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Nationale Akademie
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DEUTSCHE AKADEMIE DER
TECHNIKWISSENSCHAFTEN

UNION
DER DEUTSCHEN AKADEMIEN
DER WISSENSCHAFTEN

December 2021
Discussion Paper

If not now, then when – making the energy transition happen

German National Academy of Sciences Leopoldina
acatech – National Academy of Science and Engineering
Union of the German Academies of Sciences and Humanities

Discussion Paper

The new German government has one last opportunity – but also a responsibility – to carry out an urgently needed reboot of its climate and energy policy, systematically realigning it with the goal of greenhouse gas neutrality. This reboot should be guided by the following principles:

- First and foremost, climate action must be a clear priority at a national policy level. It is not enough simply to strengthen existing measures.
- At the same time, Germany must also strengthen cooperation at a European and global level. This should include financial support for climate action in other countries.
- It is vital not to lose sight of the overall system. Sectoral and national targets can be useful for clarifying political responsibility. However, the energy transition will only succeed if they are centrally managed and aligned with the overall goal.
- It is perfectly possible to deliver effective climate policy that is also socially compatible. Targeted measures can be taken to level out the social impacts of the transformation.
- Finally, it will be essential to transparently communicate the implications of systematic climate action for households and businesses. It is important to remind people that if we do not act to limit climate change, the consequences will be far worse.

Based on the above principles, this paper sets out eleven priority action areas and a series of concrete measures.

Guidelines for effective energy and climate policy

The energy transition is our big opportunity to preserve our natural resources by taking sustainable measures to tackle climate change. It is also ushering in a global technology revolution. But its success will depend on our ability to reboot climate and energy policy, systematically realigning it with the goal of greenhouse gas neutrality. Piecemeal changes to the existing framework will not be enough to transform the energy system as profoundly and rapidly as necessary. In this discussion paper, the Academies' Project "Energy Systems of the Future" presents a series of guidelines that are key to delivering an energy policy that is fit for the future. The paper also describes the measures that the new German government must take to align the energy transition with the new climate targets.

Unless we make significant progress in transforming the energy system in Germany and the rest of the world over the next few years, anthropogenic climate change threatens to destroy the resources that our civilisation relies on and radically transform our everyday environment in a way that jeopardises our very existence. It is impossible to predict what the consequences might be for our societies. And this isn't some alarmist doomsday scenario – it is the global scientific consensus. Our only hope of averting this threat is to stop using fossil fuels altogether and bring about a global energy transition that replaces them with abundant forms of renewable energy. And there is no time to lose.

The term of the current parliament in Germany is our last chance to get ourselves on the right track. If we leave it any longer, the cost of the transition to climate neutrality will be significantly higher, and the final outcome uncertain. The incoming German government must lay the foundations for effective climate action in Germany and Europe by realigning its energy policy. The following principles will be key:

Prioritise climate action: Despite all the measures that have been taken, Germany has repeatedly failed to meet its national and European climate targets for several years. Many measures don't go far enough or aren't implemented with sufficient rigour, while technologies that are harmful to the climate continue to be subsidised. A genuinely effective climate policy requires political will on a scale not yet seen.

Drive progress in global climate policy: To succeed, climate action must be global. Germany must strengthen its efforts to promote European and global cooperation, not least by providing other countries with financial support. But in doing so, it must not be allowed to neglect climate action in Germany, since, like every other country in the world, it too will need to become climate-neutral within a few short decades.

Don't lose sight of the overall system: An integrated climate policy provides an overall framework for government, industry and civil society. It is managed systemically under the central responsibility of government and parliament, and promotes the cross-sectoral development of the relevant science and technology as a source of innovative solutions. If the energy transition is to succeed, it is vital to ensure that sectoral targets and individual measures do not cause us to lose sight of the overall goal.

Ensure that climate policy is socially compatible: Climate policy measures can present particularly difficult challenges for poorer households. But a well-designed climate policy can level out these social impacts. Moreover, the consequences of failing to act on climate change would be disproportionately higher.

Be honest about it: Concerted action to protect the climate will transform our modern lifestyle and pose major challenges for the economy. While new markets will emerge, some old business models with a long-established tradition will disappear. Rather than attempting to conceal them, the implications of policy measures for households and businesses should be communicated transparently.

11 priority action areas for a successful energy transition

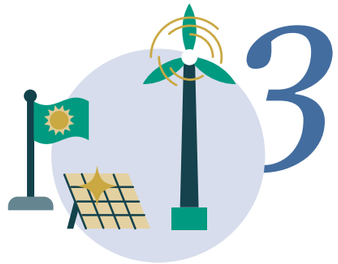
Take responsibility and develop whole system solutions

In order to drive the energy transition at every level, Germany should do everything in its power to promote the European Green Deal and help poorer countries around the world to tackle climate change. It must also seek to pool, systematically utilise and increase the relevant knowledge and develop joint solutions with the stakeholders.

Displace fossil fuels

Carbon pricing should be strengthened as the key instrument for reducing fossil fuel consumption. At the same time, government should provide targeted support for investment in the necessary infrastructure, such as hydrogen and electricity grids, EV charging stations and long-term storage systems.

Expand renewables faster



If the climate targets are to be met, wind and solar capacity will need to increase by between 15 and 25 gigawatts a year. This is three to four times the rate achieved in recent years. The governments of Germany's federated states must make sufficient land available for this expansion, while it will also be necessary to reform planning and licensing law and include local residents from an early stage.

Use more green electricity for heating and transport

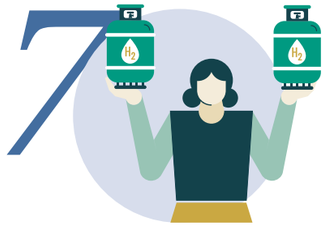
The key to reducing emissions in the heating and transport sectors is more competitively priced electricity – and the single most important measure for achieving this is the abolition of the EEG surcharge. It will also be necessary to build storage systems, reward flexibility, and leverage energy efficiency opportunities that make environmental and economic sense.

Make the electricity supply fit for the future

In the future, the electricity supply will be more connected, decentralised, flexible and participatory. In order to maintain a secure energy supply, it will be necessary to gear the system's technical and regulatory aspects towards renewable energy systems, significantly expand and digitalise the electricity grid, and build long-term storage systems.

Target climate-neutral industry

The German government can play a key part in driving the necessary transformation of industry by setting an effective carbon price, introducing Carbon Contracts for Difference for businesses, and striving to build a global climate action alliance, with Chinese and US participation a top priority.



Use hydrogen appropriately, leverage its opportunities

Hydrogen has a key role in enabling a climate-neutral global economy, both as a fuel and as a raw material. In order to ensure a secure, long-term hydrogen supply, urgent action is required to build global markets and infrastructure, establish equal partnerships, and ensure that the relevant areas of application are appropriately prioritised.

Use bioenergy where it benefits the system

A comprehensive biomass strategy must ensure that biomass is used where it delivers the greatest benefits, for instance in industry and as a liquid fuel for aviation and shipping. In the future, bioenergy should be derived from residual and waste material rather than energy crops.

Secure the supply of raw materials for the energy transition and use them sustainably

In order to meet the high demand for raw materials that will arise in connection with the energy transition, it will be necessary to reduce the amount of raw materials used to make products, exploit new sources of raw materials, and improve recycling rates.

Negative emissions: remove CO_2 from the atmosphere

In order to offset unavoidable emissions, especially from agriculture and parts of industry, techniques for removing CO_2 from the atmosphere will need to be publicly debated, researched and implemented.

Ensure that climate policy is transparent and just

To ensure public acceptance of and support for the energy transition, it will be necessary to communicate climate policy transparently, mitigate the associated burdens for poorer households, and take different social realities into account.

1. Take responsibility and develop whole system solutions

WHY DOES IT MATTER?

The international community has so far failed to respond adequately to the existential threat that climate change poses to humanity. Although it has set ambitious climate targets, it has not done enough to ensure that they are met. To meet the targets, climate change must be recognised at every level as an existential challenge for the whole of society, and must be placed **at the heart of decision-making and policy**. Individual citizens, businesses, local, regional and central government, the EU and the international community must all pull together to overcome this challenge.

WHAT MUST WE DO?

Coordinate at European and global level. The energy transition calls for a new decision-making culture, and the German government should take the lead on this project. It will need to create the necessary structures, ensure that the content and implementation of the European Green Deal are as ambitious as possible, and take action globally **in conjunction with the other EU member states**. The industrialised nations of Europe are responsible for a large proportion of historical emissions. Consequently, they have a duty to **contribute to globally effective solutions** – and they also have the **capacity** to do so. Germany and the rest of the EU can help poorer countries tackle and adapt to climate change by delivering projects and providing them with innovative technologies, infrastructure, model solutions and substantial financial support. An independent, science-based monitoring commission could assess progress towards a global energy transition, establish standard assessment criteria, and identify transferable examples of best practice in the policy, economic and social arenas.

Promote joint decision-making, facilitate local action. To tackle climate change effectively, the energy transition must be delivered on a global scale. However, concrete measures can and must be devised and implemented **at every level**, from the development of global and European markets for renewables and multi-regional and national power grids, to new systems and efficiency measures in municipalities, cities, districts, businesses and households. In order to encourage local citizens and businesses to contribute creative solutions and help co-design these measures, they should be included in the transformation process from an early stage and be offered **genuine opportunities to participate**.

Invest in climate-neutral infrastructure without delay. The future energy system will require different infrastructure to the current one, for example charging stations for electric vehicles, hydrogen pipelines and smart distribution grids. Government must **actively drive this transformation** by supporting the development of climate-neutral infrastructure and ending both direct and indirect support for technologies and infrastructure that damage the climate. It is not enough simply to base decisions on whether infrastructure can be operated profitably in the short term under current conditions – it is also essential to consider whether a particular infrastructure is necessary in order to meet the climate targets cost-effectively. Moreover, the goal of achieving climate neutrality by 2045 drastically limits the **scope for using bridge technologies** that reduce emissions compared to current levels but still use fossil fuels. Examples include using gas heating instead of oil, or hybrids instead of vehicles with combustion motor. By being among the first countries to establish a domestic market for the relevant products, Germany can help to achieve the goal of building a new global market and also benefit from exporting the necessary technologies.

Climate policy at a crossroads

Climate action must be the top priority for everyone, from private households to the international community. If we don't start doing the right things now, we will be forced to take much costlier measures and make much more difficult compromises to meet the Paris climate targets

What must we do?

Coordinate at European and global level

Promote joint decision-making, facilitate local action

Invest in climate-neutral infrastructure without delay

2. Displace fossil fuels

WHY DOES IT MATTER?

Around 80% of all greenhouse gas emissions are caused by burning coal, petroleum products and gas. Stopping these emissions as soon as possible is the single most effective thing we can do to tackle climate change. One of the key instruments for achieving this is **carbon pricing**, which makes it less attractive to use fossil fuels instead of climate-friendly alternatives. It is also necessary to ensure that appropriate **low-emission alternatives** are available. The impact of carbon pricing should therefore be strengthened and accelerated through a range of additional measures. The instrument mix should be simple and transparent, enable reliable, long-term planning, and be regularly reviewed to determine whether it is sufficient to ensure that the climate targets are met.

WHAT MUST WE DO?

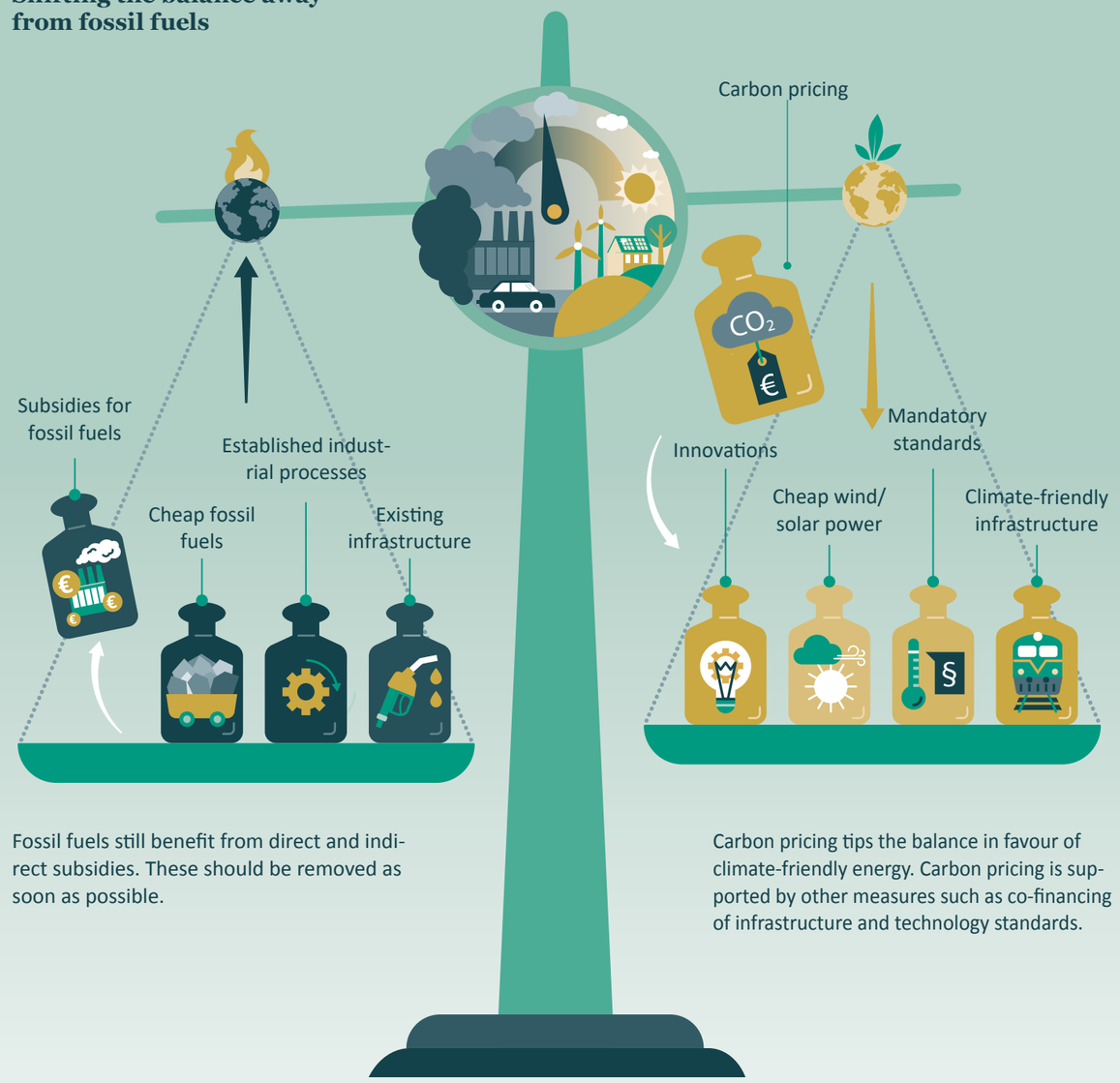
Align the different pricing systems in Europe. The EU emissions trading system (EU-ETS) sets an EU-wide carbon price that until now applied to power stations and energy-intensive industries. However, the European Commission's new Fit for 55 package includes plans to introduce an additional trading system for emissions from heating and transport. In order to stabilise expectations and achieve efficient long-term emission reductions, Germany must push for the **two emissions trading systems to be aligned** and to begin planning for the transition to an **overarching, EU-wide system** right away. The total number of CO_2 certificates should be set in accordance with the relevant climate targets, and the calculation method should be transparently communicated.

Adjust the national carbon price in Germany. Germany introduced a national carbon price for fuels used in heating and transport in 2021. To prevent dual pricing, it will be vital to review future carbon pricing in Germany before the new EU emissions trading system is introduced in 2026. Since the carbon price in the new EU emissions trading system will be aligned with the climate targets, it is likely to be higher than the price pathway currently planned in Germany. The latter should be **significantly increased** in order to stimulate early investment in low-emission technologies and prevent the risk of a sudden price hike when switching systems.

Stop subsidising fossil fuels. Direct and indirect subsidies for fossil fuels push down energy prices and **undermine the effect of carbon pricing**. These subsidies should be **stopped as soon as possible**. The EU is already planning to introduce a tax on kerosene and carry out a review of the Energy Taxation Directive in order to align it with environmental and climate objectives. Preferential national tax treatment for diesel and company cars, for example, should therefore be ended.

Create an effective national framework and support carbon pricing through other instruments. Additional instruments are necessary in order to provide targeted support for the effects of carbon pricing. It is especially important to encourage companies and private individuals to invest in climate-neutral **alternatives to high-emission plant and goods with long lifespans**, even if doing so doesn't or doesn't appear to make financial sense at the present time. Instruments that promote the development and introduction of climate-friendly alternatives can efficiently support the desired transformation of the economy if they are automatically removed once their goals have been achieved. The same applies to government co-financing of climate-friendly infrastructure, e.g. hydrogen pipelines, rail infrastructure and electric vehicle charging stations. Technology standards such as the EU's fleet-wide emission standards for new vehicles and building standards can support the transition to climate-friendly technologies until the carbon price reaches a sufficiently high level.

Shifting the balance away from fossil fuels



Fossil fuels still benefit from direct and indirect subsidies. These should be removed as soon as possible.

Carbon pricing tips the balance in favour of climate-friendly energy. Carbon pricing is supported by other measures such as co-financing of infrastructure and technology standards.

What must we do?

Align the different pricing systems in Europe

Adjust the national carbon price in Germany

Stop subsidising fossil fuels

Create an effective national framework and support carbon pricing through a range of measures

3. Expand renewables faster

WHY DOES IT MATTER?

Just under half of all electricity produced in Germany today already comes from renewable sources. But in a climate-neutral energy system, we will need enough green electricity to meet **all of our country's electricity demand**. And **demand for electricity is set to rise sharply** as heat pumps and electric vehicles become increasingly common in the building and transport sectors. In addition, large amounts of green electricity will be needed to replace fossil fuels in industry, while electricity is also necessary to produce climate-neutral fuels such as hydrogen for steel production, hydrocarbons to replace crude oil, and synthetic fuels for aviation and heavy goods vehicles. We must make full use of the significant untapped potential for affordable renewables that still exists in Germany, especially **solar power and onshore and offshore wind**. Since hydropower, bioenergy and geothermal energy can only make a relatively small contribution, wind and solar capacity will need to increase to **between four and six times** its current level by 2045, even if we import large quantities of green energy and achieve significant improvements in energy efficiency.

WHAT MUST WE DO?

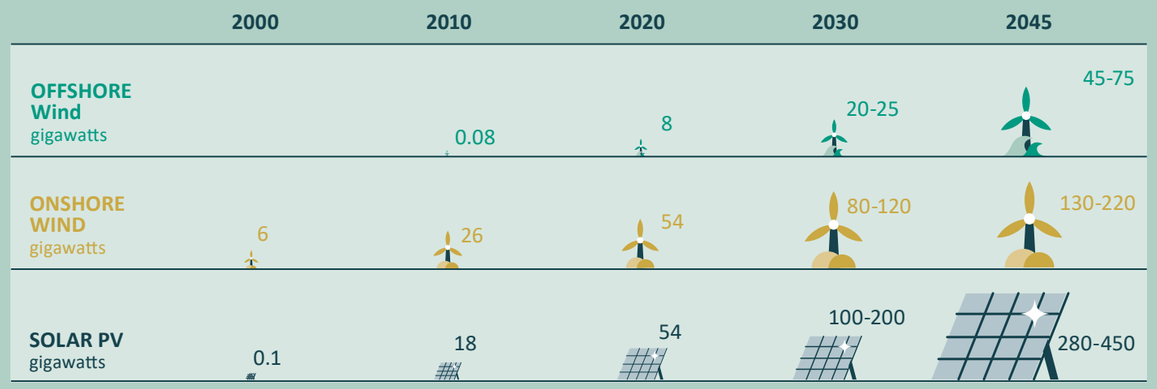
Significantly increase the statutory expansion targets. Meeting the new climate targets and the growing demand for green electricity in the heating and transport sectors will call for an annual increase of between 15 and 25 gigawatts. While this is a lot more than the 6 gigawatt increase achieved in 2019, in principle it should still be feasible – in the past, Germany has already managed to build as much as 10 gigawatts of additional wind and solar PV capacity in a single year. The projected increase in demand for green electricity should be reflected in the **statutory expansion pathways**. Regional and local government in Germany should be required to make sufficient land available for this expansion as soon as possible, so that the relevant targets can be met. Moreover, the national targets should be incorporated into the overall European strategy.

Use the available space smartly. The new solar and wind installations will require space. Dual-use solutions can **reduce the amount of space needed** and **defuse land use conflicts**. For instance, solar and wind technology can be mounted on facades, car park canopies, or currently unused roof space. Dual-use solutions are also possible in the agricultural sector, where space can be saved by designing solar parks that double up as cropland, pasture or habitat to support biodiversity.

Actively include local residents. Local support is absolutely vital to the expansion of renewable energy. Sociological and behavioural economics studies have found that **providing more opportunities to participate**, **offering compensation for negative impacts** and encouraging the **financial involvement of local authorities and residents** helps to ensure that people welcome the changes associated with the energy transition and actively engage in shaping them.

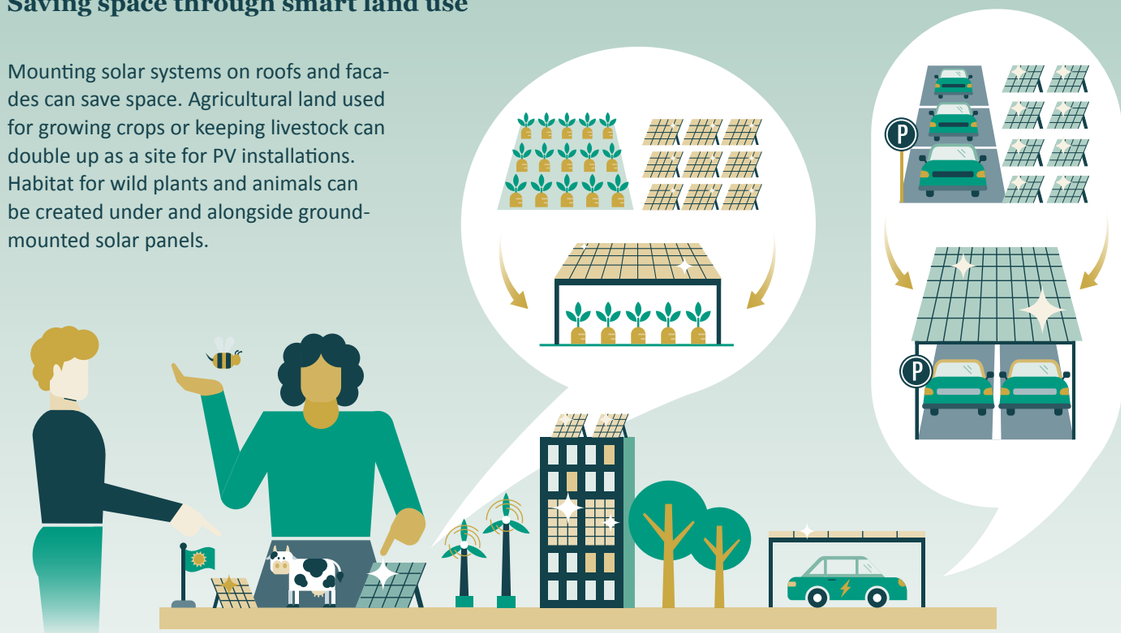
Speed up the procedures. The current rate of progress wil not be enough to achieve the expansion required by 2030. The planning and licensing procedures for wind farms currently take between **four and five years**. These procedures can be accelerated by implementing changes in planning law, including the public from an early stage, and recruiting additional personnel in the responsible planning and licensing authorities and courts.

We need 4 – 6 times our current wind and solar capacity to meet the climate targets



Saving space through smart land use

Mounting solar systems on roofs and facades can save space. Agricultural land used for growing crops or keeping livestock can double up as a site for PV installations. Habitat for wild plants and animals can be created under and alongside ground-mounted solar panels.



What must we do?

Significantly increase the statutory expansion targets

Use the available space smartly

Actively include local residents

Speed up the procedures

4. Use more green electricity for heating and transport

WHY DOES IT MATTER?

While the increase in wind and solar capacity has reduced emissions from electricity generation, emissions from heating and transport are stagnating. **Fossil fuels must now be replaced by green electricity** in these sectors, too ("sector coupling"). However, since even in the future Germany and other countries will not have an unlimited supply of green electricity, it remains important to use electricity as efficiently as possible. Since some energy is lost during every conversion stage, it is generally more efficient to use electricity directly than to convert it e.g. into hydrogen. Electric motors and heat pumps, for instance, use significantly less energy than internal combustion engines and conventional heaters. In the long run, these technologies can thus help to reduce the overall energy demand that will need to be met by green electricity. Where feasible and appropriate, electricity can be supplemented by deep geothermal and solar thermal energy.

WHAT MUST WE DO?

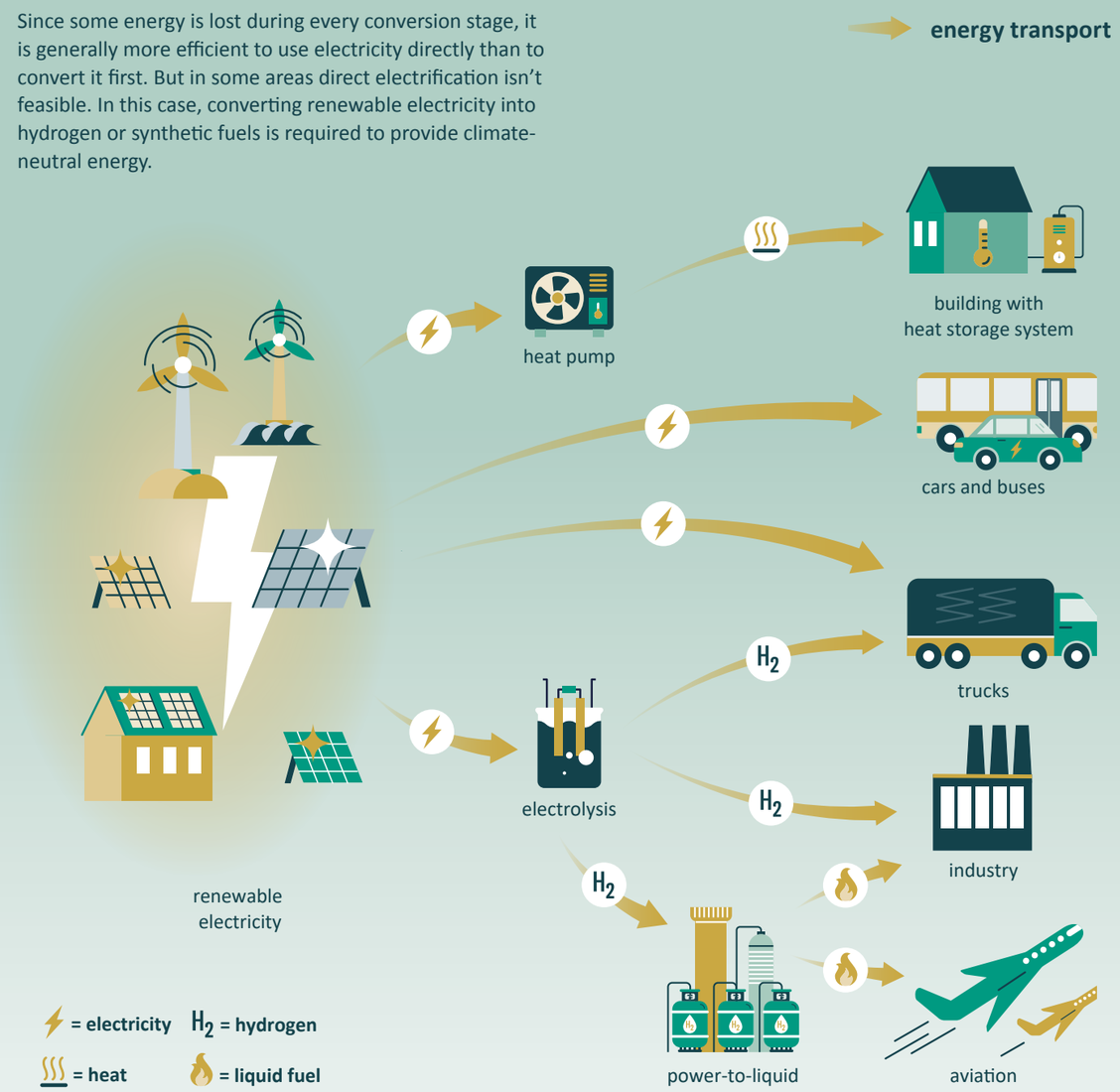
Create a level playing field for different types of energy. The prices that households and businesses pay for different types of energy influence which ones they use. However, the current pricing system is distorted – electricity is much more heavily taxed than heating oil and natural gas, for example. Following the introduction of carbon pricing for the heating and transport sectors through the fuel emissions trading system, the most important step that can now be taken is to bring the price of electricity down by **abolishing the EEG surcharge**. Support for renewable energy generation should instead be delivered through other forms of government funding. This could be done – at least to a large extent – by using the revenue from German and European carbon pricing. In addition, the new German government should contemplate **reducing tax on electricity**. As well as promoting electricity use, bringing down the price of electricity would lessen the burden on households and businesses, while the complex EEG surcharge exemptions would also disappear. An effective price reform will require private households in particular to be provided with detailed information about the cost benefits – consumers need to understand that using electricity instead of fossil fuels to heat their homes and power their vehicles will generally work out cheaper for them in the long run, as carbon prices rise.

Increase the number of electric vehicles, storage systems and heat pumps. Only climate-neutral technology will be permitted in a climate-neutral Germany in 2045. Consequently, any high-emission vehicles and heating systems bought after 2030 will have to be scrapped before they reach the end of their technical service life. Strong and immediate growth in the proportion of **electric vehicles** and **heat pumps** is thus essential. In the interests of security of supply, it is also necessary to increase the number of **electricity storage and heat storage systems** in order to balance the fluctuating supply of renewables. Government can support this growth by **subsidising** large-scale investments and through targeted **co-financing** of the necessary infrastructure. **Non-monetary incentives** such as electric vehicle only lanes and parking spaces can also help with the transition to climate-neutral mobility.

Reward flexibility. In addition to storage systems, flexible consumers such as electric vehicles and flexibly operated industrial systems will also be needed to balance out fluctuations in the supply of renewable energy. They can do this by charging and operating mainly at times when a lot of electricity is being generated. The technologies already exist, but we do not yet have the requisite **business models or the necessary level of digitalisation**. The regulatory framework should be modified to create incentives for flexible consumption, for instance through time-dependent electricity tariffs.

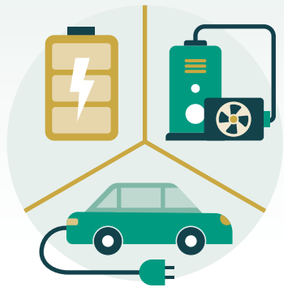
Green electricity for heating and transport

Since some energy is lost during every conversion stage, it is generally more efficient to use electricity directly than to convert it first. But in some areas direct electrification isn't feasible. In this case, converting renewable electricity into hydrogen or synthetic fuels is required to provide climate-neutral energy.



What must we do?

Create a level playing field for different types of energy



Increase the number of electric vehicles, storage systems and heat pumps

Reward flexibility

5. Make the electricity supply fit for the future

WHY DOES IT MATTER?

The electricity supply is becoming **more connected, decentralised, flexible** and **participatory**. Wind and solar farms are feeding fluctuating amounts of electricity into the grid, home owners, farmers and renewable energy communities are all using their own installations to generate electricity, and there are plans to increase cross-border electricity trading within Europe. At the same time, demand for electricity is growing and could even double due to new consumers such as electric vehicles and heat pumps. All of this is posing **new challenges** for the electricity infrastructure and market. Fundamental changes must be made to the electricity system if we are to maintain high security of supply and keep costs as low as possible in years to come.

WHAT MUST WE DO?

Put renewables at the heart of the system. Until now, we have tried to shoehorn renewables into a system dominated by coal, natural gas and nuclear power by establishing special rules for them. But with renewables now accounting for almost half of all electricity generated, the time has come for a **paradigm shift**. In order to achieve a rapid and affordable transition to 100% renewable energy, the entire electricity system must be adapted to the requirements of wind and solar electricity generation. This will involve technical, economic and regulatory reforms.

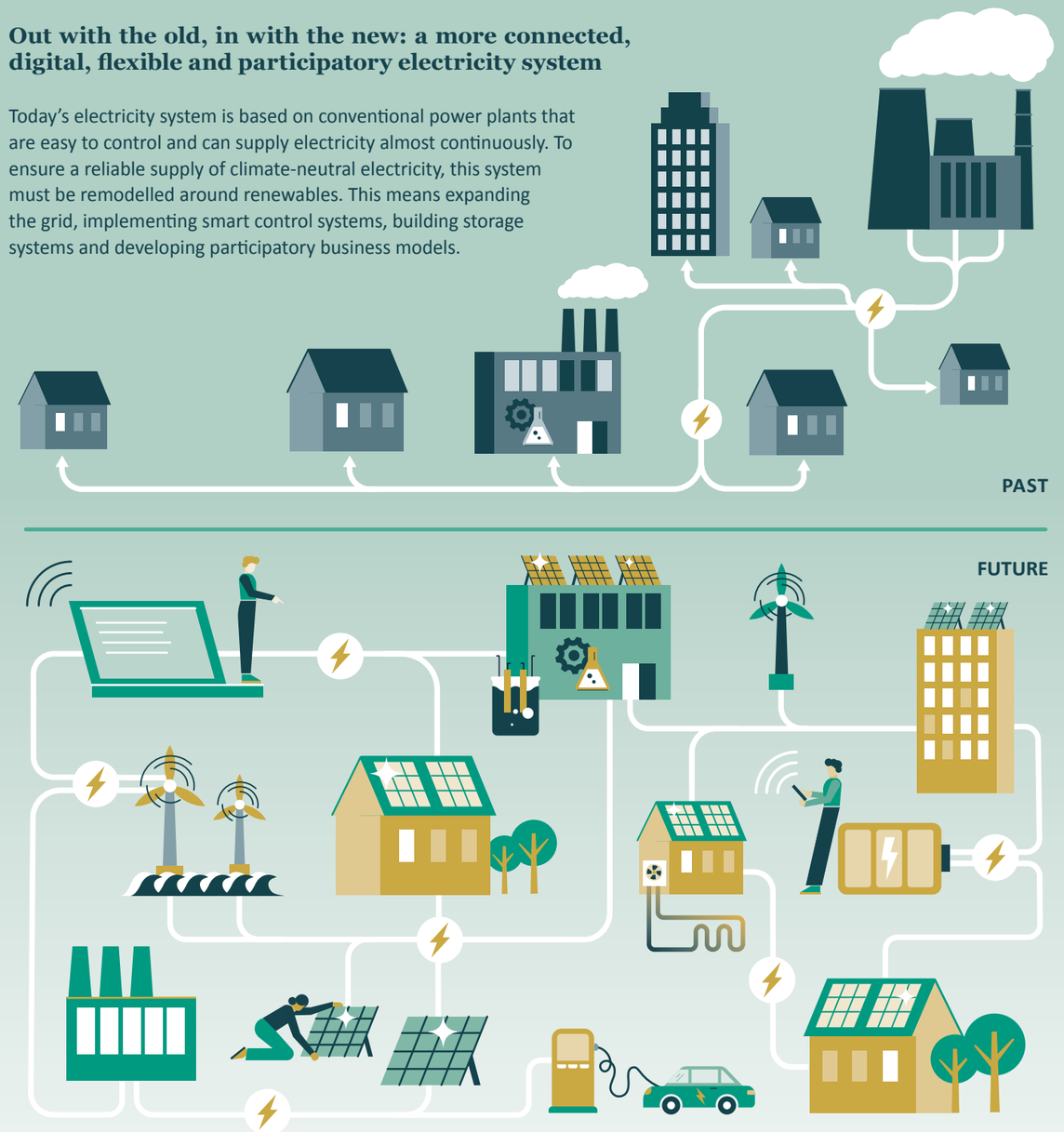
Expand the electricity grid. Even if large numbers of decentralised generators supply electricity locally, it will not be possible to achieve the energy transition without expanding and improving the performance of electricity grids at every voltage level, so that they can distribute and balance a growing, spatially and temporally variable input. Moreover, ensuring that grids throughout Europe are closely connected to each other will make it possible to harness weather-related regional input differences to provide electricity for everyone. **Grid expansion plans** must be rapidly and systematically aligned with the **goal of achieving climate neutrality by 2045**. This will prevent public confidence from being undermined by constant readjustments of the grid expansion targets.

Accelerate digitalisation. Accelerating the digitalisation of the energy system is key to coordinating the large number of decentralised generators, storage systems and consumers. Digitalisation will make it possible to **achieve a better balance between supply and demand in the electricity market**, thereby **stabilising the grid**. However, it will also be necessary to develop strategies to protect the digitalised energy system against software bugs and cyber attacks (resilience) and to prevent breaches of consumer privacy through effective data protection.

Enable and secure long-term investment. As well as more renewables, the electricity system of the future will also need back-up capacity and long-term storage to cover those times when there is not enough wind and solar power. There is no consensus about whether the current electricity market can offer enough long-term security to guarantee investment in the necessary systems. This question should be thoroughly investigated so that we can start setting the course for **tomorrow's electricity market** as soon as possible.

Out with the old, in with the new: a more connected, digital, flexible and participatory electricity system

Today's electricity system is based on conventional power plants that are easy to control and can supply electricity almost continuously. To ensure a reliable supply of climate-neutral electricity, this system must be remodelled around renewables. This means expanding the grid, implementing smart control systems, building storage systems and developing participatory business models.



What must we do?

Put renewables at the heart of the system

Expand the electricity grid

Accelerate digitalisation

Enable and secure long-term investment

6. Target climate-neutral industry

WHY DOES IT MATTER?

Industry is responsible for around one third of global greenhouse gas emissions, and a significant proportion of these emissions is linked to the production of basic materials such as steel, cement and plastic. The fact that industrial facilities have a lifespan of several decades means that there is a particularly high risk of long-term dependency on high-emission processes, often referred to as carbon lock-in. A three-pronged approach is required to reduce emissions from industry: (i) **reduce demand for basic materials** through enhanced material efficiency and by using products longer and more intensively; (ii) **close material cycles** as part of a circular economy approach, for instance by designing products so that their materials can be easily separated and recycled; (iii) **make production processes and raw materials climate-neutral** through electrification and by using green hydrogen and domestically produced green hydrogen-based hydrocarbons.

WHAT MUST WE DO?

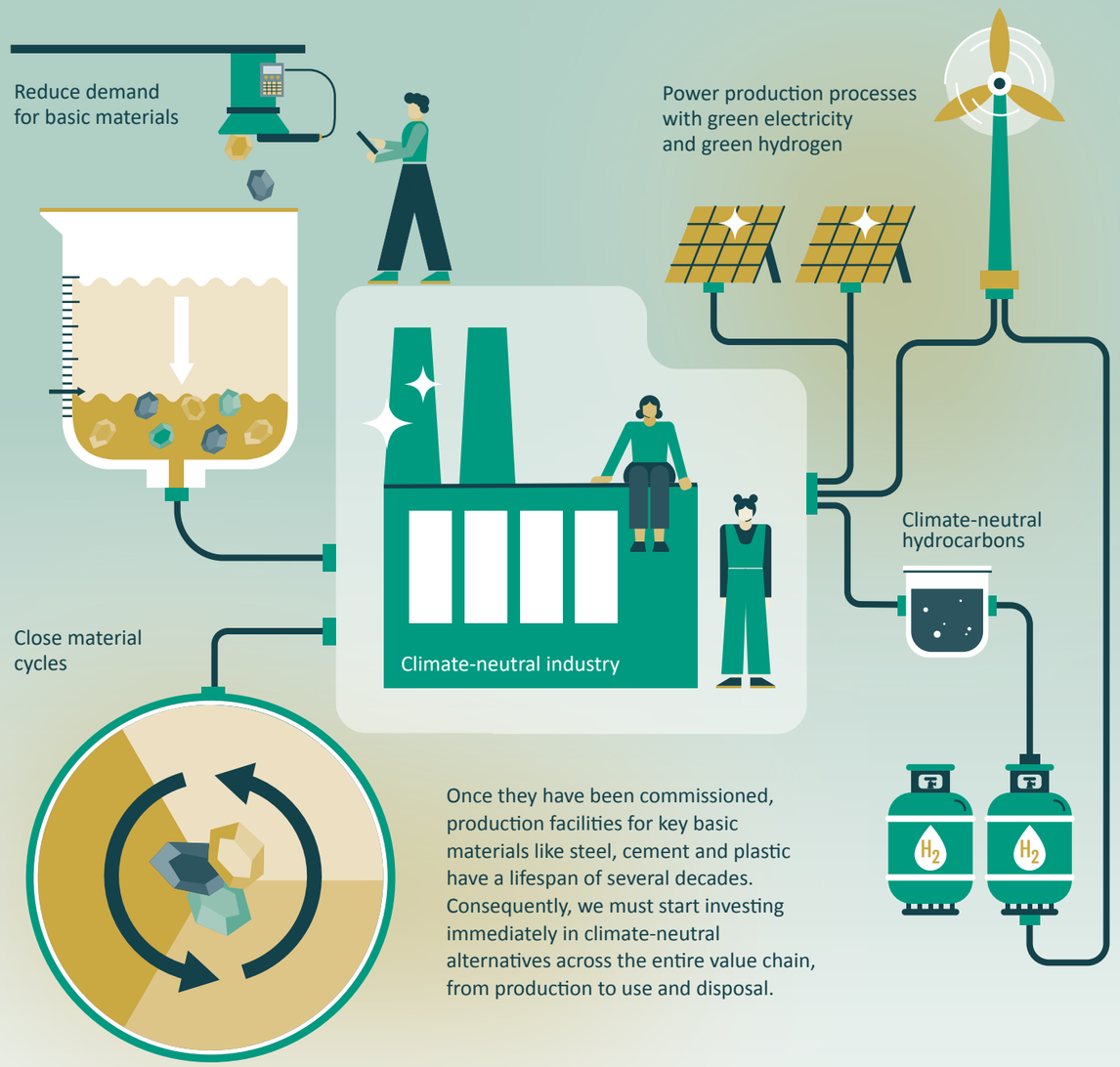
Ensure that climate-neutral products can compete in the global market. The Fit for 55 package creates an awkward dilemma for the European Commission. On the one hand it needs to create strong incentives for effective climate action in Europe, while on the other it also has to prevent carbon leakage by taking measures to stop industrial enterprises from moving production to countries with less stringent climate policies. The German government must do everything in its power to forge **a climate action alliance** that includes the US and China as soon as possible. The unilateral introduction of a carbon border adjustment mechanism by the EU would be a highly risky policy.

Stimulate investment through Carbon Contracts for Difference. The carbon prices in the EU emissions trading system are likely to be too low, both now and in the near future, to ensure the market success of key climate-neutral production processes. Carbon Contracts for Difference (CCfDs) can help to overcome this problem by encouraging companies to press ahead with **investments in climate-friendly processes**. By fully compensating the difference in cost between climate-neutral and conventional processes, CCfDs allow businesses to invest with confidence. This is extremely important, since many existing facilities are due significant reinvestment in the period between 2020 and 2030. One key benefit of CCfDs is that government support is reduced as carbon prices rise. Once the carbon price reaches a sufficiently high level, the subsidies are automatically terminated.

Support the circular economy and climate-friendly materials at national and EU level. Closing material cycles can help to reduce emissions and environmental costs that until now have been largely overlooked in terms of pricing. Measures to promote a **circular economy and the use of climate-friendly materials** are needed across the entire value chain – from the choice of basic materials and the production of goods right through to the waste management process. Examples include the product design standards in the EU's Ecodesign Directive, and incentives created through charging structures for the Green Dot and deposit return schemes.

Develop the necessary infrastructure in good time. If industry is to achieve climate neutrality, it will need large quantities of competitively priced green electricity and green hydrogen, with a safe transport infrastructure. For unavoidable process emissions, e.g. from the cement and lime industry, it will be necessary to build carbon capture systems and the associated transport infrastructure, and to develop appropriate carbon storage sites (Carbon Capture and Storage). While the relevant changes in licensing law will need to be made as soon as possible, the priority must be to engage in a public debate about this technology, which remains controversial in Germany.

Investing in the future: laying the foundations for climate-neutral industry



Once they have been commissioned, production facilities for key basic materials like steel, cement and plastic have a lifespan of several decades. Consequently, we must start investing immediately in climate-neutral alternatives across the entire value chain, from production to use and disposal.

What must we do?

Ensure that climate-neutral products can compete in the global market

Stimulate investment through Carbon Contracts for Difference

Support the circular economy and climate-friendly materials at national and EU level

Develop the necessary infrastructure in good time

7. Use hydrogen appropriately, leverage its opportunities

WHY DOES IT MATTER?

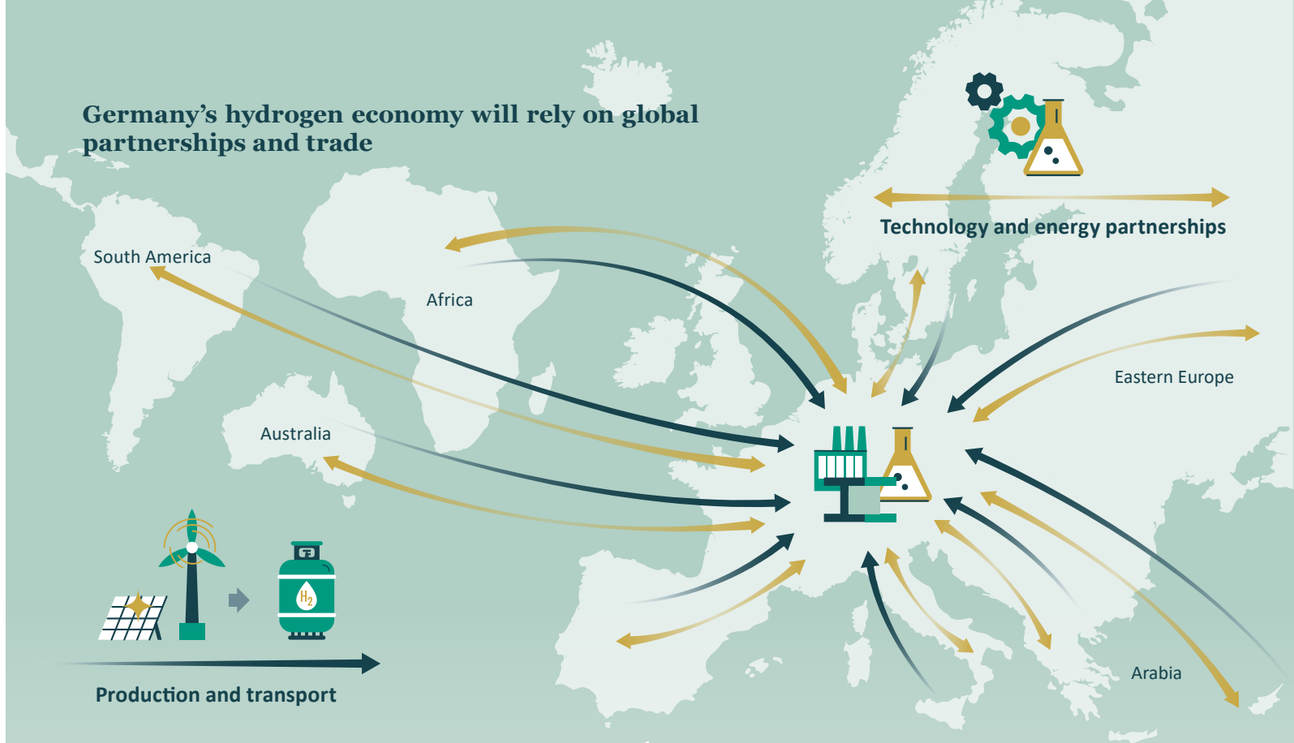
Hydrogen has a key role in enabling a climate-neutral energy supply. Hydrogen and hydrogen-based synthesized products (such as ammonia, methanol, synthetic kerosene and other hydrocarbons) can **store energy from the wind and sun and allow it to be transported and used in a variety of different ways**, including applications where it is not possible to use green electricity directly. Hydrogen-based energy carriers can also be imported from distant countries with more wind and solar resources than Germany. This will be vital, since it is likely that, in the future, Germany will still lack sufficient domestic resources to meet its demand for energy and for the hydrocarbons used as raw materials in the production of things like plastic, fertilizer and pharmaceuticals.

WHAT MUST WE DO?

Cooperate as equals with partner countries, think European and global. A lot will need to happen in a short space of time if the climate targets are to be met. It will be necessary to create **global markets and value chains** for climate-neutral hydrogen, covering everything from its production to its transport and utilisation. Moreover, the relevant regulations will need to be amended and new ones introduced. It will be vital to create **stable, long-term partnerships** for hydrogen imports that also benefit people in the producer countries by creating local value. Continuous assessment of whether it is better to use renewable electricity locally will also be key. After all, it is no good for the climate if coal- and gas-fired power stations are used to supply local electricity because all the green electricity is being used to produce hydrogen for export.

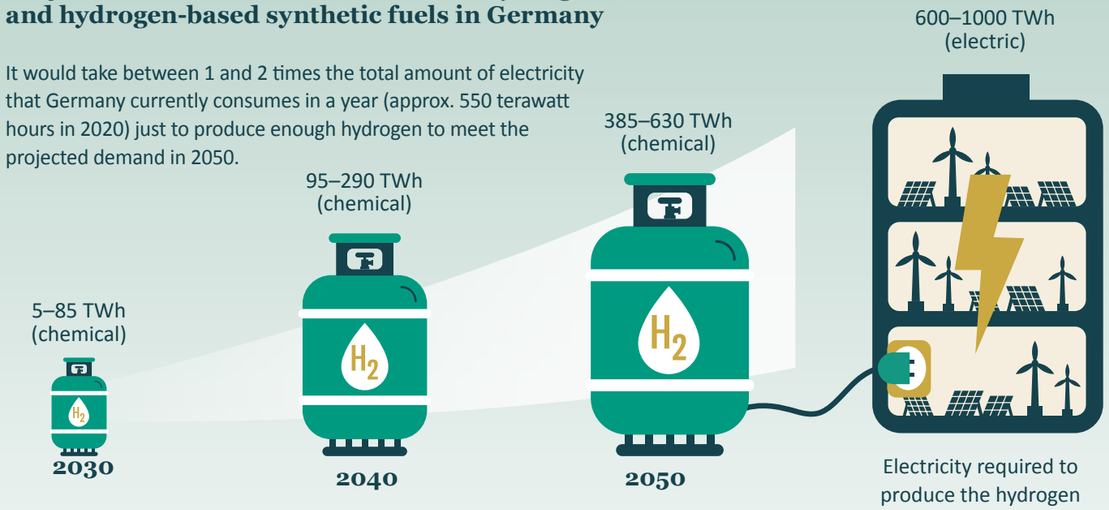
Be realistic about how much will be available, clearly prioritise areas of application. Germany already consumes around 1.7 million tonnes of hydrogen a year (approximately 55 terawatt hours). This hydrogen is mainly produced from natural gas and is mostly used by refineries and the chemical industry. It would take approximately 90 terrawatt hours of electricity just to meet this level of demand with green hydrogen – equivalent to around 15% of the electricity currently generated in Germany each year. And much higher amounts of electricity will be needed if we also want to use green hydrogen as a fuel and raw material in industry. In view of these **huge electricity requirements**, it is important **to be realistic** about hydrogen's potential and how much of it will be needed in both the short and the longer term. The expectation that we will be able to import hydrogen in the future must not result in the postponement of measures such as the electrification of road transport and heating, the expansion of renewables and efforts to reduce energy consumption. Since there will initially only be a **limited supply** of green hydrogen and green hydrogen-based liquid fuels, these should be used first and foremost for applications where electricity cannot (yet) be used directly, such as steel production, aviation and shipping.

Strengthen R&D, build infrastructure. **R&D** must be accelerated and large-scale **demonstration projects** established to help hydrogen technologies make the leap from the drawing board to practical applications. The infrastructure for storing hydrogen and transporting it both within Germany and internationally must also be built as quickly as possible. Appropriate **government support** will be key to making this possible. Of particular importance are those plants that are due to receive long-term investments in the next few years, and for which **switching to hydrogen is likely to be the only alternative**. In the steel industry, for example, fossil fuel-based hydrogen could be used for a limited transition period in order to prevent long-term investments in conventional technologies. In this scenario, it would be necessary to establish a regulatory framework requiring a gradual transition to 100% green hydrogen.



Projected demand for climate-neutral hydrogen (H2) and hydrogen-based synthetic fuels in Germany

It would take between 1 and 2 times the total amount of electricity that Germany currently consumes in a year (approx. 550 terawatt hours in 2020) just to produce enough hydrogen to meet the projected demand in 2050.



What must we do?

Cooperate as equals with partner countries, think European and global

Be realistic about how much will be available, clearly prioritise areas of application

Strengthen R&D, build infrastructure

8. Use bioenergy where it benefits the system

WHY DOES IT MATTER?

Biomass is the only renewable energy source that exists in material form. It can be used to generate electricity and heat or as a biofuel, and is also increasingly being used by manufacturing industry to replace climate-wrecking materials and raw materials such as petroleum, concrete and steel. On the other hand, the cultivation of energy crops such as maize, oilseed rape and oil palms requires large areas of land and can damage the soil, cause water pollution and harm biodiversity. Moreover, biomass has a much lower energy yield per unit of area than solar power. It is also important to ensure that growing energy crops does not further compromise our ability to feed the rising global population, especially at a time when agriculture is facing increasing threats due to climate change. And it should be remembered thatusing wood to produce energy only in some cases actually contributes to reducing harmful emissions. Since **there is only a limited supply of sustainably produced biomass**, it should be used in a way that generates the greatest benefits for the system as a whole.

WHAT MUST WE DO?

Implement a comprehensive bioenergy strategy. At present, bioenergy is used in various different ways. Wood is mainly used for heating, while agricultural biomass ("energy crops") is used to produce biogas, primarily for generating electricity and heat, or liquid biofuels. As the supply of wind and solar power grows, bioenergy applications should be adapted accordingly, ensuring that bioenergy is only employed to **complement green electricity as and where necessary**. A comprehensive bioenergy strategy should ensure that biomass is used where wind and solar power cannot be used directly, i.e. in **industry** and **aviation**, and to **generate electricity** in flexible biogas plants **at times when little or no wind and solar power is being generated**.

Use residual and waste material instead of growing biomass crops. Currently unused wood waste, straw and animal excrement have considerable potential. If greater use were made of these resources to **produce energy**, they could **gradually replace energy crops** without reducing overall bioenergy use. This would maintain the benefits of bioenergy for the energy system while at the same time minimising the threats to nature, the environment and food security.

Consider the global repercussions of using bioenergy in Germany. In view of the associated environmental threats, the use of timber and agricultural raw materials to produce energy should not be increased – the resulting **land use intensification would put even more pressure on nature and the environment**. Since timber and agricultural raw materials such as vegetable oils are traded on global markets, their use in Germany can have repercussions for ecosystems all over the world. Germany should promote effective global instruments to protect our forests and ensure climate- and nature-friendly land use. As well as bioenergy, these instruments should encompass all other agricultural and forestry products. Only very limited use of bioenergy should be allowed until these instruments take effect.

Trial bioenergy with carbon capture and storage (CCS). It is possible to use bioenergy to power industrial facilities and capture the resulting CO_2 emissions. If this CO_2 – previously removed from the atmosphere by the plants making up the biomass – is stored underground using carbon capture and storage (CCS) technology, the net effect is to **reduce the amount of CO_2 in the atmosphere** ("negative emissions"). Alternatively, the CO_2 can be used to produce climate-neutral synthetic fuels or hydrocarbons for industrial use, for example.

Producing sustainable bioenergy and using it smartly

What must we do?

Implement a comprehensive bioenergy strategy

Use residual and waste material instead of growing energy crops

Consider the global repercussions of using bioenergy in Germany

Trial bioenergy with carbon capture and storage (CCS)

9. Secure the supply of raw materials for the energy transition and use them sustainably

WHY DOES IT MATTER?

Wind turbines, solar PV systems, storage systems and electric vehicles are all made from metals such as steel and copper, as well as rare earth elements, cobalt and lithium. For some of these metals, Germany and Europe are even more reliant on imports from a handful of countries than they are for mineral oil. Supply shortages for these raw materials could hamper the development of a climate-friendly energy supply. An **active raw material policy** is needed to guarantee the supply of the raw materials needed for the energy transition. After all, it is easier to overcome individual supply shortages if the raw materials are sourced from several different suppliers. At the same time, alternative products and manufacturing processes should be promoted in order to reduce demand for critical raw materials.

WHAT MUST WE DO?

Reduce raw material consumption by being smart about how we produce and use products. We can reduce raw material consumption by making **longer-lasting, more easily repairable products and making better use of them** (e.g. through solutions like carsharing, where several people share a single product). The amount of raw materials needed to make products can also be reduced through lightweight design and by preventing material loss during the manufacturing process. Moreover, **concerted materials research** can help to find more readily available replacements for critical raw materials.

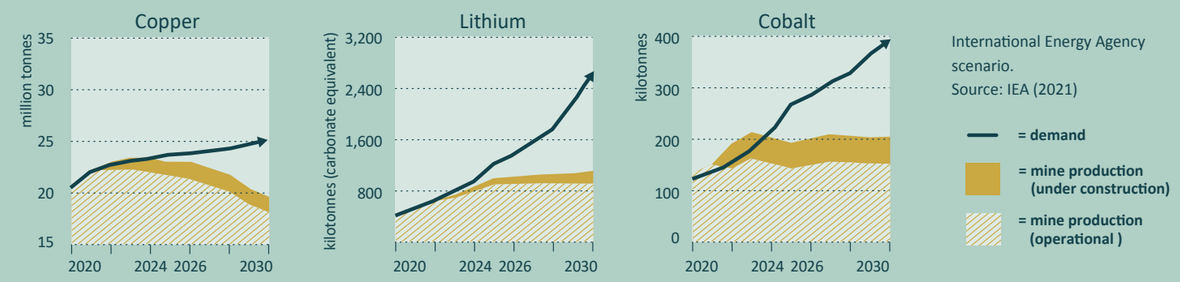
Improve recycling. While steel, aluminium and copper are already widely recovered from scrap metal, recycling rates for high-tech raw materials such as the rare earth elements, indium and gallium remain very low. In order to reduce reliance on imports, the German government should take measures to increase recycling rates. **Efficient recovery of valuable raw materials** must be enabled and promoted throughout the entire product life cycle. This should include everything from recyclable product design and more consumer-friendly collection systems to stricter export controls on used goods in order to prevent the illegal export of electronic waste, and waste legislation stipulating high recycling standards for special and precious metals.

Exploit untapped raw material sources in Europe. Even if it were hypothetically possible to recycle everything, this would still not be enough to fully meet the growing demand for raw materials without some mining. **Stepping up mining activity in Europe again** would make us less dependent on politically unstable countries and the countries that dominate the market. The recent change in German mining law to make it easier to mine lithium in Germany is a step in the right direction.

Help industry to secure our raw material supply, safeguard environmental and social standards. Germany should work internationally to promote open and transparent raw material markets and support private-sector supply relationships through trade agreements and intergovernmental treaties. Strategic investment in raw material projects can also help to **improve security of supply**. As well as being a moral imperative, **improving environmental and social standards around the world** is key to ensuring a level playing field in both the mining industry and the recycling sector. Binding transparency mechanisms can force companies to disclose their production conditions.

The energy transition will push up demand for raw materials

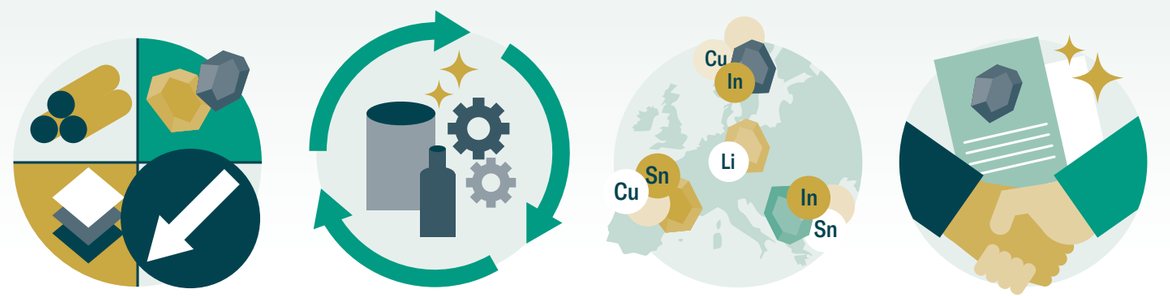
The transformation of the energy system will push up demand for mineral resources. Meeting this demand will require the development of additional mining capacity over the next 10 years. Projections by the International Energy Agency (IEA) show how demand could grow for the key raw materials used in clean energy technologies.



Supporting the energy transition through an active raw material policy

An active raw material policy would reduce material consumption and critical raw material dependency, improve recycling and exploit new mining opportunities.

What must we do?



Reduce raw material consumption by being smart about how we produce and use products

Improve recycling

Exploit untapped raw material sources in Europe

Help industry to secure our raw material supply, safeguard environmental and social standards

10. Negative emissions: remove CO_2 from the atmosphere

WHY DOES IT MATTER?

Even in the best-case scenario, it is probable that agriculture and some parts of industry will still be emitting greenhouse gases in 2045. Offsetting these emissions is the final piece in the puzzle of achieving climate neutrality. This will call for techniques capable of removing CO_2 from the atmosphere and storing it permanently, sequestering it in vegetation and soil, or locking it into long-lived products such as construction timber. According to the IPCC, from the middle of this century on we will actually need to remove more greenhouse gases from the atmosphere than we emit if we are to limit global warming to 1.5°C. This is referred to as net negative emissions.

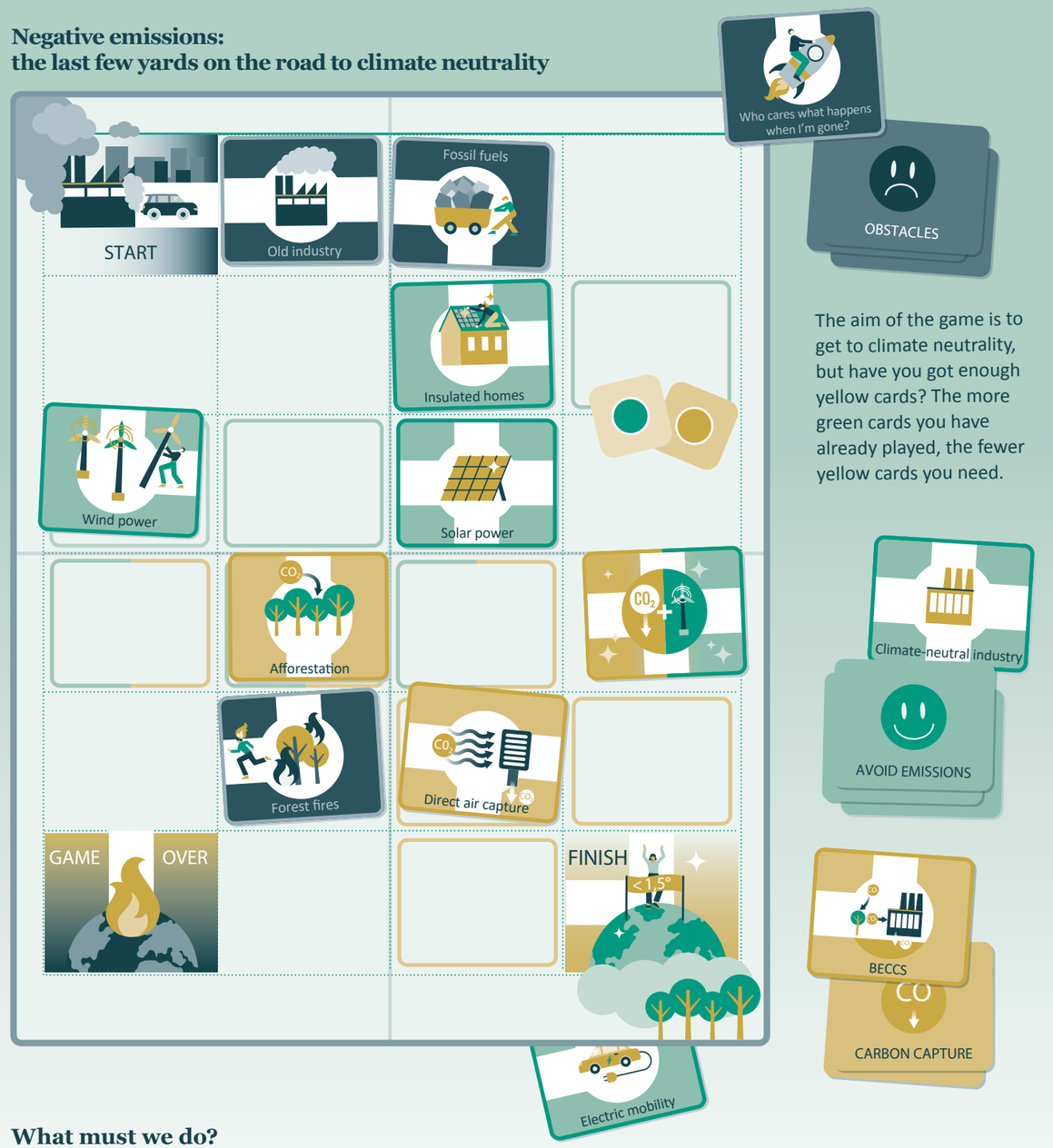
WHAT MUST WE DO?

Engage in a public debate to determine the role of CO_2 removal. There are various different ways of removing CO_2 from the atmosphere. The German government has hitherto focused mainly on "**natural sinks**", i.e. ecosystems such as forests, that sequester carbon. However, it is unlikely that this approach has enough potential in Germany to achieve net negative emissions in the long run. Moreover, since climate change poses a particular threat to forests, there is no guarantee that they will actually be able to store CO_2 on a permanent basis. Forest fires, droughts and pests can damage forests so badly that the sequestered carbon ends up escaping back into the atmosphere. As well as natural sinks, various **technological solutions for removing CO_2 from the atmosphere** are also being discussed. CO_2 can be captured from bioenergy plants or directly from the air and permanently stored in geological formations using Carbon Capture and Storage (CCS) technology. However, there is still uncertainty about the long-term potential and cost of these technologies. Although CCS is controversial in Germany, it will probably be needed to meet the climate targets. Carbon Capture and Storage could also be used in other countries where green energy is cheaper and there is less opposition to CCS. The German government should therefore initiate a **public debate** that looks beyond 2045 with a view to establishing which CO_2 removal methods should be used and when to start using them.

Research and implement CO_2 removal methods. Following further **research and testing**, the different CO_2 removal methods will need to be **brought to market** within the next 10 to 20 years. Since it is not yet possible to fully assess the potential, cost and risks of individual techniques, a broad mix of different solutions should be pursued for the time being.

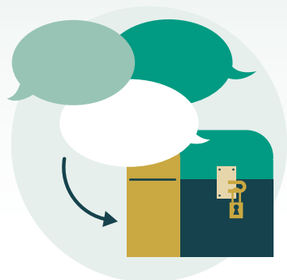
Don't exaggerate the potential. We do not know how much CO_2 can actually be removed from the atmosphere over the next few decades and how much it will cost to do so. Consequently, the top priority should be to prevent emissions so that we can minimise our reliance on uncertain and as yet unproven CO_2 removal technologies. We should thus only resort to removing CO_2 from the atmosphere to offset emissions that cannot be prevented.

Negative emissions:
the last few yards on the road to climate neutrality



The aim of the game is to get to climate neutrality, but have you got enough yellow cards? The more green cards you have already played, the fewer yellow cards you need.

What must we do?



Engage in a public debate to determine the role of CO_2 removal

Research and implement CO_2 removal methods

Don't exaggerate the potential

11. Ensure that climate policy is transparent and just

WHY DOES IT MATTER?

The energy transition cannot succeed without the acceptance and active support of the public. According to the opinion polls, the majority of people are in favour of the energy transition and rate tackling climate change as very important. However, many are unhappy with how climate measures are being implemented in practice. Among other things, this is because they think the burden of the energy transition and of tackling climate change is not being shared fairly, and because they feel that existing structures make it difficult to behave in a climate-friendly manner. For instance, transport policy does not currently provide sufficient support for climate-friendly mobility. Climate policy should seek to ensure that the burdens associated with the transformation are shared fairly and communicated transparently. It will be important to take different social realities into account and find socially acceptable solutions that still send out the right climate action signals.

WHAT MUST WE DO?

Communicate climate policy openly and transparently. The energy transition and other measures to tackle climate change will mean big changes for society, including a transformation in how we behave as consumers and how we live our everyday lives, and a huge amount of investment. But if we fail to act decisively now, the long-term costs will be much higher. If we keep missing our targets, in just a few years' time governments will be forced to take even costlier measures and impose even greater restrictions on our individual freedom in order to deliver the climate goals. The German government should promote an **extensive debate** about the scale of the challenge, about the costs and benefits of climate action, and about how its burden will be shared. Everybody should have a clear understanding of what the measures will mean for them as individuals.

Make targeted use of carbon pricing revenue. Sharing the burden fairly means that the people and companies who generate the most emissions should pay proportionately more. Carbon pricing is key in this context, since it is a transparent mechanism that automatically ensures that high emitters pay more. However, the burdens associated with carbon pricing and other measures to tackle climate change can hit poorer households harder because they have less disposable income. The revenue from carbon pricing could be used both to finance government climate measures and to reduce the burden on businesses and the public. **Abolishing the EEG surcharge** would be a particularly beneficial measure, since it would bring the price of electricity down, making green electricity more attractive while also reducing the burden on businesses and (especially poorer) households. However, it is important to ensure that measures to reduce the burden do not negate the impacts of carbon pricing. For instance, a higher flat-rate tax allowance for commuters would also benefit long-distance commuters, even though more than 80% of them already travel by car today.

Create climate-friendly alternatives. It can often be difficult for individuals to behave in a climate-friendly manner. Behaviours that rely on fossil fuels are deeply rooted, and it is not always easy to find attractive, climate-friendly alternatives. It is vital to create these alternatives so that people are actually able to change their behaviour. This includes everything from well-developed, accessible public transport and safe, attractive cycle paths to giving people the option of working from home. It is essential to take different social realities in urban and rural areas into account so that good solutions are found for everyone. For example, a road toll could be introduced that made it more expensive for people to drive a car in cities with good public transport, but did not penalise people living in rural areas. Similarly, it is necessary to develop ways of paying for air-conditioning in buildings that are fair to both tenants and landlords.

Putting people at the heart of climate policy

What must we do?

Communicate climate policy openly and transparently

Make targeted use of carbon pricing revenue

Create climate-friendly alternatives

List of sources

Further information

Many of the assertions and views expressed in this discussion paper are based on the conclusions of the position papers, analyses, discussion papers, materials and other publications produced by the Academies' Project ESYS over the past few years. Direct references to project findings are listed below. The full publications list is available at **https://energiesysteme-zukunft.de/publikationen.**

1 Take responsibility and develop whole system solutions

(…) the existential threat that climate change poses to humanity.

Ranasinghe, R./Ruane, A.C./Vautard, R. et al.: *Climate Change 2021: The Physical Science Basis. Working Group I contribution to the Sixth Assessment Report of the Intergovernmental Panel on Climate Change. Chapter 12. Climate change information for regional impact and for risk assessment.* URL: https://www.ipcc.ch/report/ar6/wg1/downloads/report/IPCC_AR6_WGI_Chapter_12.pdf [Retrieved 21.09.2021].

The international community has so far failed to respond adequately (…) Although it has set ambitious climate targets, it has not done enough to ensure that they are met.

Climate action tracker: *Addressing global warming*, 2021. URL: https://climateactiontracker.org/global/temperatures/ [Retrieved 07.10.2021].

According to the Climate Action Tracker, The Gambia is the only country in the world whose climate policy is consistent with the Paris Agreement 1.5°C warming limit:

Climate action tracker: *Addressing global warming, 2021.* URL: https://climateactiontracker.org/countries/ [Retrieved 22.09.2021].

(…) ensure that the content and implementation of the European Green Deal are as ambitious as possible (…)

European Union (EU): *Der europäische grüne Deal*. Brussels, 11.12.2019. URL: https://eur-lex.europa.eu/resource.html?uri=cellar:b828d165-1c22-11ea-8c1f-01aa75ed71a1.0021.02/DOC_1&format=PDF [Retrieved 21.09.2021].

EU information page on the European Green Deal:

European Commission (EU): *Europäischer Grüner Deal,* 2021. URL: *https://ec.europa.eu/info/strategy/priorities-2019-2024/european-green-deal_de* [Retrieved 21.09.2021].

The industrialised nations of Europe are responsible for a large proportion of historical emissions (…)

Based on the sum of CO_2 emissions between 1751 and 2019, the EU is second only to the US:

Hannah Ritchie: *Who has contributed most to global CO_2 emissions?,* 2019. URL: *https://ourworldindata.org/contributed-most-global-co2* [Retrieved 11.10.2021].

An animation of the historical emissions trend between 1850 and 2021. The EU countries are only shown individually:

CarbonBrief: *Analysis: Which countries are historically responsible for climate change?,* 2021. URL: *https://www.carbonbrief.org/analysis-which-countries-are-historically-responsible-for-climate-change* [Retrieved 11.10.2021].

Further information:

On Germany's goal of becoming climate-neutral by 2045

Die Bundesregierung: *Klimaschutzgesetz 2021, Generationenvertrag für das Klima,* 2021. URL: https://www.bundesregierung.de/breg-de/themen/klimaschutz/klimaschutzgesetz-2021-1913672 [Retrieved 23.09 2021].

Klimaschutzgesetz KSG 2021: Bundesanzeiger Verlag: *Erstes Gesetz zur Änderung des Bundes-Klimaschutzgesetzes,* 2021. URL: https://www.bgbl.de/xaver/bgbl/start.xav?startbk=Bundesanzeiger_BGBl&start=//*[@attr_id=%27bgbl121s3905.pdf%27]#__bgbl__%2F%2F*%5B%40attr_id%3D%27bgbl121s3905.pdf%27%5D__1633640639297 [Retrieved 11.10.2021].

Summary of the Federal Climate Change Act's key points: Die Bundesregierung: *Klimaschutzgesetz 2021, Generationenvertrag für das Klima,* 2021. URL: https://www.bundesregierung.de/breg-de/themen/klimaschutz/klimaschutzgesetz-2021-1913672 [Retrieved 11.10.2021].

2 Stop using fossil fuels

Around 80% of all greenhouse gas emissions are caused by burning coal, oil products and gas.

This refers to energy-related emissions. In Germany, energy-related emissions account for around 85% of greenhouse gas emissions. 98% of these are CO_2 emissions.

Umweltbundesamt: *Energiebedingte Emissionen*, 02.06.2021. URL: https://www.umweltbundesamt.de/daten/energie/energiebedingte-emissionen#energiebedingte-treibhausgas-emissionen [Retrieved 28.09.2021].

Energy-related emissions are responsible for around 73% of global greenhouse gas emissions.

Our world in Data: *Emissions by sector,* 2021. URL: https://ourworldindata.org/emissions-by-sector [Retrieved 11.10.2021].

One of the key instruments for achieving this is carbon pricing (…)

Sachverständigenrat zur Begutachtung der gesamtwirtschaftlichen Entwicklung: *Aufbruch zu einer neuen Klimapolitik (Special Report 2019, Chapter IV.),* 2019. URL: https://www.sachverstaendigenrat-wirtschaft.de/sondergutachten-2019.html [Retrieved 28.09.2021].

Cramton, P. C./MacKay, D. J. C./Ockenfels, A. (Eds.): *Global Carbon Pricing: the Path to Climate Cooperation*, In: Cambridge, MA: MIT Press 2017.

Edenhofer, O./Flachsland, C./Kalkuhl, M./Knopf, B./Pahle, M.: *Optionen für eine CO_2-Preisreform. MCC-PIK-Expertise für den Sachverständigenrat zur Begutachtung der gesamtwirtschaftlichen Entwicklung,* Mercator Research Institute on Global Commons and Climate Change (MCC) gGmbH, Berlin 2019. URL: https://www.mcc-berlin.net/fileadmin/data/B2.3_Publications/Working%20Paper/2019_MCC_Optionen_f%C3%BCr_eine_CO2-Preisreform_final.pdf [Retrieved 11.10.2021].

Expertenkommission zum Monitoring-Prozess "Energie der Zukunft" (Expertenkommission): *Stellungnahme zum zweiten Fortschrittsbericht der Bundesregierung für das Berichtsjahr 2017*, Berlin: 2019. URL:

https://www.bmwi.de/Redaktion/DE/Downloads/E/ewk-stellungnahme.pdf?__blob=publicationFile&v=4 [Retrieved 12.10.2021].

The EU emissions trading system (EU-ETS) sets an EU-wide carbon price that until now applied to power stations and energy-intensive industries.

European Parliament and European Council: *Richtlinie 2003/87/EG des Europäischen Parlaments und des Rates vom 13. Oktober 2003; consolidated version from 2018 [online*]. URL: https://eur-lex.europa.eu/legal-content/DE/TXT/PDF/?uri=CELEX:02003L0087-20180408&from=DE [Retrieved 12.12.2021].

Aviation has also been included in the EU ETS since 2012. Through this measure, the EU is supporting "the efforts of the International Civil Aviation Organization (ICAO), to establish a global, market-based climate instrument to reduce emissions from international aviation."

Umweltbundesamt*: Der europäische Emissionshandel,* 2021. URL: https://www.umweltbundesamt.de/daten/klima/der-europaeische-emissionshandel [Retrieved 12.12.2021].

Explanations of how the EU ETS operates can be found e.g. on the German Emissions Trading Authority website:

Umweltbundesamt: *Grundlagen*, 2017. URL: https://www.dehst.de/DE/Europaeischer-Emissionshandel/EU-Emissionshandel-verstehen/Grundlagen/grundlagen-des-emissionshandels_node.html [Retrieved 12.12.2021].

(…) the European Commission's new Fit for 55 package (…)

European Commission: *Mitteilung der Kommission an das Europäische Parlament, den Rat, den Europäischen Wirtschafts- und Sozialausschuss und den Ausschuss der Regionen. "Fit für 55": Auf dem Weg zur Klimaneutralität – Umsetzung des EU-Klimaziels für 2030,* 2021. URL: https://eur-lex.europa.eu/legal-content/DE/TXT/PDF/?uri=CELEX:52021DC0550&from=EN [Retrieved 28.09.2021].

Germany introduced a national carbon price for fuels used in heating and transport in 2021.

The Fuel Emissions Trading Act (Brennstoffemissionshandelsgesetz) came into force on 1 January 2021.

Bundesministerium der Justiz und für Verbraucherschutz: *Gesetz über einen nationale Zertifikatehandel für Brennstoffemissionen (Brennstoffemissionshandelsgesetz – BEHG),* 2019. URL: https://www.gesetze-im-internet.de/behg/BJNR272800019.html [Retrieved 10.12.2021].

See also the information page of the Federal Ministry for the Environment, Nature Conservation and Nuclear Safety:

Bundesministerium für Umwelt, Naturschutz und nukleare Sicherheit: Fragen und Antworten zur Einführung der CO_2-Bepreisung zum 1. Januar 2021, 2020. URL: https://www.bmu.de/service/fragen-und-antworten-faq/fragen-und-antworten-zur-einfuehrung-der-co2-bepreisung-zum-1-januar-2021 [Retrieved 28.09.2021].

(…) before the new EU emissions trading system is introduced in 2026 (…)

The European Commission published its plans to introduce a second emissions trading system in the Fit for 55 package. See above for references.

(…) the price pathway (for the carbon price) currently planned in Germany.

The Fuel Emissions Trading Act (BEHG) adopted at the end of 2019 was based on the national and European climate targets that existed at the time. Since then, more ambitious climate targets have been adopted, both nationally through the amendment of the Climate Change Act, and at European level through the European Green Deal and the associated goal of achieving climate neutrality by 2050. It is likely that the price pathway set out in the BEHG will be too low to meet these more ambitious climate targets.

Direct and indirect subsidies for fossil fuels push down energy prices and undermine the effect of carbon pricing.

An overview of environmentally harmful subsidies is provided e.g. on the Federal Environment Agency information page:

Umweltbundesamt: *Umweltschädliche Subventionen*, 2019. URL: https://www.umweltbundesamt.de/themen/wirtschaft-konsum/wirtschaft-umwelt/umweltschaedliche-subventionen#subventionen-nach-bereichen [Retrieved 10.10.2021].

3 Expand renewables faster

Just under half of all electricity produced in Germany today already comes from renewable sources

Umweltbundesamt *Erneuerbare Energien in Zahlen,* 2021 URL: https://www.umweltbundesamt.de/themen/klima-energie/erneuerbare-energien/erneuerbare-energien-in-zahlen#ueberblick [Retrieved 28.09.2021].

We must make full use of the significant untapped potential for affordable renewables that still exists in Germany, especially solar power and onshore and offshore wind.

Several studies investigate the potential for wind and solar power in Germany at high spatial resolution, e.g.:

Agentur für Erneuerbare Energien: *ERNEUERBARE ENERGIEN 2020 POTENZIALATLAS DEUTSCHLAND,* 2020 URL: https://www.unendlich-viel-energie.de/media/file/319.Potenzialatlas_2_Auflage_Online.pdf [Retrieved 11.10.2021].

This study focuses on the compatibility of the energy transition with nature conservation objectives:

Walter A./ Wiehe, J./ Schlömer, G./ Hashemifarzad, A./ Wenzel, T./ Albert I./ Hofmann, L./ zum Hingst, J./ von Haaren, C: *Naturverträgliche Energieversorgung aus 100 % erneuerbaren Energien 2050 (BfN-Skripten 501)*, Bundesamt für Naturschutz, 2018. URL: https://www.bfn.de/fileadmin/BfN/service/Dokumente/skripten/Skript501.pdf [Retrieved 11.10.2021].

This study and two scenarios, one with a strong increase in wind power and another with a strong increase in solar PV, investigate the impact on land use:

WWF Deutschland: *ZUKUNFT STROMSYSTEM II Regionalisierung der erneuerbaren Stromerzeugung,* 2018. URL: https://www.oeko.de/fileadmin/oekodoc/Stromsystem-II-Regionalisierung-der-erneuerbaren-Stromerzeugung.pdf [Retrieved 11.10.2021].

For the potential of innovative dual land use technologies, see:

Fraunhofer-Institut für Solare Energiesysteme (ISE): *Integrierte Photovoltaik - Flächen für die Energiewende,* 2021. URL*: https://www.ise.fraunhofer.de/de/leitthemen/integrierte-photovoltaik.html* [Retrieved 11.10.2021].

(…) wind and solar capacity will need to increase to between four and six times its current level by 2045

The exact amount of wind and solar power required depends, among other things, on how energy demand develops over time (as a result of advances in energy efficiency, demand for energy services, and factors

such as average living space per person). The amount of energy that is imported (electricity from the Synchronous Grid of Continental Europe, climate-neutral hydrogen and hydrogen-based synthetic fuels) will also influence the extent to which capacity needs to be increased in Germany. Furthermore, there is some flexibility in terms of the ratio of wind power to solar PV. Different energy scenarios set out a variety of ways of achieving a climate-neutral energy supply by 2045.

The expansion pathways shown in the illustration are based on scenarios that achieve climate neutrality by 2045 or 2050, and also achieve a 65% reduction in greenhouse gas emissions compared to 1990 by 2030. For scenarios that only achieve climate neutrality in 2050, it is assumed that the 2050 expansion level is actually achieved five years earlier.

The following scenarios met all these inclusion criteria:

- Prognos, Öko-Institut, Wuppertal-Institut: *Klimaneutrales Deutschland 2045. Wie Deutschland seine Klimaziele schon vor 2050 erreichen kann*. Full report commissioned by Stiftung Klimaneutralität (Climate Neutrality Foundation), Agora Energiewende and Agora Verkehrswende. September 2021. URL: https://www.agora-energiewende.de/veroeffentlichungen/klimaneutrales-deutschland-2045-vollversion/ [Retrieved 12.10.2021].

- Prognos, Öko-Institut, Wuppertal-Institut: *Klimaneutrales Deutschland*. Study commissioned by Agora Energiewende, Agora Verkehrswende and Stiftung Klimaneutralität (Climate Neutrality Foundation), November 2020. URL: https://www.agora-energiewende.de/veroeffentlichungen/klimaneutrales-deutschland/ [Retrieved 12.10.2021].

    - only scenario KN2050, scenario KNMin does not meet the 2030 criterion.

- Fraunhofer ISE: *Wege zu einem klimaneutralen Energiesystem 2050. Update unter einer Zielvorgabe von 65% CO_2-Reduktion in 2030 und 100% in 2050* (December 2020)
  URL: https://www.ise.fraunhofer.de/content/dam/ise/de/documents/publications/studies/Fraunhofer-ISE-Studie-Wege-zu-einem-klimaneutralen-Energiesystem-Update-Zielverschaerfung.pdf [Retrieved: 12.10.2021].

    - Reference, Sufficiency and Status Quo scenarios

    - The "Public Opposition" scenario is not included in the expansion corridors shown in the illustration. In this scenario, there is hardly any increase in wind power due to public opposition to this technology. This is compensated for by a larger increase in solar PV. The lower full-load hours of solar PV compared to wind power means that the total installed wind and solar PV capacity is much higher than in all the other scenarios. Since the relationship between the expansion of wind power and the expansion of solar PV is not obvious from the illustration, the values here would be misleading.

- Fraunhofer ISE: new, unpublished scenarios for achieving climate neutrality by 2045 (planned publication date in late 2021). These are updates of the scenarios described above.

- Consentec/Fraunhofer ISI et al.: *Langfristszenarien für die Transformation des Energiesystems in Deutschland 3. Kurzbericht: 3 Hauptszenarien.* Study commissioned by the BMWI. *May 2021* URL: https://www.isi.fraunhofer.de/content/dam/isi/dokumente/cce/2021/LFS_Kurzbericht.pdf [Retrieved: 12.10.2021].

    - Three scenarios: TN-Strom, TN-H2-G and TN-PtG/PtL. Only the TN-Strom scenario meets the 2030 climate targets.

    - For data on the expansion figures, see also Lux, B/Sensfuß, F. et al: slide presentation *"Langfristszenarien für die Transformation des Energiesystems in Deutschland. Angebotsseite Treibhausgasneutrale Szenarien"*, 02.07.2021. URL: https://www.langfristszenarien.de/enertile-explorer-wAssets/docs/LFS_Webinar_Angebot_final.pdf [Retrieved: 11.10.2021].

- Umweltbundesamt: *Wege in eine ressourcenschonende Treibhausgasneutralität RESCUE – Studie*. Climate Change series | 36/2019. November 2019. URL: https://www.umweltbundesamt.de/rescue [Retrieved: 12.10.2021].

    - Only the Green Supreme scenario meets the 2030 climate target. This scenario assumes zero economic growth. Since economic growth is in fact still a key policy goal, it would be inconsistent to base the wind and solar PV expansion targets on this scenario. Consequently, it is not reflected in the expansion corridors shown in the illustration. Nevertheless, this scenario does set out some interesting approaches to reducing energy demand through energy efficiency, a systematic circular economy and more frugal lifestyles.

Meeting the new climate targets will call for an annual increase of between 15 and 25 gigawatts.

This figure was calculated on the basis of the required installed wind and solar PV capacity in 2045 in the above scenarios.

(…) this is a lot more than the 6 gigawatt increase achieved in 2019 (…)

Bundesministerium für Wirtschaft und Energie (BMWi): *Erneuerbare Energien in Zahlen. Nationale und internationale Entwicklung im Jahr 2019. Berlin: s.n.,* 2020. URL: https://www.bmwi.de/Redaktion/DE/Publikationen/Energie/erneuerbare-energien-in-zahlen-2019.html [Retrieved 13.10.2021].

(…) in the past, Germany has already managed to build as much as 10 gigawatts of additional wind and solar PV capacity in a single year.

Bundesministerium für Wirtschaft und Energie (BMWi)*: Erneuerbare Energien in Zahlen. Nationale und internationale Entwicklung im Jahr 2019. Berlin : s.n.,* 2020. URL: https://www.bmwi.de/Redaktion/DE/Publikationen/Energie/erneuerbare-energien-in-zahlen-2019.html [Retrieved 13.10.2021].

The planning and licensing procedures for wind farms currently take between four and five years.

Bundesverband Windenergie (BWE): *Planung von Windenergieanlagen,* 2020.URL: https://www.wind-energie.de/themen/mensch-und-umwelt/planung/ [Retrieved 11.10.2021].

4 Use more green electricity for heating and transport

While the increase in wind and solar capacity has reduced emissions from electricity generation, emissions from heating and transport are stagnating

In 2019, transport emissions were almost exactly the same as in 1990. See:

Umweltbundesamt: *Emissionsquellen*, 2021. URL: https://www.umweltbundesamt.de/themen/klima-energie/treibhausgas-emissionen/emissionsquellen#energie-stationar [Retrieved 11.10.2021].

In the heating sector, the percentage of renewables is stagnating and heating demand for buildings has only fallen slightly. Consequently, there has only been a small reduction in emissions in this sector, too. See:

Bundesministerium für Wirtschaft und Energie (BMWi): *Energie der Zukunft. 8. Monitoring-Bericht zur Energiewende, Berichtsjahre 2018 und 2019*, 2021. URL: https://www.bmwi.de/Redaktion/DE/Publikationen/Energie/achter-monitoring-bericht-energie-der-zukunft.pdf?__blob=publicationFile&v=32 [Retrieved 11.10.2021].

Electric motors and heat pumps, for instance, use significantly less energy than internal combustion engines and conventional heaters.

acatech/Leopoldina/Akademienunion: *Sektorkopplung - Optionen für die nächste Phase der Energiewende*, 2017. URL: https://energiesysteme-zukunft.de/publikationen/stellungnahme-sektorkopplung [Retrieved: 11.10.2021].

(…) electricity is much more heavily taxed than heating oil and gas, for example.

acatech/Leopoldina/Akademienunion (Eds.): *CO_2 bepreisen, Energieträgerpreise reformieren. Wege zu einem sektorenübergreifenden Marktdesign* (Schriftenreihe zur wissenschaftsbasierten Politikberatung – Monograph Series on Science-based Policy Advice), 2020. URL: https://energiesysteme-zukunft.de/publikationen/stellungnahme-co2bepreisen [Retrieved: 13.10.2021].

(…) high-emission vehicles and heating systems bought after 2030 will have to be scrapped before they reach the end of their technical service life.

The average lifespan of vehicles is around 10 years, while for heating systems it is often 20 - 30 years. If Germany is to achieve climate neutrality by 2045, it will not be possible for most fossil fuel-powered vehicles and heating systems bought after 2030 to be used until the end of their service life, since by that time only very low levels of emissions will be permitted.

Technical service life of cars

Statista: *Typische Lebensdauer von Autos in Deutschland nach Automarken,* 2014. URL: https://de.statista.com/statistik/daten/studie/316498/umfrage/lebensdauer-von-autos-deutschland/ [Retrieved: 28.09.21].

Technical service life of heating systems

FOCUS Online: *Lebensdauer einer Heizung: Informationen zu Verschleiß und Haltbarkeit,* 2019. URL: https://praxistipps.focus.de/lebensdauer-einer-heizung-informationen-zu-verschleiss-und-haltbarkeit_98439#:~:text=Heizungen%20-%20so%20lange%20ist%20die%20allgemeine%20Lebensdauer,kann%20sie%20auch%20l%C3%A4nger%20als%2030%20Jahre%20halten. [Retrieved 28.09.2021].

5 Make the electricity supply fit for the future

At the same time, demand for electricity is growing and could even double due to new consumers such as electric vehicles and heat pumps.

acatech/Leopoldina/Akademienunion: *Sektorkopplung - Optionen für die nächste Phase der Energiewende*, 2017. URL: https://energiesysteme-zukunft.de/publikationen/stellungnahme-sektorkopplung [Retrieved: 11.10.2021].

But with renewables now accounting for almost half of all electricity generated in Germany (…)

Strom-Report: *DEUTSCHER STROMMIX: STROMERZEUGUNG DEUTSCHLAND BIS 2021*. URL: https://strom-report.de/strom/ [Retrieved: 28.09.21].

6 Target climate-neutral industry

Industry is responsible for around one third of global greenhouse gas emissions (…)

For a breakdown of global emissions, see e.g.

Hannah Ritchie: *Sector by sector: where do global greenhouse gas emissions come from?*, 2020. URL: *https://ourworldindata.org/ghg-emissions-by-sector* [Retrieved: 11.10.2021].

Energy use in industry: 24.2%, process emissions from cement production and chemicals: 5.2% (2016).

For industrial emission trends in Germany, see:

Bundesumweltministerium [BMU], *Klimaschutz in Zahlen – Fakten, Trends und Impulse deutscher Klimapolitik Ausgabe,* 2021. Berlin URL: https://www.bmu.de/fileadmin/Daten_BMU/Pools/Broschueren/klimaschutz_zahlen_2021_bf.pdf [Retrieved: 6.10.2021].

Carbon Contracts for Difference (CCfDs) can help to overcome this problem by encouraging companies to press ahead with investments in climate-friendly processes.

Bundesministerium für Wirtschaft und Energie [BMWi]: *Was sind eigentlich Carbon Contracts for Difference?* 2020. URL: https://www.bmwi-energiewende.de/EWD/Redaktion/Newsletter/2020/12/Meldung/direkt-erklaert.html [Retrieved: 07.10.2021].

This is extremely important, since many existing facilities are due significant reinvestment in the period between 2020 and 2030.

Agora Energiewende: *Klimaneutrale Industrie - Schlüsseltechnologien und Politikoptionen für Stahl, Chemie und Zement*, 2020. URL: https://static.agora-energiewende.de/fileadmin/Projekte/2018/Dekarbonisierung_Industrie/164_A-EW_Klimaneutrale-Industrie_Studie_WEB.pdf [Retrieved: 07.10.2021].

Examples include the product design standards in the EU's Ecodesign Directive (…)

European Commission: *Vorschriften und Anforderungen für Energieverbrauchskennzeichnung und Ökodesign* .URL: https://ec.europa.eu/info/energy-climate-change-environment/standards-tools-and-labels/products-labelling-rules-and-requirements/energy-label-and-ecodesign/rules-and-requirements_de [Retrieved: 07.10.2021].

If industry is to achieve climate neutrality, it will need large quantities of competitively priced green electricity and green hydrogen, with a safe transport infrastructure.

Agora Energiewende: *Klimaneutrale Industrie - Schlüsseltechnologien und Politikoptionen für Stahl, Chemie und Zement*, 2020, p. 38. URL: https://static.agora-energiewende.de/fileadmin/Projekte/2018/Dekarbonisierung_Industrie/164_A-EW_Klimaneutrale-Industrie_Studie_WEB.pdf [Retrieved: 07.10.2021].

7 Use hydrogen appropriately, leverage its opportunities

This will be vital, since it is likely that, in the future, Germany will still lack sufficient domestic resources to meet its demand for energy and for the hydrocarbons used as raw materials in the production of things like plastic, fertilizer and pharmaceuticals.

Several different energy system studies come to the conclusion that Germany will need to import green energy if it is to successfully transition to a climate-neutral energy supply. See e.g.:

acatech/Leopoldina/Akademienunion: *Sektorkopplung - Optionen für die nächste Phase der Energiewende* (Schriftenreihe zur wissenschaftsbasierten Politikberatung - Monograph Series on Science-based Policy Advice), 2017.

The Boston Consulting Group (BCG) and Prognos, commissioned by the Federation of German Industries (BDI), *Klimapfade für Deutschland*, 2018.

Deutsche Energie-Agentur GmbH (dena), *dena-Leitstudie Aufbruch Klimaneutralität. Eine gesamtgesellschaftliche Aufgabe*, 2021.

Prognos, Öko-Institut, Wuppertal-Institut, *Klimaneutrales Deutschland 2045. Wie Deutschland seine Klimaziele schon vor 2050 erreichen kann Zusammenfassung,* commissioned by Stiftung Klimaneutralität (Climate Neutrality Foundation), Agora Energiewende and Agora Verkehrswende, 2021.

Fraunhofer Institute for Systems and Innovation Research ISI, commissioned by the Federal Ministry for Economic Affairs and Energy (BMWi), Consentec GmbH, *Langfristszenarien 3 – Kurzbericht*, 2021.

Germany already consumes around 1.7 million tonnes of hydrogen a year.

Bundesministerium für Wirtschaft und Energie (BMWi): *Dialogprozess Gas 2030 – Erste Bilanz*, 2019.

It would take approximately 90 terawatt hours of electricity just to meet this level of demand with green hydrogen – equivalent to around 15% of the electricity currently generated in Germany each year.

This calculation is based on an electrolysis efficiency figure of around 60%. Since the comparison refers to the near future, a value in the lower range of projected electrolyser efficiency figures has been used. See e.g.:

Pichlmaier, S./ Hübner T./ Kigle, S.: *Elektrolyse – Die Schlüsseltechnologie für Power-to-X,* Forschungsstelle für Energiewirtschaft e.V., 2021. URL: https://www.ffe.de/publikationen/pressemeldungen/892-elektrolyse-die-schluesseltechnologie-fuer-power-to-x [Retrieved 11.10.2021].

In 2020, gross electricity generation in Germany stood at around 572 terawatt hours.

Bundesministerium für Wirtschaft und Energie, *Zahlen und Fakten: Energiedaten. Nationale und internationale Entwicklung* [Retrieved 05.03.2021].

Illustration: Projected demand for climate-neutral hydrogen (H_2) and hydrogen-based synthetic fuels in Germany

The figures in the illustration are based on the "Metastudie Wasserstoff – Auswertung von Energiesystemstudien" (Metastudy Hydrogen – Evaluation of Energy System Studies) produced by several Fraunhofer institutes on behalf of the German National Hydrogen Council, Figure 25, p. 38.

Wietschel, M./Zheng, L./Arens, M./Hebling, C./Ranzmeyer, O./Schaadt, A./Hank, C./Sternberg, A./Herkel, S./Kost, C./Ragwitz, M./Herrmann, U./Pfluger, B.: *Metastudie Wasserstoff – Auswertung von Energiesystemstudien. Studie im Auftrag des Nationalen Wasserstoffrats*, 2021. Fraunhofer ISI, Fraunhofer ISE, Fraunhofer IEG (Eds.). URL: https://www.wasserstoffrat.de/fileadmin/wasserstoffrat/media/Dokumente/Metastudie_Wasserstoff-Abschlussbericht.pdf [Retrieved 11.10.2021].

An efficiency figure of around 65% was used to convert the cited quantities of hydrogen into the quantities of electricity required to produce them. It is true that, in practice, electrolysers are expected to achieve higher efficiencies in the future (see reference above, Forschungsstelle für Energiewirtschaft). However, the conversion of hydrogen into other synthetic products reduces the efficiency of the overall process.

8 Use bioenergy where it benefits the system

On the other hand, the cultivation of energy crops such as maize, oilseed rape and oil palms requires large areas of land and can damage the soil, cause water pollution and harm biodiversity.

Klepper, G./Thrän, D.: *Biomasse im Spannungsfeld zwischen Energie- und Klimapolitik. Potenziale – Technologien – Zielkonflikte*, 2019. URL: https://energiesysteme-zukunft.de/publikationen/analyse/analyse-bioenergie [Retrieved: 11.10.2021].

Moreover, biomass has a much lower energy yield per unit of area than solar power.

Wirth, H., Fraunhofer ISE: *Aktuelle Fakten zur Photovoltaik in Deutschland,* Freiburg: s.n., 2021.

Kompetenzzentrum Naturschutz und Energiewende: *Vergleich der Flächeneffizienz zwischen den verschiedenen Technologien der Erneuerbaren Energie,* 2018. URL: https://www.naturschutz-energiewende.de/fragenundantworten/147-vergleich-flaecheneffizienz-bioenergie-photovoltaik-windenergie/ [Retrieved: 11.10.2021].

(...) agriculture is facing increasing threats due to climate change.

World Scientific: *Agriculture and Food Systems to 2050. Global Trends, Challenges and Opportunities*, New Jersey: World Scientific Publishing Co. Pte. Ltd, 2018.

(...) in many cases, using wood (...) does not actually reduce harmful emissions at all.

Klepper, G./Thrän, D.: *Biomasse im Spannungsfeld zwischen Energie- und Klimapolitik. Potenziale – Technologien – Zielkonflikte*, 2019, Chapter 2.2. URL: https://energiesysteme-zukunft.de/publikationen/analyse/analyse-bioenergie [Retrieved: 11.10.2021].

Wood is mainly used for heating (...) biogas, primarily for generating electricity and heat.

Overview of how different types of biomass are used:

Klepper, G./Thrän, D.: *Biomasse im Spannungsfeld zwischen Energie- und Klimapolitik. Potenziale – Technologien – Zielkonflikte*, 2019, Fig. 6. URL: https://energiesysteme-zukunft.de/publikationen/analyse/analyse-bioenergie [Retrieved 11.10.2021].

(...) land use intensification would put even more pressure on nature and the environment.

Klepper, G./Thrän, D.: *Biomasse im Spannungsfeld zwischen Energie- und Klimapolitik. Potenziale – Technologien – Zielkonflikte,* 2019, Chapter 2.1. URL: https://energiesysteme-zukunft.de/publikationen/analyse/analyse-bioenergie [Retrieved 11.10.2021].

Alternatively, the CO_2 can be used to produce climate-neutral synthetic fuels or hydrocarbons for industrial use, for example.

Institut für transformative Nachhaltigkeitsforschung Potsdam: *CO_2: Vom Abfall zum Rohstoff*, 2021. URL: https://www.iass-potsdam.de/de/ergebnisse/dossiers/co2-vom-abfall-zum-rohstoff [Retrieved 07.10.2021].

9 Secure the supply of raw materials for the energy transition and use them sustainably

Wind turbines, solar PV systems, storage systems and electric vehicles are all made from metals such as steel and copper, as well as rare earth elements, cobalt and lithium.

This interactive illustration provides an overview of the key metals and the main countries where they are mined:

acatech/Leopoldina/Akademienunion: *Metalle für die Energiewende. Wege zu einer sicheren und nachhaltigen Versorgung*. URL: https://energiesysteme-zukunft.de/themen/metalle-fuer-die-energiewende [Retrieved 29.09.2021].

An overview of the metals needed for different technologies:

Angerer, G. et al.: *Rohstoffe für die Energieversorgung der Zukunft: Geologie – Märkte – Umweltein-flüsse*, 2016, p. 59, Fig. 3.11. URL: https://energiesysteme-zukunft.de/publikationen/analyse/rohstoffe-fuer-die-energieversorgung-der-zukunft [Retrieved 11.10.2021].

For some of these metals, Germany and Europe are even more reliant on imports from a handful of countries than they are for oil.

acatech/Leopoldina/Akademienunion: *Metalle für die Energiewende. Wege zu einer sicheren und nachhaltigen Versorgung.* URL: https://energiesysteme-zukunft.de/themen/metalle-fuer-die-energiewende [Retrieved 29.09.2021].

For a detailed analysis of the criticality of different metals, see:

Angerer, G. et al.: *"Rohstoffe für die Energieversorgung der Zukunft: Geologie – Märkte – Umweltein-flüsse"*, 2016, p. 145 ff. URL: https://energiesysteme-zukunft.de/publikationen/analyse/rohstoffe-fuer-die-energieversorgung-der-zukunft [Retrieved 11.10.2021].

For details of the countries in which the supply of several raw materials is concentrated, see:

Deutsche Rohstoffagentur: *DERA Rohstoffliste 2021,* Berlin, 2021. URL: https://www.deutsche-rohstoffagentur.de/DE/Gemeinsames/Produkte/Downloads/DERA_Rohstoffinformationen/rohstoffinformationen-49.pdf?__blob=publicationFile&v=4 [Retrieved: 11.10.2021].

While steel, aluminium and copper are already widely recovered from scrap metal, recycling rates for high-tech raw materials such as the rare earth elements, indium and gallium remain very low.

acatech/Leopoldina/Akademienunion: *Rohstoffe für die Energiewende,* 2016. Fig. 3.25. URL: https://energiesysteme-zukunft.de/publikationen/analyse/rohstoffe-fuer-die-energieversorgung-der-zukunft, [Retrieved: 11.10.2021].

Even if it were hypothetically possible to recycle everything, this would still not be enough to fully meet the growing demand for raw materials

acatech/Leopoldina/Akademienunion: *Rohstoffe für die Energiewende,* 2016. Fig. 3.27. URL: https://energiesysteme-zukunft.de/publikationen/analyse/rohstoffe-fuer-die-energieversorgung-der-zukunft, [Retrieved: 11.10.2021].

Illustration: The energy transition will push up demand for raw materials

International Energy Agency: *The Role of Critical Minerals in Clean Energy Transitions. World Energy Outlook Special Report.* 2021, p. 119, illustration shows demand growth scenarios for copper, lithium and cobalt. URL: https://www.iea.org/reports/the-role-of-critical-minerals-in-clean-energy-transitions [Retrieved: 11.10.2021].

10 Negative emissions: remove CO_2 from the atmosphere

Even in the best-case scenario, it is probable that agriculture and some parts of industry will still be emitting greenhouse gases in 2045.

Scenarios for a climate-neutral Germany assume residual emissions of approx. 36 - 63 million tonnes CO_2 equivalent:

Prognos, Öko-Institut, Wuppertal-Institut: *Klimaneutrales Deutschland 2045. Wie Deutschland seine Klimaziele schon vor 2050 erreichen kann*. Full report commissioned by Stiftung Klimaneutralität (Climate Neutrality Foundation), Agora Energiewende and Agora Verkehrswende. September 2021, Fig. 60, URL: https://www.agora-energiewende.de/veroeffentlichungen/klimaneutrales-deutschland-2045-vollversion/ [Retrieved 12.10.2021].

Umweltbundesamt: *Wege in eine ressourcenschonende Treibhausgasneutralität RESCUE – Studie,* 2019, Table 6.1. URL: https://www.umweltbundesamt.de/themen/klima-energie/klimaschutz-energiepolitik-in-deutschland/szenarien-konzepte-fuer-die-klimaschutz/rescue-wege-in-eine-ressourcenschonende#hintergrund [Retrieved: 11.10.2021].

According to the IPCC, from the middle of this century on we will actually need to remove more greenhouse gases from the atmosphere than we emit if we are to limit global warming to 1.5°C.

Masson-Delmotte, V./Zhai, P./Pörtner, H.-O./Roberts, D./Skea, J./Shukla, P.R./Pirani, A./Moufouma-Okia, W./Péan, C./Pidcock, R./Connors, S./Matthews, J.B.R./Chen, Y./Zhou, X./Gomis, M.I./Lonnoy, E./ Maycock, T./Tignor, M./Waterfield, T. (Eds.): *Global Warming of 1.5°C. An IPCC Special Report on the impacts of global warming of 1.5°C above pre-industrial levels and related global greenhouse gas emission pathways, in the context of strengthening the global response to the threat of climate change, sustainable development, and efforts to eradicate poverty*, Intergovernmental Panel on Climate Change, 2019, Summary for Policy Makers C3, URL: https://www.ipcc.ch/site/assets/uploads/sites/2/2019/06/SR15_Full_Report_High_Res.pdf [Retrieved: 13.10.2021].

However, it is unlikely that this approach [natural sinks] has enough potential in Germany to achieve net negative emissions in the long run.

For example, this study assumes that the current contribution of natural sinks (-27 million tonnes CO_2 equivalent) cannot be sustained in the long term. Meanwhile, there are 63 million tonnes of unavoidable emissions that need to be offset:

Prognos, Öko-Institut, Wuppertal-Institut: *Klimaneutrales Deutschland 2045. Wie Deutschland seine Klimaziele schon vor 2050 erreichen kann*. Full report commissioned by Stiftung Klimaneutralität (Climate Neutrality Foundation), Agora Energiewende and Agora Verkehrswende. September 2021, p. 14. URL: https://www.agora-energiewende.de/veroeffentlichungen/klimaneutrales-deutschland-2045-vollversion/ [Retrieved 12.10.2021].

Moreover, (…) climate change poses a particular threat to forests

Bundesministerium für Ernährung und Landwirtschaft [BMEL]: *Waldbericht der Bundesregierung 2021*, 2021, Bonn. URL: https://www.bmel.de/DE/themen/wald/wald-in-deutschland/waldbericht2021.html [Retrieved: 07.10.21].

(…) this technology [CCS] is controversial in Germany, (…)

acatech – Deutsche Akademie der Technikwissenschaften (Ed.): *CCU und CCS – Bausteine für den Klimaschutz in der Industrie. Analyse, Handlungsoptionen und Empfehlungen, acatech POSITION,* p. 41 f., Munich 2018.

(…) it [CCS] will probably be needed to meet the climate targets.

This scenario for a climate-neutral Germany in 2045 minimises the use of CCS as far as possible. However, its use is still unavoidable for achieving negative emissions and for a climate-neutral cement industry.

Prognos, Öko-Institut, Wuppertal-Institut: *Klimaneutrales Deutschland 2045. Wie Deutschland seine Klimaziele schon vor 2050 erreichen kann*. Full report commissioned by Stiftung Klimaneutralität (Climate Neutrality Foundation), Agora Energiewende and Agora Verkehrswende. September 2021. URL: https://www.agora-energiewende.de/veroeffentlichungen/klimaneutrales-deutschland-2045-vollversion/ [Retrieved 12.10.2021].

CCS is used in all the global IPCC scenarios that meet the 1.5°C target:

Masson-Delmotte, V./Zhai, P./Pörtner, H.-O./Roberts, D./Skea, J./Shukla, P.R./Pirani, A./Moufouma-Okia, W./Péan, C./Pidcock, R./Connors, S./Matthews, J.B.R./Chen, Y./Zhou, X./Gomis, M.I./Lonnoy, E./ Maycock, T./Tignor, M./Waterfield, T. (Eds.): *Global Warming of 1.5°C. An IPCC Special Report on the impacts of global warming of 1.5°C above pre-industrial levels and related global greenhouse gas emission pathways, in the context of strengthening the global response to the threat of climate change, sustainable development, and efforts to eradicate poverty*, Intergovernmental Panel on Climate Change, 2019, Summary for Policy Makers C3, URL: https://www.ipcc.ch/site/assets/uploads/sites/2/2019/06/SR15_Full_Report_High_Res.pdf [Retrieved: 13.10.2021].

Some other countries have better local conditions than Germany for the removal and storage of CO_2

In Europe, significant potential for storing CO_2 exists under the North Sea in the exclusive economic zone of the United Kingdom and under the Norwegian Sea:

acatech – Deutsche Akademie der Technikwissenschaften (Ed.): *CCU und CCS – Bausteine für den Klimaschutz in der Industrie. Analyse, Handlungsoptionen und Empfehlungen, acatech POSITION,* Fig. 11 , Munich 2018.

Iceland and Norway are driving the development of CCS and also plan to import and store CO_2 from other countries:

Záboji, N.: *CO_2 lässt sich bald nach Island verschiffen*, 2021. URL: https://www.faz.net/aktuell/wirtschaft/klima-nachhaltigkeit/co2-island-will-kohlendioxid-im-untergrund-speichern-17305351.html [Retrieved: 11.10.2021].

Stratmann, K.: *Norwegen buhlt um deutsches Kohlendioxid*, Berlin, 2021. URL: https://www.handelsblatt.com/politik/international/klimaneutralitaet-norwegen-buhlt-um-deutsches-kohlendioxid/27010730.html?ticket=ST-10135827-XpVkoyMpDmg7oj0TV0Fq-ap6 [Retrieved: 11.10.2021].

11 Ensure that climate policy is transparent and just

According to the opinion polls, the majority of people are in favour of the energy transition and rate tackling climate change as very important. However, many are unhappy with how climate measures are being implemented (…)

Agora Energiewende: *Akzeptanz und lokale Teilhabe in der Energiewende,* Berlin, 2021. URL: https://static.agora-energiewende.de/fileadmin/Projekte/2020/2020_07_EE-Akzeptanz/182_A-EW_Akzeptanz-Energiewende_WEB.pdf [Retrieved: 11.10.2021].

Copernicus Project Ariadne: *Soziales Nachhaltigkeitsbarometer der Energie- und Verkehrswende 2021*, 2021. URL: https://snb.ariadneprojekt.de/sites/default/files/medien/dokumente/soziales_nachhaltigkeitsbarometer_2021.pdf [Retrieved 11.10.2021].

For instance, a higher flat-rate tax allowance for commuters would also benefit long-distance commuters, even though more than 80% of them already travel by car today.

Statistisches Bundesamtes: *Pendlerpauschale: 88% der Berufspendlerinnen und -pendler nutzen das Auto,* 2021. URL: https://www.destatis.de/DE/Presse/Pressemitteilungen/2021/06/PD21_N038_73111.html [Retrieved 12.10.2021].

Recommended citation

Bett, Andreas W./ Erlach, Berit/ Glotzbach, Ulrich/ Haucap, Justus/ Henning, Hans-Martin/ Kühling, Jürgen/ Lapac, Anja/ Matthies, Ellen/ Pittel, Karen/ Ragwitz, Mario/ Renn, Jürgen/ Sauer, Dirk Uwe/ Schmidt, Christoph M./ Spiecker genannt Döhmann, Indra/ Staiß, Frithjof/ Seiler, Annika / Stephanos, Cyril/ Umbach, Eberhard/ Weidlich, Anke: *"If not now, then when – making the energy transition happen"* (Discussion Paper), Academies' Project "Energy Systems of the Future" (ESYS), 2021, https://doi.org/10.48669/ESYS_2021-2

Authors

Prof. Dr. Dirk Uwe Sauer (ESYS Board of Directors | RWTH Aachen University), Prof. Dr. Karen Pittel (ESYS Board of Directors | ifo Institute), Prof. Dr. Hans-Martin Henning (ESYS Board of Directors | Fraunhofer Institute for Solar Energy Systems ISE), Prof. Dr. Jürgen Renn (ESYS Board of Directors | Max Planck Institute for the History of Science), Prof. Dr. Christoph M. Schmidt (ESYS Board of Directors | RWI – Leibniz Institute for Economic Research), Prof. Dr. Indra Spiecker genannt Döhmann (ESYS Board of Directors | Goethe University Frankfurt)

Prof. Dr. Andreas W. Bett (Fraunhofer Institute for Solar Energy Systems ISE), Prof. Dr. Justus Haucap (Heinrich Heine University Düsseldorf), Prof. Dr. iur. Jürgen Kühling (University of Regensburg), Prof. Dr. Ellen Matthies (Otto von Guericke University Magdeburg), Prof. Dr. Eberhard Umbach (acatech), Prof. Dr. Mario Ragwitz (Fraunhofer Research Institution for Energy Infrastructures and Geothermal Systems), Prof. Dr. Frithjof Staiß (Center for Solar Energy and Hydrogen Research Baden-Württemberg, ZSW), Prof. Dr. Anke Weidlich (University of Freiburg, Department of Sustainable Systems Engineering, INATECH)

Dr. Berit Erlach (ESYS Project Office | acatech), Dr. Ulrich Glotzbach (ESYS Project Office | acatech), Anja Lapac (ESYS Project Office | acatech), Annika Seiler (ESYS Project Office | acatech), Dr. Cyril Stephanos (ESYS Project Office | acatech)

Additional contributors

Christiane Abele (ESYS Project Office | acatech), Dr. Munib Amin (E.ON), Prof. Dr. Christoph Böhringer (Carl von Ossietzky University of Oldenburg), Prof. Dr. Tom Brown (Technische Universität Berlin), Dr. Peter Buchholz (German Mineral Resources Agency (DERA) at the Federal Institute for Geosciences and Natural Resources, BGR), Dr.-Ing. Frank-Detlef Drake (E.ON Group Innovation GmbH), Prof. Dr. Ottmar Edenhofer (Potsdam Institute for Climate Impact Research, PIK), Gabriel Ehren (ESYS Project Office | acatech), Univ.-Prof. Dr.-Ing. Bernd Engel (Technische Universität Braunschweig), Prof. Dr.-Ing. Manfred Fischedick (Wuppertal Institute for Climate, Environment and Energy), Dr. Christian Hagelüken (Umicore AG & Co. KG), Prof. Dr. Anja Hentschel (Darmstadt University of Applied Sciences), Prof. Dr.-Ing. Jutta Hanson (Technical University of Darmstadt), Dr. Patrick Jochem (German Aerospace Center, DLR), Prof. Gernot Klepper Ph.D. (Institute for the World Economy), Prof. Dr. Michèle Knodt (Technical University of Darmstadt), Prof. Dr. Katharina Kohse-Höinghaus (Bielefeld University), Prof. Dr.-Ing. Thomas Kolb (Karlsruhe Institute of Technology, KIT), Prof. Dr. Wolfgang König (Technische Universität Berlin), Prof. Dr. Jochen Kreusel (Hitachi Energy), Prof. em. Dr. Wolfgang Kröger (ETH Zurich), Leif Christian Kröger (acatech), Prof. Dr. Hans-Joachim Kümpel (Federal Institute for Geosciences and Natural Resources, BGR (retd.) | acatech), Prof. Dr. Andreas Löschel (Ruhr-Universität Bochum), Inga Michalek (ESYS Project Office | acatech), Prof. Dr. Martin Muhler (Ruhr-Universität Bochum), Thorsten Müller (Stiftung Umweltenergierecht), Prof. Dr. Felix Müsgens (Chair of Energy Economics, Brandenburg University of Technology), Prof. Dr. Karsten Neuhoff (DIW Berlin), Daniela Niethammer (ESYS Project Office | acatech), Dr. Marion Ott (Centre for European Economic Research, ZEW), Prof. Dr. Johann-Christian Pielow (Ruhr-Universität Bochum), Dr. Mirko Schäfer (University of Freiburg, Department of Sustainable Systems Engineering, INATECH), Britta Seegebrecht (ESYS Project Office | acatech), Christoph Stemmler (acatech), Philipp Stöcker (RWTH Aachen University), Florentine Straub (ESYS Project Office | acatech), Prof. Dr.-Ing. Daniela Thrän (Helmholtz Centre for Environmental Research, UFZ), Georg van de Braak (Amprion GmbH), Prof. Dr.-Ing. Hermann-Josef Wagner (Ruhr-Universität Bochum, Chair of Energy Systems and Energy Economics), Prof. Achim Wambach (Centre for European Economic Research, ZEW), Prof. Dr.-Ing. Friedrich-Wilhelm Wellmer (Federal Institute for Geosciences and Natural Resources, BGR (retd.)), Dr. Kirsten Westphal (German Institute for International and Security Affairs), Prof. Dr. Kurt Wagemann (Society for Chemical Engineering and Biotechnology, DECHEMA), Prof. Dr. Hartmut Weyer (Clausthal University of Technology), Prof. Dr. Frauke Wiese (Europa-Universität Flensburg), Dr. Jenny Winkler (Fraunhofer Institute for Systems and Innovation Research ISI), Sven Wurbs (ESYS Project Office | acatech)

Visual design, infographics and illustrations

Ellery Studio
Creative Direction: Luca Bogoni
Illustrations: Hannah Kristin Schrage, Julia Zimmermann, Gaja Vičič
Project Management: Martin Steffens

Series editor

acatech – National Academy of Science and Engineering (lead institution)
Munich Project Office, Karolinenplatz 4, 80333 Munich | www.acatech.de

Deutsche Akademie der Naturforscher Leopoldina e. V.
– German National Academy of Sciences –
Jägerberg 1, 06108 Halle (Saale) | www.leopoldina.org

Union of the German Academies of Sciences and Humanities
Geschwister-Scholl-Straße 2, 55131 Mainz | www.akademienunion.de

DOI

https://doi.org/10.48669/ESYS_2021-2

Project duration

03/2016 to 12/2023

Funding

This project is funded by the Federal Ministry of Education and Research (funding code 03EDZ2016).

SPONSORED BY THE

Federal Ministry
of Education
and Research

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In the initiative "Energy Systems of the Future" (ESYS), acatech – National Academy of Science and Engineering, the German National Academy of Sciences Leopoldina and the Union of the German Academies of Sciences and Humanities provide input for the debate on the challenges and opportunities of the German energy transition. Within the Academies' Project, over 100 experts from the science and research communities come together in interdisciplinary working groups to develop policy options for the implementation of a secure, affordable and sustainable energy supply.

Kontakt:

Dr. Berit Erlach & Dr. Cyril Stephanos
Head of Project Office "Energy Systems of the Future"
Pariser Platz 4a, 10117 Berlin
phone: +49 30 206 30 96 - 0
e-mail: erlach@acatech.de | stephanos@acatech.de
web: energiesysteme-zukunft.de/en

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German National Academy of Sciences Leopoldina
Jägerberg 1
06108 Halle (Saale)
phone: +49 (0) 345 47239-600
fax: +49 (0)345 47239-919
e-mail: leopoldina@leopoldina.org

Berlin Office:
Reinhardtstraße 14
10117 Berlin

acatech – National Academy of Science and Engineering
Karolinenplatz 4
80333 München
phone: +49 (0) 89 520309-0
fax: +49 (0) 89 520309-9
e-mail: info@acatech.de

Berlin Office:
Pariser Platz 4a
10117 Berlin

Union of the German Academies of Sciences and Humanities
Geschwister-Scholl-Straße 2
55131 Mainz
phone: +49 (0) 6131 218528-10
fax: +49 (0) 6131 218528-11
e-mail: info@akademienunion.de

Berlin Office:
Jägerstraße 22/23
10117 Berlin