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Accelerating the Expansion of Wind and Solar Power

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Accelerating the Expansion of Wind and Solar Power

Preface

Germany must quickly take major steps to come in reach of its climate targets. Not least the geopolitical upheavals caused by the Russian war on Ukraine make it clear that renewable energies must be expanded as fast as possible in order to become independent of fossil fuel imports. The expansion of photovoltaics and wind energy plays a central role in this endeavour. But recently, even the previous annual expansion targets, which were less ambitious than the current ones, were not or just barely met. Minimizing or, at best, eliminating obstacles to the expansion of these technologies is therefore a high priority task for the German government.

A working group of the German Academies of Sciences project ESYS ("Energy Systems of the Future") used an interdisciplinary approach to analyze the obstacles to renewables expansion and develop policy options to accelerate the expansion of photovoltaics and wind energy. With the proposed measures, the experts also address the area of tension related to the expansion.

The energy transition is sometimes painted as expensive, slow and remote from the people. Yet photovoltaics and wind energy are already today among the cheapest technologies for generating electricity. And while around 20 percent of wind turbine projects are subject to legal action initiated by members of the public, studies show that people who live near wind turbines which are already in operation have a particularly positive attitude toward wind power.

In order to expedite the expansion of photovoltaics and wind energy, the ESYS experts see it as essential to transform planning and approval processes and to involve the population earlier and more comprehensively in the planning of new plants. They see this as a chance to raise participation to a new level that promotes an understanding of systemic interrelations and creates opportunities to shape one's own environment.

Moreover, they propose adjustments to the regulatory and economic framework which aim at increasing land availability and exploiting technological potentials. Last but not least, they suggest a paradigm shift to put renewables front and center in the design of the future energy system.

We would like to thank the experts and reviewers who contributed to this paper for their valuable input.

Contents

Abbreviations, acronyms and units

BauGB	Federal Building Code
BauNVO	Federal Land Utilisation Ordinance
BbgWindAbgG	Act on the payment of a special levy to municipalities in the vicinity of wind turbines
BImSchG	Federal Immission Control Act
BMU	Federal Ministry for the Environment, Nature Conservation and Nuclear Safety
BMWi	Federal Ministry of Economic Affairs and Energy
BMWK	Federal Ministry for Economic Affairs and Climate Action
BNetzA	Federal Network Agency
COP	Conference of the Parties (to the UN Framework Convention on Climate Change)
DIN SPEC	Standard document of the Deutsches Institut für Normung
EEG	Renewable Energy Sources Act
EIC	European Innovation Council
EnSiG	Energy Security Act
EnWG	Energy Industry Act
ErdölBevG	Oil Stockholding Act
GW	Gigawatt(s) (unit)
ICT	Information and Communication Technology
IEA	International Energy Agency
IPCC	Intergovernmental Panel on Climate Change
IPCEI	Important Project of Common European Interest
KSG	Federal Climate Change Act
kWh	Kilowatt hour(s) (unit)
LCOE	Levelised Cost of Electricity
LSPV	Large-scale PV
MBauO	Model Building Regulation
MW	Megawatt(s) (unit)
PPA	Power Purchase Agreement
PV	Photovoltaic(s)
ROG	Spatial Planning Act
THeGA	Thüringer Energie- und GreenTech-Agentur (State Energy Agency of Thuringia)
VwGO	Code of Administrative Court Procedure
WHG	Federal Water Act
WindSeeG	Offshore Wind Energy Act

Glossary

Agrivoltaics	The simultaneous use of land for agriculture and solar power generation.
Binding land use plan	The binding land use plan (German: Bebauungsplan, B-Plan) is the second stage of urban land use planning. Based on the preparatory land use plan, it sets out the legally binding use for individual plots of land. It stipulates which land may be used for vehicular infrastructure, permitted building uses, and land earmarked for development.
Climate neutrality (also net greenhouse gas neutrality)	An equilibrium between the anthropogenic emissions of greenhouse gases from sources and the reduction in the volume of such gases by means of sinks.[1]
Concentration zone	In accordance with Section 35 of the Federal Building Code, land in an undesignated outlying area where the construction of wind installations may be prioritised.
Energy conversion efficiency	Energy conversion efficiency is the ratio that describes how efficiently one form of energy is converted into another (e.g. solar or wind power into electrical energy).
Feed-in tariff	The feed-in tariff rate is set by the Renewable Energy Sources Act. It is usually payable for a period of 20 years to operators of PV installations who feed electricity they have generated into the grid.
Floating PV	PV modules that are operated on the surface of unused waterbodies.
Framing	A term taken from the social sciences and psychology. Refers to how the same information can be presented in different ways in order to influence how people perceive and react to it.
Landlord-to-tenant electricity model	Electricity that is generated in close proximity to consumers (e.g. by roof-mounted PV systems) and used by these consumers. Only surplus electricity is fed into the grid. The system is installed by the landlord or by a third party. This model should theoretically offer cost benefits, since there are no grid tariffs or electricity taxes to pay.
Levelised Cost of Electricity	The Levelised Cost of Electricity (LCOE) is the cost of supplying a unit of electricity (megawatt hour or kilowatt hour).

1 As defined by the Federal Climate Change Act 2021.

Planning culture	The term "planning culture" aims to achieve a deeper understanding of planning practice by incorporating cultural aspects. These include e.g. patterns of action, interactions and behaviours that are reflected in common interpretations or rules. The concept of planning culture considers not only the rational, technical aspects of planning, but also how the relevant actors implement the formal planning process in practice.
Preparatory land use plan	The preparatory land use plan (German: Flächennutzungsplan, FNP) is the first stage of urban land use planning. It sets out a municipality's future land uses and general development goals, and is binding for the public authorities, but not for members of the public.
Preferential treatment	Section 35 of the Federal Building Code stipulates that the construction of wind installations in undesignated outlying areas is eligible for "preferential treatment". Developments are not permitted in undesignated outlying areas unless they are eligible for preferential treatment. Wind installations are thus permitted by planning law, provided that they are not contrary to the public interest. The public interest includes matters relating to nature conservation, landscape conservation, aviation safety and the protection of local residents.
Regional planning	Regional planning is the intermediate level between development planning at the federal state level and urban land use planning at the municipal level. Regional planning gives concrete expression to how the goals of spatial planning and federal state-level planning are to be implemented in the development of the different regions that make up a federal state. It takes the form of regional plans that are based on the corresponding state regulations. Depending on the federal state, responsibility for regional planning either lies fully with the municipalities or with regional planning communities whose members also include representatives of industry.
Repowering	Refers to the process of wholly or partly replacing older PV and wind installations with newer, more powerful technology.
Sector coupling	Sector coupling involves connecting the electricity, heating and mobility sectors to create an integrated energy system that provides the necessary energy services to private, commercial and industrial customers. Examples include combined heat and power, power-to-gas, or heat pumps and heating resistors (power-to-heat).

Spatial planning	This term describes the supra-local, superordinate uses and functions of all spaces within Germany. Spatial plans and the Spatial Planning Act (German: Raumordnungsgesetz, ROG) provide the regulatory framework for governing liveable and sustainable spatial development.
Taboo zone	Taboo zones must be taken into account when developing plans for wind installations. The term refers to areas that are unavailable for the installation of wind turbines. A distinction is drawn between hard and soft taboo zones. Hard taboo zones have physical or legal constraints (e.g. locations with insufficient wind power potential or nature reserves) that make them unsuitable for wind installations. Soft taboo zones are areas that could in principle be considered for installations in the formal process of weighing up a development's pros and cons, but which are deemed unsuitable by the planning authority.
Urban land use planning	A municipal planning tool for regulating urban development and local flexibility. Urban land use planning entails a two-stage process involving the generally binding adoption of a preparatory land use plan, followed by a binding land use plan.
Wind power potential	The average amount of wind in a particular location. The wind power potential figure is used to calculate a wind installation's cost-effectiveness.

Summary

Despite widespread public acceptance, wind and solar power are not growing fast enough to meet Germany's climate targets. The following four priority areas are key to achieving a severalfold increase in the annual rate of expansion:

- A **proactive planning culture** incorporates the national and federal state expansion targets into the regional planning process. Ensuring clear, uniform nationwide nature conservation criteria and increasing staffing levels in the relevant authorities can help to expedite planning and licensing processes.

- Public acceptance can be strengthened through **greater public involvement from an earlier stage** and the **financial participation of local authorities and residents**. Participation processes should seek to unlock the public's positive creative potential and encourage them to experience the energy transition as a worthwhile collective endeavour.

- **National and federal state land allocation targets** can help to ensure that sufficient land is designated for wind and ground-mounted PV installations. In addition, multiple space uses can be supported by leveraging the potential of solar panels on suitable building roofs and promoting agrivoltaics and floating PV.

- In the future, most electricity will be generated from solar and wind power. It will therefore be necessary to modify the **electricity supply's technical infrastructure and regulatory framework** to ensure that wind and PV installations can contribute to system stability. It will also be necessary to determine whether reliance on imported renewable energy technologies poses a threat to the energy transition and, if so, how this threat can be countered.

Faster expansion of wind and solar power is key

In order to achieve the goal of climate neutrality by 2045, Germany's entire energy demand will need to be met by renewables within just over two decades. Wind and PV installations will be the main pillars of the future energy supply. They still have considerable untapped potential and are now among the cheapest technologies for generating electricity, thanks to the huge reductions in their cost. In principle, public acceptance is also high. The majority of the population wants more ambitious climate action and supports the energy transition, especially the expansion of wind and solar power.

Energy scenarios show that if the future energy supply is to be cost-effective, electricity generated from wind and solar power will also have to meet much of the energy demand in the heating and transport sectors and in industry. Consequently, electricity demand will still rise sharply despite major and necessary advances in energy efficiency.

A pronounced increase in the rate of expansion will be required in order to meet the German government's ambitious targets of 200 gigawatts of PV, 100 gigawatts of onshore wind and 30 gigawatts of offshore wind. By 2030, there will need to be a severalfold increase in annual new capacity compared to 2021, rising from approx. 5 gigawatts to 20 gigawatts for PV, from approx. 2 gigawatts to 10 gigawatts for onshore wind and from less than 1 gigawatt to 7 gigawatts for offshore wind.[2]

To achieve climate neutrality by 2045, total installed capacity will have to increase **fourfold** for onshore wind, up to **ninefold** for offshore wind and up to **eightfold** for PV compared to current levels.[3]

Barriers to faster expansion

Despite the significant cost reduction of wind and PV installations and high levels of public support for their expansion, in recent years the annual increase in new capacity for both technologies has fallen short of its former peaks. One reason for this is that the consequential costs of using fossil fuels are not fully reflected, either due to a lack of carbon pricing or, where it does exist, because carbon prices are too low. This prevents fair competition between the different technologies. Other barriers are found in planning and licensing practice and a lack of local acceptance of specific renewable energy projects:

- **Restrictive regional planning** practice and a **failure to designate sufficient land** hinders potential investments and renewable installation projects.

2 See BMWK 2022a.

3 The exact level of growth required will depend on various factors such as future electricity demand trends and the expansion of Europe's electricity grids with pan-European electricity trading. The necessary wind and solar capacity will also be influenced by the level of future hydrogen and hydrogen-based synthetic fuel imports and by the mix of offshore wind, onshore wind and PV.

- Processes can sometimes last several years due to **lengthy and complex licensing procedures** coupled with **staff shortages in the relevant authorities**.

- Although the public is generally in favour of the energy transition, implementation of concrete measures often encounters local opposition from **highly litigious parties**. Legal action can sometimes significantly delay new renewable energy projects.

- **Inadequate public involvement in planning processes** and a lack of **financial participation** results in failure to maximise potential support among the affected municipalities and local residents.

- **Automatic prioritisation of other interests** (military, radar, weather radar, earthquake monitoring stations, etc.) instead case-by-case consideration can hamper a project's implementation.

- **Unclear and open-ended nature and biodiversity conservation requirements** make it more difficult for authorities as they often give rise to legal disputes.

- **Excessive bureaucracy** (compulsory notification, business registration requirements, declaration on tax returns) deters property owners from installing solar panels on roofs and façades.

- The **energy industry's** current **regulatory framework**, which is designed for a centralised electricity supply, could also become a barrier if it fails to ensure fair allocation of electricity system costs, thereby creating perverse incentives.

- It will also be necessary to determine whether Germany's **near-complete reliance** on a single country (China) for **PV system imports** could pose a threat to the energy system transformation in years to come.

Public acceptance is key

Public opinion research has recorded consistently high public support for climate action and the expansion of renewables over a number of years. Solar and wind installations are among the technologies that enjoy the highest levels of support. Most people think we should all do our bit to support the energy transition. However, the practical implementation of the energy transition is frequently criticised for being expensive and slow, and for overlooking the concerns of local residents. Moreover, there are sometimes significant local problems, particularly with the implementation of wind power projects. Legal action is taken against 20% of wind installations during the licensing process, even though in many cases the majority of local residents are in favour of them.

It is thus necessary to find ways of implementing the energy transition that mobilise the significant potential support for the expansion of renewables among the public. Acceptance research has shown that offering people extensive opportunities to participate from an early stage makes it easier for them to be positive about change and identify with the energy transition as a collective endeavour.

A new, proactive and integrated planning and licensing culture

The planning and licensing processes should ensure that enough space is available for wind and PV installations and that projects can be implemented quickly enough. This will call for a reform of the legal framework. It is important for planning and licensing culture to view the energy transition as an opportunity and treat public participation as a resource. A focus on creative aspects ("visions of the local area", "development concepts", "project ideas") rather than negative aspects ("spatial vulnerability", "conflict minimisation") can help to mobilise the public's creativity.

Renewable energy installations are increasingly becoming a normal part of the landscape. Consequently, spatial planning should aim to incorporate these installations into the landscape as part of a positive reimagining of landscapes as a whole, rather than concentrating them in degraded, leftover spaces, as has largely been the case until now.

Multiple space uses can help to mitigate potential competition for space. This can be enabled by innovative solutions such as agrivoltaics and floating PV or building-integrated PV or greater use of roof-mounted PV.

An integrated system: putting renewables at the centre of the energy supply

Hitherto, the focus has been on trying to incorporate renewables into a system dominated by fossil and nuclear power plants through special regulations like the Renewable Energy Sources Act (EEG). But with renewables already accounting for about half of all electricity, this approach is unlikely to be feasible for much longer. Accordingly, a paradigm shift is required: in the future, volatile renewables must be at the centre of the system's technical design and of the market design. Technical infrastructure such as power grids, regulations governing the provision of system stability, and the design of the electricity market should all be geared towards enabling and supporting a reliable and affordable electricity supply in a system with a fast-growing percentage of volatile renewable energy.

Policy options: how can the expansion of renewables be accelerated?

In order to accelerate the expansion of wind and PV capacity, the ESYS working group proposes the following 12 policy options (POs) across 4 key policy areas:

Policy area 1:
Transforming planning and licensing processes

The regional planning level is key to enabling faster planning and licensing processes.

- **Policy option 1.1**:
  A **sustainable, integrated planning culture** incorporates the expansion targets established by policymakers into the formal planning process. Clear nature conservation criteria that are harmonised throughout Germany will help to make decisions more legally watertight, while extensive, statutory public participation from an early stage can help to prevent negative publicity and legal action.
- **Policy option 1.2:**
  Additional **staffing and professional development programmes** will allow the authorities to carry out legally watertight assessments and licensing procedures more quickly.

Policy area 2:
Strengthening a new, proactive planning culture through participation

A forward-looking, proactive and participatory planning culture enables earlier and more extensive public participation in the complex decision-making processes, giving people a chance to co-design the collective energy transition project. Opportunities for local actors to participate financially can also help to mobilise the significant potential public support for wind and PV installations.

- **Policy option 2.1**:
  Interactive information activities such as **decision theatres**, **planning cells** and **citizens' assemblies** provide a space for critical exploration of the complex issues involved in the energy transition and can nip potential conflicts in the bud.
- **Policy option 2.2**:
  Trust and acceptance can be strengthened by **embedding participation processes in the different planning stages**. It is important to ensure greater public participation in the early planning stages, when it is still possible to exert a significant influence on decisions concerning the identification and designation of suitable land, for example.
- **Policy option 2.3**:
  Making it mandatory to give a share of the revenue from wind and PV installations to the municipality where the plant is sited, as well as implementing models that help even small municipalities to invest in renewable installations can increase motivation to actively promote renewable energy projects among local politicians, civil servants and residents.
- **Policy option 2.4**:
  Citizen energy models should be strengthened in accordance with the relevant EU Directives. In particular, **renewable energy communities should be established** to support the use of locally generated electricity by the local community. Digital technology should be harnessed to enable innovative flexibility platform models, for example.

Policy area 3:
Creating the conditions to make more land available

The expansion of renewables requires space, and competes with other forms of land use such as agriculture. These conflicts can be mitigated through greater use of roofs and façades for solar power generation and through multiple space use solutions.

- **Policy option 3.1**:
  A **statutory land allocation target** for renewable installations could help to achieve a secure, climate-neutral energy supply by ensuring that sufficient land is designated for new installations. It would be up to the federal states to ensure that sufficient land is designated for wind and PV installations at the state, regional and municipal spatial planning levels to meet the agreed targets for each state.
- **Policy option 3.2**:
  Multiple space use solutions, especially involving PV installations (e.g. solar façades, agrivoltaics, floating PV) should be addressed and enabled by spatial planning and building regulations.
- **Policy option 3.3**:
  The widespread **installation** of solar panels **on suitable building roofs** can help to mitigate potential space use competition. This could be supported by stable financial incentives such as a higher feed-in tariff or market premium. One alternative or complementary option would be an obligation to install solar panels on new buildings and when renovating existing building stock.

Priority area 4:
Fully aligning the energy system with renewables

System stability and security of supply will increasingly have to be provided by wind and PV installations in conjunction with storage systems and more flexible consumption patterns. The electricity market design and other regulatory conditions relating to the energy supply must enable this and ensure that it is financially attractive enough.

- **Policy option 4.1**:
  Integrating volatile electricity generation in a manner that supports system stability will call for an appropriate ICT infrastructure and the development of the necessary power electronics.
- **Policy option 4.2**:
  A new, **integrated regulatory framework for the electricity market** should create incentives to ensure that renewable installations are built and operated in a way that supports system stability and that contributions to system stability are appropriately compensated.
- **Policy option 4.3**:
  It will be necessary to investigate whether Germany's current high **reliance** on a single country (China) **for PV module imports** could jeopardise attainment of the expansion targets. If this is found to be the case, and it is not possible to reliably diversify PV module sourcing, it will be necessary to establish whether the development of PV production in Europe could make a meaningful contribution to the German government's goal of achieving **energy sovereignty**, i.e. a robust energy supply safeguarded against crises and political intervention.

Table 1: Overview of the 12 policy options (POs)

According to the German government's climate policy, wind and solar power will be the main pillars of tomorrow's climate-neutral energy supply and are thus key to future economic development. Consequently, it is necessary to ensure that these sources of electricity are expanded quickly enough and that the energy transition is driven forward as a collective project.

1 Background and methodology

There is a widespread consensus in Germany that we must contribute our fair share to global climate action and responsibly lead the way in the transition towards climate neutrality. The key foundations have been laid in the shape of the Federal Climate Change Act and the goal of achieving climate neutrality by 2045. The coalition agreement of the new German government sets out ambitious targets to expand solar and wind power by 2030 – the government aims to have an installed capacity of 200 gigawatts of solar, 100 gigawatts of onshore wind and 30 gigawatts of offshore wind by this date. If these targets are to be met, the number of new wind and PV installations will need to grow significantly faster than in recent years.

Climate neutrality scenarios for Germany show that if the future energy supply is to be cost-effective, electricity generated from wind and solar power will also have to meet much of the energy demand in the heating and transport sectors and in industry. Consequently, demand for electricity will still rise despite major advances in energy efficiency. The scenarios assume that wind and solar power will be used to meet this demand. Domestic electricity production will be supplemented by electricity imports/exports from the integrated European grid. While imported hydrogen and hydrogen-based synthetic fuels will also form part of the picture in the longer term, their contribution between now and 2030 will be limited.

Wind and solar power are now among the cheapest technologies for generating electricity. Between 2010 and 2020, costs fell by 81% for PV installations, 31% for onshore wind installations and 32% for offshore wind installations.[4] Despite this, the rate at which these technologies are expanding in Germany has faltered in recent years.

Wind and solar power complement each other well due to their different electricity generation profiles. While waste heat recovery and other forms of renewable energy such as biomass, geothermal energy, hydropower and solar thermal energy will also be essential for a climate-neutral energy supply, their potential is more limited and there are several additional barriers to their use.

This position paper aims to identify the barriers to faster expansion of wind and solar power and formulate energy policy options for overcoming these barriers and enabling faster growth. The working group is of the opinion that incremental development of existing instruments will not be enough to deliver the climate targets. Instead, decisive changes are required in the framework governing the use of wind and solar power. Accordingly, some of the proposed policy options are geared towards overcoming the current (psychological) barriers. The policy options put forward in this

4 See IRENA 2021.

paper outline possible partial solutions for achieving a qualitative transformation in the approach to expanding wind and solar capacity.

The position paper focuses on the factors influencing widespread public acceptance, the transformation of planning and licensing processes and the multiple space use opportunities that can be leveraged in connection with the expansion of wind and PV capacity. The need to transform the electricity market to reflect the growing amount of electricity generated from wind and solar power is addressed in Policy Area 4 "Fully aligning the energy system with renewables". However, the policy options proposed under this policy area only set out the requirements and some initial suggestions for the development of a new electricity market design. A more detailed study of this issue is currently being carried out by the separate ESYS working group "Electricity Market of the Future".

In order to limit the scope of this position paper, it focuses on the **expansion of wind and solar capacity in Germany**. While stronger pan-European energy supply integration and energy imports will undoubtedly both be necessary, all the climate neutrality scenarios conclude that a rapid and very significant increase is needed in the number of wind and PV installations in Germany. **The paper concentrates on the period up to 2030.**

There is nothing new about the question of how to expand wind and solar power more rapidly, and it is also being addressed by several other actors (including the Academy for Territorial Development, the Federal Institute for Research on Building, Urban Affairs and Spatial Development, the German Sustainable Building Council, the Helmholtz Centre for Environmental Research, The German Institute of Urban Affairs, the German Advisory Council on the Environment and the Stiftung Umweltenergierecht). There are numerous publications that consider the necessary expansion of these technologies from a variety of different perspectives, focusing for example on the legal implications, on specific types of installation, or on particular German states/regions. Where this position paper does break new ground, however, is in its attempt to achieve an in-depth, interdisciplinary understanding, especially of the non-economic barriers to further expansion of wind and solar capacity. Rather than concentrating on furthering existing efforts to promote the commercial rollout of niche technologies, the resulting policy options are focused on the goal of a climate-neutral electricity supply.

1.1 Structure of the position paper

This chapter outlines the background to the position paper. Chapter 2 describes the expansion pathways required to deliver the goal of a climate-neutral energy supply, while Chapter 3 takes an in-depth look at the key role of public acceptance in enabling the expansion of renewables. It highlights the different factors influencing public acceptance and discusses how the generally high level of public support for renewables can be harnessed to accelerate their expansion. Chapter 4 describes the basic principles of the planning and licensing processes. It also highlights how, in some cases, these processes currently hamper the expansion of wind and solar power, and identifies the areas where change is required. Chapters 3 and 4 are thus intended as background chapters aimed at helping readers to understand the policy options outlined in

Chapter 5. Finally, Chapter 5 presents 12 policy options in 4 policy areas that can help to accelerate the expansion of wind and solar power.

1.2 Methodology

An interdisciplinary approach was chosen both with regard to the composition of the working group and the manner in which the topic was addressed. The aim was to develop solutions to the barriers encountered in practice. Accordingly, the members of the working group included experts on environmental and nature conservation and its legal aspects, social scientists with expertise in the fields of acceptance and environmental awareness, economists, and experts on energy systems technology and on planning law and procedures.

The working group initially explored the potential significance of different wind and PV installation types and forms of deployment for growing the market, and discussed the relevant barriers. Based on a barrier analysis supplemented by the extensive experience of the working group's members regarding current wind and solar power trends, the next step involved formulating a series of policy options. These were grouped together by policy area and discussed in 4 sub-groups that focused on planning and licensing processes, acceptance, and the economic and technological factors. This process resulted in the formulation of 12 policy options in 4 policy areas. Finally, the policy options and the urgency of their implementation were discussed in depth with 12 external experts to ensure that they struck the right balance.

1.3 Analysis of barriers to expansion

To provide a starting point for the formulation of potential solutions, the working group members were sent a questionnaire asking them to identify the key barriers to faster expansion of wind and solar power in Germany. The barriers and interim findings were discussed with practitioners at two expert workshops in October 2020 and June 2021 and are summarised without further analysis in Table 2. The working group subsequently developed a series of policy options (see Chapter 5) for overcoming the barriers that need to be addressed most urgently.

A number of specific barriers were identified for wind and PV installations. These include the fact that, as a rule, fossil fuels have a competitive advantage over climate-friendly energy sources. This is due to a lack of carbon pricing for emissions at home and abroad or, where carbon pricing does exist, because the prices are too low. In order to enable fair competition between the different technologies, it is vital to ensure that all the consequential costs are reflected through mechanisms such as a sufficiently high carbon price. Consequently, in addition to the specific measures for accelerating the expansion of wind and solar power proposed in this position paper, it is also recommended that sufficiently high carbon prices should be established in Germany and, as far as possible, at EU level. A higher carbon price would create incentives to invest in renewable energy by making renewables more financially attractive compared to fossil fuels. A higher carbon price would also reduce the need for additional funding measures to promote wind and solar power.

Category	**Barriers** (the barriers reflect the perspective of investors and project developers)
Onshore wind Larger wind farms are usually built by professional project developers, while small wind farms and individual wind turbines may also be installed by community energy cooperatives and private individuals.	
Economic	• Locations in southern Germany often have limited wind power potential, making them less profitable under the current market model. • In the absence of special regulations, repowering can often be financially unattractive.
Land availability, visual impact, acceptance	• Failure to designate enough land with sufficient wind resources (attractive locations in terms of wind power potential are often not designated). • Environmental impacts (noise emissions, threats to birds and bats) and concerns about health impacts. • Automatic prioritisation of other interests (military, radar, weather radar, earthquake monitoring stations, etc.) instead of weighing up each case on its merits. • Public opposition to changes in the appearance of the landscape. • There are several avenues for appealing against wind installations and their opponents can be highly litigious. • Opposition to siting wind installations in woodland (which is widespread in central and southern Germany). • If local authorities and actors have no or only very limited financial involvement in terms of investing in and operating installations, this can lead to low levels of acceptance.
Knowledge, guidance, technology	• Lack of policy guidelines setting out the number of wind installations required to deliver climate neutrality and where they can be built. • Because the necessary increase in the number of wind installations is underestimated by planners and the public, the total area designated for wind installations is insufficient.

Regulatory framework, other	• Not enough genuine, transparent participation in local licensing processes. • Time-consuming, laborious and complicated tender, planning and licensing procedures. • Perception that the purpose of regional and urban land use planning is to restrict rather than to develop (i.e. to approve as few wind installations as necessary, rather than as many as are required). • Regional planning is an important land use planning instrument, but regional planning decisions are frequently appealed in the courts. • Planning control of repowering installations is complicated, local authorities are uncertain about the designation of repowering locations. • Different German states have different regulations governing the distance between wind installations and residential developments and regarding participation processes. • Insufficient grid capacity for wind power feed-in, grid expansion too slow. • Wind installations are usually portrayed as having a fundamentally negative impact on the landscape. This causes the public to be prejudiced against them, to the detriment of other, more positive narratives. • A feeling that wind installations are not fairly distributed across Germany's federal states.
Offshore wind Offshore wind projects are carried out by energy suppliers and professional project developers.	
Economic	• High investment costs and long project timeframes.
Land availability, visual impact, acceptance	• The North and Baltic Seas are sensitive ecosystems that are already overexploited in some respects. • Limited new development potential due to competition for space (e.g. from shipping, sand and gravel extraction and nature conservation).
Knowledge, guidance, technology	• Significant technical challenges (e.g. with regard to water depth and grid connection). • Complex planning, procurement and logistics (need for special wind installation vessels, building materials, etc.). • Inflexible grid connection model means more efficient solutions are prevented by legal regulations and distribution system operator requirements.
Regulatory framework, other	• Time-consuming and laborious licensing procedures. • Licensing authorities lack necessary capacity. • Grid bottlenecks occur when transferring wind power to the onshore grid. • Legal uncertainty concerning the Offshore Wind Energy Act.

Roof-mounted and building-integrated PV Solar installations mounted on or integrated into buildings are generally installed by the building's owners, who are not usually experts on solar PV. In some cases, however, roof space is leased to specialist companies.	
Economic	• Certain business models are not financially attractive (e.g. feeding 100% of solar-generated electricity into the grid, or installations on rented buildings (despite the landlord-to-tenant electricity model)). • Uncertainty regarding the cost-effectiveness of new PV installations, and in particular about how changes to the regulatory framework will affect profitability. • Lack of financial resources among investors (e.g. limited access to loans for older property owners). • Commercially-focused optimisation means that a building's roof space potential is often only partially exploited. This can hold back the expansion required from a whole-system perspective. • Installing solar panels on existing buildings can be complicated and expensive. • Building-integrated photovoltaics, especially solar façades, are more expensive than roof-mounted PV. As a rule, they are not cost-effective unless their benefits are priced in (e.g. replacement of other expensive façade materials or high architectural quality). • The energy system benefits of installing solar panels on east-west facing roofs and façades (smoothing of the solar electricity generation time curve) are not reflected in the feed-in tariff. This means that panels are often not installed with this orientation due to their slightly lower output.
Land availability, visual impact, acceptance	• There can sometimes be competition between PV installations and other roof space uses (e.g. technical equipment, rooftop terraces, etc.). However, combined space uses are possible (e.g. PV installations on large green roofs). • PV installations limit options for future roof use changes. • Aesthetic uniformity of PV installations. • Lack of affordable building-integrated/other solutions that are also compatible with urban planning and historic preservation requirements.
Knowledge, guidance, technology	• Lack of awareness among policymakers that widespread installation of solar panels on suitable building roofs would help to achieve climate neutrality. • Lack of consulting and installation capacity in the trade. • Some architects and planners do not support PV installations, among other things due to a lack of training. • Property owners lack the technical and financial expertise to evaluate PV installation quotes. • Lack of knowledge regarding the technology options and the benefits of solar electricity generation.

Regulatory framework, other	• There is generally little personal gain for (private and commercial) landlords who install solar panels on their buildings. • It can be difficult to get all the property owners in a homeowner association to agree to the installation of solar panels on their building(s). • Bureaucracy (compulsory notification, business registration requirements, declaration on tax returns). • The climate benefits of PV are not taken into account by historic preservation law. • In the case of large roofs, direct marketing (mandatory for an installed capacity of 100 kW or more) and participation in tenders (optional from 300 kW and mandatory from 750 kW) are complex and challenging to implement. • The landlord-to-tenant electricity model is complex and challenging to implement. • Fire safety regulations and the associated insurance cover can be a barrier to the installation of solar panels on commercial premises. • For commercial premises, the requirement to provide evidence of the use of electricity generated on-site can involve a lot of extra work, making it less financially attractive to use this electricity. • Many older owners who will be leaving the property to their heirs have little to gain from investing in a PV installation or are unable to do so.
Ground-mounted PV Ground-mounted PV projects are usually carried out by specialist project developers.	
Economic	• Due to the highly competitive nature of the tenders, bids from locations in states with fewer solar resources tend not to be successful, meaning that the land in question remains unused for ground-mounted PV.
Land availability, visual impact, acceptance	• Large ground-mounted PV installations may be seen as “industrial structures” rather than as a “new part of the cultural landscape”, since landscape structures are difficult to appreciate in areas covered by large solar arrays, and the habitats created under the modules are not visible. • Recommendations already exist for how to implement environmentally sustainable ground-mounted PV projects that make a positive contribution to biodiversity, nature and environmental conservation and rural development. However, these recommendations are not always followed, and this can result in low levels of acceptance. • In less-favoured areas, competition with agricultural land that is hard to farm and which could be used for ground-mounted PV according to the Renewable Energy Sources Act.
Knowledge, guidance, technology	• No incentives to provide grid services (e.g. operating reserves by combining PV installations and batteries to create combined power plants).

Regulatory framework, other	• The grids in some regions have limited capacity to take in solar electricity. • Lengthy planning and licensing processes. • The volume of the tenders (e.g. 1,600 MW in 2022) for PV installations over 750 kW is too low and limits the size of the market. • Lack of standardisation of long-term power purchase agreements (PPAs) and guarantees of origin, and an inadequate overall framework for these aspects.
PV installations as part of multiple space use solutions (agrivoltaics, floating PV, solar car park canopies, etc.) At present, these only exist as pilots. The systems will presumably be installed either by specialist project developers or by the landowners (e.g. farmers).	
Economic	• Lack of remuneration regulations (apart from the innovation tenders under the Renewable Energy Sources Act). • Higher installation costs make these solutions less cost-effective (if the multiple space uses cannot be internalised). • With agrivoltaics, there is a danger that agricultural subsidies could be lost.
Land availability, visual impact, acceptance	• Agrivoltaics hamper accessibility and cultivation of farmland. • Potential opposition to visual impact of agrivoltaics on the landscape (it is possible to object on the grounds of landscape incompatibility in the binding land use plan process). • Floating PV restricts recreational use of waterbodies. Its water quality impacts are uncertain.
Knowledge, guidance, technology	• Lack of awareness of deployment options, technology and benefits (synergies generated by multiple space use). • Limited commercial supply of this new technology. • Limited experience of implementation, few experts to provide advice. • Lack of knowledge about the impacts of floating PV on water quality.
Regulatory framework, other	• Building law does not grant preferential treatment to agrivoltaics in undesignated outlying areas. • Local authority uncertainty regarding licensing law (e.g. regarding changes of use), conflicting local regulations (e.g. parking regulations that hinder the installation of solar car park canopies), inadequate urban land use planning. • Unresolved insurance law questions. • Vandalism risk to PV installations. • Grid connection can be complicated in some cases. • Uncertainty regarding legal nature conservation requirements. • Uncertainty about the importance of and need for agrivoltaics in the future energy system.

Table 2: Identified barriers used as the basis for formulating the policy options. (Source: authors' own content)

2 Solar and wind power expansion pathways to 2030

This chapter discusses the extent to which it is necessary to accelerate the expansion of PV and wind capacity. It begins with an overview of global, European and German climate targets and a discussion of the future energy system structure needed to achieve climate neutrality by 2045. Next, it considers the implications for the electricity supply and the rate at which solar and wind capacity will need to expand in order to deliver the relevant targets. The chapter concludes with a look at the different types of installation that can in principle be used to achieve this growth.

2.1 The climate targets

The Paris Agreement is a legally binding international treaty signed by the global community with the aim of limiting climate change. It was adopted by 196 Parties at COP 21 in Paris on 12 December 2015 and entered into force on 4 November 2016. The agreement's goal is to limit average global warming to well below 2°C and preferably to 1.5°C compared to pre-industrial levels. To meet this long-term temperature goal, the signatories aim to achieve a climate-neutral world by mid-century.[5] But in 2020, Earth's average temperature had already risen by 1.2°C since the late 19th century.[6] The IPCC report published on 9 August 2021 describes the urgency of the situation in the following terms: Global surface temperature will continue to increase until at least the mid-century under all emissions scenarios considered. Global warming of 1.5°C and 2°C will be exceeded during the 21st century unless deep reductions in CO2 and other greenhouse gas emissions occur in the coming decades.[7]

In Europe, the European Council adopted the goal of achieving climate neutrality by 2050 on 12 December 2019.[8] On 11 December 2020, it endorsed an increased, binding EU target of at least 55% net internal reduction in greenhouse gas emissions by 2030 compared to 1990 levels.[9] The European Commission's Green Deal sets out a concrete plan and proposes regulatory instruments for making Europe the first climate-neutral continent.[10]

In order to meet its commitments under the Paris Agreement, Germany legally enshrined[11] the goal of achieving greenhouse gas neutrality by 2050 on 12 December 2019 in the Federal Climate Change Act (KSG). However, in an order published on 29 April 2021, the Federal Constitutional Court ruled that the 2019 Federal Climate

5 See UNFCCC 2021.
6 See NASA 2021.
7 See IPCC 2021.
8 See European Council 2019.
9 See European Council 2020.
10 See Europäische Kommission 2021.
11 See Deutscher Bundestag 2019.

Change Act is incompatible with fundamental rights because it lacks sufficient specifications for further emission reductions from 2031 onwards. The ruling calls for climate action to be shared fairly between current and future generations[12] and states that climate action is an intertemporal guarantee of freedom. This means that the fundamental freedoms of future generations must not be violated by offloading necessary climate action onto the future. As a result of this ruling, and in view of the more ambitious EU climate target for 2030, the German Parliament amended the Federal Climate Change Act on 24 June 2021, setting new greenhouse gas emission reduction targets of at least 65% by 2030 and at least 88% by 2040 (compared to 1990 levels). It also brought forward the target date for achieving net greenhouse gas neutrality to 2045.[13] The new German government has set a target of meeting 80% of gross electricity demand with renewables by 2030. In a review of Germany's current climate action status presented by the Federal Ministry for Economic Affairs and Climate Action (BMWK) on 11 January 2022, Minister Habeck stressed that the climate action taken so far in all sectors is inadequate and the rate of emission reductions must be tripled.[14]

The goal of achieving climate neutrality by 2045 means that Germany's energy supply – 76% of which still came from fossil fuels in 2020[15] – will need to become carbon-neutral (i.e. renewables-based) by no later than 2045. It should be stressed that all of the energy system's sectors (electricity, heating, mobility and industrial processes) will need to be defossilised. Studies of potential transformation pathways for the energy transition show that these sectors will be more closely coupled in the future energy system and will become largely electricity-based in the long run[16]. This necessary transformation together with the more ambitious targets in the amended Federal Climate Change Act means that growth in renewables will need to accelerate significantly over the next few years if the 2030 climate targets are to be achieved.

2.2 Key structural aspects of a climate-neutral energy system

There are a number of different transformation pathways for achieving the goal of a climate-neutral energy supply in Germany by 2045. We cannot say for certain what the exact details of the energy system will look like in 2045. However, the physical and economic constraints do allow certain conclusions to be drawn about the basic structures of the future energy system. Below, we outline some of the key aspects of the future energy system's structure that are of particular relevance to this position paper.

A renewables-based energy supply: Achieving a climate-neutral energy supply without nuclear power will call for the complete or almost complete replacement of fossil energy sources with renewables, including the use of waste heat sources. This will require an increase in renewable energy capacity in Germany. Climate neutrality scenarios indicate that – even if large quantities of green energy carriers are imported

12 See BVerfG 2021.
13 See Deutscher Bundestag 2021b.
14 See BMWK 2022a.
15 See BMWi 2021b.
16 See acatech/Leopoldina/Akademienunion 2017.

and major advances in energy efficiency are achieved – wind and solar capacity will need to increase by between fourfold and ninefold by 2045, compared to current levels.[17,18] The expansion targets established by the new German government, including the goal of 80% renewables by 2030, imply a similarly ambitious trajectory for renewable energy in Germany.

Techno-economic assessments indicate that it is possible to achieve a secure energy supply for an industrialised Germany that – averaged out across a whole year – is largely based on domestic renewable energy sources.[19,20] This assumes a significant expansion of temporary power trading in Europe. The assessments also assume that Germany will import green hydrogen and hydrogen-based synthetic fuels, although there are significant differences between the relevant studies concerning the level of these imports. Since solar and wind power have greater potential than other forms of renewable energy in all the scenarios, these will become the dominant sources of energy in a climate-neutral energy system. While the fluctuations in their output and the fact that wind and PV installations are spread out across large areas of land make integrating them into the energy system extremely challenging, technical solutions do exist. Moreover, all the scenarios indicate that the switch to renewable energy will reduce Germany’s reliance on energy imports.

High electrification and rising demand for electricity: The available renewable energy resources mean that the future energy system will be characterised by a high level of electrification. While in 2019, electricity accounted for just 20.1% of total final energy consumption in Germany[21], in the long term, this figure will rise to well over 50%. Different studies and scenarios project electrification figures of between 60% and 90% for the heating and mobility sectors, as a result of sector coupling. This means that the transition to climate neutrality will lead to an increase in annual electricity demand from its current level of around 500 terawatt hours to between 1,000 and 1,580 terawatt hours.[22,23] The Federal Ministry for Economic Affairs and Climate Action projects that gross electricity demand will rise to between 680 and 750 terawatt hours by 2030, while the projected increase in the studies cited above ranges from 643 to 780 terawatt hours.[24,25,26] And demand for electricity in 2030 could be even higher if more domestically produced green hydrogen is used in Germany than has hitherto been assumed in the literature. The extensive electrification of the heating and mobility sectors is largely driven by the fact that electricity generated from solar and wind power has far more potential than any other form of renewable energy. As a result, electricity is becoming the most important energy carrier. Solar thermal energy could also play an important role in the future. However, its contribution will be limited by the mismatch between the times of year of peak solar energy availability and peak heating demand. Wind power thus has a key role in providing energy and enabling space heating during the midwinter months. The studies cited above expect fluctuating renewables to

17 See Fraunhofer ISE 2021b.
18 See Agora Energiewende 2021.
19 See Fraunhofer ISE 2021b.
20 See Agora Energiewende 2021.
21 See BMWi 2021a.
22 See Fraunhofer ISE 2021b.
23 See Agora Energiewende 2021.
24 See BMWK 2022a.
25 See Fraunhofer ISE 2021b.
26 See Agora Energiewende 2021.

account for over 85% of electricity generation. The rest will come from other types of renewable energy (hydropower, biomass, geothermal energy), with a residual amount possibly also coming from fossil fuels.[27,28] Fuels produced with renewable electricity, such as hydrogen, methane and other synthetic fuels, will also be used as additional energy sources, especially in the mobility and industrial sectors. Estimates vary as to the percentage of the future energy supply that they will account for. However, their contribution will be limited by a higher levelised cost of energy due to the additional conversion losses and the resulting significant increase in primary energy demand for renewable energy sources. In any case, the uncertainty regarding the level of domestic hydrogen production or hydrogen imports does nothing to change the fundamental energy system structures outlined above. These will still be dominated by fluctuating renewables and characterised by strong sector coupling.

Strong sector coupling, integration of storage capacity and smart systems technology: On the consumer side, the high percentages of fluctuating solar and wind power call for the following four measures: coupling of the electricity use, heating, cooling and mobility sectors, comprehensive integration of storage capacity, a significant expansion of the grid, and smart energy system management. Extra storage capacity will be needed both for short-term storage (e.g. batteries for daily electricity storage) and long-term storage (e.g. methane or hydrogen as a seasonal gas storage medium). This extra capacity will be both decentralised (e.g. PV-battery combinations in individual buildings) and centralised (e.g. pumped-storage power plants). Thermal energy storage will also play a greater role, since it is significantly cheaper than electricity storage. Demand for short-term electricity storage (especially pumped-storage power plants and batteries) is expected to reach 84 gigawatt hours by 2030 and 227 gigawatt hours by 2045 if the climate neutrality target is to be achieved.[29] By way of comparison, Germany's current pumped-storage power plants have a total output of 6.3 gigawatts and an installed storage capacity of around 37.4 gigawatt hours.[30] The transmission grid needs to be expanded so that electricity can be transported between Germany's regions, especially from sparsely populated regions with high wind and solar potential to densely populated, industrial, urban regions.[31] The distribution grid must also be expanded so that it can cope with the huge increase in solar electricity generated by decentralised installations. Grid operation will need to be modified to enable smart control of fluctuating electricity generation and increased storage capacity, and to provide other forms of flexibility. This will require the establishment of an appropriate regulatory framework.

A highly efficient overall energy system: In order to minimise the burden on the supply side, it will be necessary to significantly improve the efficiency of the overall system, not only to keep costs down but also to ensure security of supply. As well as reducing final energy consumption, this also applies to the generation of electricity, heating and cooling, the production of fuels, and their distribution, conversion and storage. There is particular potential to achieve efficiencies in final energy consumption, especially through improved thermal insulation of buildings and in the

27 Ibid.
28 See Fraunhofer ISE 2021b.
29 See Fraunhofer ISE 2021b.
30 See Heimerl et al. 2017.
31 The necessary transmission grid expansion, depending on how the growth in wind and solar capacity is spread across Germany's regions, is discussed e.g. in WWF 2018 and Öko-Institut 2018.

mobility sector. For instance, a compact electric vehicle consumes around 16 kilowatt hours of electricity per 100 km, whereas a comparable petrol car consumes around 52.5 kilowatt hours (5.9 litres of petrol) and a diesel model consumes 46.1 kilowatt hours (4.7 litres of diesel). Switching to electric vehicles would thus reduce final energy consumption by approximately two thirds.[32,33]

Low levelised cost of electricity: In terms of the levelised cost of electricity, solar and wind power is already often competitive compared to electricity generated from fossil fuels. In 2018, for example, a power purchase agreement (PPA) was signed for a large-scale PV plant in Germany to supply solar electricity at €0.043 per kilowatt hour. A study that modelled the levelised cost of electricity for different energy technologies[34] concluded that it currently ranges from €0.031 to €0.11 per kilowatt hour for PV installations in Germany, while it is between €0.039 and €0.083 per kilowatt hour for onshore wind and between €0.072 and €0.121 per kilowatt hour for offshore wind. Moreover, these figures are all expected to keep falling. This means that the levelised cost of electricity for these technologies is of a similar order to or even lower than that of new combined cycle gas turbines (€0.078 – €0.131/kilowatt hour) and gas-fired power plants (€0.115 to €0.29/kilowatt hour).[35] However, when assessing the competitiveness of renewable versus fossil fuel based electricity generation, it is not enough simply to compare the levelised cost of electricity. This is because the consequential costs of burning fossil fuels have hitherto largely been socialised, and because the fluctuations inherent in solar and wind power generation mean that storage and grid capacity must be expanded, both to guarantee security of supply and to ensure that the grid can cope with the volume of solar and wind power being fed into it. This makes the effective cost of renewables higher – for instance, the levelised cost of electricity for PV-battery systems is currently between €0.052 and €0.197/kilowatt hour[36], although it is falling rapidly. Meanwhile, the cost of electricity generated from fossil fuels is rising fast, among other things due to the rising price of carbon credits. The competitiveness of renewable energy in conjunction with storage systems is thus expected to keep improving in the future.

System costs to become more important: As far as the economic aspects are concerned, system costs are expected to become more important in the future energy system. This means that it will be necessary to adjust the relevant business and billing models. In the future, final energy prices should also reflect the temporal availability of electricity sources in order to prevent undesired developments in the transformation of the energy system. This will call for significant changes in pricing structures and the regulatory framework. For example, the standard current practice of allocating grid costs and the costs associated with maintaining the security of the electricity supply to the unit price causes undesired effects in the development of the energy system. For

32 See ifeu 2019.
33 See Chemie.de 2021.
34 See Fraunhofer ISE 2021c.
35 The sharp rises in global gas and oil market prices in 2021 suggest that the cost advantage of renewables could be even greater than described here. However, it is possible that these could just be temporary, short-term fluctuations. The cost of renewable energy installations can also fluctuate – for instance, the global market price of PV modules also rose in 2021. However, these short-term price rises are within the expected range of variation and do not alter the longer-term trend of falling module prices (experience curve).
36 See Fraunhofer ISE 2021c.

instance, the lack of relevant business models means that the necessary storage and grid infrastructure is not expanding as much as necessary.

2.3 Fundamental assumptions about the future energy system

A climate-neutral energy system with the key characteristics described above can be achieved through various different structures. For example, greater efficiency and sufficiency would reduce the need for PV and wind installations, a larger increase in the number of new wind installations would reduce the need for solar installations, and a larger increase in the number of ground-mounted PV installations would reduce the need for roof-mounted PV installations. While physical, economic and other factors limit the extent to which these parameters can vary, there is enough leeway to allow for different strategies in pursuit of the overall goals, as evidenced by the policy debate concerning the energy transition in Germany. With this in mind, the following bullet points **summarise the fundamental assumptions underpinning this position paper** in order to explain the background to its proposals and conclusions.

1. **The future climate-neutral energy system should be economically efficient** in order to maintain economic competitiveness and guarantee an affordable energy supply. Any subsidies for particular technologies and energy carriers should therefore be temporary in nature and should only be granted if they are necessary for enabling the transition to a climate-neutral energy system. Subsidies for environmentally harmful options should be ended.

2. **Economic efficiency should not be confined to minimising energy installation investment and operating costs. It should take the overall costs into account**, e.g. the extra costs associated with enabling a socially acceptable energy transition and achieving the necessary public acceptance. This can be supported through measures such as a more even geographical distribution of ground-mounted PV and wind installations and more widespread use of roof-mounted PV. An exclusive focus on the individual technologies' levelised cost of electricity should be avoided.

3. **The introduction of the future climate-neutral energy system should be accompanied by a public debate.** The energy transition will call for changes in investment decisions and other types of expenditure and in the behaviour of all private individuals, companies and other institutions. These changes are likelier to come about if there is widespread support for the goals and corresponding measures, which in turn means that the benefits and drawbacks must be distributed in a manner that is perceived to be fair. This includes both the spatial distribution of renewable energy installations and economic aspects such as the costs for investors and consumers and the revenue and returns for the installations' operators and owners. It will also be important to ensure that the drawbacks are distributed in a socially acceptable manner, potentially through the implementation of compensation mechanisms. The debate concerning the design of the carbon price and associated mechanisms such as the carbon fee and dividend (German: "Klimageld") shows that there is still a long way to go before we achieve a common understanding of what is meant by "fair". Other measures that could contribute to maintaining a high level of acceptance across the whole of German society include a

more even geographical distribution of the landscape impacts of ground-mounted PV and onshore wind installations and the participation of the affected local authorities and residents both financially and at the project design stage.

4. **It is necessary to ensure that the desired climate-neutral energy system can be implemented fast enough**. If Germany is to achieve climate neutrality by 2045, it will be necessary to significantly accelerate the transformation of the energy system. This means that the speed at which different technologies can be implemented must be taken into account when designing the future energy system. The risks associated with implementation can be reduced by adopting a diverse approach to the transformation, for example by installing the necessary PV capacity not only in the shape of ground-mounted PV systems in open spaces but also through roof-mounted systems in towns and cities. This would reduce the time pressure to install ground-mounted PV systems and would also mean that more actors would be involved in implementing PV technology.[37] The speed at which a measure can be implemented is a key factor, especially for onshore and offshore wind installations.

2.4 Required rate of expansion for PV and wind installations

In order to determine the required rate of expansion, this section quantifies the wind and PV capacity that will be needed to meet the 2045 climate neutrality target. This position paper focuses primarily on the period up to 2030. In its January 2022 review of Germany's current climate action status, the German government established clear targets for meeting 80% of electricity demand with renewables by this date. The contribution that this will make to achieving climate neutrality by 2045 can be seen by comparing the energy scenarios in the studies "Klimaneutrales Deutschland 2045" (Towards a Climate-Neutral Germany by 2045")[38] and "Wege zu einem klimaneutralen Energiesystem" (Paths to a Climate-Neutral Energy System).[39] The scenarios make different assumptions about efficiency gains in the various energy system sectors, potential technology pathways, e.g. for electric mobility and hydrogen-based mobility, and the resulting future electricity demand. They also make different assumptions about the associated costs and the level of energy imports. The Fraunhofer Institute for Solar Energy Systems (ISE) study presents additional scenarios based on different assumptions regarding public attitudes towards the energy transition (persistence, non-acceptance and sufficiency). However, in the interests of comparability, only the reference scenario is used below. These factors explain the spread of wind and PV installed capacity projections for 2045.[40] All known scenarios for the transition to a

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37 While sufficient land for new PV and wind installations is theoretically available in Germany, the actual availability of this land is currently limited by a variety of factors, meaning that it can often not be used for this purpose. This issue is becoming an increasingly serious barrier to the expansion of PV and wind capacity. Consequently, in addition to ground-mounted PV, there is a strong case for making extensive use of the available roof space for solar installations, even if the specific costs are somewhat higher.

38 See Agora Energiewende 2021.

39 See Fraunhofer ISE 2021b.

40 In some instances, other studies, e.g. Fraunhofer ISI/Consentec 2021 "Langfristszenarien für die Transformation des Energiesystems Deutschland 3" (Long-term Scenarios for the Transformation of the Energy System in Germany 3), dena 2021 "Aufbruch Klimaneutralität" (Towards Climate Neutrality), BDI 2021 "Klimapfade 2.0" (Climate Pathways 2.0) and the overview of scenarios in Ariadne 2021 "Deutschland auf dem Weg zur Klimaneutralität 2045" (Towards a Climate-Neutral Germany by 2045), have lower figures for the projected expansion by 2030 than the targets established by the German government for this date.

climate-neutral energy system show a significant rise in electricity demand and a future energy system dominated by wind and solar power.

Table 3 shows the installed capacities for 2020, the German government's installed capacity targets for 2030 and the installed capacities that will be needed in 2045 in order to achieve climate neutrality, as well as the annual increases in capacity required to meet these goals. The German government aims to roughly double onshore wind capacity and quadruple offshore wind and solar PV capacity by 2030. The annual capacity cannot rise severalfold all in one go – it must be increased continuously. Consequently, Table 3 shows the maximum increases for the period 2022–2030 that, according to the German government, will be necessary to achieve its 2030 targets. According to these figures, the annual increase in installed onshore wind capacity must rise from 1.2 gigawatts in 2020 to up to 10 gigawatts, the increase in offshore wind capacity must rise from 0.2 gigawatts to up to 7 gigawatts and the annual increase in installed PV capacity must rise from 4.8 gigawatts to up to 20 gigawatts. Even if large quantities of green energy carriers are imported and major advances in energy efficiency are achieved, current capacity will need to increase by between fourfold and ninefold if a climate-neutral energy supply is to be achieved by 2045. This is equivalent to roughly double the 2030 targets.

	Installed capacity 2020	Increase in 2020	German government targets		Expansion scenarios from climate neutrality studies	
			Installed capacity 2030	Maximum annual increase 2022–2030	Installed capacity 2045	Average annual increase[41] 2031–2045
	GW	GW/year	GW	GW/year	GW	GW/year
Onshore wind	54.4	1.2	100	10	145 – 199	3.0 – 6.6
Offshore wind	7.7	0.2	30	7	66 – 70	2.4 - 2.7
PV	53.8	4.8	200	20	385 – 429	12.3 - 15.3

Table 3: Installed capacities of PV and (onshore and offshore) wind in 2020,[42] German government targets for 2030[43] and climate neutrality study expansion scenarios to 2045.[44, 45] The average annual increase for 2031–2045 is calculated as the difference between the installed capacity in the climate neutrality scenarios for 2045 and the German government's targets for 2030.

Figure 1 shows the annual increase in onshore and offshore wind and PV installed capacity in recent years, for the period up to 2030, and for 2031–2045. The illustration

41 This figure represents the annual increase in installed capacity. The market volume is the sum of this figure and the replacement installation capacity. Based on an installation lifespan of 25 years, the required annual replacement capacity is 4 gigawatts for onshore wind, 1.2 gigawatts for offshore wind and 8 gigawatts for PV based on the installed capacity in 2030, although this demand will only occur gradually.

42 See UBA 2021a.

43 See BMWK 2022a.

44 See Agora Energiewende 2021.

45 See Fraunhofer ISE 2021b.

makes it clear that future increases should not only be compared against the 2020 figures. The largest rise to date in onshore wind capacity (4.9 gigawatts) occurred in 2014, while the biggest increase in PV capacity (8.2 gigawatts) was in 2012. The 2030 targets are slightly more than double these figures. Given that the largest rise in offshore wind capacity was 2.3 gigawatts in 2015, the target increase of 7 gigawatts a year for offshore wind would appear rather more ambitious.

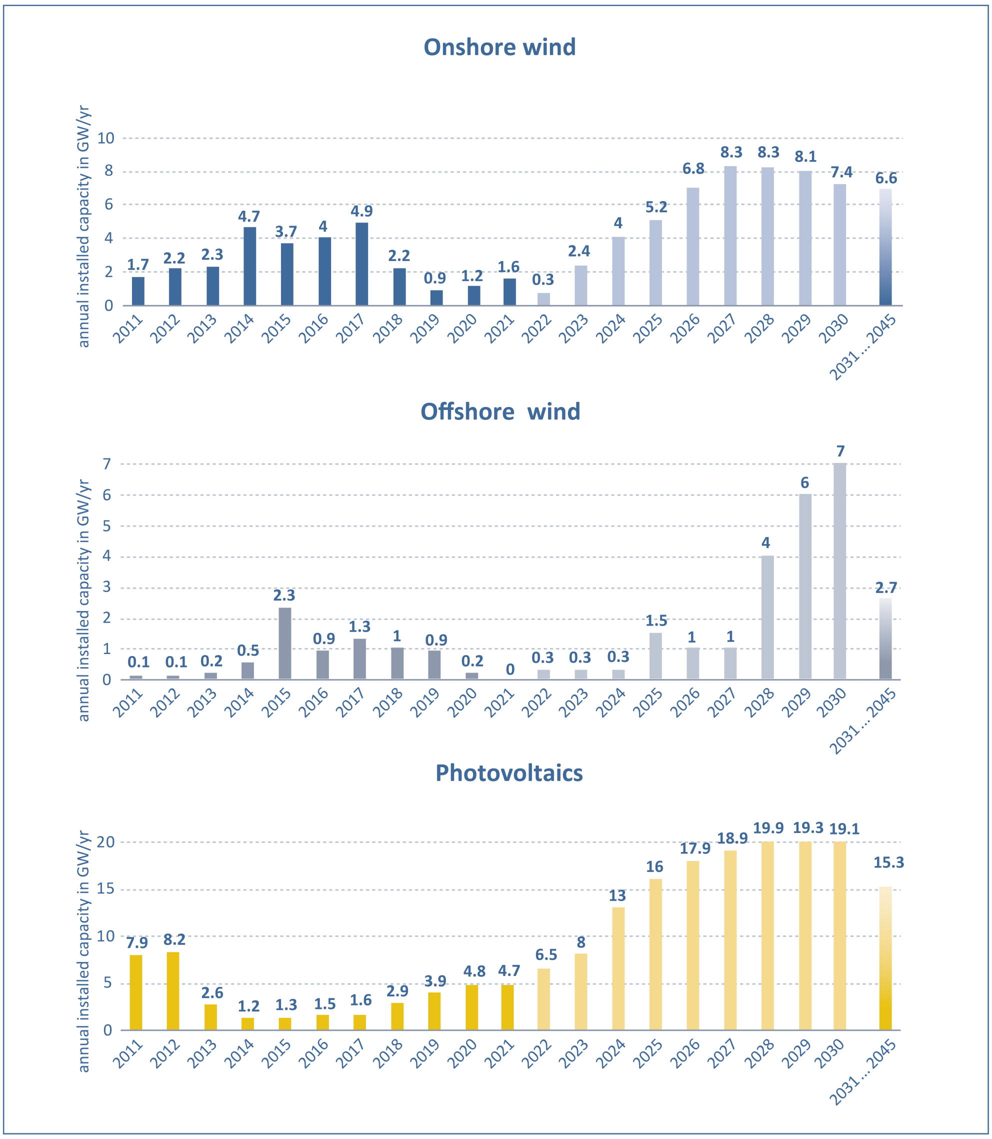

Figure 1: Annual installed capacity (2011–2022) and net installed capacity requirement (2022–2030) in gigawatts/year. The net installed capacity requirement was calculated using the German government's gross capacity increase targets[46], assuming an installation lifespan of 20 years for onshore wind and 25 years for offshore wind and PV (Source: authors' own illustration).[47]

46 See BMWK 2022a.

47 More detailed figures on the gross and net capacity increases for the different installation types are presented in Tables 6-8 in the Appendix (from p. 100).

2.5 Available forms of deployment and installation types for wind and solar technology

Wind and solar technology can be installed using different methods and in different locations. The available options are presented in Table 4.

Technology	Description
Onshore wind 	This land-based technology is sometimes also referred to as land-based wind farms. In Germany, the growth in onshore wind began with the introduction of the 1990 Electricity Feed-In Act (German: Stromeinspeisungsgesetz), which was replaced by the Renewable Energy Sources Act (EEG) in 2000. Installed capacity has risen from 55 megawatts in 1990 to 6,097 megawatts in 2000, 26,823 megawatts in 2010 and 54,938 megawatts in 2020.[48,49] 420 new onshore wind turbines with a total capacity of 1,431 megawatts were installed in 2020, of which 102 (with a capacity of 339 megawatts) replaced old turbines as part of repowering projects. Meanwhile, 203 turbines with a capacity of 222 megawatts were decommissioned, giving a net increase of 217 wind turbines with a capacity of 1,208 megawatts. On average, the turbines installed in 2020 had a capacity of 3.4 megawatts, a hub height of 135 metres, a total height of 196 metres and a rotor diameter of 122 metres. The largest turbines had a nameplate capacity of 5.8 megawatts. Onshore wind installations generated 112 terawatt hours of electricity in 2020, equivalent to approximately 2,000 full-load hours. The levelised cost of electricity for onshore wind in 2021 was between €0.039 and €0.083/kilowatt hour, with specific turbine costs ranging from €1,400 to €2,000/kilowatt hour.[50] These costs are highly dependent on wind power potential, i.e. the average annual wind strength in a given location. Mean wind speed by district ranges from a high of up to 8.5 metres/second in coastal northern Germany to as little as 2.5 metres/second in some parts of southern Germany. The reference value for the minimum speed for profitable operation of onshore wind turbines is 4.8 metres/second. Figures up to 2017 indicate that no plans for wind turbines with a capacity greater than 750 kilowatts were implemented for locations with wind speeds below this value.[51] The mean wind speed across all districts in southern Germany is thus too low to enable profitable operation of onshore wind turbines. Consequently, wind power installations in this part of the country are concentrated in exposed locations with a sufficiently high wind speed. The figures are for a hub height of 140 metres above ground level – wind speed and constancy increase with hub height. Higher turbines can also have larger rotor blades, allowing them to achieve a higher nameplate capacity and output per unit rotor area. The "entitlement to payment" stipulated for wind turbines in the EEG expires after twenty years. In July 2021, the legislator amended the EEG to include the option of temporary follow-up support lasting until 31 December 2021 in the form of an increased market value for wind turbines for which this entitlement to payment has expired.[52] Thereafter, if the turbines can no longer be operated profitably or repaired, they will usually be decommissioned. Replacement of old

48 See Deutsche WindGuard 2021.
49 See BMWi 2021b.
50 See Fraunhofer ISE 2021c.
51 See Deutsche WindGuard 2017.
52 Section 21(1)(3)(a) EEG 2021 in conjunction with Sections 23(b)(2) to (5) EEG 2021.

	wind turbines with new ones is referred to as repowering. Since new wind turbines have a significantly higher capacity, it is possible to generate more wind power with fewer turbines in the same location or its immediate vicinity.
Offshore wind 	Offshore wind turbines are installed at sea. The first offshore wind installations in German waters were connected to the electricity grid in 2009.[53] By the end of 2020, 1,501 offshore wind turbines with a capacity of 7,770 megawatts had been installed in Germany, 6,698 megawatts in the North Sea and 1,072 megawatts in the Baltic Sea. Offshore wind installations generated 27 terawatt hours of electricity, equivalent to 3,475 full-load hours. 32 new offshore wind turbines with a total capacity of 219 megawatts were installed in 2020. These turbines had an average capacity of 6.8 megawatts. The turbines are installed at an average distance of 74 kilometres from the coast in locations with an average water depth of 30 metres.[54] Offshore wind turbines have a significantly higher power output than onshore turbines due to the higher average wind speed in the North and Baltic Seas (9–10 metres/second[55]) and a more constant wind strength across the year. Moreover, as long as they are located far enough away from the coast, they do not impair the landscape as seen from land. However, it is much more technically challenging to install and anchor the turbines at sea. The turbines are exposed to greater stresses and it is harder and more expensive to connect them to the nearest terrestrial grid connection point than it is with onshore wind farms. The levelised cost of electricity for offshore wind in 2021 was between €0.072 and €0.121/kilowatt hour, with specific turbine costs ranging from €3,000 to €4,000/kilowatt of installed capacity (including connection to the mainland).[56]
Roof-mounted PV 	The majority of solar panels are installed on building roofs because they provide an (additional roof space) use without compromising the roof's function. On pitched roofs, the PV modules that convert sunlight into electricity are installed parallel to the roof surface, either above it ("roof-mounted") or set within the roof ("roof-integrated"). On flat roofs, a mounting frame is used to achieve the desired orientation and pitch. In terms of installed capacity, the percentage of solar panels installed on roofs rose from around 55% in 2015 to approximately 80% in 2019. Slightly over half of this figure is accounted for by installations with a capacity of less than 100 kilowatts.[57] By the end of 2020, a total of 53,848 megawatts of PV capacity had been installed in Germany.[58] Approximately 72% of this total was accounted for by roof-mounted PV.[59] Green roofs are becoming increasingly popular in order to reduce the amount of impervious surfaces and the associated flooding risk, improve the microclimate and support biodiversity. Solar panels can easily coexist with extensively greened roofs, although this does reduce the maximum installation density. Depending on the federal state, planning permission for installing solar

53 See BMWi 2021b.
54 See Deutsche WindGuard 2020.
55 See Fraunhofer IEE 2019.
56 See Fraunhofer ISE 2021c.
57 See Fraunhofer ISE 2021a.
58 See UBA 2021b.
59 See Kelm et al. 2019.

	panels on buildings is either not required at all or is only required if they exceed a certain size. Planning permission must only be obtained for listed buildings. One advantage of installing solar panels on roofs is that a power point for feeding the solar electricity into the grid is usually already present in the building and does not need to be installed separately. In southern Germany, the levelised cost of electricity for small PV installations (< 30 kilowatts peak) is between €0.058 and €0.08/kilowatt hour, while in northern Germany it is between €0.08 and €0.11/kilowatt hour. Larger roof-mounted PV installations (> 30 kilowatts peak) currently have a levelised cost of electricity of between €0.046 and €0.071/kilowatt hour in southern Germany and between €0.063 and €0.098/kilowatt hour in northern Germany.[60]
Solar façades 	PV modules can also be integrated into building façades (building-integrated PV – BIPV). Compared to a south-facing PV module installed at an optimal pitch of about 35 degrees, the electricity output of a building-integrated PV module is around 30% lower for a south facing façade and around 40% lower for an east or west facing façade. This is because the sun's rays hit the module at a less favourable angle. Solar façades perform like conventional façades while also generating electricity. Their costs are higher than conventional façades because the planning and installation processes are more complicated. However, they can be competitive with high-grade façade systems on prestigious functional buildings, for example. To date, relatively few solar façades have been installed, although they do not require planning permission in most of Germany's federal states. Balcony or plug-in solar panels are another option that can be easily installed in locations like balconies. They are connected to the consumer household's power circuit so that the household can use the solar electricity generated. However, their potential is relatively low in terms of the overall energy system. Solar façades could play an important role in supplementing roof-mounted PV. Particularly in winter, when the sun is lower in the sky, the electricity they generate can be used in conjunction with heat pumps to heat the buildings where they are installed.
Ground-mounted PV 	Solar arrays of different sizes can be cheaply installed on undeveloped land such as grassland or brownfield sites. Ground-mounted PV installations come in all sizes, although larger installations tend to be preferred due to economies of scale. In order to receive payments under the EEG, ground-mounted PV installations with a capacity of more than 750 kilowatts must participate in a tender. The annual volume of this tender (e.g. 1,850 megawatts in 2021) and the maximum capacity of the ground-mounted installation (up to 20 megawatts) are both limited. Moreover, the EEG stipulates that ground-mounted solar arrays can only be installed on sealed surfaces, former military sites, a 200-metre strip alongside motorways or railway lines, or in less-favoured areas. However, since the levelised cost of electricity for large ground-mounted PV installations is now very low, the installation of solar arrays for direct power purchase agreements (PPAs) that do not fall under the EEG is becoming increasingly common. These installations are not subject to the EEG's restrictions on the annual volume, size and installation location of ground-mounted arrays. Ground-mounted PV installations must obtain planning permission from the responsible local authority. Moreover, a binding land use plan and, where relevant,

60 See Fraunhofer ISE 2021c.

	an amendment of the preparatory land use plan are required, since they are classified as non-preferential projects in undesignated outlying areas. The percentage of installed capacity in Germany accounted for by ground-mounted PV fell from around 45% (approx. 0.6 gigawatts) in 2015 to around 20% (approx. 0.7 gigawatts) in 2019.[61] At the end of 2020, ground-mounted PV accounted for approximately 28% of Germany's total installed PV capacity of 53,848 megawatts.[62,63] Large ground-mounted solar arrays with a capacity of more than 1 megawatt currently have a levelised cost of electricity of between €0.0312 and €0.0416/kilowatt hour in southern Germany and between €0.0427 and €0.057/kilowatt hour in northern Germany.[64]
Agrivoltaics 	Agrivoltaics refers to solar arrays installed on land also used for agriculture. If installed at the correct height and with the correct spacing, PV modules can be sited on farmland used to grow crops such as vegetables, berries, fruit and vines without detriment to its agricultural use. Crop yields are barely affected and may even improve in some cases (e.g. heat-sensitive plants). It is also possible to install vertically-mounted, bifacial modules (that generate solar power by exposing both the front and the back of the panel to sunlight) in the gaps between crops. Research is ongoing into the crops, cultivation methods and mounting techniques that are best suited to this technology. In agrivoltaics, land already used for other purposes is also used for solar arrays, meaning that no new land is needed. The levelised cost of electricity for agrivoltaics is between €0.07 and €0.12/kilowatt hour. This is higher than the cost of conventional ground-mounted PV due to the extra height of the mountings and the extra spacing between modules. At present, only a handful of pilot agrivoltaic systems have been installed.
Floating PV 	PV modules can also be installed on the surface of waterbodies not used for other purposes, such as flooded former gravel pits or lakes on the sites of former opencast mines. Some countries such as China have also installed floating PV systems on the sea. In Europe, floating PV is currently confined to a few pilot installations.

Table 4: Overview of forms of deployment and installation types (Source: authors' own illustration)

61 See Fraunhofer ISE 2021a.
62 See UBA 2021b.
63 See Kelm et al. 2019.
64 See Fraunhofer ISE 2021c.

3 Public acceptance and taking responsibility: the keys to expanding renewable energy

Achieving the expansion of renewables required by 2030 will constitute a major challenge for society. Because renewables have a lower energy density than fossil fuels, renewable installations take up more space,[65] and are thus more visible to the public. According to the literature, 1.9-3.4% of Germany's land area would need to be used for PV and wind installations to meet the relevant targets.[66] Even though their impact on the landscape and the risk potential per installation are significantly lower than e.g. opencast lignite mines and nuclear power plants, the planning processes for renewable installations sometimes result in local residents taking legal action. As well as holding back the expansion of renewables, this can also transfer to higher-level barriers. Public acceptance is a dynamic phenomenon that can be affected by politicisation and ideologisation. In order to enable a high expansion rate over several years, it is therefore vital to address this issue in a nuanced and constructive manner. Within the energy transition debate, the term "acceptance" is used in very different ways, sometimes in a very broad sense. It tends to appear whenever something deemed desirable or advisable at a higher level meets with local opposition, making it seem as if the (feared) lack of acceptance is the fault of local residents and the involved actors. However, this fails to recognise the fact that barriers to the expansion of renewables can also exist in the relevant structures and processes. Examples include bureaucratic barriers for private PV installation operators, inconsistent policy guidelines and bureaucratic obstacles to the expansion of renewables, or a lack of resources in municipal licensing authorities.

A nuanced approach to acceptance is essential in order to identify barriers and develop ways of overcoming them. This chapter presents an overview of the different dimensions of acceptance and the key factors that influence it. The concept of acceptance used here draws on Wüstenhagen et al. 2007, who distinguish between three different facets: sociopolitical acceptance, local acceptance and market acceptance. **Sociopolitical acceptance** refers to overall acceptance by society as a whole, i.e. the extent to which the public supports or approves of the overall phenomenon. **Local acceptance** refers to the acceptance of specific installations by the affected local residents or local decision-makers. **Market acceptance** describes the extent to which market players adapt and embrace innovations. The use of a psychological term like "acceptance" to describe this market process can be considered appropriate because investment decisions in the renewable energy sector are taken on environmental grounds as well as for financial gain.[67,68,69,70] It is also important to

65 See Tröndle 2020.
66 See PIK et al. 2021.
67 See Bobeth/Kastner 2020.
68 See Kastner/Stern 2015.
69 See Kastner/Matthies 2016.
70 See Korcaj et al. 2015.

distinguish between passive and active acceptance[71]. Passive acceptance means that the – predominantly local – affected members of the public, civil servants and policymakers come to terms with the changes. This is distinct from active acceptance (although the boundaries between the two can be fluid), which refers to the conscious assumption of responsibility for the transformation process – i.e. for implementing and driving the energy transition – by building contractors, farmers, policymakers and entrepreneurs.

3.1 Sociopolitical acceptance: public attitudes to the expansion of renewables

3.1.1 Current level of sociopolitical acceptance

Public opinion research has revealed consistently high support for climate action in Germany over a number of years.[72,73] Three quarters of those interviewed think that the energy transition is essential,[74] while there is also widespread support for the expansion of renewables (83%–86%[75,76]) and for phasing out coal (64%).[77]

The Soziales Nachhaltigkeitsbarometer 2021 (Social Sustainability Barometer 2021) is the latest edition of a long-running survey that provides a detailed insight into the public's views and attitudes regarding the energy transition. The majority of the population (70% in the most recent survey)[78] is generally in favour of the energy transition, and an even higher proportion of the public (78%) regards the energy transition as a collective responsibility. However, almost half of people in Germany are concerned that the energy transition could exacerbate social divides or have a negative impact on prosperity. There is widespread public acceptance (83%) for renewable electricity generation. Roof-mounted PV is the most widely accepted technology (92%) while energy from biomass is the least popular option. As many as 71% of people say they are in favour of onshore wind.

When it comes to the practical implementation of renewable technology, however, negative associations come to the fore. The energy transition is described as expensive, slow and poorly executed, and is also criticised for overlooking the concerns of local residents.[79] Just 14% of respondents said they thought the energy transition was a success, a trend that was already apparent in the previous sustainability barometers in 2018 and 2019.[80]

When asked about the biggest problems and challenges of the energy transition, the main barriers cited by many members of the public are bureaucracy, the fact that the expansion of renewable installations and the grid is happening too slowly, and the

71 See Schweizer-Ries 2008.
72 See BMU 2020.
73 See UBA 2019.
74 See BMU 2020.
75 See AEE 2021.
76 See IASS 2020.
77 Ibid.
78 See IASS 2021.
79 Ibid.
80 See IASS 2020.

associated lack of storage capacity.[81] Other challenges mentioned include political disputes, contradictory decisions and a reluctance among businesses to convert to renewable energy. A lack of public acceptance and awareness of the problems only comes eighth on this list.

82% of people think that everyone should do their bit to support the energy transition.[82] Other than those in low-income groups, most people are willing to accept the additional cost of climate action (40–49% in low-income groups, 57–73% in middle to high income groups). 73% of people think that the extra government revenue from carbon pricing should be spent on making the transport system climate-friendlier, while 70% think it should be invested in expanding renewable energy.[83]

3.1.2 Sociopolitical acceptance: potential problems and opportunities

Public opinion about the energy transition is formed against the backdrop of prevailing narratives that influence how people rate the importance and validity of expanding renewables.[84] Given the technical complexity of the overall system, of the scientific scenarios and of the expansion pathways that inform policy, the layperson must rely on more accessible sources of information to form an opinion. In addition to people's own perceptions, social communication[85] and communication via the media[86] play a key role. The way that laypeople select information can result in them acquiring snippets of very different, contradictory information, making it impossible for them to form a clear overall picture of a complex system. **Many people will thus have only a superficial understanding and will be prone to making false assumptions.** Examples of this include the cost of the energy transition, concerns about the threat to security of supply, and the impacts on people and the natural world. This superficial understanding can become problematic if it coalesces into the narrative that it is impossible to achieve the energy transition, or if the issue is framed in populist terms, for example as something that only serves to make the green, urban elite even richer.[87] We currently lack the spaces and formats for a constructive discussion of these issues, since they are not addressed in the regional planning system's formal participation processes.[88] However, this means that there is also an opportunity to introduce processes that deal with this challenge more effectively (see Chapter 3.2.6).

3.2 Local acceptance: factors and opportunities

Despite widespread support for the expansion of renewables, local opposition can be a problem in some cases. While hardly any legal action is taken against PV installations,[89] legal action is taken against 20% of wind installations during the licensing process.[90] Nature and biodiversity conservation are by far the most common reasons for legal action, but cases are also brought by people personally affected by factors such as noise

81 See IASS 2021.
82 See IASS 2020.
83 Ibid.
84 See Borner 2019.
85 See Berger/Luckmann 1970.
86 See Keller et al. 2012.
87 See Reusswig et al. 2016b.
88 See Reusswig et al. 2016a.
89 See KNE 2017.
90 See FA Wind 2019b.

and visual impact. Accordingly, 61% of actions are brought by environmental and nature conservation organisations, 36% by private individuals and 14% by community action groups. However, these figures do not reveal the extent to which biodiversity conservation in particular is used as a pretext for legal action by people or organisations who are in fact opposed to wind power for other reasons that would stand less chance of being accepted in a court of law (e.g. visual impact on the landscape).[91,92]

3.2.1 What do we currently know about local acceptance?

A study by Hübner et al. 2020 provides an insight into the aspects that influence local acceptance of renewable energy installations. The study explores the factors that play the biggest part in shaping local residents' attitudes towards solar, wind and biogas installations at renewable energy installation sites in Schleswig-Holstein, Thuringia and Baden-Württemberg. Five main factors are identified. A positive overall attitude among local residents regarding (1) the benefits to the local economy and (2) the energy transition favours local acceptance. The other relevant factors are (3) confidence in the planning process and the actors involved in it, (4) the expectation of negative impacts on people and the natural world, and (5) the opinions of other local people (the social norm). Attitudes towards the energy transition are discussed above (Chapter 3.1). Accordingly, the next section focuses on the key local factors that can influence acceptance.[93]

3.2.2 Economic benefits

Renewable energy installations are likelier to be seen in a positive light if it is clear to residents that they will bring benefits to the local economy. On the other hand, people are likelier to be more sceptical if no economic benefits are expected or it is feared that they could even damage the economy.[94,95,96] As well as general economic impacts such as more work for local businesses or more local jobs, the benefits can also include profit sharing with the local community or the financial participation of individual residents, e.g. through share certificates or discounted electricity tariffs. However, residents may also have concerns about the economic risks. For example, fears about the possible impacts on tourism or property prices can result in negative attitudes.[97,98]

While similar challenges arose when large power plants were built in the past, the wide geographical distribution of new renewable installations means that these concerns have acquired new significance and received more widespread attention. Ensuring the broad and equitable inclusion of the whole community and avoiding the impression that only a select minority is profitingisthe key in order to the acceptance of local residents.[99] For example, problems can arise if a share subscription requires a high minimum investment that most people can't afford.[100] On the other hand, arrangements where the local council receives a share of the profits and uses it to

91 See KNE 2017.
92 See FA Wind 2020a.
93 See BfN 2020.
94 See Lienhoop 2018.
95 See Stadelmann-Steffen/Dermont 2021.
96 See Schweizer-Ries et al. 2010.
97 See Grebe 2018.
98 See Vogel 2005.
99 See Fahrenkrug et al. 2016.
100 See Bertelsmann Stiftung 2014.

benefit the whole community are often preferred to arrangements where the profits are shared among private individuals.[101] While direct financial participation of local residents can sometimes have a positive impact, profit sharing proposals can backfire if the community is already opposed to the project. In these cases, people may get the impression that they are being bought off.[102,103]

3.2.3 Trust

The planning process for renewable installations has a major influence on their acceptance.[104,105,106,107] If people experience difficulties and injustices in the planning process, it is likelier that they will subsequently feel more inconvenienced by wind installations once they have been built.[108] By the same token, attitudes can be much more positive if the process is perceived to be fair and reasonable and the responsible individuals are regarded as trustworthy. The way the information provided to local residents is perceived and the extent to which their expectations of inclusion in the process are met are both key factors. In practice, however, people often feel that they have not been properly informed and that there has not been enough transparency.[109,110] Moreover, their expectations regarding inclusion in the process are often disappointed, especially in formal participation processes.[111,112,113]

Trust is important for a range of different actors, including investors, developers, licensing authorities, nature conservation experts drafting impact assessments, local mayors and nature conservation organisations. The trustworthiness of opponents of renewable projects is also a factor. If populist narratives frame people with different views as enemies, for example, the whole dispute can end up being dominated by a climate of mistrust.[114,115] Local circumstances are key to whether people trust or mistrust a project.

3.2.4 Impacts on nature, the landscape and people

Local residents generally attach particular value to nature and the landscape in the area where they live and can be concerned that renewable projects will pose a threat to them. If, instead of regarding the landscape as a purely physical space, we also consider social norms, it becomes clear that the term itself and the notion of what the landscape is are socialised, i.e. that certain aesthetic norms are internalised.[116] The landscape's familiar appearance and unique qualities form an important part of local residents' identity, and renewable installations can alter these features,[117,118] either through their sheer size and prominence, or because they change the landscape's familiar character.[119]

101 See García et al. 2016.
102 See Hoen et al. 2019.
103 See Itten/Mono 2014.
104 See Huijts et al. 2012.
105 See Langer et al. 2016.
106 See Walker et al. 2010.
107 See Wolsink 2013.
108 See Hübner et al. 2019.
109 See Renn 2015.
110 See FA Wind 2017.
111 See Hoeft et al. 2017.
112 See Barth et al. 2018.
113 See Huge/Roßnagel 2018.
114 See Reusswig et al. 2020.
115 See also the Stiftung Mercator project Demokon.
116 See Kühne 2018.
117 See Devine-Wright/Howes 2010.
118 See Devine-Wright et al. 2017.
119 See Kühne/Jenal 2021.

Environmental psychology studies have found that people have a particular preference for "untouched" landscapes[120,121]. This means that areas perceived as (virtually) untouched are especially sensitive, even if they are in fact working farms. This is in marked contrast to attitudes towards land that has already been developed – installing solar panels on the roofs or façades of buildings is less controversial, since people expect further development to occur on this type of land.

Conflicts can also arise between renewable installations and other environmental concerns of local residents, for example the threat that wind turbines can pose to birds and bats. These aspects are often viewed critically and can have a negative impact on acceptance.[122,123,124] On the other hand, people are generally not well informed about the impact assessments and mitigation measures designed to protect local flora and fauna and the local landscape.[125] As a result, local residents may fail to fully appreciate the connection between the construction of specific renewable installations where they live and the pursuit of general nature conservation goals. The same applies when people feel that the choice of location for an installation is based on private outside interests or decisions taken by non-local politicians and experts, and thus on an unsatisfactory planning process with no positive benefits for the local community or landscape compatibility that would give the project something for residents to identify with.[126] Several studies have shown that distributive and/or procedural justice have a positive influence on local acceptance of energy installations. Procedural justice refers to the perceived fairness of the decision-making process, while distributive justice refers to the perceived fairness of the outcomes of the decision-making process. The intrapersonal (am I worse off because of the decision?), interpersonal (are others worse off because of the decision?) and intergenerational (will future generations be worse off because of the decision?) facets of distributive justice are all significant in this context.[127,128,129,130,131,132,133,134,135,136] **There is thus an opportunity to develop a communication strategy that clearly highlights measures to mitigate the impact on local flora and fauna and the local landscape while at the same time showing how the installations contribute to the overall energy and climate transition**.

Residents also sometimes worry about the impacts on human health. This is particularly true of wind installations, where past concerns about shadow flicker[137] have more recently given way to concerns about noise pollution[138,139]. There are gaps in the

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120 See Yang/Brown 1992.
121 See Herzog/Miller 1998.
122 See Ellis/Ferraro 2016.
123 See Schuler et al. 2017.
124 See Wolsink 2007b.
125 See KNE 2020.
126 See Schöbel 2012.
127 See Aitken 2010.
128 See Bell et al. 2005.
129 See Dimitropoulos/Kontoleon 2009.
130 See Gross 2007.
131 See Hall et al. 2013.
132 See Hübner/Pohl 2015.
133 See Jobert et al. 2007.
134 See Jones et al. 2011.
135 See Walter/Gutscher 2013.
136 See Wolsink 2007a.
137 See Pohl et al. 2000.
138 See Hansen/Hansen 2020.
139 See van Kamp/van den Berg 2018.

research in this area: low-frequency noise from wind turbines has only been studied for a few years,[140] and there are hardly any long-term studies of the associated stress effects.[141] These gaps in our knowledge can make local residents apprehensive and have sometimes been cited in lawsuits brought by opponents of wind farms.[142] In Germany, these concerns were exacerbated by the fact that the Federal Institute for Geosciences and Natural Resources recently had to revise[143] its calculations of low-frequency noise levels from wind turbines after the original calculations were found to be inaccurate.[144]

3.2.5 The social norm

Whether consciously or unconsciously, the behaviour and opinions of others influence people's attitudes in almost every area of their lives,[145] including their attitudes towards renewable energy projects. Yet the perceived social norm is rarely a true reflection of the actual situation. Local residents often overestimate the number of local opponents and underestimate the number of people who support the project.[146,147,148,149] While those in favour of renewable installations base their support on a cognitive evaluation, their opponents usually also display an emotional response to the installations.[150] People who are more emotionally involved are likelier to actively campaign against a project. This can result in the formation of an active minority that has a disproportionate influence on public opinion.[151]

3.2.6 Co-design: a key factor in achieving acceptance

The environment that people live in is constantly changing (e.g. if they move house or change jobs). These changes require them to adapt their daily routine, their social relationships or the way they think and feel about things. In order to cope with the changes and any associated pressures, people can draw on resources such as discussing shared challenges with others and cultural patterns of interpretation that enable a positive attitude towards the change. Studies of renewable energy projects show that despite initial opposition, in the end residents usually view them as a positive experience.[152,153,154,155]

Lazarus and Folkman's Transactional Model of Stress and Coping describes how people cope with challenges like the changes caused by renewable energy installations, and offers an explanation for the positive adaptation effect described above. The model shows that events initially experienced as stressful can be coped with by reappraising

140 See UBA 2020.
141 See Pohl et al. 2018.
142 See Reusswig et al. 2016b.
143 See BMWi 2021c.
144 See Baumgart et al. 2021.
145 See Keizer/Schultz 2018.
146 See FA Wind 2020a.
147 See Hübner et al. 2018.
148 See Hübner et al. 2020.
149 See Teune et al. 2021.
150 See KNE 2020.
151 See Reusswig et al. 2016a.
152 See FA Wind 2020a.
153 See Hübner et al. 2020.
154 See Langer et al. 2018.
155 See Hübner/Pohl 2014.

them.[156] This need for appraisal or reappraisal and classification is reflected in local residents' desire for more information and transparency.[157]

Participation processes facilitate (re)appraisal of and identification with specific projects. By engaging in such processes, residents acquire more in-depth information and are better able to understand and actively influence decisions.

Currently, participation measures are almost exclusively project-specific and take place at a relatively late stage in the project planning process. Part of the problem with current formal public participation processes is that the planning process is stratified – decisions from earlier stages in the planning process establish the framework for the subsequent stages[158]. For the people affected by a development, the planning permission process is the most important stage to be involved in, since it concerns the construction of a specific installation that will have tangible impacts on their lives. But by this stage, their scope to influence the development is already very limited. On the other hand, the earlier stages in the planning process relating to land designation (urban land use planning, preparatory land use planning and regional planning) seem very abstract to ordinary members of the public who thus have little interest in participating in them (participation paradox[159]).

Processes that are intentionally initiated at an earlier stage (often referred to as informal processes) offer an opportunity to address potential conflicts in more detail and prevent them from coming about by ensuring that the process is carried out fairly.[160,161,162] Various criteria must be taken into account in order for a participation process to be regarded as fair and useful. Factors widely regarded as important[163] include the depth of participation,[164] the way the participants are selected[165] and the support provided to laypeople during the process.[166] Various guidelines are available for designing informal participation processes (see e.g. the FA Wind website[167]). As far as **depth of participation** is concerned, Arnstein (1969) classifies participation processes on the basis of how much control citizens have. The ladder of citizen participation goes from "nonparticipation" to "informing", "consultation", "partnership" with citizens in the planning process and ultimately "citizen control", where it is the citizens who make the decisions. The different participation guidelines emphasise the importance of ensuring that the depth of participation and the rules for participating are transparently explained right from the outset. It is vital to clearly

156 See Lazarus/Folkman 2013.
157 See Renn 2015.
158 See Agora Energiewende 2018.
159 See Huge/Roßnagel 2018.
160 See Cain/Nelson 2013.
161 See Gross 2007.
162 See Wolsink 2007a.
163 See Matthies/Blöbaum 2008.
164 See Arnstein 1969.
165 See Horelli 2002.
166 See Dienel 2002.
167 An overview of guidelines on participation in wind power projects is available on the FA Wind website: https://www.fachagentur-windenergie.de/themen/beteiligungundteilhabe/linksammlung-zum-thema-beteiligung/; retrieved: 11.10.2021.
A general overview is provided by the Netzwerk Bürgerbeteiligung: www.netzwerk-buergerbeteiligung.de, retrieved: 18.11.2021

communicate at the start of the process how much influence the participants can expect to have and where the limits lie in terms of their ability to affect decisions.[168]

It is also necessary to think about **who can participate and how participants are selected**. It is important to consider whether the participants are representatives of those affected by the development or only represent their own private interests. In unguided selection procedures, it is mainly the more affluent, better-educated groups who take up the offer to participate.[169,170] Alternatively, participants can be selected by a guided, random sampling procedure in order to ensure that a wider cross-section of the public is represented.[171,172]

Several different forms of participation are used in practice. Some of these methods are outlined below in order to illustrate different ways of answering the abovementioned questions about the design of participation processes.

- The **decision theatre** is an information format developed by Arizona State University that is used for in-depth public information and consultation. Participants enter an arena where immersive data visualisations are employed to help them understand complex problems. They are encouraged to interact with the data and discuss it with each other. 3D visualisations, dynamic simulation models and other computer-assisted tools help them to make data-based appraisals and decisions. This participatory format is particularly well suited to the early planning stages such as the formulation of a preparatory land use plan.

- The **planning cell** is a procedure that was developed in the 1970s to help with municipal planning processes.[173] Around 25 randomly selected participants are brought together to develop proposed solutions to a particular planning problem. The participants are given time off from their routine commitments and are paid for their involvement. They are supported by experts, and discuss the issues in small, fluid groups. The outcomes are documented in a final citizens' report.

- **Citizens' assemblies** (German: Bürgerrat) such as the ones organised as part of the Modellprojekt Bürgerrat (Citizens' Assembly Model Project) in 2019 and 2021 and the Citizens' Climate Assembly (German: Klimabürgerrat) have their roots in the planning cell procedure. They comprise around 160 citizens chosen by lot with the aim of achieving a representative sociodemographic sample of the affected community. Expert input ensures that the participants in a citizens' assembly are provided with objective information and assistance with their deliberations and with the formulation of recommendations. Recommendations are developed in professionally moderated groups of up to eight people seated around the same table. At the end of the citizens' assembly, the recommendations are discussed and voted on by all the participants. While

168 See Roßnagel et al. 2016.
169 See Fiorina 1999.
170 See Fung 2006.
171 See Smith/Wales 2000.
172 Ibid.
173 See Dienel 2002.

the recommendations put forward by citizens' assemblies are not formally binding, they are often taken into account in the policy decisions made by parliaments and local councils.

3.2.7 Local acceptance: potential problems and opportunities

As outlined at the beginning of this chapter, local opposition can slow down the planning process for installations that require a lot of space, especially onshore wind and ground-mounted PV installations. The following potential barriers can be identified on the basis of the acceptance factors described above:

- The economic benefits for the local community are considered to be too small or unfairly distributed.

- Local residents do not trust the process and the responsible actors because they do not understand the processes and associated decisions well enough, and because their expectations of participation in the process have not been met.

- If the communication process begins too late, wind installations in particular can often be perceived as having an entirely negative impact on the environment, even by local authorities. This can give rise to uncertainty and fears about their effects on the landscape, wildlife and human health, resulting in the a priori rejection of compensatory measures as inadequate. It is also mainly issues like this that are cited in lawsuits.

- The debate is often dominated by opponents of the development, whereas its supporters (the silent majority in favour) tend to have a very low public profile, causing their numbers to be underestimated.

3.2.8 Can participation increase acceptance and help to accelerate the expansion of renewables?

The past 40 years or so have seen an increase in participation processes, especially in the democratic nations of the global north,[174,175] and this trend continues unabated today across all spatial levels. The reason for this trend can be traced to a change in how society understands the relationship between state and civil society and to the fact that complex challenges, especially in the context of climate change, cannot be solved purely through regulatory measures.[176]

Surprisingly, despite the multitude of participation processes with their different rationales and potential applications and the wide range of methods employed, there have been no systematic scientific studies of problem-specific approaches and methodologies.[177] The (impact) assessments of participation processes that do currently exist are anecdotal in nature.[178,179] Consequently, nobody has yet investigated

174 See Arnstein 1975.
175 See Walk et al. 2015.
176 See Baasch et al. 2012.
177 See Baasch/Blöbaum 2017.
178 See Selle 2013.
179 See Walk et al. 2015.

whether and under which circumstances participatory methods can help to accelerate the overall process.

In practice, there are several examples of cases where the potential barriers outlined above were addressed and the opportunities leveraged. The panel below describes a case study that addressed several different barriers and opportunities in a targeted manner (especially trust, distribution of the benefits, transparency, inclusion and compensation). In addition to this case study, further examples are provided in the research project "Regionale Wertschöpfung. Akzeptanz. Beteiligung" (Adding Regional Value. Acceptance. Participation), which was funded by the Federal Ministry for Economic Affairs and Climate Action (BMWK)[180]. This project describes ten examples of renewable energy project planning processes with a particular emphasis on participation models.[181]

Several empirical studies have shown that low levels of acceptance are associated with perceptions of unfairness and a lack of transparency.[182,183] There are also numerous case studies demonstrating the link between depth of participation and acceptance/approval.[184,185,186,187,188,189,190,191,192,193] There is thus ample evidence to support the assumption that the involvement of the local community in the land designation process for wind power projects can result in higher levels of acceptance.

If the transformation of the energy system is to be achieved, it is clear that the already substantial number of existing renewable energy installations will need to be significantly increased over a period of several years. As described above, acceptance is a dynamic phenomenon that can be positively influenced by communication and participation measures. These measures can help to secure acceptance of the overall process. Moreover, there is very little empirical evidence to support the alternative notion that a major, long-term expansion can be successfully achieved through regulatory measures alone.

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180 For more on this project, see: https://unendlich-viel-energie.de/rewa-projekt, retrieved: 18.11.2021.
181 For a description of the case studies, see: https://unendlich-viel-energie.de/rewa/die-kommunen, retrieved: 18.11.2021.
182 See Ruddat/Sonnberger 2019.
183 See Gölz/Wedderhoff 2018.
184 See Gross 2007.
185 See Hall et al. 2013.
186 See Hübner/Pohl 2015.
187 See Jobert et al. 2007.
188 See Jones et al. 2011.
189 See Walter/Gutscher 2013.
190 See Wolsink 2007a.
191 See Aitken 2010.
192 See Bell et al. 2005.
193 See Dimitropoulos/Kontoleon 2009.

Case study Rauhkasten/Steinfirst wind farm

Where: Gengenbach, Ortenau district, Baden-Württemberg

When:

- 09/2016 permission granted for the installation of 4 wind turbines
- 06/2017 turbines connected to the grid

Process

In 2011, Gengenbach town council decided to draw up a preparatory land use plan geared towards promoting and managing the expansion of wind power. A strategy was developed together with the neighbouring towns and a consulting firm (endura kommunal) was employed to advise and support the local communities. The local council sought to retain enough control over the process to ensure that a suitable project developer was chosen and that the project's proceeds were fairly distributed. With this in mind, a land lease community (German: Pachtgemeinschaft) was established to represent the interests of the landowners. The project was completed within four and a half years – sooner than originally planned.

Transparency

An effort was made from an early stage to keep the local community informed about the project. The most important tool for doing this was a specially created website that provided regularly updated information about the project's progress and answered people's questions. In addition, members of the public could use the website to register an interest in providing loans for two of the turbines. An effort was also made to engage with the local media reporting on the project. Dozens of public information evenings and open committee meetings were held, providing an opportunity for discussion and consultation. Site inspections and tours organised during the installation of the turbines were given a festive atmosphere through the involvement of the fire service and the local music society. Live drone images were also shown during these events. The project partners emphasised the importance of being available to answer email and telephone inquiries on working days. Particular attention was also paid to people living along the access routes – separate discussions were held with this group, and special contact persons were appointed for them.

Impacts on people, nature and the landscape

As part of the planning permission process, the investors had to submit the standard reports on shadow flicker, noise control and bat and bird distribution. The key findings of the reports were clearly presented on the wind farm website. On-site monitoring measures were implemented to protect the bat population, while compensation sites were created for birds. To compensate for the 2.4 hectares of woodland cleared for the wind farm, approximately 7.6 hectares of woodland have been left commercially unexploited. An additional historic preservation report was commissioned to assess the visual impact on a ruined castle located 2.5 kilometres away from the turbines.

Financial participation

Following the granting of planning permission for the turbines in 2016, strategies were developed for the financial participation of the local councils and residents. Windenergie Gengenbach was established as a subsidiary of the municipal utility company. As the operator of two of the four turbines, this company enables the participation of local residents in the project. This also means that the project developer Enercon only has to cover half of the investment costs. The other half is borne by the local councils and financed through capital provided by local residents. Until 2018, members of the public could apply to participate financially in the project by providing a loan. They could invest between a minimum of €1,000 and a maximum of €10,000.

Further information is available at:

- https://www.windenergie-gengenbach.de/
- https://www.endura-kommunal.de/projekte/kommunaler-windpark-gengenbach/

3.3 Overarching factors for active acceptance

3.3.1 Active acceptance and market acceptance

Active acceptance is a term used in acceptance research to refer to situations where, rather than simply having a positive or "accepting" attitude towards something like a wind installation, people actively promote initiatives such as the installation of more wind turbines. In order to achieve the required expansion of renewables, as well as gaining the support of the affected local residents, it will ultimately be necessary for a wide range of actors to be positively motivated to take responsibility by engaging in concrete action to support the energy transition in their own particular field. The success of the energy transition will not be determined solely by the technological aspects of renewable energy and its ability to compete with conventional energy sources. It will also depend on the existence of favourable social, policy and economic conditions[194] that accelerate the transformation of the energy supply's sociotechnical system[195]. In acceptance research, the term "market acceptance"[196] is employed when the focus of the transformation is on the technology's adoption by the market and the degree of technology diffusion. Market acceptance denotes acceptance by the relevant market players on the supply and demand sides, intermediaries providing distribution and consultancy services and, in the case of energy, grid operators. Economists usually measure market acceptance using criteria such as sales and earnings potential, projected growth rate, return on sales and market share. In the context of renewable energy expansion, market acceptance is traditionally assessed by comparing the additional capacity installed in a given year against the growth rates for previous years. Although the market is already established, it is nevertheless characterised by successive waves (such as the wave caused by the "electricity price brake" market intervention in 2013), and market acceptance continues to be measured on the basis of annual capacity increases.

In their study of research into the transition, Dütschke et al. 2019 conclude that the research has hitherto focused on the demand side, especially private demand. There has been less research into the supply side of renewable energy, i.e. the initiators of renewable energy projects, including contractors, companies, farmers, landowners, community investors (community energy projects), major investors and intermediaries.

3.3.2 Active market acceptance: potential problems and opportunities

The Masterplan Solarcity Berlin study[197] identifies the barriers that currently exist for different property owners considering investing in a roof-mounted PV installation. It

194 See Grunwald 2019.
195 See Geels et al. 2017.
196 See Wüstenhagen et al. 2007.
197 See Stryi-Hipp et al. 2019.

covers the entire process, from the reason for the investment decision to the planning process and the construction and commissioning of the installation.

The study found that the investors need to put a lot of time and effort into coordination over the course of the project. They have to devote a lot of energy to acquiring the necessary knowledge, weighing up multiple decisions, ensuring that the different steps in the process are carried out in the correct order, and coordinating communication with the actors responsible for different parts of the process. While in theory the current legal and regulatory framework does make it possible to invest profitably in roof-mounted PV, the study backs up the findings of other research [198,199] which concludes that people are unlikely to invest in roof-mounted PV purely on hard economic grounds. The key drivers for investing in a roof-mounted PV installation are non-monetary, for example the desire to help tackle climate change, the need to implement climate action commitments, image building and autonomy. If active acceptance is to be increased, it will be necessary to reduce the time and effort involved and to support other motives for investing (cf. low-cost hypothesis[200]).

Active engagement can be promoted through financial incentives (e.g. government financial support such as feed-in tariffs), but also through additional non-monetary incentives such as **social identity** (e.g. renewable energy communities, cf. EU market role of energy communities), **high environmental value** (100% renewable energy regions), **transparency** (digital solutions such as blockchain) and **resilience** (generating your own electricity, self-sufficiency).[201] Actively engaged actors need flexibility and support, since their solutions do not always fit neatly within the current regulatory framework. The ability to network and create platforms for sharing ideas is particularly important in the young persons' energy transition community.

Several other measures can help to increase active acceptance, for example reducing bureaucracy and the number of different procedures, facilitating access to practical know-how by providing tailored information resources, creating personal advice centres, improving the financial conditions and providing independent advice services. Doing these things benefits all the actors, since it gives them confidence that the overall energy transition strategy and investment framework are environmentally and socially just and well communicated and understood.

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198 See Ecker et al. 2017.

199 See Korcaj et al. 2015.

200 See Kastner/Matthies 2016.

201 From the perspective of the overall system, maximising the self-sufficiency of smaller entities (e.g. households, regions) isn't necessarily desirable. "Soft" autarky, where an entity generates enough electricity on average to meet its needs over a long period (e.g. a year) still relies on structures such as grids and power plants that are outside of the "self-sufficient" entity. The extent to which this type of approach strengthens resilience must be assessed on a case-by-case basis (see acatech et al.: Zentrale und dezentrale Elemente im Energiesystem, box "Dezentralität ist nicht Autarkie" (Decentralization is not self-sufficiency)).

3.4 Basic principles for maintaining and increasing acceptance of faster renewables expansion

On the basis of the challenges outlined above, a number of basic principles can be identified for promoting acceptance of a faster expansion of renewables. Action will be necessary in the following areas:

Clearer communication of system interrelations: The perception that the energy transition is chaotic and unjust is partly due to its sheer complexity. A more in-depth discussion than usually provided in the media of the energy transition's mechanisms and system interrelations can help people to understand it better. Innovative forms of communication can help to achieve this.

Increase financial participation: Financial participation allows local residents and councils to share in the economic success and benefits of renewable energy installations.[202] Justice is a key factor in this context, and it is important that participation should be open to the whole community. Financial benefits will in principle only have a positive influence on attitudes towards a project if they are easy for local residents to see and understand. Consequently, it is important to ensure transparent and straightforward communication of how the financial benefits will be shared and how they will affect the local community.

Promote active participation: Giving members of the public more opportunities to participate actively in regional planning processes addresses their desire for more transparency and influence. It can help to strengthen trust in the process and identification with the energy transition as a collective endeavour. Concerns about negative impacts on nature, people and the landscape can be addressed proactively through negotiation, allowing them to be framed more positively. This makes for a more constructive debate, rather than one dominated by negative attitudes. As described in Chapter 3.2.6, people must be given the chance to participate actively from an early stage and should have sufficient opportunity to meaningfully influence the process.

Create new ways of mobilising people: People can be encouraged to actively engage in new renewable energy projects through financial incentives (e.g. government financial support such as feed-in tariffs) and through additional non-monetary incentives such as social identity, high environmental value (regional electricity products, e.g. "our energy for our region"), innovation and resilience. Many of these non-monetary incentives are called for in the community-based solutions of EU energy policy (e.g. the energy communities and energy sharing in Directives 2019/944 and 2018/2001/EU). These could also be transposed into law in Germany.

202 See Salecki/Hirschl 2021.

4 The regulatory framework for the expansion of wind and solar power

In most cases, the construction of renewable energy installations is governed primarily by planning law in conjunction with the regional and urban land use planning processes, while licensing and immission control law and building regulations also play an important role. In both areas, the provisions of other laws such as nature conservation law must also be taken into account. This chapter summarises the current regulatory framework for the **planning** and **licensing** of PV and wind installations. It also identifies the barriers that currently exist in each of these two key areas. The principal policy areas for accelerating the expansion of renewables are identified, and concrete policy options are presented for each area.

4.1 The regulatory framework for planning

As illustrated in Figure 2, the different policy levels in the field of energy and climate action interact with and are in some respects dependent on each other. Central legislative power lies with the federal government. In addition, most German states have established quantified targets for reducing GHG emissions, while some have also adopted concrete targets for the amount of energy produced from renewable sources and/or for energy-efficient building retrofits. The German states' quantified targets for reducing GHG emissions, which are still mostly based on the reduction targets in the 2019 Federal Climate Change Act (KSG), must now be adjusted to reflect the amendment to the KSG that came into force on 31 August 2021. Several regional and municipal climate action plans and programmes also contain reduction targets. Moreover, many regional and local authorities are making voluntary commitments to reduce their GHG emissions and drafting climate action strategies.

Responsibility for the territorial implementation of the climate targets lies with the state, regional and municipal authorities and is chiefly discharged on the basis of **spatial planning law** at the regional, district and municipal levels. This is where the decisions are taken regarding the type and number of renewable energy installations that can be built and their location. The land control process for wind installations varies from one federal state to another but is usually carried out at the regional planning and/or preparatory land use planning levels, whereas the land control process for ground-mounted PV usually occurs at the urban land use planning level (comprising the preparatory and binding land use plans).

Rather than implementing rigid centralised decrees, the aim of spatial planning is to develop solutions that reflect local and regional circumstances. Thus, although the **Spatial Planning Act (Raumordnungsgesetz – ROG)** is a federal act that contains federal and framework law provisions pertaining to the conditions, functions and general principles of spatial planning, different states nonetheless regulate the implementation of the ROG in different ways within their regions, districts and municipalities Indeed, since the reform of Germany's federal system in 2006, they are allowed to diverge from the regulations contained in the ROG. Spatial planning is intended to be a flexible process. Before it acquires legal force, it must be legitimised by the relevant policy level.

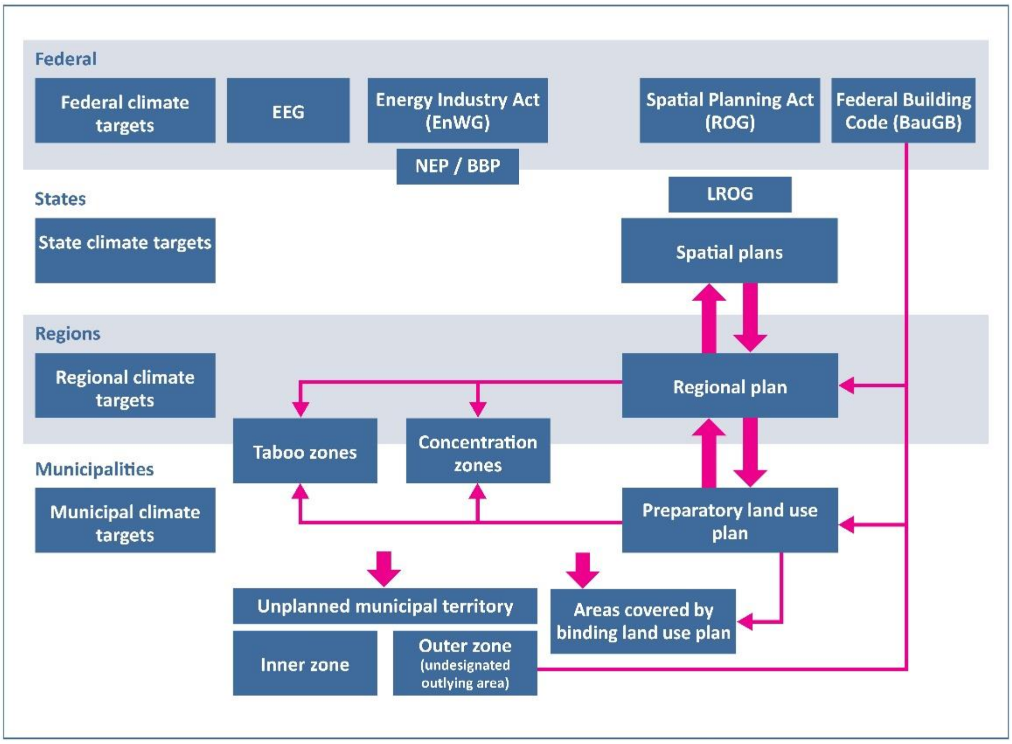

Figure 2: Responsibilities and instruments relating to the implementation of the energy transition at the planning level (Source: authors' own illustration)

The remainder of this chapter describes the regional planning process, the preferential treatment of wind power as a land use in undesignated outlying areas, and the function of urban land use planning. It concludes by identifying the main problems at the regional planning and urban land use planning levels that are hampering faster expansion of wind power in particular.

4.1.1 Description of regional planning as defined by the Spatial Planning Act (ROG)

According to ROG Section 13, the role of regional planning is to resolve or at least minimise conflicts with other spatially relevant uses, with the involvement of local authorities and the general public. For instance, the regional planning level can regulate wind installations by designating priority areas or suitable areas for development in accordance with ROG Section 7(3). In priority areas, the land designated for wind installations cannot be used for other, incompatible purposes. Suitable areas for development, on the other hand, link the designation of certain land as suitable for wind installations with the exclusion of wind installations from all other areas (“concentration with exclusion criteria”).[203]

However, only regional plans that have duly weighed up all the relevant interests can regulate wind installations in this way. According to ROG Section 7(2) Sentence 1, public and private interests must be fairly weighed up against and among each other. In relation to the planning control of wind installations, the fact that the designation of concentration zones with exclusion criteria constitutes a final decision means that the law requires there to be a coherent plan for the entire area that provides substantial space for wind installations in keeping with the preferential treatment accorded to them by law.[204] In order to meet the requirements of the weighing up process, the plan must not only explain the factors that resulted in a positive site designation but must also set out the reasons supporting the intended exclusion of wind installations from the rest of the planning area. The negative and positive components of the designated concentration zones are thus mutually dependent.[205] Accordingly, a purely negative regional plan is not permitted on the grounds that the sole aim of such a plan would be to prevent development. The planning control of wind installations using concentration zones may take place at the spatial planning level through the establishment of spatial planning goals in accordance with ROG Section 3(1)(2), or at the urban land use planning level through inclusion in the preparatory land use plan in accordance with Section 5(2)(2b) of the Federal Building Code.

The planning authorities must follow a step-by-step approach in order to meet these requirements for the development of a plan for the entire area. The first step in the planning process involves the designation of “taboo zones” that can be discounted right from the outset as areas that are unavailable for the construction of wind installations. When designating these exclusion areas, the planning authority must draw a deliberate distinction between **hard taboo zones** (where wind installations are prohibited due to legal requirements such as mandatory exclusion for immission control or biodiversity conservation reasons) and **soft taboo zones** (where they are prohibited due to local planning criteria such as the minimum distance from residential or recreational areas). This distinction must be documented in the plan.[206,207,208] In other words, an area should be classified as a hard taboo zone if it cannot be used for wind installations due to physical and/or legal constraints (e.g. because it is a nature reserve), whereas soft taboo zones are areas that could in principle be considered for installations in the formal process of weighing up the different interests, but which the planning authority deems unsuitable for wind installations on the basis of general planning considerations.[209]

In the next step, the available land remaining once the taboo zones have been excluded should be assessed in terms of its suitability for wind installations versus other, competing uses. The planning authority has to weigh up the public interests that stand in the way of designating an area of countryside as a concentration zone against

203 See Grotefels 2021.
204 See BVerwG, ruling of 13.03.2003 - 4 C 4.02 -.
205 See BVerwG, ruling of 18.08.2015 - 4 CN 7.14 -.
206 See Hentschel 2019.
207 See Albrecht/Zschiegner 2019.
208 See Münkler 2014.
209 See BVerwG, ruling of 13.12.2012 - 4 CN 2.11 -.

the requirement to use suitable locations for wind installations in accordance with the preferential treatment granted to wind installations by Section 35(1)(5) of the Federal Building Code. Substantial space must be made available for wind power once this process of weighing up the different interests has been completed. If the planning authority establishes that this is not the case, it must review its plan and amend it as necessary.

Biodiversity conservation is one important factor that must be taken into account when designating land for wind installations. Section 44(1) of the Federal Nature Conservation Act (Bundesnaturschutzgesetz – BNatSchG) prohibits the killing of specially protected species such as the Red Kite. The law is based on the criterion of "significantly higher mortality". In other words, a distinction must be drawn between mortality risks that pose a serious nature conservation threat (e.g. that threaten a population) and less serious individual losses that do not need to be considered by the planning process.[210] Species-specific susceptibilities and risks relating e.g. to movement patterns, flight altitude and attraction to lights can be relevant in this context. The mortality assessment should also include population biology parameters such as the natural reproduction rate and nature conservation parameters such as the concrete threat to or scarcity of a species,[211] since the nature conservation law relating to wind installations implements strict European directives (e.g. the prohibition of killing), and it is thus vital to check their legality in this regard. Projects that violate the prohibition of killing are illegal unless they meet the conditions for an exemption. The situation is different for ground-mounted PV (see also 4.1.4). While it is still necessary to weigh up the impacts of PV installations on nature and the landscape and implement any necessary compensatory measures, these factors are highly unlikely to result in a PV project being deemed illegal.

Immission control to protect local residents is another important consideration. This issue is being addressed through the introduction of minimum distances/the ongoing discussion regarding the regulation of distances from residential areas.

Participation in the formulation of regional plans is regulated by state planning law. Most of these laws stipulate that the participants in the formulation and (partial) updating of regional plans should include the public authorities (local and district councils and other relevant agencies), recognised nature conservation organisations (and other relevant groups and associations) and the general public. To this end, the draft plan including the environmental report and explanatory memorandum must be put on public display by the regional organisations and the local and district councils. The way this participation is implemented in many German states means that the regional planning level does not include representative (directly elected) local councillors. As a result, it is perceived more as a part of central government spatial planning than as a part of the devolved, local self-government level, even though it is in fact supposed to perform both functions in equal measure.

It should be noted that, by the time it is put on public display, the draft regional plan is already a concrete plan in which certain spatial decisions have been made. Spatial plans have to strike a balance between long-term spatial development planning

210 See BVerwG, ruling of 12.03.2008 - 9 A 3.06 -.
211 See Hentschel 2021.

and shorter-term requirements that call for changes and partial updates. There is significant variation in the age of spatial plans across Germany and how up-to-date they are.[212]

4.1.2 Preferential treatment of wind installations under Section 35 of the Federal Building Code

Since 1997, wind installations have been classified as developments in undesignated outlying areas that are eligible for preferential treatment under Section 35(1)(5) of the Federal Building Code (Baugesetzbuch – BauGB). Undesignated outlying areas (also known as "outer zones") include all land that is neither within the spatial ambit of a binding land use plan nor within an associated built-up area. The development of undesignated outlying areas is only permitted by the building code if it is not detrimental to the public interest and if the provision of adequate public infrastructure is guaranteed.

If the construction of wind installations is to be enabled throughout the entire planning area, the planning authority does not have to take any action due to the preferential treatment given to wind installations under BauGB Section 35(1)(5). In these cases, the planning permission process for an installation in an undesignated outlying area should be carried out in accordance with the provisions of BauGB Section 35. The preferential treatment principle overrides the examples of public interests listed in BauGB Section 35(3)(1)-(8). In this case, the construction of wind installations is not subject to planning control.

Nevertheless, in order to prevent the untrammelled construction of wind installations and the danger of regional overexploitation of undesignated outlying areas, BauGB Section 35(3) Sentence 3 stipulates a certain degree of planning control as a counterbalance to the preferential treatment principle. This gives planning authorities the option of designating concentration zones, i.e. areas where wind installations are concentrated. As a rule, the construction of wind installations outside of these concentration zones is not permitted.

Where concentration zones are linked to the exclusion of wind installations from the rest of the planning area, the construction of wind installations outside of the designated concentration zones will generally be deemed incompatible with the public interest, and will therefore not be permitted under the building code. On the other hand, the construction of wind installations will be prioritised within the designated area.

4.1.3 Urban land use planning under the Federal Building Code

Urban land use planning is the responsibility of local authorities. The function of urban land use planning is to prepare and organise the use of land for building and other purposes at a local level. The instruments used in urban land use planning are the preparatory and binding land use plans.

212 See BBSR 2020.

The process of designating concentration zones for wind installations in a municipality via a preparatory land use plan is far closer to the local community than the planning control of land use for wind power at the regional planning level. It relates to more clearly defined areas and the public is more likely to be aware of it. General or project-specific binding land use plans tend to be drawn up for ground-mounted PV installations in order to meet the legal remuneration requirements stipulated by the Renewable Energy Sources Act.[213] The preparatory land use plan may also need to be amended in some cases.

In order to comply with the law, urban land use plans must duly weigh up all the relevant interests. The overall planning strategy for the planning control of preferentially treated wind installations in undesignated outlying areas through concentration zones must also provide substantial space for these wind installations through preparatory land use plans (see the discussion of regional planning).

The public has two opportunities to participate in the formulation of urban land use plans. Firstly, the public must be informed as early as possible about the general aims and purposes of the plan. This includes alternative options for the development of the area and the expected impacts of the plan pursuant to BauGB Section 3(1) Sentence 1. Members of the public may express their views and request further clarification. Once a concrete draft plan is available, this early-stage participation is followed by the **formal participation** process in accordance with BauGB Section 3(2). At this point, the draft plan, explanatory memorandum, environmental report and key comments relating to the environment are placed on public display for a period of one month. As well as comments made by the authorities, the comments put on public display must include comments made by members of the public during the early-stage public participation process.

In addition to this formal participation, informal participation processes may take place at any time at the regional and municipal planning levels, i.e. before and during ongoing plan drafting processes. Informal participation processes enable public discussion not only of concrete decisions about specific areas but also of the (soft) exclusion, suitability and design criteria, providing input for the corresponding decisions. The processes described in 3.2.6 are usually structured as informal participation processes.

4.1.4 Urban land use planning for ground-mounted PV under the Federal Building Code

Unlike wind installations, biogas plants and hydroelectric power plants, ground-mounted PV installations do not enjoy preferential treatment in undesignated outlying areas. This is to prevent land suitable for growing food from being built on. However, it has the unintended consequence that the construction of ground-mounted PV installations always requires the designation of a special development area in a laborious urban land use planning process that generally involves the formulation of preparatory and binding land use plans. It also means that farmers who install ground-mounted PV systems are no longer able to claim agricultural subsidies for the land in question, since it is now classified as land used for construction. However, they need

213 See Seht 2020.

agricultural subsidies if they are to continue farming this land, since they cannot farm it profitably without them. Since the same applies to subsidies for agrivoltaics, it should be possible to simultaneously claim subsidies for both land uses.

The resulting financial constraints favour the most intensive possible use of the land in question, which, under the current regulations, means building ground-mounted PV. This leaves little scope for nature and landscape conservation measures or multiple uses. From an energy generation perspective, there is no particular optimal way of using land for agrivoltaics – the layout of the solar panels is thus designed to ensure that the plants receive enough sunlight to maintain a good yield.

Unlike wind installations, there are no physical reasons for PV installations to be large in size. While it is necessary to consider differences in feed-in conditions in different areas, acceptance can be promoted by opting for multiple small arrays spread over a larger area rather than a single large array, since installations that cover several dozen hectares have a significant visual impact on the open countryside and also create structural barriers.

4.1.5 Barriers at the regional and urban land use planning levels, with particular reference to wind installations

In order to achieve the climate targets established by the August 2021 amendment to the Federal Climate Change Act and drive forward the energy transition, extensive areas of additional land will be needed for wind installations in particular. However, the ambitious expansion of wind power is currently being hindered first and foremost by the failure to designate enough sufficiently windy areas (attractive areas with good wind power potential are often not designated). While 0.8% of Germany's total land area is currently designated, only 0.5% is actually usable in practice. The barriers are as follows:

- The automatic prioritisation of other interests (military, radar, weather radar, earthquake monitoring stations) instead of weighing up each case on its merits.

- Unclear rules for the assessment of environmental impacts (noise emissions, threats to birds and bats) and concerns about health impacts.

- The time taken to complete the procedures for designating land at the planning level (as a result of the complex current regulations for matters such as nature conservation and public participation and a shortage of qualified staff in the public authorities).

- Local opposition e.g. to changes in the appearance of the landscape or the siting of wind installations in woodland (which is widespread in central and southern Germany).

In order to ensure that sufficient land is available, the German government recently passed an Onshore Wind Energy Act requiring 2% of Germany's land area to be designated for wind installations.[214]

4.2 Licensing

In addition to the planning processes described above, the licensing of renewable energy installations is an area of law that is pivotal to implementation of the energy transition. Consequently, this section describes the current requirements for wind installations under the Federal Immission Control Act (Bundes-Immissionsschutzgesetz – BImSchG) and state building regulations, the function of legal protection (actions to annul a decision), and the principal barriers in connection with licensing.

The construction and operation of wind and PV installations is governed by different areas of the law. Large-scale PV installations (ground-mounted PV) and small roof-mounted installations and solar façades are not regulated by the Federal Immission Control Act. This means that their construction and operation does not need to be licensed under immission control law, although their environmental impacts may need to be assessed as part of the building permission procedure of the relevant state building regulations. Building permission is an "administrative act resulting in a benefit that may have a negative impact on third parties" – it benefits the party who obtains permission to build, but may have a negative impact on their neighbours. It constitutes a legally binding "declaration of no objection" to the effect that the construction work does not contravene the regulations with which compliance must be checked as part of the permission procedure established by building control law. This means that, unlike planning procedures, building permission procedures must verify compliance with a statutory list of criteria – there is very little scope to weigh up the pros and cons of a development as in the planning process.

Ground-mounted PV installations often are in competition with other land uses. The inclusion of PV installations as part of multiple space use solutions (agrivoltaics, floating PV) can help to address this problem. However, these solutions are still relatively new and are not yet catered for in urban land use planning.

4.2.1 Licensing procedure under the Federal Immission Control Act

Wind installations must in principle be licensed under immission control law. According to the Federal Immission Control Act (Bundes-Immissionsschutzgesetz – BImSchG) Section 4 ff., licensing is a "bound decision" – the licence must be granted if all the statutory requirements have been met. This means that the responsible authority has no discretion regarding the decision to grant a licence. The fact that discretionary planning decisions may be taken prior to the immission control law licensing procedure does not alter this principle.

According to the BImSchG, a licence may only be granted under immission control law if the requirements stipulated by this law have been met (Section 6(1)(1)) and there are no other public law provisions or health and safety standards preventing the construction and operation of the installation (Section 6(1)(2)). The requirements

214 See BMWK 2022a.

under immission control law include compliance with the noise guidelines in the Technical Instructions on Noise Abatement (German: TA Lärm) and the periods of shadow recommended by the Joint Working Group of the Federal Government/Federal States on Immission Control (German: Länderausschuss für Immissionsschutz). However, other public law provisions must also be observed. Ongoing research into the noise pollution caused by wind installations will determine whether the Technical Instructions on Noise Abatement need to be amended to reflect the specific characteristics of noise emissions from wind installations. Depending on the location in question, it may be necessary to comply with the provisions of planning law and building regulations, soil protection law, circular economy law, nature and landscape conservation law, the law on highways and public rights of way, aviation law, water and waterways law, forest law, historic preservation law and the law on restricted military areas.

Either a simplified or a formal licensing procedure may be used to determine whether a wind installation can be granted a licence. The difference between the formal and simplified licensing procedures is that the former must include public participation. For projects involving more than a certain number of wind turbines, the licensing procedure must also include an environmental impact assessment in accordance with the Environmental Impact Assessment Act (Gesetz über die Umweltverträglichkeitsprüfung – UVPG). Public participation in this assessment is also mandatory.

In principle, a simplified licensing procedure without public participation may be used for the simultaneous erection of a small number of wind turbines. The formal licensing procedure involving public participation is only required if more than twenty wind turbines are installed on the same site, or if the responsible authority deems that the installation of a lower number of turbines requires an environmental impact assessment due to its significant environmental impacts.

Since August 2021, the repowering of wind installations has been subject to the requirements of BImSchG Section 16b. Repowering is generally taken to mean the modernisation of an installation for producing electricity from renewable energy. In this context, the legal definition of modernisation is the complete or partial replacement of installations or operating systems and equipment to replace capacity or to increase the efficiency or capacity of the installation. BImSchG 16b(2) Sentence 2 establishes additional requirements for the complete replacement of a wind installation, which is likely to be the most common scenario in practice. Repowering is only deemed to have occurred in accordance with the law if the new installation is erected no later than 24 months after the previous installation was dismantled and at a distance from the old installation of no more than twice the total height of the new installation. According to BImSchG Section 16b(1), if these conditions are met, upon application of the project developer, it shall only be necessary to carry out delta testing of requirements as part of the repowering licensing procedure if the repowering will have negative impacts compared to the status quo and if these impacts could significantly affect the testing of the requirements in accordance with BImSchG Section 6.[215]

215 See Hentschel 2021.

4.2.2 Building permission procedure according to state building regulations for wind and ground-mounted PV installations

Since most modern wind turbines – with the exception of small and micro wind turbines – are over 50 metres in height, they must be licensed in accordance with immission control law. Immission control licences include building permission and any other necessary decisions ("concentration effect" pursuant to BImSchG Section 13).

Ground-mounted PV installations, on the other hand, are classified as "built structures" as defined by Section 2(1) of the Model Building Regulation (Musterbauordnung – MBauO). Accordingly, their licensing procedure is determined by the relevant building regulations.

As with licensing under the Federal Immission Control Act, building permission is a "bound decision" – the responsible authority has no discretion regarding the decision to grant a licence. The requirements that must be met for building permission to be granted are set out in the state building regulations. Built structures must comply with public law regulations. First and foremost, this means that they must meet the relevant building regulation and planning law requirements.

The applicable building regulations include the distance regulations stipulated in MbauO Section 6, the stability regulations stipulated in MBauO Section 12 and the fire safety regulations stipulated in MbauO Section 14. PV installations must also be compatible with their environment – they must not mar the streetscape, townscape or landscape or interfere with their intended design (MBauO Section 9(2)).

The planning law assessment of ground-mounted PV installations mainly depends on the type of planning area they are to be installed in. If the installation site is within the area covered by a qualified binding land use plan as defined in Section 30(1) of the Federal Building Code, the permissibility of the development under planning law is exclusively determined by the provisions of this plan. The type of land use is generally determined by the designation of a land use area in accordance with the Federal Land Utilisation Ordinance (Baunutzungsverordnung – BauNVO). In unplanned inner zones, the permissibility of PV installations is determined in accordance with the provisions of Section 34 of the Federal Building Code. These state that such installations shall be permissible if the type and scale of their use is compatible with the character of their immediate environment, or if this corresponds to one of the land use area categories in the BauNVO. Unlike wind installations, ground-mounted PV installations are not explicitly allowed in undesignated outlying areas under the preferential treatment provisions of Section 5(1) of the Federal Building Code. In principle, they are thus subject to the requirement that undesignated outlying areas should be kept free of any kind of development. Consequently, it is common practice to draw up binding land use plans for ground-mounted PV installations. This is also one of the requirements set out in Section 37 of the Renewable Energy Sources Act for participation in Federal Network Agency tenders, as well as for other financial support in accordance with Section 48 of the 2021 Renewable Energy Sources Act. Unlike ground-mounted PV installations, preferential treatment is accorded to PV installations on the roofs and façades of buildings in undesignated outlying areas where this use is permitted under Section 35(1)(8) of the Federal Building Code, provided that the installation is structurally subordinate to the building.

According to the building regulations of Germany's federal states, PV installations mounted on or integrated into buildings/on roofs and façades do not require a licence if they are under a certain size. In some states, this exemption is conditional on the installation not being on or in the vicinity of a cultural monument.

The licensing procedure poses a number of challenges for agrivoltaics and floating PV. While the licensing of agrivoltaics is governed by the relevant building regulations, the installation and operation of floating PV units is governed by water resources law.

The building regulations licensing procedure does not currently require public participation or an environmental impact assessment. Only the applicant and their directly affected neighbours are included in the process.

4.2.3 Legal protection

The licensing of wind installations is frequently the subject of administrative law actions. Residents can use "actions to annul a decision" in accordance with Section 42(1) of the Code of Administrative Court Procedure (Verwaltungsgerichtsordnung – VwGO) to challenge a licence granted under immission control law on the grounds that it contravenes the regulations governing the distance from residential areas or could cause unreasonable levels of noise pollution. According to the Environmental Appeals Act (Umweltrechtsbehelfsgesetz – UmwRG), recognised environmental organisations can request a full review of these licences, including the regional planning decisions. The legislator reduced the number of appeal stages in 2020 – the Higher Administrative Courts now rule at first instance on appeals against the licensing of wind installations (VwGO Section 48(1) Sentence 1 No. 3a).

4.2.4 Licensing procedure barriers

The key barriers to the licensing of wind and PV installations are the length of the licensing procedure and the delays in the use of licences caused by legal action. Contributory factors include the following:

- The process of assessing and licensing wind installations is slowed down by the complex current regulations for assessing environmental impacts (noise emissions, threats to birds and bats) and health impacts, coupled with a shortage of qualified staff in the public authorities.

- Opposition from individual actors or groups of actors is often a key factor. It is associated with extensive legal action during the licensing process and a high propensity to lodge appeals, especially against wind installations.

- Concern about the threat of legal action (due to procedural errors) can cause public authorities to ask for reports to be resubmitted, thereby delaying the licensing process.

- Legal action challenging licences causes delays in their use.

- In the case of PV installations intended to form part of multiple space use solutions (agrivoltaics, floating PV), the main issue is licensing authority uncertainty concerning the legal requirements that must be assessed, e.g. with regard to changes of use.

- The licensing process is also slowed down by conflicting local regulations (e.g. parking regulations that hamper the installation of solar car park canopies), since these must first be amended or rescinded.

- Various inconsistencies in the new regulations on the repowering of installations for the generation of electricity from renewable energy are causing legal problems with their application.

- Staff shortages due to cutbacks in the relevant authorities mean that the immission control authorities, planning departments and other involved authorities (nature conservation/historic preservation, etc.) no longer have the necessary capacity.

4.3 Regulatory scope for faster expansion

The problems described under 4.1.5 and 4.2.4 call for an urgent review of the legal basis for the planning and licensing of wind and PV installations (not only ground-mounted PV, but also agrivoltaics and floating PV) in order to enable faster expansion of these technologies. The regulatory scope should be explored in the following areas:

Translate the expansion targets in the Renewable Energy Sources Act into land allocation targets for Germany's federal states: There is currently no guarantee that the total available land actually designated by Germany's federal states will be enough to achieve the renewable energy expansion targets set by central government. Consequently, it will be necessary to introduce a new mechanism that translates the expansion targets in the Renewable Energy Sources Act into the concrete area of land needed in each individual state. This quantity structure should be developed in a transparent manner. Possible solutions have already been discussed in the literature for wind power,[216,217] but these should also be extended to PV.[218] This mechanism would allow the increase in wind installations to be spread more evenly across Germany's federal states, instead of location choices being driven solely by economic considerations. This would have a positive effect on perceived distributive justice, especially in those federal states where large numbers of wind installations have already been built.[219] Nature conservation issues should also form part of this process from an early stage. One possible approach is outlined in a discussion paper by the OWL University of Applied Sciences and Arts.[220] A serious game played by experts with a view to identifying criteria revealed that there is currently no unanimous agreement regarding the ranking of spatial allocation criteria.[221] In order to ensure that the development of the allocation targets is transparent to the whole of society throughout all of Germany's regions, the process should be accompanied by informal information activities, while planning cells/citizens' panels could also be employed to support public participation. In addition, interactive information and participation offers

216 See SRU 2022.
217 See Kment 2020.
218 See Wagner 2021.
219 See Lehmann et al. 2021.
220 See BfN 2021.
221 See Lehmann et al. 2021.

should be used to promote the wider public's system knowledge of the quantity structure and the basis used for establishing the federal states' allocation targets.

Expedite the planning process for wind and PV projects: Regional planning practice should take a more forward-looking , longer-term view and prioritise the use of land for wind and ground-mounted PV installations from an early stage. Clear, nationwide criteria should be established for nature conservation, concentration zones and participation processes. Regional planning also needs more flexibility to adapt faster, for example to higher expansion targets (that have been set e.g. at the federal and state level) and to rectify mistakes – based on the law of mistake in planning law. Another requirement for expediting the planning process is more qualified staff to ensure that the necessary assessments can be carried out more rapidly but without compromising on standards, and that the decisions taken are legally watertight. The authorities are currently unable to cope with the increasingly complex procedures.

Expedite the licensing process for wind and PV projects: The most pressing need is to provide clear decision-making criteria for local licensing procedures on matters such as minimum distances, biodiversity conservation, etc. These are key to expediting the licensing of individual projects. More qualified staff is also needed at the local level in order to carry out the necessary assessments more rapidly and ensure that the licences issued are legally watertight.

Participation as an integral part of future planning and licensing processes: A planning culture that is proactive and participatory right from the earliest stages can mobilise the significant potential support that exists for climate action and the expansion of renewables and help to prevent disputes. Extensive participation early on in the licensing process can reduce the number of lawsuits, which in turn means that licences can be used sooner and the installations built and operated without delay. Early participation calls for trained staff in the relevant authorities and a legal framework that motivates the authorities and project developers to take on board and support the concepts and solutions developed by the public and incorporate them into ongoing processes.

Contrary to the current optional regulation in EEG Section 6, the EEG should make it mandatory to offer local authorities the opportunity to participate financially in the expansion of wind power and ground-mounted PV, in order to recognise their contribution to the herculean task that the energy transition poses for the whole of society and support proactive local actors.

5 Policy options

Meeting the current climate targets will call for a much faster expansion of wind and PV capacity. As well as ensuring the economic and technical feasibility of this transformation of the energy system, it will also be vital to maintain security of supply. A faster expansion of wind and PV capacity will also require aspects such as acceptance, participation and transparency to be adequately reflected in planning and licensing processes, together with an appropriate legal and economic framework. Accordingly, the working group has developed a proposal for a new planning culture and corresponding responsibility architecture geared towards channelling high levels of public acceptance into a new, fair and proactive planning practice. Planning culture encompasses all the actors, procedures, regulations and interpretations involved in spatial planning.[222] It should be stressed that informal *and* formal processes *and* contexts are constantly interacting with each other in planning processes. Formal planning refers to planning processes and outcomes based on the relevant law (Federal Building Code, Nature Conservation Act, etc.) where decisions are taken by the entities with territorial jurisdiction (planning authorities). Informal planning refers to planning processes and outcomes that, although also involving decisions taken by planning authorities, are not legally binding and are primarily intended to provide policymakers and the general public with information, mediation and decision-making support prior to the commencement of formal planning processes.

Accelerating the expansion of wind and PV capacity will require systemic change in the energy system. Fluctuating renewables will dominate the future electricity supply, the transport and heating sectors will be closely coupled, and renewable energy installations will be a more prominent part of the landscape and more widely distributed across the whole of Germany than in today's energy system, where fossil fuels still play a significant role.

The working group has formulated 12 policy options in 4 policy areas with the aim of enabling this systemic change and addressing the main barriers to the expansion of renewables.

Policy area 1 "Transforming planning and licensing processes" identifies the barriers in current licensing and planning practice (delays caused by extensive litigation and staff/qualified personnel shortages) and outlines how it might be possible to achieve goal-oriented planning practice with adequate staffing levels.

The four policy options under **policy area 2 "Strengthening a new, proactive planning culture through participation"** outline how, even if the expansion of renewables is accelerated, the high current level of general acceptance in

222 See Othengrafen/Reimer 2018.

society can be sustained through a new, fair and proactive planning culture and strengthened through participation at the local and regional levels.

Policy area 3 “Creating the conditions to make more land available” addresses the fact that the current legal framework and current planning practice do not ensure that enough land will be available for a rapid expansion of wind and solar power that is accepted by the whole of society. Systematic multiple space use is key to ensuring that this expansion is sustainable. In other words, the conditions should be created to enable the use of land that has already been developed and facilitate synergies with other uses (agriculture, biodiversity conservation) and hybrid uses.

Finally, **policy area 4 “Fully aligning the energy system with renewables”** identifies policy options for guaranteeing security of supply and creating a coherent regulatory framework for the electricity market that reflects the fact that fluctuating renewable energy now accounts for approximately 50% of the electricity supply and is thus its main source. Both this percentage and demand for electricity will continue to rise, making electricity the cornerstone of the energy transition in every sector. Security of supply is discussed from a broad perspective that also addresses energy sovereignty and PV module imports.

The following policy areas and policy options (POs) were identified by the working group:

Policy area 1:
Transforming planning and licensing processes

- **PO 1.1** – Expedite planning through a sustainable, integrated planning culture with clear nature conservation criteria
- **PO 1.2** – Address staff and specialist shortages, build and develop expertise

Policy area 2:
Strengthening a new, proactive planning culture through participation

- **PO 2.1** – Strengthen transparency and understanding through interactive information activities
- **PO 2.2** – Maintain and promote trust and acceptance of change through participation
- **PO 2.3** – Make it possible for local authorities to share in the revenue
- **PO 2.4** – Expand renewable energy communities and strengthen community energy companies

Policy area 3:
Creating the conditions to make more land available

- **PO 3.1** – Ensure the availability of sufficient land for wind and ground-mounted PV installations through national and federal state land allocation targets
- **PO 3.2** – Enable multiple uses of spaces already in use
- **PO 3.3** – Enable widespread installation of solar panels on building roofs

Policy area 4:
Fully aligning the energy system with renewables

- **PO 4.1 –** Ensure that wind and PV installations can support system stability
- **PO 4.2 –** Reform and harmonise the electricity market's regulatory framework
- **PO 4.3** – Assess the risks of reliance on solar panel imports

Table 5: Overview of the 4 policy areas and 12 policy options (POs)

Policy area 1: Transforming planning and licensing processes

Chapter 4 describes the formal planning processes (regional and urban land use planning), as well as the licensing processes under immission control law and the building permission requirements for individual projects.

The current processes for the licensing and implementation of ground-mounted PV and wind power projects take too long. Licensing authorities often lack the resources to cope with the complex current regulations relating to nature conservation, public participation, etc., and this leads to delays in planning and licensing processes. For wind power projects, it takesbetween 3 and 5 years from the start of the planning process until the completion of the installation.[223] In 2020, licensing processes involving an environmental impact assessment took an average of 21.5 months in Germany.[224] This time could be reduced by **consolidating planning practice at the regional level** and **increasing the number of licensing personnel**, since the shortage of qualified personnel is also apparent in this area and is exacerbated by the growing complexity of licensing processes.

Chapter 4.1 describes how the regional planning level is responsible for designating priority areas or suitable areas for development in order to resolve or minimise conflicts with other spatially relevant uses, with the involvement of local authorities, the general public and other authorities and public agencies.[225]

At the formal planning level, public interests (e.g. environmental impacts) and private interests (e.g. development projects) must be fairly weighed up against and among each other, especially when it comes to the designation of concentration zones with exclusion criteria. This is a requirement for the legality of the relevant planning decisions relating to concentration and exclusion. In order to meet the requirements of the weighing up process, the plan must not only explain the factors that resulted in a positive site designation but also set out the reasons supporting the intended exclusion of wind installations from the rest of the planning area. The negative and positive components of the designated concentration zones are thus mutually dependent, and the preferential treatment accorded to wind installations in undesignated outlying areas supports the expansion of this technology. **Regional planning can be expedited** first and foremost by modifying environmental impact assessment practice and by speeding up the process of adapting regional plans (for example to higher expansion targets set at state level) and of rectifying mistakes in the plans.

In order to accelerate the expansion of wind and solar power, it is also urgently necessary to **increase the number of qualified staff in the relevant authorities and companies**. Staff shortages are currently causing additional delays in the processing of environmental impact assessments, for example. Complicated and detailed planning and licensing procedures can only be carried out in good time and in a legally watertight manner if sufficient trained personnel are available.

PO 1.1 – Expedite planning through a sustainable, integrated planning culture with clear nature conservation criteria

The challenge: Planning processes take a long time. Planning relies on political will to resolve conflicts between different uses and make land available. The measures required to expedite planning processes are thus different to those for expediting licensing processes (which involve fulfilling certain criteria, with little or no discretion). One potential mean of expediting planning procedures would be to modify environmental impact assessment practice when developing spatial plans. These assessments involve drawing up reports in a time-consuming process that can take several years. Moreover, dynamic changes in the fauna under assessment (e.g. in how birds use the area, or colonisation of the area by endangered species) may continue to

223 See FA Wind 2015.
224 See FA Wind 2020b.
225 Authorities and agencies that have statutory public functions.

occur, requiring repeated amendments. Biodiversity protection and nature conservation issues can often lead to legal disputes, preventing prompt implementation of planning decisions.

It is not biodiversity and nature conservation per se that slows down the process so much as the difficulty that the authorities have in implementing unclear and open-ended regulations, especially in nature conservation law. For instance, there are no widely recognised nationwide sub-statutory methodological standards[226] to ensure legally watertight biodiversity conservation assessment of individual cases. Similarly, there is a lack of clarity concerning the assessment of the significantly higher mortality risk that wind installations pose for certain bird species and how this can be prevented by maintaining an appropriate distance between the installations and the relevant habitat.[227]

Furthermore, the effect of current planning law is to make the authorities' main task the prevention of encroachment on the landscape. This results in a cautious, conservative approach to planning processes and land designation.

In practice, moreover, the planning authorities (to some extent based on policy directives or wind power decrees) often see it as their responsibility when designating concentration zones with exclusion criteria to prevent encroachment on the landscape by automatically excluding small areas of land for individual turbines from the plan. Once again, this results in a rather cautious and conservative approach to land designation.

Another barrier that occurs in practice is that regional plans (and urban land use plans) are often deemed unlawful due to formal errors, errors in the categorisation of hard and soft taboo criteria, or failure to properly weigh up the different interests.[228,229,230] Amending regional plans (to comply with court rulings) and rectifying planning errors can be a lengthy process.

Possible solutions: Accelerating the expansion of wind power (and ground-mounted PV) will require a proactive, integrated regional planning practice that involves local authorities. An "integrated" planning culture means that the formal planning process should continuously integrate the policy targets for the expansion of renewable energy as set out in the Renewable Energy Sources Act and as required in order to meet the 2045 climate targets. It is also necessary to establish clear, nationwide criteria for nature conservation, concentration zones and participation processes. These should be based on a long-term planning approach that prioritises land use for wind and ground-mounted PV installations (and also certain types of agrivoltaic installation in the future).

Drawing on the principles of urban planning, in addition to the current standard practice of including a minimum number of wind turbines (usually three) in a

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226 Some initial proposals are provided here.
227 The use of the distance recommendations in the "Heligoland Paper" is disputed, not least within the planning community. Different federal states have different approaches, and not all of them follow the "Heligoland Paper" recommendations.
228 See FA Wind 2016.
229 See Wegner 2016.
230 See Wegner 2018.

concentration zone, **sites for individual wind turbines** could also be considered, provided that these sites follow urban planning and landscape structure organising principles. Making it easier to deviate from regional planning objectives (regarding the designation of concentration zones) would give local authorities more discretion to diverge from the final regional plan (e.g. if "suitable sites" can be identified in a local authority energy plan). In terms of concrete implementation, one option would be to allow local authorities to designate individual turbine sites in addition to the areas designated in the regional plan. Alternatively, individual turbine sites could already be considered in the regional plans.

While one-size-fits-all regulations for the minimum distance from residential areas rarely help to increase acceptance, they can in some cases significantly restrict the available sites.[231,232] Local acceptance can be increased by adopting solutions tailored to local circumstances rather than having to comply with standard minimum distance regulations. State planning guidelines should also be reviewed to ensure that the most suitable sites for wind installations (which may be in woodland or exposed locations, for example) are not automatically excluded on landscape protection grounds.

Clearer planning regulations would help to strengthen **regional planning**. Ensuring that the regional planning level's tasks are clearly defined would prevent additional assessments or assessments that are unnecessary at this planning level from being carried out in order to avoid legal action, as currently happens in practice. For example clear requirements should be established regarding participation in the site designation process.

Regional plans must be adapted in order to integrate national and state expansion targets for wind and solar power. These targets must be jointly agreed by the federal and state governments based on the Renewable Energy Sources Act. The federal states are then responsible for their implementation. The adaptation of the regional plans is currently a very lengthy process that could be expedited by focusing on "substantive partial regional plans" (German: sachliche Teilregionalpläne) that specifically address the supply of renewable energy and refrain from re-regulating all other land uses. Regulations enabling retrospective rectification of errors in regional plans are also necessary. At present, a revised version of the entire regional plan must be published even if it "only" contains a single formal error. This process would be expedited by the introduction of amendment regulations in the Spatial Planning Act, in line with the Federal Building Code regulations on urban land use planning (Federal Building Code Sections 214-216). It is also necessary to facilitate the designation of additional land over and above the concentration zones already included in a plan without needing to rescind and completely redraft the existing plan. This would expedite the process of making additional land available for renewable energy installations.

The use of informal participation is another key component of an integrated planning culture. The regional planning level needs support with the implementation

231 See Hoen et al. 2019.
232 See Hübner/Pohl 2015.

of **informal participation processes**, since in some cases regional planning authorities lack the staff resources and their employees the professional expertise to deliver them.[233] Local authorities also need support in designing a wind power strategy tailored to their specific circumstances in order to achieve a consensus among landowners and enable the financial participation of the local authority and local residents. It is important that an adequate standard of informal participation [234] is available to local actors (see PO 2.2. and 2.3 regarding the use of digital technology to modernise participation culture) in the planning and licensing process for wind and large-scale PV installations. The federal states should therefore provide funding for professional, impartial third parties (mediators, moderators, coaches, etc.) to deliver local support to regional planning authorities and, where relevant, local authorities with (informal) communication, early visualisation (e.g. to assist with designation of suitable land) and, if necessary, mediation. These third parties could also advise those responsible about the level of participation that should be provided for the individual stages of the planning and licensing processes.

While biodiversity loss is a serious problem in Germany, wind power is not the main threat to bird species. Clear **nature and biodiversity conservation** criteria are needed in order to provide a sound basis for planning decisions in particular. These should include comprehensive mapping of sensitive areas so that they can be kept separate from wind power developments. Decisions should be based on the local population density of species that are sensitive to wind installations (the process can be expedited with the aid of comprehensive biodiversity conservation maps that map sensitive and less sensitive areas and by installing bird detection systems). Appropriate short-term land use measures could promote population surpluses to compensate for losses in other areas until technologies for preventing bird collisions (e.g. IdentiFlight) are sufficiently mature. Biodiversity conservation should prioritise the protection of populations rather than individuals. In order to make both biodiversity conservation measures and the corresponding planning decisions more legally watertight, their assessment (including the granting of exemptions) should in practice be governed by nationwide federal law standards that are aligned with EU law. Moreover, greater importance should be attached to the indirect positive impacts of wind power on nature conservation when weighing up the pros and cons of a development. As far as the licensing process is concerned, clear guidance for species recording and evaluation benchmarks and criteria would facilitate the assessment and also provide greater clarity when checking biodiversity conservation law exemptions.

Actors: The federal government should create a legal framework that establishes the same nature and biodiversity conservation criteria for all German states. In addition, planning law should allow land to be designated and used for individual turbines outside of concentration zones. This will first and foremost require amendments to federal state law. The states should provide funding to train their personnel and to bring in expert third parties to support participation measures at the regional planning level and in districts and municipalities (e.g. the Forum Energiedialog for municipalities in Baden-Württemberg, see PO 2.2).

233 See Leibenath 2019.
234 See FA Wind 2019a.

Intended outcome: An integrated planning culture allows more land to be made available for wind and ground-mounted PV installations (and for agrivoltaics and floating PV). Licensing procedures are expedited by ensuring that the authorities have clear requirements with regard to issues such as biodiversity conservation. Compulsory informal participation and better communication help to reduce the number of lawsuits later on in the process. Moreover, public involvement in drawing up the plan can result in more positive attitudes towards the planning process.

PO 1.2 – Address shortage of staff and specialists, build and develop expertise

The challenge: Even today, the planning, licensing and other relevant authorities lack the staff resources to carry out the necessary procedures within a reasonable timeframe.[235] In the short to medium term, the acceleration of the energy transition will depend on the availability of qualified staff in the public sector (e.g. licensing authorities and environment agencies) and the private sector (for the technology's production, installation, operation and maintenance).

The availability of staff in the public administration, energy sector[236] and other relevant industries is influenced by supply (suitably qualified staff, age structure) and demand. In the next few years, the number of graduates and people with vocational training qualifications will no longer be high enough to replace the number of people leaving the relevant professions. By 2030, the public sector is projected to be one of the sectors worst affected by a shortage of skilled professionals.[237] 27% of public sector employees are due to retire in the next 10 years.[238] Yet if the authorities are going to implement more extensive public participation (see PO 1.1), they will need more staff, both at the planning level and for the licensing process.

A shortage of skilled professionals is also expected in the private sector if the expansion of wind and solar power accelerates significantly. Demand for skilled professionals will be especially strong in fields such as electrical equipment and metal products.[239] And it should not be forgotten that the wind and solar industry has to compete with other industries for skilled professionals.[240]

It is estimated that, by 2030, approximately 11% of public sector posts and over 5% of energy industry posts will be vacant.[241] Demand will be especially strong for energy transition experts and architects, and there will be a particular need for people qualified as power engineers and IT experts.[242]

The energy transition will also call for specialist qualifications (e.g. mechatronics engineers specialising in wind installations) that are not yet fully covered by current training provision,[243] while the planning and licensing processes (e.g. environmental

235 According to the Federal Immission Control Act, procedures with environmental impact assessments should be concluded within a period of 9 months. The median duration of licensing procedures for wind installations is 17 months, while the mean is 22 months.
236 See Statistisches Bundesamt 2021.
237 See PwC 2018.
238 See DBB Beamtenbund and Tarifunion 2021.
239 See O'Sullivan/Edler 2020.
240 See O'Sullivan/Edler 2020.
241 See PwC 2018.
242 See Lutz et al. 2018.
243 Ibid.

impact assessments and public participation) will also need to be adjusted to the changing legal requirements.

Possible solutions: The following measures are proposed in order to ensure the required expansion of renewables and expedite the relevant planning and licensing processes:

- Build qualified personnel capacity and offer more attractive employment conditions in public authorities so that they can implement participation processes and a new planning culture (e.g. through continuing professional development).

- Build and expand public agencies (intermediaries) that support implementation of the energy transition (for example C.A.R.M.E.N. in Bavaria and the FachAgentur Wind).

- Develop needs-based (based on monitoring programme findings) training and professional development programmes tailored to the requirements of the energy transition (e.g. in cooperation with Chambers of Skilled Trades).[244]

- Set clear, long-term expansion targets that provide incentives to train skilled professionals in industry and make the renewable energy sector more attractive.

- Provide continuing professional development for people who will lose or have already lost their job due to structural change or the coronavirus pandemic.[245]

- Promote immigration of skilled renewable energy workers in line with the Canadian model[246] in order to make up the personnel and skilled professional shortfall in a targeted manner.

Actors: Additional public and private investment will be required to implement the relevant measures in the public and private sectors. As far as the public sector is concerned, continuous monitoring and the provision of training and professional development tailored to the energy transition can help to prevent staff shortages in the medium to long term.

Intended outcome: Additional staffing helps to ensure legally watertight assessments (e.g. of environmental impacts by nature conservation agencies) during the planning process and expedites licensing procedures. Legally watertight planning also creates greater stability in the renewable energy industry. Additional staff resources are also key to regional and municipal participation in the development of individual projects and to delivering communication and visualisation measures geared towards achieving widespread acceptance among local communities. Moreover, recruiting more staff sends out a signal about the importance of expanding solar and wind power both regionally and for society as a whole. Increasing staff numbers and

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244 Ibid.
245 See Grunau et al. 2020.
246 See ifo 2018.

training more skilled professionals helps to avert the threat of skilled professional shortages in both the private and public sectors.

Policy area 2: Strengthening a new, proactive planning culture through participation

Current regional and local planning practice is characterised by lengthy procedures. When members of the public engage in the planning process, it is usually to express opposition, even though there is strong support for climate action throughout society as a whole[247,248] and a clear majority of people have a positive attitude towards renewable energy.[249,250] At first sight, the (public) participation measures outlined below may seem to require a lot more time and effort. However, practical experience with such measures[251] (see e.g. the case study in Chapter 3.2.7 and FED, THeGA, etc.) shows that, by preventing vociferous opposition from local action groups, destructive disputes and legal action against renewable energy projects from an early stage in the process, they can actually result in projects being completed faster than is currently the case.

The current legal framework does provide for participation. However, it does not stipulate how extensive participation should be realised or ensure that participation occurs at an early stage in the planning process. In practice, participation usually only occurs once a plan has already been drafted (see Chapter 3), meaning that its influence is mainly confined to minimising the negative impacts of the planned installations. Local residents view participation processes as their last chance to prevent apparently negative projects undertaken by outsiders, rather than as a creative opportunity to co-design the development. The financial participation of local authorities and the opportunity to establish renewable energy communities helps to create favourable conditions at a local level and encourage local initiatives. At present, local authorities' economic participation consists in receiving a share of local business tax[252], while the financial participation of local authorities (or individual members of the public) by investing in local renewable energy installations entitles them to receive a return on their investment or share of the profits. On 11 June 2019, Brandenburg became the first federal state to adopt a "Windenergieanlagenabgabengesetz" (BbgWindAbgG). According to this Act, in order to operate wind turbines in a particular local authority area, the installation operators must pay a special levy directly to the local authority, to be used in the area in question. Local residents also have the opportunity to participate financially. Investors can participate indirectly, for example through fixed-interest

247 See BMU 2020.
248 See UBA 2019.
249 See AEE 2021.
250 See IASS 2020.
251 As yet, there has been no systematic research.
252 Until recently, the Trade Tax Act (Gewerbesteuergesetz – GewStG) allocated local business tax liability from companies' individual permanent establishments to local authorities based on the payrolls of these individual permanent establishments. If however, as is usually the case, no personnel are employed in the local authority area of the installation site and the registered office of the installation operator is in another local authority area, the local authority where the installation is situated does not receive a share of the local business tax paid by the installation operator. Following the May 2021 amendment to the GewStG, the local authority area of the installation site now gets a larger share of the local business tax paid by the installation operators, since the percentage paid to the local authority area of the installation site has been increased and the allocation key has been changed.

subordinated loans, while investors and co-owners can also participate directly, for instance as limited partners in the operating company.

PO 2.1 – Strengthen transparency and understanding through interactive information activities

The challenge: Despite high levels of support for the expansion of renewable energy,[253] the percentage of people who criticise the energy transition for being chaotic (66%) or unfair (56%) is rising.[254] This hints at potential conflicts that could hinder the expansion of renewables. In order to enable constructive solutions, the public should have the opportunity to engage in critical discussion at different levels and to acquire expertise about the overall system.[255]

Possible solutions: Interactive information and participation formats should be developed to support the energy transition. These formats should facilitate the exploration of interrelationships, helping members of the public to understand the complexity of the energy transition through discursive processes so that they can form informed opinions. Possible formats include the **decision theatre**[256], **planning cells/citizens' panels**[257], or a **citizens' assembly** with members randomly selected by lot. These formats are discussed in more detail in Chapter 3.2.6. The planning cell/citizens' panel process, for example, could be used to establish criteria for selecting land at a regional level. Some regions already have fully digital interactive information measures (e.g. the "Anhalt-Bitterfeld-Wittenberg Regionaler Energiebalancekreis" scenario calculator).[258] Solutions like this are also useful for understanding the complex interrelationships between decarbonisation targets, expansion requirements, tariff structures and funding formats (see e.g. PO 4.2 re. the consequences of electricity market regulation) and should be implemented by federal government institutions (e.g. the BMWK and BMU).

Actors: At present, interactive information measures are provided on the initiative of civil society and often funded through donations or by charities. The legislator should initiate action to make these processes mandatory, for instance to assist with the preparation of planning decisions [see PO 2.2].

Intended outcome: Interactive information measures help participating members of the public to gain a comprehensive understanding of policy decisions, the overall strategy and planning instruments. Participation also generates input for policy decisions, thereby strengthening confidence in democratic structures. Gaining an insight into the complexity of the situation and the intended outcomes increases trust in and acceptance of planning measures. Formats that actively involve the public (e.g. a citizens' panel on criteria for selecting land) also provide an opportunity to debunk half-truths and myths or at least openly identify gaps in people's knowledge. They also provide a chance to correct misconceptions such as the tendency to underestimate overall support for the expansion of renewables. This can help the public to cope with

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253 See AEE 2021.
254 See IASS 2020.
255 The ability to recognise chains of effects, draw conclusions, gauge potential impacts and make predictions.
256 See Vesikko 2013.
257 See Dienel et al. 2014.
258 See RLI 2021.

the uncertainty caused by gaps in their knowledge and counteract the narratives employed by opponents of the energy transition.

Digital formats (e.g. interactive information measures or participation formats such as online citizens' assemblies) help to reach new target groups. This can be a particularly good way of including younger people, in the interests of intergenerational equity.

PO 2.2 – Maintain and promote trust and acceptance of change through participation

The challenge: At present, planning processes for wind installations are stratified, in the sense that decisions from earlier stages in the planning process establish the framework for the subsequent stages. For the people affected by a development, the planning permission process is the most important stage to be involved in, since it will have tangible impacts on their lives. But by this stage, their scope to influence the development is already very limited,[259] and those who do get involved are forced into the role of opposing the development. While the current regulatory framework does provide for participation earlier on in the process (e.g. in the drafting of urban land use plans), in practice the authorities only provide information at this stage rather than enabling full participation.[260] A further challenge involves ensuring that local authorities acquire the necessary expertise to adequately coordinate the complex planning, design and licensing process in a way that reflects local interests. Local authorities that lack this expertise can often be afraid of making mistakes. Consequently, rather than actively engaging with wind power projects, they try to stay at arm's length from them as far as possible. The result is that the process is driven by the project developers (or, once details of a wind power project have been made public, by its opponents), with the local authority only able to play a reactive role and being completely overburdened due to a lack of the relevant expertise.

Moreover, the project developers rarely give everyone an equal opportunity to participate, especially when it comes to financial participation. This can lead to resentment about the distribution of the drawbacks and benefits.

Current practice thus squanders the opportunity to actively engage local communities – including everyone from the mayor and the local council and administration to the general public – in shaping the energy transition and to make people feel that they are involved in a valuable community project.

For successful participation, it must be possible to repeatedly challenge decisions at every stage of the planning process. In practice, this often leads to multiple appeals, on the grounds that the planning process has failed to duly weigh up all the relevant interests. In land use planning, for example, it is currently common practice for project developers to strike deals with private landowners to secure land that is not designated for use in the plan.[261]

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259 See Roßnagel et al. 2014.
260 See Roßnagel et al. 2016.
261 See Beckers et al. 2017.

Possible solutions: Empowering local authorities, embedding participation in the different planning stages in order to leverage its positive creative potential. Extensive participation already takes place at the regional planning and urban land use planning levels (e.g. regarding the selection of land use designation criteria). Citizens' assemblies are a useful participation format at this level (see PO 2.1; they should have access to the expertise of nature conservation organisations and wind power experts). However, there are also currently a number of innovative local planning solutions such as the 2020/21 project "Aktive Bürgerexperten in Klimaschutz und Energiewende" (Active citizen experts in climate action and the energy transition), which is funded by the Stiftung Mercator.[262]

One key requirement for the long-term success of participation is to ensure that members of the public are able to engage in the planning process in a pertinent manner and with the opportunity to influence the outcome, and that local authorities have the know-how and resources to coordinate this participatory planning process. This planning culture has been shown to succeed if the local community (and in the first instance especially the mayor and local council and administration) is informed and advised about how wind installations could fit within the local area by an actor without any financial interests in the project. The relevant local actors will accept wind power projects in the vast majority of cases where advice is provided in this way.

The second step involves moderating the negotiations between the local authority, local residents and landowners regarding how the land should be used.

The third step involves establishing the decision-making criteria to be used for implementing a project with the acceptance of the local actors. As well as spatial criteria (see PO 1.1), it is particularly important to establish criteria for the economic participation of the relevant local authority or municipal enterprise, in order to define the value-added and benefits for the municipality and its residents (see POs 2.3 and 2.4).

In a planning culture characterised by consultation and participation, it is vital that the local authority and local residents should be the process owners throughout and that they should acquire the necessary expertise to develop and implement the relevant measures in a competent manner.

Additional resources will be necessary to help the planning authorities meet these new participation requirements. Recent experiences have demonstrated the importance of the moderating/coordinating agency not having any financial interest of its own in the project – in other words, its costs should be covered by the federal state or by central government (examples include the Forum Energiedialog in Baden-Württemberg and Windkümmerer in Bavaria). The project developers should not perform this role – although they have the necessary expertise, their financial interests might prevent them from being impartial.

It is also important for local authorities to exchange information in order to raise awareness of the numerous participation opportunities already enabled by the current legal framework. Moreover, ordinances concerning the expansion of wind power and

262 For more information, see https://aktivbueke.de/

informal materials and planning tools should describe alternatives and suggested formats that can supplement the statutory provisions.

Actors: The authorities involved in the planning process can implement the measures described without delay, since the legal framework already provides for proactive planning and early participation-although this is not mandatory. A solution that has proven to be effective is for the federal states to create a framework that allows meaningful participation to be incorporated into the planning process as standard and in a legally watertight manner.

There are now various specialised institutes that have extensive experience in carrying out participation processes, and it is important that the planning authorities should acquire similar expertise. This includes complying with appropriate standards for selecting and contacting the participants and ensuring that the participation activities are delivered by people with the relevant expertise (either in-house staff, non-partisan public institutions, or trained external mediators). Other experts appropriate to the format should also be included, for example representatives of civil society organisations such as nature conservation groups, scientists, etc. It may also be appropriate to establish new official structures with expertise in participation, along the lines of the Commission on the Storage of High-Level Radioactive Waste. Successful examples include the Forum Energiedialog Baden-Württemberg[263] and TheGA, which were established by the state governments of Baden-Württemberg and Thuringia to help local authorities prevent or de-escalate disputes through information and communication. Existing structures of this type should be strengthened and consolidated as necessary.

Intended outcome: As with PO 2.1, public understanding of and trust in the relevant strategies, planning measures and actors is strengthened. Furthermore, participation processes lead to decisions being more widely accepted because they are more closely aligned with local residents' needs and normative concepts. In addition, early-stage participation promotes positive identification with both the local project and the expansion of renewables in general. The process also helps to build expertise for future involvement in the energy transition within the region or municipality. However, it is important to be aware that if expectations raised during the participation are not fulfilled in the rest of the process, this can result in a boomerang effect that leaves people feeling even more frustrated.[264] Participants are also likely to get frustrated if plans that they were involved in developing are rejected by the courts. To prevent this from happening, it is vital to formally ensure that the outcomes of the participation process are legally watertight. The ability to rectify errors in a plan while retaining the remaining, error-free parts of the plan could play a key role in this regard (see PO 1.1).

PO 2.3 – Make it possible for local authorities to share in the revenue of renewable energy projects

The challenge: Local opposition to wind and PV installations is often driven by a sense of injustice about the way the benefits and drawbacks of the installation are distributed, especially in projects where there is no opportunity for the local community

263 For more information, see http://www.energiedialog-bw.de/. Retrieved 18.01.2022
264 See Renn et al. 2017.

to participate financially. Projects that do provide for direct financial participation by local residents are far likelier to be successfully implemented. But even in these cases, justice is still important. Arrangements where the local council receives a share of the profits and uses this money to benefit the whole community (e.g. in Brandenburg, where the local council decides how to use the wind installation levy) are often preferred to arrangements where the profits are shared among private individuals[265] because they are perceived as being fairer. There is always a danger that, in situations where public opinion is already negative, giving individuals the opportunity to participate financially could be interpreted in a negative light (e.g. by giving local residents the impression that the project developers are trying to buy them off).

Possible solutions: If the local authorities either share in the profits (e.g. through a wind power levy) or initiate and invest in the renewable energy project themselves, the local administration and political parties will be more motivated to drive the project forward. Participation ensures that the project's economic transactions are communicated openly and transparently, helping to prevent perceived injustice and loss of trust. Moreover, projects add significantly more value to the region if the installations are (at least partly) owned and operated by the local authority, a municipal enterprise or other local actors, instead of being owned and operated by a company from outside of the region.

Section 6 of the amendment to the Renewable Energy Sources Act (EEG) that came into force on 27 July 2021 states that installation operators can offer local authorities the chance to participate financially in the expansion of renewables. This optional offer of participation by the project developers applies to both wind power and ground-mounted PV projects. In the case of ground-mounted PV, the opportunity to participate is only open to local authorities if the installation is located within their boundaries. However, due to the size of wind installations, the opportunity to participate in wind power projects is somewhat wider. Affected communities are defined as those whose boundaries fall at least partly within a radius of 2,500 metres from the centre of the wind turbine tower.

However, the recent amendment to the Act still doesn't make it mandatory for local authorities to participate in the expansion of wind and solar power – it relies on the installation operator voluntarily offering them this opportunity. It is vital for the legislator to amend the EEG to make local authority participation mandatory, without any loopholes – even if this means additional costs. It is also necessary to determine the extent to which this regulation can be extended to include new technologies such as agrivoltaics and floating PV.

It should thus be made mandatory to offer local authorities the opportunity to have a financial stake in wind and ground-mounted PV installations. It is necessary to determine how this regulation can also be extended to ground-mounted PV installations implemented as PPA (Power Purchase Agreement) projects and, in the case of EEG funding, new PV technologies such as agrivoltaics and floating PV. In order to ensure that financially weak local authorities can also invest in renewable energy installations, it is necessary to find solutions to prevent them from being denied this opportunity (e.g. by amending the rules relating to the financial oversight of local

265 See García et al. 2016.

authorities by the federal states). One instrument that should be investigated would be to give local authorities first right of refusal for renewable energy installations intended for reselling. It is also important to ensure that smaller local authorities and those without suitable municipal enterprises have appropriate advice and support structures for financial participation and investment models of this type.

Actors: The legislator could include a requirement in the EEG for installation operators to offer affected local authorities the chance to participate in the revenue from renewable energy installations. The federal states must amend their financial oversight rules for financial participation in renewable energy installations and, together with central government, establish support structures to enable the continued success of existing initiatives such as Mecklenburg-Vorpommern's law on local community financial participation.

Intended outcome: Greater local authority participation in the revenue from renewable energy projects will create a significantly stronger basis for achieving local acceptance through greater distributive justice. Additional revenue for local authorities motivates politicians, civil servants and local residents to actively participate in the expansion of renewable energy and make the most of the existing potential.

PO 2.4 – Expand renewable energy communities and strengthen community energy companies

The challenge: The early years of the energy transition saw the establishment of large numbers of community energy companies ("traditional" community wind/solar companies) and community energy cooperatives. This contributed to widespread local acceptance of wind and PV installations. However, the importance of these actors has diminished significantly due to the tender model.[266] Now, the EU is promoting a possible revival of community energy companies and cooperatives. The EU's 2018 Renewable Energy Directive and 2017 Internal Market in Electricity Directive strengthen the rights of individual energy consumers. Rather than focusing primarily on financial profit, the EU sees renewable energy communities[267] as a means of delivering local environmental, social and economic benefits. Renewable energy communities can produce, store, share and sell their own renewable electricity, and are exempt from charges and fees for the consumption of self-generated renewable electricity (Renewable Energy Directive 2018, Arts. 21 and 22). Renewable energy communities should be able to use electricity from joint, regional installations collectively and without a disproportionate financial burden (charges, levies and taxes).[268] The EU required the Directive to be transposed into German law by 30 June 2021, however this has still not happened.[269,270,271]

266 See Gawel/Purkus 2016.
267 Ibid.
268 When implementing this provision, it is necessary to establish how the renewable energy community members can contribute reasonably and fairly to energy system costs.
269 Act of 18 August 2021 on the transposition of Directive (EU) 2018/2001 of the European Parliament and of the Council of 11 December 2018 on the promotion of the use of energy from renewable sources (recast) for licensing procedures in accordance with the Federal Immission Control Act, the Federal Water Act and the Federal Waterways Act; Federal Law Gazette (BGBl.) I, 3901.
270 Act of 16 July 2021 on the transposition of European law and the regulation of pure hydrogen networks in energy law, Federal Law Gazette (BGBl.) I, 3026.
271 See IZES 2021.

Possible solutions: The introduction of renewable energy communities and the establishment of a comprehensive framework for them should make it possible to share the electricity from collective wind and PV installations cost-effectively. The involvement of local residents in communities that operate renewable energy installations and supply locally generated electricity strengthens local acceptance. In the interests of increased consumption of self-generated electricity by the new market players (renewable energy communities and community energy companies) in accordance with the EU Directives, the legislator must adapt the existing form of community energy initiatives for Germany. Connecting these initiatives through digital technology will be especially important for the German energy market.

Actors: The Directive must be transposed by the legislator, with the involvement of the relevant market actors.

Intended outcome: The autonomous and participatory spatial organisation of the renewable energy supply (in cells comprising areas, companies, properties, etc.)[272] provides members of the public with a framework that they can relate to personally and within which they have a degree of freedom. With the aid of digital infrastructure, these small-scale, decentralised generating and storage systems can increase local consumption of renewable electricity and help to stabilise the system. Digitalisation also makes it possible to connect the electricity, mobility and heating sectors in an efficient, automated manner in order to further reduce GHG emissions in these sectors. Increasingly, digital connectivity is making it possible to use smaller-scale flexibility to balance out mismatches between supply and demand (e.g. through the FlexPlattform concept).

Policy area 3: Creating the conditions to make more land available and enable efficient, multiple land uses

Renewable energy technologies for producing wind and solar power (and bioenergy) require more space than fossil fuel power plants. The amount of space needed for wind and PV installations varies depending on the type of installation.[273] As part of the immediate climate action programme, the BMWK is currently planning an Onshore Wind Energy Act requiring 2% of Germany’s land area to be designated for wind installations.[274]

Accelerating the expansion of renewables will call for comprehensive, integrated spatial planning, especially in the case of wind power. Although the targets for the expansion of renewables are established at the federal level, the federal government does not have a direct channel for controlling implementation of these targets at the regional and municipal planning levels – the current coordination of the federal and state levels is not working well enough. As a result, regional planning is the most important instrument for designating land for wind power projects. However, there are significant differences in the spatial planning regulations of different federal states for designating land (i.e. regarding the planning control of wind power projects and the requirements for the different planning levels). In addition to the problem of not

272 See Haller et al. 2020.
273 See Rinneberg 2020.
274 See BMWK 2022a.

enough land being designated for the necessary expansion of renewables,[275] the distribution of installed capacity across Germany's federal states is increasingly imbalanced, especially for wind installations. This is leading to growing opposition to new wind power projects on distributive justice grounds. For energy system reasons, too, this imbalance and the associated further expansion of the grid are a barrier to faster expansion of renewables and increase the overall cost of the transformation.

Land is a limited resource and there is constant competition for it between different uses. Conflicts can arise between energy generation and uses such as agriculture, housing developments, infrastructure and nature conservation. The federal government's sustainability strategy states that the amount of land lost to development in general should be reduced by 2030 and that no further land should be developed for housing and transport by 2050.[276] In view of the growing competition between different land uses, single-use solutions are unlikely to be sustainable. Consequently, the spatial planning process that designates land for new uses should enable compatible multi-use solutions. This will improve the quality of the solutions in regions where additional wind and solar capacity is installed. Economic viability must also be borne in mind when designating future land uses. Ground-mounted PV installations in the megawatt range can already be implemented profitably through bilateral power purchase agreements (PPAs) between the installation operator and a grid operator, without relying on the EEG remuneration regulations. However, smaller installations – especially integrated PV on transport routes, sealed urban land and farmland – still rely on guaranteed payments through the EEG or other mechanisms. Nevertheless, some integrated PV cell technologies are already mature and affordable enough to make their deployment during the current decade a realistic option.[277] Efforts to leverage the potential of integrated PV technology are hampered by the current spatial planning and land use planning regulations and the rest of the regulatory environment.

There is still a huge amount of untapped potential to use roofs for PV installations.[278] Especially in urban areas, roofs have enormous potential for generating solar power without taking up extra space. This includes green roofs, which can also be an economically viable solution – combining green roofs with solar power generation is an effective multi-use solution for roof space.

PO 3.1 – Ensure the availability of sufficient land for wind and ground-mounted PV installations through national and federal state land allocation targets

The challenge: In order to achieve a climate-neutral energy supply in Germany, it will be necessary to make extensive use of the existing renewable energy potential and develop a highly efficient energy system. A balanced resource mix of solar, wind, biomass, geothermal energy, hydropower and waste heat and an upgraded infrastructure (grids, storage and control systems, etc.) will be key to an affordable energy system that guarantees security of supply. As well as coping with fluctuations in the supply of different energy resources over time, the mix must also address their geographical distribution. The future energy system will rely on a balance between the

275 See BBSR 2015.
276 See Die Bundesregierung 2020.
277 See Fraunhofer ISE 2021d.
278 See Palacios et al. 2020.

use of locally generated energy, nationwide and pan-European balancing of temporary local supply shortages, and imports of gas and green hydrogen. This will call for an optimum system mix of local energy storage over different timescales and the transport of energy from other locations. It will be necessary to build an adequate level of public acceptance for the associated energy transport infrastructure. While these challenges are nothing new, the further expansion of renewables[279] makes them far more urgent and necessitates a shift from the rather tentative current approach towards an approach based on targeted planning.

As outlined in Chapter 4.1, responsibility for implementing climate targets is regulated through the federal states' spatial planning law, the aim being to develop solutions that reflect local and regional circumstances rather than rigidly implementing centralised decrees. However, there is no guarantee that the total available land designated by all of Germany's federal states will be enough to deliver the level of renewable energy resources required for Germany as a whole. Consequently, it will be necessary to introduce a new mechanism to ensure that the required land is made available.

Possible solutions: The introduction of a statutory land allocation target for wind power that provides a basis for targeted energy infrastructure planning would help to achieve a secure, cost-effective and climate-neutral energy supply. Given the urgent need for action, a deadline should be established for meeting this target. Based on the statement of the German Advisory Council on the Environment (SRU), the renewables expansion targets in the EEG, including the associated tender volumes, could be linked to a target establishing the amount of land to be made available for this purpose. This target could be progressively increased over time.[280] It should also be possible to update the process to reflect future technological developments such as bird detection systems and taller next-generation wind turbines. The federal states would then have to ensure that sufficient land is designated (see PO 1.1) at the state, regional and municipal planning levels to meet the agreed targets for each state. It would be advisable to strengthen the regional planning level by enabling cooperation between regions (joint designation of land for wind and large-scale PV installations and permitted total height of wind installations). Studies could be carried out to determine the criteria and procedures for establishing consistent targets for the federal states and central government regarding the amount of land allocated in order achieve the relevant goals, and the balancing mechanisms and flexibility that could be established between the federal states.

Actors: The methodology and regulatory structures would be developed by federal and state legislators in consultation with energy experts and industry associations.

Intended outcome: This approach can enable a clear increase in security of supply for the entire energy system, ensure that the targets are actually delivered and that this is accomplished efficiently, prevent misinvestment in the energy infrastructure, and facilitate more targeted spatial planning at the state, regional and municipal levels. Local and regional targets will also be more transparent, providing a stronger basis for

279 From 45.4% renewable electricity and 19.3% of gross final energy consumption in 2020 to close to 100% by 2045 (i.e. in the next 24 years).
280 See SRU 2022.

building the necessary public acceptance. It will also help to initiate cooperation between different regions and generally ensure that the new renewable installations are distributed transparently and fairly across Germany's federal states. Minimum targets and buffers in case they are not met will allow the states to retain a degree of flexibility that can also be used to adapt to changes in expected electricity demand.

PO 3.2 – Enable multiple uses of spaces already in use

The challenge: Appropriate land use planning will be key to accelerating the increase in new wind and solar capacity. Suitable undeveloped land should be designated for multiple uses. The use of undeveloped land solely for PV or wind installations could exacerbate conflicts with agricultural and nature conservation uses and is inefficient from a sustainable land use perspective. Compatible multiple uses (e.g. PV installations sited in dry locations, set aside maize fields or marshland) can benefit wildlife and make a significant contribution to biodiversity conservation. PV installations can also be profitably sited on land used mainly for agriculture (agrivoltaics), and can furthermore help to improve the aquatic ecology of lakes in operational quarries (floating PV – see Table 4, Chapter 2.5).

At present, the implementation of integrated photovoltaics as part of multiple space use solutions often fails due to a lack of clear regulatory criteria in spatial planning regulations and/or building law, making it difficult to issue licences.[281]

Possible solutions: PV installations in particular should be systematically enabled as part of multi-use solutions on land that is already used or could be used for other purposes. Other benefits can be realised in addition to electricity generation, for example increasing biodiversity, improving aquatic ecology, supporting power grid stability, protecting against damage from extreme weather (e.g. solar car park canopies, agrivoltaics in fruit orchards, solar panels on green roofs) and maintaining crop yields. In order to qualify for EEG funding, it should be clearly demonstrated that integrated PV installations provide a relevant additional benefit. Furthermore, the regulatory framework in Germany should be adapted to allow both agricultural subsidies and EEG funding to be claimed.

Agrivoltaics can help to deliver a strategy of utilising all the available space to accelerate the expansion of renewables, although this is admittedly not always the most cost-effective option. Where agrivoltaics are deployed, it is particularly important to ensure that agricultural yield comes before energy yield. One solution would be to establish a statutory minimum yield percentage. DIN SPEC 91434, for example, specifies a minimum yield of 90% of the reference yield (Section 5.2.10). In order to facilitate the market rollout of agrivoltaics, the reference yield should initially be set in accordance with the DIN SPEC, with the option of increasing it at some point in the future. This would also ensure eligibility for agricultural subsidies under the Direct Payments Implementing Regulation (German: Direktzahlungen-Durchführungsverordnung). Preferential treatment is key to the expansion of agrivoltaics, since built structures that do not qualify for preferential treatment are prohibited in undesignated outlying areas. If preferential treatment were to be granted to agrivoltaics in undesignated outlying areas,

281 All types of integrated PV have significant potential for increasing PV capacity.

regional spatial planning could employ some form of numerical site limit[282] in order to prevent too highconcentration of integrated photovoltaics.

As well as feeding electricity into the grid, PV installations in urban spaces (multi-storey car parks, public spaces, bus stations, etc.) can also enable innovative solutions such as charging of electric vehicles parked under solar canopies. This will require the adoption of regulations allowing publicly-owned spaces to be used for commercial energy generation by local authorities, municipal enterprises, etc. As far as building-integrated PV is concerned, it will be necessary to improve the cost-effectiveness of solar façades. It will also be necessary to provide better training for architects, planners, facility managers, etc., so that they appreciate the role that façades can play alongside roofs and understand that PV is compatible with green façades created for climate adaptation purposes.

As far as floating PV is concerned, conflicts can largely be prevented by optimising its impacts on aquatic ecology and leisure activities. It will first be necessary to wait for the results of the innovation tender[283] in April 2022. It will also be necessary to determine the type of waterbodies where floating PV is eligible for funding because of its aquatic ecology benefits. As soon as robust data is available for this, the relevant provisions should be incorporated into the EEG so that this technology can be deployed well before 2030 in order to support the accelerated expansion of renewables.

Actors: To ensure that the new regulations on multiple uses can be implemented in practice, the federal government and the states will need to clarify which statute books (Federal Building Code, Renewable Energy Sources Act, Spatial Planning Act, etc.) and ordinances (Federal Land Utilisation Ordinance, state building regulations, Federal Water Act, etc.) will codify the relevant changes. For new technologies like agrivoltaics and floating PV, it will also be necessary to discuss the concrete details of their expansion with scientists and the general public. The findings from the relevant projects, some of which are still ongoing, will provide valuable input in this context.

Intended outcome: Clear regulation and targeted funding can enable extensive opportunities to access additional space through multiple space use solutions. The key tenet for multiple use solutions is that the new uses should only have a limited impact on the existing use of the space/cultivation of the land in question.

PO 3.3 – Enable widespread installation of solar panels on building roofs

The challenge: The German government's climate neutrality goal calls for a severalfold increase in installed wind and solar capacity (see Chapter 2.4). There is significant potential to increase the number of ground-mounted PV installations and the number of roof-mounted PV installations in urban areas (see Chapter 2.3). However, cost-effective ground-mounted PV installations can face competition from other uses such as agriculture, leisure activities and nature conservation. The installation of solar panels on building roofs, on the other hand, does not usually interfere with their function and still leaves a large area available e.g. for technical structures, thereby avoiding competition between different uses. Installing solar panels on buildings has the added advantage of generating electricity close to the consumer,

282 These are widely used in the Federal Land Utilisation Ordinance for specific land use areas.
283 The Federal Network Agency (BNetzA) is currently holding a consultation process regarding the tender.

thereby reducing infrastructure requirements and increasing consumption of self-generated electricity. It is thus desirable to make extensive use of suitable roof space for the installation of solar panels, although the higher levelised cost of electricity should be taken into consideration. Doing so can help to accelerate the expansion of renewables while at the same time reducing the pressure to make land urgently available for ground-mounted PV.

Germany has approximately 19.3 million residential and around 21 million non-residential buildings,[284,285] with a total of 2.2 million roof-mounted PV installations.[286] This means that just 5% of buildings currently have a solar installation. It has been calculated that, in Berlin, around 40.8 million m^2 out of a total available roof space of 106.8 million m^2 is in principle suitable for solar installations. Solar panels would thus need to be installed on approximately 20.0 million m^2 of roof space in order to achieve the City of Berlin's target of meeting 25% of electricity demand with solar electricity.[287] This illustrates the fact that a large proportion of suitable roof space will need to be utilised if roof-mounted PV is to account for a significant percentage of overall electricity generation.

Ground-mounted PV installations have a high to very high output (generally between over 100 kilowatts and 20 megawatts) and are usually installed by specialist project developers. Realising the potential of roof-mounted PV, on the other hand, will call for the mobilisation of very large numbers of property owners, since the installed systems will only be small to medium-sized (usually 1 to 10 kilowatts on private properties and between 10 and a few 100 kilowatts on commercial properties). For most property owners, this will be a one-off investment. It is therefore important to ensure that the instruments for motivating property owners and providing them with advice and support for the planning and installation of solar panels on suitable roofs are tailored to the relevant target groups.

The rapid installation of large numbers of roof-mounted solar panels will call for a simple, unbureaucratic regulatory framework with no administrative barriers. It will also be necessary to investigate the need, from a whole-system perspective, of further stimulating demand, either by increasing the financial incentives or through regulatory measures such as an obligation to use suitable roofs for generating solar power.

Since the introduction of the EEG, the legislator has systematically removed market barriers (e.g. through guaranteed connection to the grid and feed-in priority) and created financial incentives (e.g. a guaranteed feed-in tariff for 20 years). This approach led to a strong increase in demand until 2012. The significant fall-off in demand that has occurred since is presumably due to the fact that the reduction in the solar feed-in tariff has been much greater than the fall in the price of solar PV systems, thereby significantly reducing the financial incentive.[288] This demonstrates the effectiveness of using strong financial incentives to stimulate the market. However, we do not know exactly how profitable solar PV systems must be to achieve a given level of

284 See DESTATIS 2021.
285 See IWU 2022.
286 Up-to-date figures from the Federal Network Agency's Market Master Data Register are available at https://www.marktstammdatenregister.de/. Retrieved: 31.01.2022.
287 See Stryi-Hipp et al. 2019.
288 See Ritter/Bauknecht 2021.

demand and growth in capacity. There is also no data on the percentage of property owners who can be motivated by a given level of profit and the percentage who cannot be motivated by financial incentives at all.

Psychological studies have shown that householders find the process of deciding whether to invest in energy-efficient heating technology extremely complex and overwhelming. Investment decisions fail to adequately take rising energy prices into account, and payback periods are calculated that are shorter than the systems' average lifespan.[289] Prospect theory[290] tells us that, when faced with uncertainty, lay investors tend to underestimate long-term gains. Investments in solar PV systems are likely to be particularly susceptible to this cognitive error, since the returns vary (e.g. depending on roof pitch and orientation), the ratio of electricity fed into the grid to electricity used by the property owner depends on a variety of factors, and there is a tendency to overlook future increases in self-generated electricity consumption due to the replacement of fossil fuel technologies by e.g. electric cars and heat pumps. In other words, in addition to bureaucratic barriers, the complexity of the decision-making process and cognitive barriers make people less likely to invest, even if a solar PV system would actually be cost-effective.

In view of the above, it would seem that an obligation for property owners to use their roofs or make them available for solar power generation – provided that this can be done cost-effectively – would help to overcome possible cognitive barriers. In the construction sector, regulatory measures already exist requiring implementation of mandatory energy efficiency measures in all new buildings and for renovations of existing buildings. Given the German government's target of achieving half of the necessary increase in solar installations through ground-mounted PV and half through roof-mounted PV[291], it would be advisable to investigate the extent to which different types of measures can stimulate the market.

Possible solutions: The use of suitable roof space for solar power generation can make a substantial contribution to accelerating the decarbonisation of the energy supply. Assuming that a significant increase in the utilisation of this potential is supported on social and economic grounds, it will be necessary to create conditions and incentives that, in principle, allow solar PV systems to be operated cost-effectively and bring about the desired increase in demand. The following two options can help to achieve this and should be investigated accordingly:

(1) **Promote the use of most suitable roofs for solar power generation through the creation of stable financial incentives**. Larger numbers of property owners can be motivated to invest in solar PV systems by increasing or stabilising the return on their investment. Past market trends suggest that a substantial increase in the returns will be needed in order to grow the market significantly faster.[292] This can be accomplished by increasing the feed-in tariff and potentially also the market premium to an appropriate level. One way of finding the optimal level would be to keep raising it incrementally until the market is growing at the desired rate. However, this would be counterproductive, since the

289 See Hafner et al. 2019.
290 See Kahneman/Tversky 1979.
291 See BMWK 2022c.
292 See Ritter/Bauknecht 2021.

expectation of higher returns in the future would cause investors to adopt a wait-and-see approach. Consequently, it will be necessary to estimate and implement the required target return. If this return proves to be too high, it can be reduced incrementally as and when necessary. The required level of additional incentives in the form of feed-in tariffs and market premiums will depend on various factors, including carbon price trends. A higher carbon price makes renewable energy more financially attractive compared to fossil fuels meaning that, as a rule, there is less need for additional incentives. However, a higher carbon price does not reward roof-mounted PV for the benefits that it offers over ground-mounted PV in terms of reducing land use competition. As a result, a higher carbon price is unlikely to be enough on its own to incentivise a sufficient increase in the number of (costlier) roof-mounted PV installations. Notwithstanding the above, it will also be necessary to determine the extent to which other structural factors such as a shortage of skilled professionals could hinder attainment of the desired expansion rate.

(2) **Introduce an obligation to use suitable roofs for solar power generation on new buildings and when renovating existing buildings**. An obligation could be introduced for property owners to use their roofs or make them available for solar power generation, provided that the solar PV systems can be operated cost-effectively. Like the requirement for energy-efficiency measures in the construction sector, this obligation could apply to new building projects and extensive roof renovations on existing buildings. This would be in line with the German government's goal "to use [...] all suitable roof space for the expansion of solar energy: to this end, it will be mandatory to generate solar power on new commercial buildings, and it will be the norm to do so on new residential buildings".[293] It would be necessary to determine whether the obligation should apply solely to new buildings or also to existing buildings and only to non-residential buildings or also to residential buildings. It is important to bear in mind that an obligation to install solar panels would impinge on the freedom to own and build property of those subject to this obligation under Art. 14(1) of Germany's Basic Law. Consequently, any such obligation must, as a rule, be proportional and financially reasonable.[294] The following conditions should be considered if an obligation to install solar panels is introduced:

- Property owners would only be obliged to install solar panels on the roofs of their properties if doing so is financially viable, i.e. if the solar PV system's payback period is no longer than its service life.
- Alternatively, they could also meet the obligation by allowing third parties to install solar PV systems on their roofs or by installing a solar heating system instead.
- On new buildings, the obligation to install a solar PV system would be effective from the date of completion of the building.

293 See BMWK 2022a.
294 See Longo/Stryi-Hipp 2021.

- On existing buildings, the obligation would apply in the case of extensive roof renovations. Consideration should also be given to eventually introducing the obligation for all existing building roofs, regardless of whether or not they are being renovated.

- It may be that the most appropriate solution is to introduce the solar obligation gradually. The obligation could initially apply only to new buildings before being extended to existing buildings at a later point in time. Alternatively, it could be introduced for non-residential buildings first and residential buildings later.

- Solar PV systems would need to be a minimum size in order to comply with the solar obligation. They should be big enough to utilise a significant proportion of the roof's solar power potential.

- The obligation to install solar panels should still apply to large green roofs. However, the installation density requirements for the solar panels (module area per unit of surface area) would have to be reduced to allow for essential maintenance of the green roof. Since public buildings set an important example, the installation of solar PV systems on public buildings should be stimulated concurrently with the introduction of a solar obligation, in order to promote widespread acceptance of the obligation.

Actors: The regulation could be drafted and enacted by the federal legislator in consultation with the relevant stakeholder organisations. It would also be advisable to coordinate with the state governments, some of which have already introduced their own incentive schemes or solar obligations (e.g. Baden-Württemberg, Hamburg and Berlin).

Intended outcome: The removal of barriers and guarantee of cost-effectiveness would create the conditions for a further increase in the number of PV installations. However, additional financial incentives or regulatory measures will be needed to achieve significantly faster growth. An approach based on higher returns would increase acceptance among property owners and help to utilise the potential of existing buildings that are not undergoing roof renovations (and would thus not be covered by a solar obligation). The alternative approach of a solar obligation, on the other hand, would apply to all property owners with a suitable roof, without exception.

Unintended outcome: Depending on the financing model, higher returns for solar PV system operators would either lead to higher electricity prices or a higher tax burden, since the additional costs would be socialised. This would be undesirable at a time when energy prices are already rising due to other reasons. There is also a danger that high returns for solar PV systems could cause envy among those who do not have them, thereby jeopardising public acceptance of the policy measures introduced to promote them. If a solar obligation was introduced, there is a risk that the people it applies to might only meet the minimum requirements rather than using all the available roof space. Moreover, depending on how the obligation was implemented, the public administration might need to devote significant resources to compliance monitoring.

Policy area 4: Fully aligning the energy system with renewables

In order to successfully accelerate the expansion of wind and solar capacity, the energy system's technical and regulatory structures must be able to cope with a higher proportion of volatile power generation. As well as replacing the electricity generated by fossil and nuclear power plants, the new wind and PV installations will – in conjunction with other technologies – also have to take over their role in ensuring security of supply. Faster expansion of renewables also depends on the components needed to build wind and PV installations being available in sufficient quantities and at affordable prices. This policy area proposes three policy options to tackle these challenges. PO 4.1 addresses measures to maintain security of supply by integrating wind and PV installations into the energy system in a manner that supports system stability. PO 4.2 calls for the creation of a coherent regulatory framework for the electricity market. This is necessary to prevent undesired developments in the expansion of renewables and in the way that the costs are shared between different consumer groups. The development of a new electricity market design is thus vital. However, a proposal for a new electricity market design is beyond the scope of this position paper and has therefore not been attempted. This is something to be addressed by initiatives such as the Climate-Neutral Electricity System (German: "Klimaneutrales Stromsystem") platform which, according to the German government's coalition agreement, is due to be established in 2022. PO 4.3 highlights the need to investigate whether Germany's current reliance on imports, especially of components and PV modules from China, could become a barrier to faster expansion of renewables. If this is found to be the case, it would also be necessary to determine whether what is essentially a Chinese production monopoly could be overcome through global supplier country diversification, or whether targeted support for the development of production capacity in Germany/Europe could help to fulfil the German government's ambition of strengthening energy sovereignty.

PO 4.1 – Ensure that wind and PV installations can support system stability

The challenge: If, over the next few years, more and more conventional power plants are decommissioned and replaced by wind and PV installations, the spinning reserve created by increasing the power output of their generators will no longer be available. The availability of this operating reserve is necessary to ensure a secure electricity supply – but wind and large-scale PV (LSPV) installations are not yet able to adequately take over the role of providing it due to a lack of the necessary equipment and because they are not sufficiently integrated into the electricity system. If large-scale installations continue to be built without contributing to power grid stability, it will be necessary to maintain more reserve fossil power plants, while security of supply will be diminished and curtailment of wind installations and LSPVs will increase. This would present a major barrier to faster expansion of renewable capacity.

Wind installations and LSPVs are technically capable of providing an operating reserve. The first step is to integrate them into the power grid frequency regulation system in a way that enables targeted reduction of their output in response to high grid frequency events (surplus output in the control area) in order to reduce grid frequency (negative operating reserve provision). A positive operating reserve can be provided through targeted output restriction and an increase in output when necessary. While this approach would not make sense at the present time, there will be more and more occasions in the future when the instantaneous power of wind installations and LSPVs is higher than the total grid load. In these situations, the surplus output could be used to charge storage devices and, if necessary, to provide a positive operating reserve, provided that the necessary requirements are in place.

Combining wind installations and LSPVs with electrical or gas-based energy storage systems to create combined power plants can deliver a continuous operating reserve for frequency regulation purposes. Combined power plants can be implemented physically at a particular location (e.g. a wind farm and/or LSPV with a large-scale battery and/or electrolyser, hydrogen storage system and fuel cell). Alternatively, individual installations operated at different locations can be connected to form a virtual combined power plant that is centrally controlled so that the operating reserve is provided by all the installations together.

The need for changes in the operating reserve market in order to guarantee security of supply should be investigated separately for the energy system transformation phase (during which the percentage of renewable electricity will rise from its current level of around 45% to e.g. 90%) and for the operation of an electricity supply based almost entirely on renewables at the end of the transformation phase. During the first phase, it will be necessary to remove the relevant market barriers, since wind installations and LSPVs will be competing to provide the operating reserve with existing fossil and nuclear power plants. Once the transformation has been completed, although only climate-neutral electricity sources will now be available to provide the operating reserve, it will nonetheless be important to guarantee free competition between them.

Possible solutions: The further expansion of wind and solar power will mean that, in the future, wind and PV installations have to support system stability if security of supply is to be guaranteed. The following measures can go a long way towards making this possible:

- Development and integration of the necessary power electronics and algorithms for wind installation and LSPV control systems so that they are able to support system stability.

- Specification and development of the information and communication technology (ICT) infrastructure needed to connect wind installations and LSPVs with the grid operators' operational control centres.

- Integration of wind installations and LSPVs into the processes for restoring system stability in the event of frequency deviations.

- Investigation and development of concepts for local or virtual combined power plants based on a whole-system assessment of the development potential of different solutions (e.g. electricity and gas storage systems), their market potential and the regulatory framework. Implementation of pilot projects to field-test these concepts and the development of a regulatory framework for combined power plants.

- Investigation of the extent to which regulatory and economic barriers to the operating reserve market exist for wind installations and LSPVs and of the need for a transformation roadmap detailing how wind installations and LSPVs will take over operating reserve services from fossil and nuclear power plants.

- Investigation of whether the payments system for operating reserve services will adequately and effectively guarantee their provision by wind installations and LSPVs when this becomes necessary. It is recommended that this should be investigated by the working group "Electricity Market of the Future".

Actors: System and technology developers will need to develop and implement technological solutions, investors and installation operators will need to adapt their business models, grid operators and other energy industry companies will need to incorporate wind installations and LSPVs into the operating reserve system, while the federal government will need to establish an appropriate regulatory framework.

Intended outcome: Maintenance of high grid stability despite the phase-out of conventional power plants and their rotating masses. This will help to sustain acceptance of the electricity system transformation and reduce the cost to grid operators, who would otherwise have to resort to other means to maintain grid stability, such as a reserve thermal power plant capacity or the construction of rotating phase shifters. It will also enable new system services business models for wind installation and LSPV operators.

PO 4.2 – Reform and harmonise the electricity market's regulatory framework

The challenge: The original version of the Renewable Energy Sources Act (EEG) came into force on 29.03.2000. At that time, its aim was to at least double renewables' share of electricity generation (which stood at 6.6% in 2000) within the next 10 years, in line with the targets established by the EU and Germany. The EEG sought to counteract the barriers faced by renewables in the electricity market. These included the market dominance of the established electricity providers and the fact that wind and solar power's volatility made it harder to market. Moreover, renewables were not yet competitive at this point in time, since the levelised cost of electricity for solar and wind power was still at the beginning of its learning curve and the environmental costs of electricity from fossil and nuclear power plants were not internalised. The approach adopted by the government in the EEG focused on offering renewable electricity producers priority access to the electricity market and guaranteeing them a payment to cover their costs throughout the installations' service life. The extra cost of renewable electricity arising from this approach was shared among the majority of consumers.

The removal of market barriers by the EEG resulted in new actors and investor groups entering the electricity market. This stimulated decentralised energy solutions such as roof-mounted PV and biogas CHP plants and made it possible to circumvent the path dependencies of conventional energy providers that were conditioned by past investments and the existing knowledge base within their companies. The diversity of actors in the electricity market increased significantly as a result. As well as companies specialising in electricity generation, electricity was now also being generated by private individuals, cooperatives, companies whose core business was not generating electricity and other actors. The number of installations generating electricity also increased significantly, as did their output range. These installations now include everything from 1 kilowatt solar panel systems on private houses to 100 kilowatt biogas CHP plants owned by energy cooperatives, ground-mounted PV installations in the 1 megawatt range and wind farms with a capacity of over 100 megawatts.

The introduction of grid priority for renewable electricity and the guaranteed payments throughout the installations' service life protect investors against the commercial, market risks associated with selling electricity. This means that the only risk for investors is the risk associated with the installations' operation. Multiple amendments to the EEG have altered the conditions, for example the level of the feed-in tariff. For LSPVs, this is now increasingly established via tenders rather than being laid down by statute. The guaranteed payment principle has also been watered down by the introduction of direct marketing. Nevertheless, even after the latest amendment to the EEG that came into force on 01.01.2021, the Act's basic principles remain the same.

There is little doubt that the EEG has succeeded in expanding renewables, which have increased their share of Germany's gross electricity consumption from 6.3% in 2000 to 42.6% in 2021.[295] Renewable energy is thus casting off its former role as a supplementary source of electricity in a market dominated by fossil and nuclear power plants, and will soon become the main source of electricity. As a result, the current legal framework – in which the EEG counteracts the barriers to renewables created by the Energy Industry Act (EnWG) – will no longer be appropriate. Instead, it will be necessary to **create a regulatory framework that reflects the fact that renewables are the main source of electricity while still enabling a secure and affordable electricity supply**.

A reform of the legal framework would also help to address problems that are already apparent today and that will keep getting worse if the expansion of renewables continues without any changes to the legal framework. For example, the allocation of system costs for grid operation and the provision of an operating reserve to the unit price means that consumers of self-generated electricity contribute less to the allocation-based financing of system costs, even though they benefit from e.g. the guaranteed security of supply provided by an electricity system financed in this way. Moreover, the payments system means that most renewable energy installations are built and operated in a way that maximises their output, without considering whether the electricity they generate supports grid stability. For instance, most solar PV systems are currently south-facing because this maximises their solar power output. However, installing east or west facing PV modules would generate only slightly less solar electricity, but would do so at a far more constant rate throughout the day, thereby making a greater contribution to system stability. At present, however, there is no incentive to do this.

The removal of the current, perverse incentives will require a single, harmonised regulatory framework for the entire electricity market. This framework should stimulate the necessary expansion of renewable electricity generation while at the same

295 See BMWK 2022a.

time guaranteeing security of supply and affordability, for example through payment structures and other price signals that reflect the extent to which installations support system stability.

Possible solutions: The EnWG should be reformed to create a modern legal framework that addresses the challenges of an electricity market dominated by renewables. If the aspects of the EEG designed to achieve the desired diversity of providers and technologies in a renewables-dominated market are incorporated into the new EnWG, the EEG itself would become superfluous. The new EnWG should thus guarantee or enable the following conditions:

- Non-discriminatory access to the electricity market for actors who produce renewable electricity (including e.g. private individuals with low-output solar panels).

- Stimulate the support of system stability by renewables (e.g. by combining wind and PV installations with electricity storage systems).

- Cost and payment structures that fairly reflect the environmental impacts of different energy sources (e.g. through a carbon tax) and the extent to which the different electricity producers support system stability and contribute to security of supply (e.g. by breaking the costs down into a demand charge and a unit price, or through the introduction of a time-based payment).

- Stimulate sufficiently rapid expansion of renewable installations by limiting the investment risk and making it possible for investors to plan ahead reliably (including investors with low-output installations).

- Stimulate a regional distribution of renewable energy installations that supports system stability in order to limit the need to expand the grid while still guaranteeing security of supply.

- Introduce market mechanisms to ensure that additional renewable generation capacity is needs-based (in terms of quantity, location and installation design; this could be achieved through regional expansion plans that make it easier to build new installations if the plan is not being met, and harder if it is being met).

The development of a concrete proposal for the new electricity market design is an extremely wide-ranging and complex challenge that was not addressed by the working group, since it would have far exceeded the scope of this position paper. However, in the new German government’s coalition agreement, the coalition parties announced plans to establish a “Climate-Neutral Electricity System” platform tasked with formulating concrete proposals for the electricity market design by the end of 2022.

Actors: A single, harmonised legal framework for the electricity market that addresses the challenges of a climate-neutral energy market design should be developed by the federal government in close consultation with science, the energy industry, professional associations and other stakeholders. The ESYS working group "Electricity Market of the Future" will develop further important input on this topic.

Intended outcome: Creation of an integrated legal framework for the electricity market that guarantees security of supply despite a high percentage of renewable energy, enables faster expansion of renewable electricity generation and addresses the problems of the current framework. The transformation of the electricity system and market must not jeopardise security of supply or affordability, despite the fluctuating nature of renewable electricity generation.

PO 4.3 – Assess the risks of reliance on solar panel imports

The challenge: One of the key requirements for accelerating the expansion of wind and solar power is the availability and deliverability of sufficient components and installations at affordable prices, even in a context of rising demand. Since most of the wind turbines installed in Europe are currently also made in Europe, it seems likely that the existing European manufacturers could increase production. In contrast, current PV module production capacity in Europe is only enough to meet around 4% of the continent's installed PV capacity; Asia currently accounts for 92% of global PV module production, with around 75% in China alone[296]. At present, there is virtually no solar cell and wafer production in Europe. In anticipation of the strong increase in German and global demand for PV installations forecast by organisations such as the IEA,[297] it is therefore necessary to determine whether there will still be a reliable supply of affordable PV modules in years to come. Since solar power will sit alongside wind power as one of the pillars of the future German and European energy supply, it is also essential to investigate and, if necessary, address the specific risks of over-reliance on certain countries for solar technology imports. This is particularly pertinent in the light of the current problems caused by Europe's reliance on Russian gas.

As a nation with limited domestic fossil fuel and nuclear power resources, Germany has ample experience of reliance on energy imports from other countries – the amount of energy it imports has risen steadily since the end of World War II. In 1955, Germany was still able to meet its energy demand entirely from domestic energy sources.[298] Thereafter, net primary energy imports rose continuously, reaching 73.8% in 2001. Since then, the figure has oscillated between 73.8% and 68.6% – in 2020, it stood at 69.5%.[299] Renewables' share of primary energy consumption rose from 3% in 2001 to 17% in 2019, preventing a further increase in fossil fuel imports.

Various instruments such as the Energy Security Act (Energiesicherungsgesetz – EnSiG) and Oil Stockholding Act (Erdölbevorratungsgesetz – ErdölBevG) have been introduced over the years in order to secure the energy supply in view of the risks associated with high reliance on imports. A series of policy measures were also taken to secure gas transport routes. However, since Russia launched its war against Ukraine on 24.02.2022, the German government and the European Union have come to realise that they must end their reliance on Russian oil and gas imports as soon as

296 See Jäger-Waldau 2021.
297 See IEA 2021.
298 See AG Energiebilanzen 1998.
299 See BMWK 2022e.

possible.[300,301] The German government has stressed the need to put Germany's energy supply on a more robust footing by progressively reducing reliance on Russian imports and fossil fuels in general. It believes that the expansion of renewables is key to achieving energy sovereignty and is thus a matter of national and European security.[302] The German Institute for International and Security Affairs (SWP) defines energy sovereignty as follows:

> "Strategic sovereignty in the realm of energy is characterised by an environment in which sufficient, reliable and affordable energy supplies and services are provided in a manner that does not conflict with, or further yet, endanger a country's values, interests or foreign policy goals (Daniel Yergin). Sovereignty in energy affairs is therefore not synonymous with supply security but instead requires a technically robust energy system that is resilient in crises and fortified against political influence, thereby forming the basis of the state's strategic autonomy and capability to act in energy affairs."[303]

In a fossil fuel and nuclear power based energy sector, a country's energy import dependency is determined by its imports of coal, oil, gas and uranium. The uneven global distribution of these resources inevitably means that many nations are highly reliant on imports from countries where they are abundant. By contrast, in a climate-neutral energy sector, sunlight and wind are the main sources of energy. These are available everywhere, even if their potential varies from one country to another. This means that it is in principle possible to achieve a higher degree of self-sufficiency and to source imports from several different countries, thereby significantly strengthening energy sovereignty. Since sunlight and wind are freely available, the energy sources and primary energy carriers are no longer the critical components in a climate-neutral energy system, with the possible exception of material climate-neutral energy carriers such as biomass and green hydrogen.

However, countries could still be reliant on imports of the technologies for generating electricity, for heating and cooling, and for producing gas and fuel from renewable energy. It should not be forgotten that, once they have entered service, these systems will continue to produce energy for the rest of their lifetime. This means that any dependency would be at its greatest during the expansion of capacity in the energy system transformation phase and would decline thereafter, since new systems would only be required to replace installations that had reached the end of their service life. It follows that, in the future, a country's energy import dependency should not only be calculated on the basis of its primary energy carrier imports – reliance on imports of the technology required to produce final energy from renewables should also be taken into account. For example, solar power, which met around 9% of Germany's and 5% of Europe's[304] electricity demand in 2021, is regarded as a "domestic" energy source, yet the vast majority of the PV modules used to generate it were imported.

Assessments of import dependency risks should consider both the extent to which global production is concentrated in just a few countries and the expected reliability of deliveries from these countries. In the space of a decade or so, China has

300 See BMWK 2022b.
301 See Europäische Kommission 2022.
302 See BMWK 2022d.
303 See Westphal/SWP 2020.
304 See Statista 2022.

built a largely dominant position in the global market for the production of wafers, solar cells and PV modules for PV installations.[305] It is therefore necessary to determine how seriously this could threaten the required expansion of PV in Germany and Europe and the fulfilment of their ambition of achieving energy sovereignty.

The first thing to establish is the likelihood of China or other countries increasing production capacity enough to meet the projected rise in global demand at affordable prices. The probability of a diversification of global production will also need to be assessed, since this would reduce the risks of reliance on Chinese imports. It will then be necessary to investigate the extent to which the market dominance of China or other potential exporters of wafers, solar cells and PV modules could hamper the desired rapid expansion of renewables in Germany or make it significantly more expensive.

If Germany's reliance on PV module imports is found to be critical, it will be important to weigh up the available policy options. This will involve determining the conditions that would be necessary for the globally competitive production of wafers, solar cells and PV modules in Germany or Europe, and the support that would be required to stimulate this production. It will also be necessary to explore the desirability of incorporating PV and other renewables into the European Important Project of Common European Interest (IPCEI) to support the development of strategically important value chains such as microelectronics, battery technology and hydrogen technology.[306,307] Since the aim of a technology policy like this would be to secure the future energy supply, it would be comparable to the abovementioned statutory measures to safeguard oil and gas supplies.

If, on the basis of these assessments, measures are adopted to support PV production in Germany or Europe, it will be important to ensure that the technological innovation and international cost competition benefits of a functioning global market are maintained. The state should only pursue and support energy sovereignty in a targeted manner geared towards preventing dependencies that could lead to supply shortfalls and high prices, thereby potentially jeopardising attainment of the targets for the transformation of the energy system. It should therefore explicitly pursue Germany's active participation in a growing global renewable energy market and avoid any form of technological autarky.

Germany is at the forefront of international photovoltaics research and German manufacturers are also global leaders in production technology for PV factories. The basic requirements for increasing PV production are thus already in place. It will be necessary to determine whether the overall current conditions in Germany and other European countries would provide a level playing field with other production locations around the world. The aim should be to identify the requirements for the development and scaling of a European PV production capability that, after an initial start-up phase, is able to compete in the global market without subsidies. The literature indicates that this should be possible once PV production capacity in Europe reaches a minimum of 10 gigawatts.[308]

305 See Jäger-Waldau 2019.
306 See BMWi 2021.
307 See Deutscher Bundestag 2021a.
308 See Fraunhofer ISE 2020.

Possible solutions: It is necessary to assess the extent to which supplier country diversification or a reduction in the currently very strong reliance on PV module imports could help to strengthen energy sovereignty. This will involve investigating the risks of reliance on imports and the prospects of effectively reducing these risks through short-term support for the development of the entire PV production value chain in Germany and Europe.

The organisation tasked with carrying out this assessment should address the following questions:

- In view of the strong reliance on the Chinese market, what risks – in terms of supply shortfalls, price rises and the associated vulnerability to extortion – does importing components for new solar and wind installations pose to the goal of accelerating the expansion of renewables? What are the prospects of reducing these risks through the diversification of supplier countries?

- To what extent could the development of a PV production capability in Germany or Europe help to strengthen energy sovereignty?[309]

It would also be advisable to investigate the following questions if the development of a PV production capability in Germany or Europe is deemed desirable on energy sovereignty grounds:

- Which industrial policy conditions would need to be created in order to establish a globally competitive PV production capability in Germany or Europe? Options that should be assessed include support for private sector initiatives through better access to venture capital, the introduction of regulations regarding products' carbon footprint and measures to strengthen innovation in companies.

- The suitability of the IPCEI instrument for PV and possibly also wind power technology should also be investigated.

Actors: The German government should commission the relevant studies and explore ways of creating the necessary frameworks at national and European level. Science and industry should investigate likely future innovations in the solar and wind power sectors and determine how a competitive wind and PV installation production capability can be developed and expanded in Europe.

Intended outcome: There would be less risk of reliance on imported PV installation components preventing faster expansion of PV. Germany's and Europe's energy sovereignty and the resilience of the future energy system would be strengthened.

309 This could also include the supply chains for the raw materials needed to make the PV systems, since this is another area where dependencies can arise.

6 Conclusion

Wind and solar power will be the most important pillars of the future, climate-neutral energy supply. Despite the energy efficiency improvements that will be achieved through electric mobility, heat pumps and other sector coupling technologies, electricity demand is still set to rise significantly. To meet this demand, the annual increase in wind and solar capacity will need to rise from 6.2 gigawatts in 2020 to as much as 36 gigawatts over the coming years.[310]

There is widespread public support for climate action, the energy transition and the expansion of renewables, and this support is even greater in locations where installations have already been built close to where people live. Thanks to the huge cost reductions achieved in recent years, especially for PV, it is now cheaper to generate electricity with wind and PV installations than with new conventional power plants. The wide range of different technologies – from roof-mounted PV to large offshore wind farms – means that the opportunity to actively contribute to the energy transition by operating their own installations is now open to private individuals, farmers and renewable energy communities as well as the big energy providers. Biodiversity can also benefit if habitat for endangered animal and plant species is created in solar parks.

Despite the huge opportunities offered by renewable energy, the transition from the old fossil fuel and nuclear power system to the new, climate-neutral energy system is not happening fast enough. It is vital to remove as many as possible of the existing barriers and constraints so that the expansion of renewables can be accelerated and the relevant targets met.

Barriers to a faster expansion of renewable energy often come about due to attempts to integrate renewables into the existing system, which is dominated by coal, gas and nuclear power plants, and adapt them to the requirements of this system. While this approach made sense when renewables first came onto the market, it is no longer appropriate. A paradigm shift is now required: the entire electricity supply system – including its technical, economic, legal and social aspects – must be redesigned with renewables at its centre, so that it is fit to meet the challenges of an electricity generation system dominated by wind and solar power.

An integrated planning culture in planning and licensing processes, more public participation and more attractive opportunities to invest in wind and PV installations can help to accelerate the expansion of renewables. Statutory land allocation targets can also help to ensure that enough land is made available for renewable installations. In this context, it will be important to ensure that Germany's federal states and regions all make an appropriate contribution. It will also be important to create the necessary

310 See BMWK 2022a.

framework for the future energy system, for example by developing a new electricity market design. In view of the fluid geopolitical situation, it would be advisable to assess the risks of reliance on PV module imports and explore options for strengthening Germany's and Europe's renewable energy sovereignty.

This position paper proposes twelve policy options to address these requirements. If used as the basis of a strategy for the accelerated expansion of wind and solar power, these policy options can help to overcome the various economic, regulatory and social barriers.

A more proactive planning culture focused on the common, positive goal of delivering the energy transition will be of vital importance in this regard. It will be especially important to harness the widespread public support for the energy transition within the planning process and give members of the public a say in the expansion of renewables. Various participation methods can be used to strengthen public participation, including citizens' assemblies, decision theatres and planning cells. This approach allows the benefits and drawbacks to be distributed in a manner that is perceived to be fair and transparent.

If we are smart about how we expand wind and solar power, in 25 years' time they will have become the fundamental pillars of our electricity supply and renewable installations will be accepted as a normal and valid part of the landscape throughout every part of Germany. This can be accomplished by ensuring that the installations are seamlessly integrated with the surrounding architecture and landscape, adding value and contributing to the local sense of identity in Germany's municipalities and regions. Now is the time for bold action to make this vision reality.

Appendix

	New installed capacity = gross increase	Decommissioned installations	Net increase	Total installed capacity
	GW/year	GW/year	GW/year	GW
2011	7.9	0.0	7.9	25.9
2012	8.2	0.0	8.2	34.1
2013	2.6	0.0	2.6	36.7
2014	1.2	0.0	1.2	37.9
2015	1.3	0.0	1.3	39.2
2016	1.5	0.0	1.5	40.7
2017	1.6	0.0	1.6	42.3
2018	2.9	0.0	2.9	45.2
2019	3.9	0.0	3.9	49.0
2020	4.8	0.0	4.8	53.7
2021	5.3	0.0	5.3	58.7
2022	6.5	0.0	6.5	65.6
2023	8.0	0.0	8.0	73.6
2024	13.0	0.0	13.0	86.6
2025	16.0	0.0	16.0	102.6
2026	18.0	0.1	17.9	120.5
2027	19.0	0.1	18.9	139.3
2028	20.0	0.1	19.9	159.2
2029	20.0	0.7	19.3	178.5
2030	20.0	0.9	19.1	197.6

Table 6: Installed capacity in Germany - PV. (Sources: 2011-2021: AGEE-Stat,[311] 2022-2030: BMWK Eröffnungsbilanz Klimaschutz[312] (gross increase), net increase: authors' own calculations based on PV installations with 25-year lifespan)

311 See AGEE Stat 2022.
312 See BMWK 2022a.

	New installed capacity = gross increase	Decommissioned installations	Net increase	Total installed capacity
	GW/year	GW/year	GW/year	GW
2011	2.1	0.2	1.9	29.1
2012	2.4	0.5	1.9	31.0
2013	3.0	0.3	2.7	33.7
2014	4.8	0.4	4.4	38.1
2015	3.7	0.2	3.5	41.7
2016	4.6	0.4	4.3	45.9
2017	5.3	0.5	4.9	50.8
2018	2.4	0.2	2.2	52.9
2019	1.1	0.1	1.0	53.9
2020	1.4	0.4	1.0	54.9
2021	1.6	0.4	1.2	56.1
2022	3.5	3.2	0.3	56.4
2023	5.0	2.6	2.4	58.7
2024	6.0	2.0	4.0	62.7
2025	7.0	1.8	5.2	67.9
2026	9.0	2.2	6.8	74.7
2027	10.0	1.7	8.3	83.0
2028	10.0	1.7	8.3	91.3
2029	10.0	1.9	8.1	99.4
2030	9.0	1.6	7.4	106.9

Table 7: Installed capacity in Germany – onshore wind. (Sources: 2011-2021: BWE,[313] 2022-2030: BMWK Eröffnungsbilanz Klimaschutz[314] (gross increase), net increase: authors' own calculations based on wind installations with 20-year lifespan)

313 See BWE 2022.
314 See BMWK 2022a.

	New installed capacity = gross increase	Decommissioned installations	Net increase	Total installed capacity
	GW/year	GW/year	GW/year	GW
2011	0.1	0.0	0.1	0.1
2012	0.1	0.0	0.1	0.2
2013	0.2	0.0	0.2	0.4
2014	0.5	0.0	0.5	0.9
2015	2.3	0.0	2.3	3.2
2016	0.9	0.0	0.9	4.1
2017	1.3	0.0	1.3	5.4
2018	1.0	0.0	1.0	6.4
2019	0.9	0.0	0.9	7.3
2020	0.2	0.0	0.2	7.5
2021	0.0	0.0	0.0	7.5
2022	0.3	0.0	0.3	7.8
2023	0.3	0.0	0.3	8.1
2024	0.3	0.0	0.3	8.4
2025	1.5	0.0	1.5	9.9
2026	1.0	0.0	1.0	10.9
2027	1.0	0.0	1.0	11.9
2028	4.0	0.0	4.0	15.9
2029	6.0	0.0	6.0	21.9
2030	7.0	0.0	7.0	28.9

Table 8: Installed capacity in Germany – offshore wind. (Sources: 2011-2021: BWE,[315] 2022-2030: BMWK Eröffnungsbilanz Klimaschutz [316](gross increase), net increase: authors' own calculations based on offshore wind installations with 25-year lifespan)

[315] See BWE 2022.
[316] See BMWK 2022a.

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The Academies' Project

In the Energy Systems of the Future initiative, 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 a fact-based debate on the challenges and opportunities of the German energy transition. Around 100 experts collaborate in interdisciplinary working groups to develop policy options for the transition to a sustainable, secure and affordable energy supply.

The working group "Development of Photovoltaics and Wind Energy"

Recent studies make it clear that the expansion of renewables must be accelerated if Germany is to meet the desired and required national and European climate targets. Despite advances in energy efficiency, demand for electricity is set to rise due to sector coupling and the EU's more ambitious climate targets for 2030. It is therefore necessary to accelerate the expansion of renewables in Germany. The technologies with the greatest potential for achieving this expansion are wind and solar power.

The interdisciplinary working group analysed the reasons for the faltering current rate of expansion and developed policy options for overcoming the existing barriers. The key themes addressed were how to expedite planning and licensing processes, how to create an integrated planning culture with more opportunities for participation, the options available for reducing the space taken up by installations, and the necessary regulatory framework for the energy market.

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