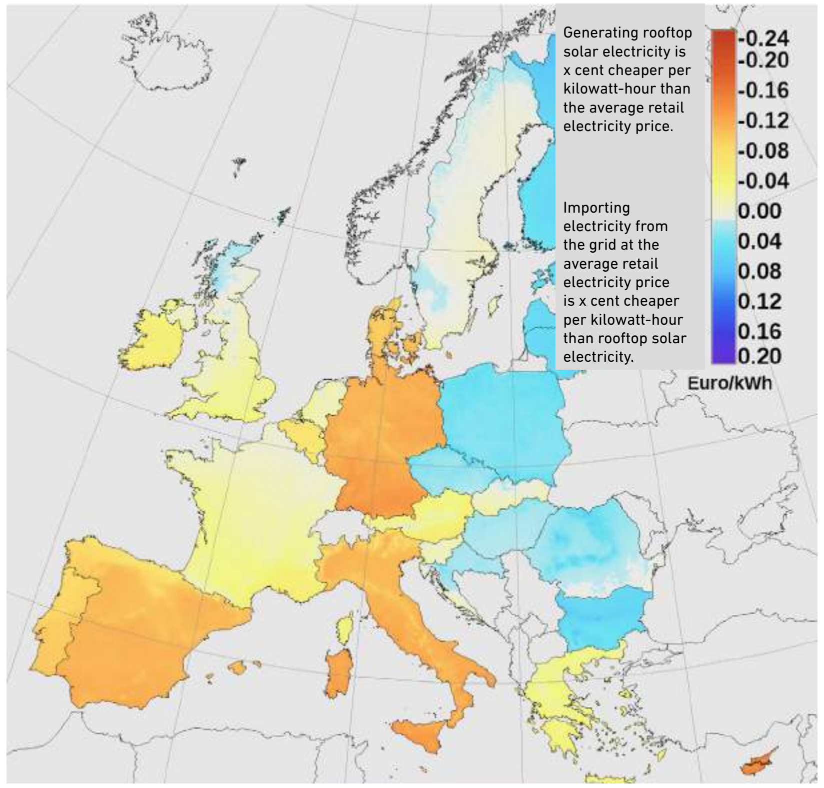
Jean-Claude Juncker, Strasbourg, 15 July 2014

CITIZENS OF EUROPE TOGETHER FOR RENEWABLE ENERGY

A renewable and efficient energy supply will liberate Europeans from the price spiral of finite fossil fuels. By switching to domestic renewable energy sources, less money will be drained from the EU to pay for energy bills. At the same time, the local value generation is increasing.

More and more EU citizens actively take part in the energy transition thanks to renewable energy. They join together in cooperatives or engage with their communities to promote climate protection. The European energy transition does not only ensure quality of life and prosperity. This Europe-wide movement democratises our energy supply and gives new momentum to the integration of Europe.

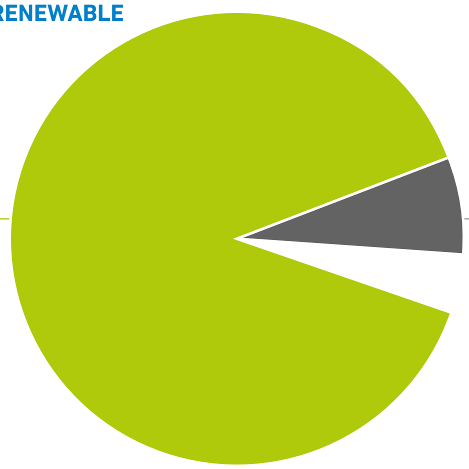
ROOFTOP SOLAR POWER IS USUALLY CHEAPER THAN THE AVERAGE RETAIL PRICE OF ELECTRICITY IMPORTED FROM THE GRID



Source: Joint Research Centre (JRC): Cost Maps for Unsubsidised Photovoltaic Electricity 2014, September 2014. Assumptions: 1,400 euro/kW system price plus national VAT rate, levelised cost of electricity generation with 20 years payback without subsidies or compensation for electricity fed into the grid.

HOW IMPORTANT DO YOU THINK IT IS THAT YOUR NATIONAL GOVERNMENT SETS TARGETS TO INCREASE THE AMOUNT OF RENEWABLE ENERGY USED BY 2030?

VERY IMPORTANT, FAIRLY IMPORTANT: 89%



Not very important, not at all important: 7%

Don't know: 4%

Source: Eurobarometer 459, September 2017

CROSS-BORDER GRASSROOTS MOVEMENT FOR CLIMATE PROTECTION

- over 7,500 signatories
- over 235 million inhabitants
- more than 40% greenhouse gas reduction by 2030

Covenant of Mayors for Climate & Energy

Renewable energy is the fast track energy supply, as its potential is available for decentralised use practically anywhere. The local level is therefore essential for the practical implementation of the energy transition and for the involvement of the public.

After the EU set its climate and energy targets, ambitious mayors joined forces to take it a step further. These mayors and their municipalities have pledged to exceed the EU climate protection targets of 40 per cent less greenhouse gas emissions by 2030. With local climate and energy plans, they systematically reduce their consumption while expanding the use of renewable energy in a targeted manner. **www.eumayors.eu**

EVERY OTHER EU CITIZEN COULD BECOME AN ENERGY CITIZEN

More and more energy consumers are becoming energy producers thanks to falling costs, especially of photovoltaic installations. By 2050, 264 million EU citizens could be active "prosumers" (= producer and consumer), for example through tenant models, renewable energy cooperatives, in small businesses and public buildings or by participating in demand response. This could satisfy up to 45% of the power demand in the EU.

POTENTIAL FOR ACTIVE RENEWABLE PROSUMERS IN THE EU

2015 **12 million** energy citizens

2030 **112 million** energy citizens

2050 **264 million** energy citizens

Source: CE Delft: The potential for energy citizens in the EU, September 2016

ACCEPTANCE
The public's willingness to endorse something. In order to switch our energy supply over to renewable energy resources, it is not only the technical development and profitability of the resources that are crucial, but also their public acceptance. Acceptance of renewable energy involves a number of issues. These include the installation and operation of plants that use different types of renewable energy, the costs involved in the energy transition, as well as the acceptance of energy storage systems or the extension and modification of the power grids, which are necessary for the further expansion of renewable energy. On the whole, renewable energy is widely accepted and extremely popular in Germany.

BALANCING ENERGY
Energy that is held in readiness to balance short-term fluctuations in the production and consumption of electricity, so that exactly the same amount of energy is fed into the grid as is needed at any point in time. Balancing energy is traded on the balancing power markets of the electricity exchange. The market makes a distinction between positive and negative balancing energy, according to whether there is a shortage or a surplus of capacity compared to the power supply forecast. When there is a need for positive balancing energy, additional power generation capacity is made available for the short term. Steam turbine, storage, pumped-storage and gas turbine power plants are used to supply balancing energy; these plants are either operating below capacity (partial load operation) or can be started up as required. Negative balancing energy is necessary when there is a surplus of power. This happens when the demand for electricity is unexpectedly low, or the solar radiation or the wind level is higher than forecast. Negative balancing energy can involve plants that have a high power capacity, which can be switched on as additional consumers in order to absorb the surplus power (e.g. pumped-storage plants or other storage facilities). In principle, negative balancing capacity can also be achieved by switching off wind farms, for example. A distinction is made between the various types of balancing energy (primary, secondary, tertiary reserve) in terms of the speed of activation or changeover to provide power or to consume it.

BIODIESEL
Biodiesel is the most widely used biofuel in Germany. Biodiesel is produced from vegetable oil reacted with alcohol, by means of a chemical process called transesterification. The oil most commonly used in Germany is rapeseed. Sunflower oil, soya and palm oil may also be processed, if producers provide evidence that they are meeting certain minimum ecological criteria. As well as using vegetable oils for fuel production, residual materials such as frying fat or dripping can be used for biodiesel production. Glycerine, which is used in the chemical industry, is a by-product in the production of biodiesel. Rapeseed meal, which is another by-product of biodiesel production, is used as animal feed. In Germany, biodiesel can either be used pure or can be blended with fossil diesel up to a concentration of seven per cent.

BIOETHANOL
In contrast to biodiesel, bioethanol can be used in petrol engines. Plants that contain high levels of sugar or starch, such as sugar beet, sugar cane, rye, wheat, maize and potatoes, are suitable raw materials for producing bioethanol. Grain and sugar beet are mainly used in Germany. As is the case with normal alcohol, bioethanol is produced from sugar by alcoholic fermentation with the help of microorganisms and then purified by a process of thermal separation. In Germany, bioethanol can either be used pure (known as E85) or can be blended with fossil-based diesel up to a concentration of at least five per cent.
See also >Dried distillers grains with solubles

BIOFUEL
Fuel produced from biomass to power internal combustion engines (e.g. in vehicles or cogeneration units) or heating systems. Biofuels include biodiesel, bioethanol, biomethane (from biogas), pure vegetable oils and the synthetic biomass to liquid (BtL) fuels.
See also >Biodiesel, >Bioethanol, >Biogas, >Biomass, >By-products

BIOFUEL QUOTA
The biofuel quota sets the minimum percentage of fuel sales that must be covered by biofuels. According to the Biofuel Quota Act, at least 6.25 per cent of the fuel used in Germany between 2010 and 2014 was covered by biofuels. Since 2015, the biofuel quota has been determined by the criterion of the contribution the biofuel in question makes towards reducing greenhouse gas emissions. Since 2007, the Biofuel Quota Act has set the minimum quota for biofuels in terms of fuel consumption. Oil companies can achieve this percentage by mixing biofuel with fossil fuels, by selling pure biofuel or by purchasing quotas of sold biofuels from other providers.

BIOGAS
Biogas is produced when biomass, which is cut off from light and oxygen in a fermentation container (the digester of a biogas plant), is broken down by certain bacteria. Biogas consists of methane, carbon dioxide and oxygen, nitrogen and trace gases (including hydrogen sulphide). The main component, methane, can be used as a source of energy. Biogas can be produced from energy crops (e.g. maize, grain) as well as from residual materials such as organic waste, crop residues and straw, and from animal excrements such as slurry and manure. The biogas produced in a biogas plant can be turned into electricity and heat in a cogeneration unit. If biogas is treated and purified (to form the product known as biomethane) it can also be fed directly into the existing natural gas network and blended with fossil-based natural gas, or used as fuel in vehicles with gas-powered engines. See also >Cogeneration unit, >Combined heat and power, >Biomass

BIOMASS
Biomass is a generic term for all material of organic origin, which owes its growth ultimately to the use of solar energy. From a bioenergy perspective, a distinction can be made between

- plants and animals living in the natural environment,
- residues from these (e.g. dead plants such as straw) and by-products (e.g. excrement such as slurry),
- in a broader sense, all organic material which is produced by means of a technical transformation (e.g. paper, cellulose, vegetable oil) or which is produced from another usage (e.g. organic waste, waste from the food industry).

See also >Energy crops, >By-products, >Renewable resources, >Residual materials, >Triticale

BIOMASS SUSTAINABILITY ORDINANCE
The Biomass Electricity Sustainability Ordinance (abbreviated in German to BioSt-NachV) and the Biofuel Sustainability Ordinance (Biokraft-NachV) have been in existence since 2009 and serve to ensure the sustainable recovery and use of biomass. They stipulate how liquid biomass, especially vegetable oils, such as palm, soya and rapeseed oils, should be produced and used. In the interest of nature conservation, environmental and climate protection, the cultivation of these crops is not allowed to destroy any areas that are particularly valuable from the point of view of nature conservation (e.g. rain forests) or land with high stocks of carbon (e.g. wetlands, peatbogs), and their use for energy supply must lead to a reduction in greenhouse gas emissions to a level that is at least 35 per cent lower than those produced by fossil fuels. Social conditions related to the cultivation of these crops are also taken into consideration.

BIOMETHANE
Methane is the main component of biogas, which is generated from the fermentation of biogenic substances. After it has been treated, in the course of which other biogas components are separated out, it can be fed into the natural gas network. It is then available for use in cogeneration units or as fuel for vehicles, for example. Methane that is produced from biogas is called biomethane.

BOREHOLE HEAT EXCHANGER
Borehole heat exchangers (BHE), also called downhole heat exchangers (DHE), are installed in vertical boreholes with a depth of between a few metres and over 100 metres. A heat transfer fluid circulates in the borehole heat exchanger system and absorbs the heat that is stored underground. The temperature is further increased by means of a heat pump and the heat extracted can be used for heating and supplying hot water.
See also >Heat pump

BY-PRODUCTS
By-products are secondary products that arise during the production of, for example, biofuel. Around 40 per cent of the land used for biocrops also serves to produce animal feed, since the production of rapeseed oil and bioethanol always gives rise to animal fodder such as rapeseed meal and dried distillers grains. Glycerine, which is also a by-product of the production process, is used as a raw material in the chemical industry.
See also >Biofuel, >Biomass, >Dried distillers grains with solubles

CARBON DIOXIDE (CO_2)
Carbon dioxide is a colourless, odourless gas made up of oxygen and carbon. It occurs when fuels containing carbon are combusted, particularly fossil fuels. Carbon dioxide contributes substantially to climate change, which has led to an average global temperature increase of 0.8 degrees Celsius over the past century. The consequences of this include sea level rise, the increase in storms and droughts and the melting of glaciers.

COGENERATION UNIT
A cogeneration unit (or combined heat and power plant, CHP) is a power plant that simultaneously generates electricity and heat based on the principle of combined heat and power. See also >Combined heat and power

COMBINED HEAT AND POWER (CHP)
When electricity is generated in a thermal power plant heat is also produced. In conventional power plants, this waste heat is emitted unused into the environment via cooling towers. In a CHP unit, on the other hand, the heat is extracted and made useable for local or district heating via a heating network. This increases the efficiency of the plant and leads to a significantly higher level of energy efficiency.
See also >Cogeneration unit, >District heating, >Local heating

COMBINED POWER PLANT
A combined power plant connects and controls a number of small, decentralised power generation facilities. The combination of wind, solar, biomass and hydro-electric power plants makes it possible to produce electricity at a level that is just as reliable and efficient as using conventional large power plants. With this system, wind turbines and solar panels make their contribution to power generation according to the availability of wind and sun. Biogas and hydro-electric power are used to balance the supply when needed.

DEMAND SIDE MANAGEMENT / LOAD MANAGEMENT
Under the existing power supply system, the demand for electricity usually determines the level at which power plants operate. The electricity supply is adjusted to meet fluctuations in demand by modifying the mode of operation of the power plants. In the context of a power supply system that is increasingly reliant on renewable energy, it is important, in the future, to adjust the demand to the supply to some extent, i.e. above all to the availability of wind and solar power. In this way, the need for fossil fuel power plants and storage capacity can be reduced. This type of demand side management requires the appropriate infrastructure however: consumers must be constantly informed about the power capacity that is available and given incentives to adapt their demand for electricity by means of appropriate tariffs and price signals. In addition, it must be possible to control and programme appliances such as dishwashers, dryers and washing machines accordingly.
The potential of demand side management (load management) is influenced by a range of different factors. The technical potential of demand side management is very high and equates to several gigawatts, but the practical and economically feasible potential is considered to be significantly lower. Pilot projects being run as part of the German Federal Ministry for Economic Affairs and Energy's "E-Energy" programme are investigating the range of potential related to demand side management and experimenting with the digital networking and optimisation of the power supply system by using advanced information and communication technology.

DISTRIBUTION GRID
Includes low, medium and high voltage networks. They ensure that electricity is distributed at the regional level. Consumers ranging from households to medium-sized companies are connected to the distribution grid, which is in turn connected to the transmission grid (extra high voltage) via transformer stations.
See also >High voltage, >Medium voltage, >Low voltage >Transmission grid

DISTRIBUTION NETWORK OPERATOR
Distribution network operators are responsible for transporting electricity on the distribution grid and are therefore responsible for the local power networks. As well as servicing and maintaining the networks and operating metering points, their tasks include ensuring that electricity traders and suppliers, such as operators of smaller renewable energy plants, have access to the network. In 2010, there were around 900 distribution network operators across the whole of Germany.

DISTRICT HEATING
District heating is thermal energy which reaches consumers through a system of insulated pipes. The energy is predominantly used for heating buildings. The hot water that is fed into the district heating network comes from heating or cogeneration plants. The latter simultaneously generate electricity and usable waste heat by means of combined heat and power generation. Most plants are still powered by coal or natural gas, but there are also plants that use biomass (e.g. wood chips) or geothermal energy.
See also >Combined heat and power, >Local heating

DRIED DISTILLERS GRAINS WITH SOLUBLES
Dried distillers grains occur as a by-product in a plant where bioethanol is produced on the basis of grains that contain starch. During the production process, vapour is generated, which leaves residues after cooling. This by-product is called stillage. After it has been dried, the product, which is then known as dried distillers grains, is pelleted and used as storable animal feed.
See also >Bioethanol

EFFICIENCY
The relationship between energy used and output achieved (e.g. electricity or heat). The overall efficiency of electricity generation plants is made up of electrical and thermal efficiency. Consequently, it is possible to increase the efficiency by also using the heat that is produced in generating electricity.
See also >Combined heat and power

ELECTROLYSIS
In general, a process by which an electric current triggers the exchange of electrons between two reactants. The best-known example of this is the electrolysis of water, where water is broken down into its two components, oxygen and hydrogen, by means of an electric current being passed through it. Electrical energy is thus converted into chemical energy. Hydrogen can be used as a storage medium for a period of months.
See also >Energy storage systems, >Power to gas

ELECTROMOBILITY
Covers all vehicles that run on electricity. Electrically-powered vehicles dominate the rail sector; electric bicycles are also part of electromobility. Currently, however, electromobility is predominantly associated with electric cars, which are experiencing a renaissance on the roads, but have yet to make it onto the mass market. Batteries or fuel cells that are not yet powerful enough, high prices and a lack of charging points are still considered to be barriers in this field.
The renewed interest in electromobility has resulted from the potential combination of car, power grid and renewable energy. If electric vehicles are charged with renewable electricity or hydrogen, they can reduce the greenhouse gas emissions from traffic and be beneficial from an ecological point of view. If integrated into a > smart grid, electric vehicles with batteries can potentially play a significant role as "mobile power stores", which can provide > balancing energy to a certain extent. This could make a significant contribution to balancing the fluctuating electricity production from wind farms and solar energy facilities and to stabilising the power grid. A range of different forums, funding programmes and strategies have been introduced in Germany to promote research and the launch of electric vehicles onto the market. Examples of these are the National Electromoblity Development Plan and the National Electromobility Platform. The Electromobility Forum, which was set up in 2009, pools the research activities of the 33 participating Fraunhofer Institutes and their industrial partners. Critics complain that electromobility with batteries does not make ecological sense as long as the majority of the electricity comes from fossil fuel sources. If the additional electricity needed to power electric cars is generated by coal–fired power stations, carbon emissions will rise even further. On the other hand, electromobility based on fuel cells proves more ecologically sound if the hydrogen is produced using electricity from renewable resources.

ENERGY CONSERVATION
Generally covers all measures to reduce energy consumption. Energy conservation is not the same as increasing energy efficiency, however: increasing energy efficiency involves using technical means in order to expend less energy to achieve the same performance. In contrast, the term energy conservation usually refers to a change of user behaviour which reduces energy consumption. In the case of motor traffic, for example, increasing energy efficiency means that less energy in the form of fuel is needed for the same distance travelled, by making technical developments. Energy conservation, however, can be achieved by changing user behaviour, for example by reducing the driving speed or by using a bicycle.
See also >Energy efficiency

ENERGY CROPS
Energy crops are crops that are grown specifically for use as a source of energy. In Germany, the arable crops that are particularly suitable for use as energy sources are grains such as maize, wheat, rye or triticale, as well as other grasses such as miscanthus and ryegrass. Oil seeds such as rape and sunflower are also used as energy crops, as are palm oil and soya outside of Germany. Other domestic energy crops include fast-growing trees such as poplar and willow and also turnips and hemp. Whether arable crops are used for energy may only be decided after they are harvested, since most of the energy crops grown in Germany can also be used as raw materials for animal fodder and food products, or for other material uses, e.g. in the chemical industry.
See also >Biomass, >Renewable resources, >Residual materials, >Triticale

ENERGY EFFICIENCY
In general, the word efficiency refers to the relationship between the resources invested and the return achieved, i.e. the relationship between costs and benefits. With energy efficiency, it is a question of the highest possible efficiency rate of energy conversion, or the smallest possible energy consumption for buildings, equipment and machinery. An increase in energy efficiency means that the same (or a better) performance is achieved using less energy.

ENERGY INTENSITY
The relationship between the primary energy consumption and the gross national product of a national economy. Energy intensity can also be calculated for smaller sectors or for individual products. Energy intensity is a key figure that provides information on the efficiency with which energy is used. It is measured, for example, in millions of tonnes of oil equivalents per 1,000 US dollars of gross national product.

EXTRA HIGH VOLTAGE
In the electrical engineering sector, power lines over 200 kilovolts are generally described as extra high voltage. They are chosen to transport electricity over long distances in order to keep line losses to a minimum. The extra high voltage network represents the top level of the hierarchically-structured power grid. Large power plants, such as nuclear plants, coal-fired plants or also offshore wind farms, feed the electricity they produce directly into the transmission grid (also known as the transmission network), where the power is distributed over long distances. Once it has been transformed to high, medium and low voltage, the electricity is then further distributed until it reaches the final consumers. See also >High voltage

FAULTS
Faults develop in the Earth's crust when the rocks react to tectonic forces affecting it, usually causing fractures. Faults can have significantly greater permeability than the surrounding rocks. Rising thermal water therefore accumulates in the fracture zones, so that heat is transmitted to shallower depths. This makes faults attractive for geothermal use. So far, fault zones have not been used for extracting geothermal heat in Germany.
See also >Geothermal energy, >Hydrothermal geothermal energy

FINAL ENERGY
Final energy is the term used for that percentage of the primary energy which is available for consumers to use, after deducting transport and conversion losses.
See also >Primary energy

FOSSIL FUELS
Fossil fuels were formed over long periods of time due to biological and physical processes in the Earth's interior or on its surface. They include crude oil and natural gas, as well as lignite and coal. When they are burned, greenhouse gases such as carbon dioxide are released and these contribute significantly to climate change.
See also >Carbon dioxide (CO_2)

GEOTHERMAL ENERGY
Thermal energy below the Earth's surface. In the case of deep geothermal energy (from a depth of more than 400 metres), energy that comes to the surface from the Earth's interior is used to produce electricity and/or heat. With deep geothermal energy there is a distinction between hydrothermal geothermal energy and petrothermal geothermal energy. Near-surface geothermal energy refers to using the energy that is stored in the uppermost layers of the Earth's surface or in ground water. Even the low temperatures that prevail here can be used in a range of different ways. According to temperature and necessity, they can serve both to supply heat and also provide air conditioning. Heat pumps, horizontal ground heat exchangers and borehole heat exchangers can be deployed to utilise the energy that is available just below the Earth's surface.
See also >Horizontal ground heat exchangers, >Borehole heat exchangers, >Hydrothermal geothermal power, >Petrothermal geothermal energy

HEAT PUMP
A heat pump raises the temperature of the natural heat that surrounds it (e.g. from the soil, the ground water or the air) to a higher level. To do so, it makes use of the effect that gases heat up under pressure (e.g. as in the case of a bicycle pump).
See also >Geothermal energy

HIGH VOLTAGE
Voltages over one kilovolt are divided into medium voltage, high voltage and extra high voltage. There are no standardised delimitations for the different categories, however. Normally, in Germany, voltage ranges between 30 and 110 kilovolts are considered to be high voltage. High voltage power lines belong to what is known as the distribution grid. They are used for the regional transport of electricity and to supply smaller towns. Smaller and medium-sized power plants, such as wind farms, solar power plants or biogas facilities, are connected to the medium and high voltage network. Even large electricity consumers, such as industrial companies, are directly connected to the medium and high voltage network in some instances.

HORIZONTAL GROUND HEAT EXCHANGER
Horizontal ground heat exchangers are laid horizontally at a depth of 80-160 cm. The exchangers contain a heat transfer fluid which absorbs the heat passed into the ground by the rain and the sun and transfers it to a heat pump. Once the heat pump has increased the temperature, the heat can be used for heating and supplying hot water.
See also >Heat pump

HOT DRY ROCK PROCESS (HDR)
The hot dry rock process makes it possible to use deep geothermal energy where there is no thermal water present deep below the Earth's surface. The general term for stimulation techniques that are used when there is a lack, or too small a quantity, of thermal water, is Enhanced Geothermal Systems (EGS), although the term HDR is more popular. Under EGS or the HDR process, water is forced underground at high pressure through a borehole to a depth of more than 3,000 metres, which creates fissures in the rock. Water is then piped through the borehole into the underground system of fissures, where it heats up and is then pumped back to the surface via another borehole. The water supplied by the HDR process reaches temperatures that make it possible to generate electricity.
See also >Geothermal energy, >Petrothermal geothermal energy

HYDROELECTRIC POWER
Energy that is recovered from running water using water wheels or water turbines. Hydroelectric power is a natural source of energy which is available in any place where there is a sufficient quantity of water and/or constantly running water falling from a sufficient height. A water turbine drives a generator which produces electricity from hydropower.

HYDROGEN
Chemical element. In the context of the transformation of the energy supply system to rely on renewable sources of energy, hydrogen is gaining importance as a storage medium. This gas can be produced by splitting water into its component parts, oxygen and hydrogen, by means of elect-

rolysis. In future, temporary surplus quantities of wind and solar power can be used for the process. Since hydrogen is a fuel that can be easily stored and transported (up to five per cent can be directly fed into the natural gas network), it can be used for long-term storage and in a wide variety of applications. Hydrogen can also be used to power cars that run on fuel cells.
See also >Methanation

HYDROTHERMAL GEOTHERMAL ENERGY
Hydrothermal geothermal energy is the term used for the generation of electricity and/or heat using thermal water. The temperature of the water must be at least 80-100 °C to make it possible to generate electricity. At temperatures below 80 °C, newly-developed Organic Rankine Cycle (ORC) facilities or the Kalina Cycle process are used. With these two processes, materials that evaporate at lower temperatures are used instead of water (for example, pentane or ammonia). Thermal water can be simultaneously or exclusively used for supplying heat. The thermal energy of the extracted water is given off into the heating network by means of a heat exchanger.
See also >District heating, >Geothermal energy, >Local heating, >Petrothermal geothermal energy

ICE STORAGE TANK
Ice storage tanks make use of what is known as latent heat, which is produced in the transition from solid ice to liquid water. A great deal more energy is actually required to heat ice to above the melting point of 0 °C than is needed to effect the same temperature change in the case of a material in a constant state of aggregation. This is because the forces of attraction between the water molecules in the ice crystals have to be overcome in order to turn solid ice into liquid water. So if a kilogramme of ice is to be melted, approximately as much heat has to be applied to it as would be needed to heat the same quantity of water from 0 to 80 °C. Conversely, the equivalent amount of heat must be withdrawn from the water to turn it back into its solid state. In order to use this principle for heat storage in detached houses, a storage tank with a volume of ten to twelve cubic metres is buried in the ground at a depth of up to four metres and is filled with tap or ground water a single time. The heat present in the water can be removed by means of a heat pump until the ice storage tank is completely frozen, i.e. emptied. An ice storage tank is usually filled, however, with surplus heat from solar panels, which makes the ice melt and also possibly warms it up further. A full ice storage tank is therefore filled with warm liquid water. The ground around the tank also acts as an additional constant heat source, since temperatures significantly above 0 °C prevail all year around from a depth of one metre.

INSTALLED CAPACITY
The installed capacity indicates the maximum electrical output of a power plant or of the entire power facility. For smaller power plants it is stated in kilowatts (kW), otherwise in megawatts (MW) or even gigawatts (GW). One megawatt equals 1,000 kilowatts. One gigawatt equals 1,000 megawatts, or the same capacity as that needed to power 1 million kettles or hair dryers.

KALINA CYCLE
A process used to power steam turbines in order to produce geothermal power at relatively low temperatures. Conventional steam turbines need temperatures of way over 100 °C. In order to allow the use of temperatures of around 90 °C to produce geothermal power, the heat of the deep water is transferred into a mixture of ammonia and water with a significantly lower boiling point. The steam generated is then used instead of pure water vapour to power turbines.
See also >Geothermal energy, >Hydrothermal geothermal energy, >Organic Rankine Cycle

KILOWATT-HOUR
The unit used to measure quantities of energy. One watt-hour (1 Wh) is equivalent to approx. 3.6 kilojoules (kJ). 1,000 Wh equal one kilowatt-hour (1 kWh) and 1,000 kWh equal one megawatt-hour (MWh). The power consumption in Germany is around 615 terawatt-hours (TWh), which equates to 615 billion kilowatt-hours. An average 3-person household consumes about 3,500 kilowatt-hours of electricity a year. With one kilowatt-hour, for example, you can listen to the radio for 15 hours, do one wash in the washing machine or cook lunch for four people.

LOCAL HEATING
Local heating is the transfer of heat over relatively short distances between buildings, using a local heating network in order to provide heating. There is no legal distinction between local and district heating. In contrast to district heating, local heating is implemented in small decentralised units and is transferred at relatively low temperatures. Heat can therefore be recovered from cogeneration units but also from solar thermal or geothermal plants. The expansion of local heating thus has a major role to play as part of the increasing use of renewable energy.
See also >Cogeneration unit, >District heating, >Solar thermal energy

LOW VOLTAGE
Refers to the lowest voltage level, which reaches a maximum of 1,000 volts (1 kilovolt) in the case of AC voltage and 1,500 volts (1.5 kilovolts) in the case of DC voltage. A voltage of 400 volts is normal in the low voltage network. It is used to distribute power to the final consumer and is the most extensive network in the German power grid in terms of the distance covered. Low voltage networks therefore represent the lowest level of the hierarchically-structured power grid. Households are supplied with low voltage electricity at around 230 volts.
See also >High voltage, >Extra high voltage, >Medium voltage

MEDIUM VOLTAGE
In the power engineering sector, medium voltage usually refers to a voltage range between one and 30 kilovolts (kV). There is, however, no exact delimitation and voltages up to 75 kV are also often referred to as medium voltage. Medium voltage is used in the medium voltage grid, which is responsible for transmitting power within a region, over a distance stretching between a few kilometres and 100 kilometres. Medium voltage grids serve to supply power to individual urban districts, villages or industrial enterprises.
See also >High voltage, >Extra high voltage, >Low voltage

OFFSHORE WIND POWER
The generation of electricity from wind energy at sea. Electricity from offshore wind farms is expected to make a significant contribution to Germany's power supply in the future. The high average wind speeds at sea promise a high power yield. Offshore wind farms are already in place off the coasts of Denmark, Great Britain and the Netherlands, for example.

ONSHORE WIND POWER
The use of wind energy on land. Onshore wind power is the renewable energy that provides the largest percentage of the renewable electricity produced in Germany (approx. 6.5 per cent of the total electricity consumption in Germany in 2008).

ORGANIC RANKINE CYCLE (ORC)
An operating process by means of which steam turbines in power plants are driven by a working medium other than water vapour. The decisive factor is the lower boiling point of organic substances, which makes it possible to increase the vapour pressure at relatively low temperatures. This process is used when producing electricity from geothermal energy, for example, in Germany's first geothermal power plant in Neustadt-Glewe. See also >Geothermal energy, >Hydrothermal geothermal energy

PEAK POWER OUTPUT
The power output rating of photovoltaic systems is stated in kWp (kilowatt-peak units). "Peak" refers to the output which is achieved under international standard test conditions. This process is used for standardisation purposes and to compare different solar cells. As rule of thumb, an energy yield of at least 800 kWh per kWp of installed system capacity per year can be achieved at our latitude.
See also >Performance Ratio, >Photovoltaics

PERFORMANCE RATIO
In reality, solar panels hardly ever achieve the stated nominal efficiency which is determined under standard test conditions. This is because adverse conditions such as dust, bird droppings, reflections, temperature increases in the panels, wiring and inverter losses reduce the actual output. Hence, we also speak of actual efficiency. The relationship between actual efficiency and nominal efficiency is called the performance ratio (PR). This is referred to as a quality factor. New systems, which are installed in an optimal position on the roof and are not dirty, have a PR value of 0.85. This means that 85 per cent of the power produced by the generator is actually available for use. An average system with slight losses due to shade has a PR value of approx. 0.7.
See also >Peak power output, >Photovoltaics, >Efficiency

PETROTHERMAL GEOTHERMAL ENERGY
In contrast to hydrothermal geothermal energy, petrothermal geothermal energy cannot rely on steam or thermal water that occur naturally. Petrothermal geothermal energy uses the natural heat of the hot rocks that are found at a depth of approx. 2,000 – 6,000 metres. The process is therefore also known as the "hot dry rock process". Hydraulic and chemical stimulation techniques are used to produce or expand fissures and cracks in the rock. Water is then forced into these fissures and cracks at high pressure through an injection borehole. The water heats up in the rocks, which have a temperature of approx. 200 °C. An extraction borehole then is used to pump the hot water at a temperature of approx. 90 – 150 °C back to the Earth's surface, where it can be utilised, just as in hydrothermal geothermal energy, using the ORC (Organic Rankine Cycle) and Kalina Cycle: the hot water transfers its heat to a heat carrier that turns rapidly to steam. This then powers a turbine to produce electricity via a separate circuit. It is also possible to connect to a local heating network.
See also >Hot dry rock process, >Hydrothermal geothermal energy, >Kalina Cycle, >Organic Rankine Cycle

PHOTOVOLTAICS
The conversion of solar energy into electrical energy. In photovoltaics, an electric field is generated in solar cells by means of incoming light (photons). Electrons can flow through an electrical conductor. The electricity can be used immediately or fed into the power grid.
See also >Peak power output, >Performance ratio

POTENTIAL ANNUAL ENERGY YIELD
The potential annual energy yield states how much electricity all the wind turbines that are installed in Germany by the end of the year would produce, if they were generating power under average conditions for one year. This parameter differs to some extent from the actual power fed into the grid since most new installations only start to operate in the course of the year and wind conditions fluctuate from year to year.

POWER GRID EXPANSION ACT (ENLAG)
The Power Grid Expansion Act, which was adopted in summer 2009, serves to speed up the expansion of the extra high voltage transmission grid. The aim is to expand the transmission grid in order to make it easier to integrate electricity from renewable energy resources, connect new power plants, facilitate international trade in electricity and to avoid structural bottlenecks. To this end, the law determines the priority need for certain route corridors.

POWER TO GAS
Method of producing methane by using the surplus power that is generated by renewable energy sources. In the future, methanation should make it possible to store energy for the medium and long term. If more electricity is produced from renewable energy sources than is consumed or can be transmitted elsewhere via the power grid, then this energy is used to split water into its constituents, hydrogen and oxygen, by means of electrolysis. Finally, the hydrogen produced is transformed into methane (which is like conventional natural gas) by adding carbon dioxide (CO_2) using the Sabatier process. This makes it possible to use the transport and storage capacities of the natural gas network. If necessary, the stored methane can be turned back into electricity in a gas turbine power plant, for example, but it can also be used to supply heating or to power vehicles that run on natural gas.

PRIMARY ENERGY
Energy that is available in the form of sources of energy that occur naturally. Primary energy is transformed into energy that can be used, i.e. into final energy, by means of various processes. An example is the production of power and heat from the primary fuel, wood, in wood-fired power plants, or the conversion of rapeseed oil into fuel that is used to drive vehicles. The process of conversion always involves a loss of energy, but the higher the efficiency of the technology used, the lower the energy loss.
See also >Final energy, >Efficiency

PROFITABILITY
The relationship between costs and revenue. Profitability is a measure of efficiency. It determines whether a product or technology is able to compete in the marketplace.

REDEVELOPMENT SITES
In urban planning, the term redevelopment is used to describe the reintegration of brownfield sites into the economic and natural cycles. The equivalent term in German (Konversionsflächen) arose following the conversion of former military facilities and was used particularly for these. Over the years, the term was also used for other areas undergoing redevelopment.

RENEWABLE ENERGY SOURCES ACT (EEG)
The Renewable Energy Sources Act came into force in the year 2000 and sets out the framework for the expansion of the renewable energy sector in Germany. It supports the launch of renewable energy onto the market and the achievement of the European and German objectives regarding the percentage of electricity consumption that has to be provided by renewable energy. This is intended to reduce the energy sector's emission of greenhouse gases. The support scheme was initially based on fixed, technology-specific feed-in tariffs, which were guaranteed for 20 years. The Renewable Energy Sources Act was amended in 2004, 2009, 2012, 2014 and 2016 in response to developments in the market. Since the 1st January 2017, the level of remuneration for renewable electricity is no longer set by the government, as was previously the case, but is determined by competitive tenders. Small plants are exempt from the tendering process.

RENEWABLE METHANE (ALSO KNOWN AS "WIND GAS")
Renewable methane is a gas which is produced using electricity from renewable resources. In the first stage of the process, hydrogen is created by means of electrolysis. This is then converted into methane by adding CO_2. The process is also known as "Power to Gas" and makes it possible to store energy for the longer term. However, the process is still at the research, development and demonstration stage.

RENEWABLE RESOURCES
Wood and energy crops are renewable resources. Renewable resources, however, can also be cultivated for material use, e.g. as building materials, as cellulose for the paper industry, as lubricants, paint or other raw materials for the chemical industry.
See also >Biomass, >Energy crops

REPOWERING
Replacement of old power plants with new, more efficient ones at the same site. The term repowering is predominantly used in the context of replacing old wind turbines.
See also >Onshore wind power

RESIDUAL MATERIALS
In contrast to energy crops, residual materials are not planted specifically for energy production, but have arisen following another previous use of biomass. What appears, at first sight, to be redundant waste is in fact valuable residual material, which can also be used to produce energy. For bioenergy, biogenic residual materials such as crop residues, organic waste, straw and animal excrement (e.g. slurry and manure) are used.
See also >Biomass, >Energy crops, >Renewable resources

SMART GRIDS
The term "Smart Grid" is the generic term used to describe a smart and efficient system of linking power production, power transmission and load management, using the latest communication and information technology. Using digital technology is expected to make it possible in future to manage the power grid in an "intelligent" and automatic way and also to integrate an ever-increasing proportion of renewable and decentralised production technology into the supply system. New, digital and "intelligent" smart meters are one aspect of this modern system of power grid management. They are intended to give the consumer much more information than the meters that have previously been used and thus make him/her an active and responsible participant in the power supply system.
See also >Demand side management / Load management

SOIL SEALING
Soil sealing is a term used for the covering of the natural soil as a result of buildings constructed by people. It is called soil sealing because precipitation can no longer penetrate the soil and therefore many of the processes that normally occur are stopped.

SOLAR COOLING
Air-conditioning using solar energy. In the case of solar cooling, solar thermal energy is used instead of electric current to operate cooling systems such as air-conditioning units.
See also >Solar thermal energy

SOLAR THERMAL ENERGY
Using solar energy to generate heat. A typical way of using solar thermal energy is via solar collectors, in which water is heated and used for heating rooms or to supply hot water.

TRITICALE
Triticale is a grain crop. It is a hybrid of wheat and rye. Its grains are about 3–5 cm long and are four-sided. Triticale combines high yields with modest requirements in terms of climate and soil quality.

TRANSMISSION GRID
The power transmission grid is used to transport electricity over long distances nationwide. Extra high voltage is chosen for this in order to minimise transmission losses. Voltage levels of between 220 and 380 kilovolts are generally used. The transmission grid is connected to the regional distribution networks by means of transformer stations.
See also >High voltage, >Extra high voltage

TRANSMISSION GRID OPERATOR
Operators of the extra high voltage networks, which transport electricity over long distances. They have the task of servicing and maintaining the transmission grid and ensuring that electricity producers, traders and suppliers have access to the network. Transmission grid operators also compensate for fluctuations in the power supply by providing balancing energy. According to the law, they are the system managers, which means that they are responsible for guaranteeing security of supply.
See also >High voltage, >Extra high voltage >Balancing energy

VIRTUAL POWER PLANT
A group of different decentralised power generating units which are interconnected. A network of smaller producers of this kind is controlled centrally. Due to the close interconnection of the individual units, the many decentralised plants assume the character of one large power plant. A virtual power plant may be made up, for example, of photovoltaic facilities, wind turbines, biogas plants, cogeneration units or hydropower plants, but also energy storage units, all of which are operated together in an interconnected way. The strengths and weaknesses of the individual technologies can be offset by linking them. The interaction of both fluctuating and adjustable energy producers guarantees the secure and flexible generation of power. A virtual power plant can smooth out load peaks or provide balancing energy, for example. The term "virtual" refers to the fact that the production network outwardly appears to be one single large power plant, but in reality no single power plant exists, rather several facilities distributed over different locations.
See also >Combined power plant, >Balancing energy

WOOD CHIPS
Wood chips are wood that has been chopped up into small pieces by machine. Standards specify a maximum chip size of approx. 3 – 5 cm^2. Not every modern fully-automatic heating system that operates on wood pellets is also designed to burn wood chips. Grants are available for wood chip heating systems under the market incentive programme. See also >Wood fuel, >Wood pellets

WOOD FUEL
Alongside residual materials and energy crops, wood is the most important pillar of the bioenergy sector in Germany. Residual wood from forestry is obtained when wood is processed from forests and industrial wood residues arise at a further stage of production, for example as by-products of sawmills. Waste wood (e.g. used wooden pallets, old wooden furniture) has previously been used for other purposes and can be reused to produce energy. Wood residues from landscape maintenance can also be used, for example.
See also >Wood pellets, >Wood chips

WOOD PELLETS
Combustible wooden material pressed into pellet form. Fully-automatic modern heating systems can operate on wood pellets. Grants are available for wood pellet heating systems under the market incentive programme. Wood pellets are pressed out of dried natural wood residues (sawdust, shavings, residual wood from forestry) without using chemical binding agents.
See also >Wood fuel, >Wood chips

BMWi	Federal Ministry for Economic Affairs and Energy
bn	billions
BUND	Bund für Umwelt und Naturschutz Deutschland
BtL	Biomass to Liquid
CH_4	methane
CHP	combined heat and power
CO_2	carbon dioxide
EEG	Renewable Energy Sources Act (Germany)
EGS	Enhanced Geothermal Systems
ENLAG	Power Grid Expansion Act (Germany)
ENTSO-E	European Network of Transmission System Operators for Electricity
Fig.	figure
GW	gigawatt (1,000 megawatts)
H_2	hydrogen
ha	hectare
HDR	Hot dry rock process
HGV	Heavy Goods Vehicle
HVDC	high-voltage direct current
KfW	Kreditanstalt für Wiederaufbau
kJ	kilojoule
kV	kilovolt
kW	kilowatt
kWh	kilowatt-hour
kWh_{el}	kilowatt-hour electric
kWh_{th}	kilowatt-hour thermal
kWp	kilowatt-peak
LED	light-emitting diode
LHV	Longer Heavier Vehicle
m	millions
MW	megawatt (1,000 kilowatts)
NABU	Naturschutzbund Deutschland e. V. (Nature And Biodiversity Conservation Union)
ORC	Organic Rankine Cycle
p.a.	per year
PCI	Projects of common interest
PJ	petajoule
PR	performance ratio
PSPP	pumped-storage power plant
P2G	Power to Gas
PtL	Power to Liquid
PV	photovoltaics
RES	renewable energy sources
ROR	run-of-river power plant

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