Federal Agency
for Nature
Conservation

Renewable Energy Report 2019

Delivering an environmentally compatible energy transition

NATURE CONSERVATION
AND RENEWABLE ENERGIES
Research at BfN

Legal notice

Published by

Federal Agency for Nature Conservation
Press and Public Relations Team
Konstantinstraße 110
53179 Bonn
Telephone: + 49 228/84 91-4444
E-Mail: presse@bfn.de
URL: www.bfn.de/en

Edited by

U. Bosch, B. Jessel, K. Ammermann

With contributions from:
S. Balzer, S. Böttner, K. Erdmann, H. Flatter, O. Hendrischke, C. Hildebrandt, U. Hoffmann, F. Igel, M. Klein, J. Kötting, R. Petermann, J. Pöllath, J. Ponitka, U. Riecken, V. Scherfose, C. Schönhofer, C. Selig, S. Stenzel, C. Strauß, A. Weber

Translation: L. Hepburn

Cover

Collage, including picture elements by ©nounours1 – stock.adobe.com (landscape) and ©Kateina – stock.adobe.com (solar plants)

This work with all its parts is protected by copyright. Any use beyond the strict limits of the copyright law without agreement of the publisher is liable to prosecution.

Reprint, as well as in extracts, is only permitted with the authorisation of the Federal Agency for Nature Conservation (BfN).

Printed on 100 % recycled paper
Print: dieUmweltDruckerei Hannover

Bonn - Bad Godesberg, Germany, July 2020, 3rd revised edition

Contents

0 Key statements and recommendations

The Renewable Energy Report 2019 is based on findings from 40 completed and current research projects at the **Bundesamt für Naturschutz (BfN)** (Federal Agency for Nature Conservation) on the environmentally compatible expansion of renewable energies. Besides species conservation, these focus primarily on the issue of "land" (i.e. the careful and efficient use of the resource of land) and "landscape" (greater attention to the protected resource of landscape, including from the viewpoint of acceptance). This report fulfils the Federal Agency for Nature Conservation's remit to produce a synthesis of the findings from the individual projects. The report focuses on solutions and approaches for cooperation between nature conservation and the energy transition.

In the face of impending climate changes and to protect the climate, the conversion of the energy supply system to renewable energies is also very important for conserving biodiversity and cultural landscapes. However, the decentralised nature of the expansion and the number of facilities required intensify the ongoing changes in land use and landscape. The expansion of renewable energies can therefore cause negative impacts on species and habitats.

One aim of the German National Strategy on Biological Diversity (NBS) is that the generation and use of renewable energies should not be at the expense of biodiversity (cf. Chapter C8 of the Strategy). The further expansion must therefore be planned and managed so that it takes place in an environmentally compatible way and not at the expense of nature and the landscape. The following **Key statements and recommendations** are derived from this:

Figure 1:
Wood is the most important renewable resource for heating (photo: Kathrin Ammermann)

Figure 2:
The expansion in renewable energies is creating ever greater changes in our landscapes (photo: Ulf Hauke)

→ The decentral high level of **land take** by renewable energies across the countryside is a major cause of the varied impacts on nature and the landscape. This land take must therefore be kept to a minimum. The expansion must use land as sparingly and efficiently as possible:

- Since the availability of land is limited, implementation of the efficiency measures and energy savings specified in the Federal Government's energy concept for an environmentally compatible development are a mandatory requirement.
- Electricity-based applications are the most efficient options for heating and transport. We need to press ahead with the energy transition, with a strategic realignment of these sectors and the expansion of sector coupling. Renewable electricity generation will therefore continue to be of major importance in the future.
- Preference should be given to technologies with low land take. There are therefore no environmentally compatible options for the expansion of bioenergy, particularly biogas, from agricultural biomass. This is due to the high land take and competition with material utilisation. Synergies with nature conservation, such as the recycling of landscape management material, are possible to a certain extent. Wood fuel can continue to be used at the current level, preferably in line with a cascaded use of the material.
- An environmentally compatible spatial distribution and control of the development in renewable energies now needs to be planned at national level. For example, corridors could be created for regional

amounts of renewable energies. This also provides the benefit of better coordination with the expansion of the electricity grid.

→ The **resource of landscape** must be incorporated to a greater degree in the planning and approval processes and in strategic deliberations on the energy transition:

- The targeted conservation of regionally important landscape qualities is essential to maintain acceptance of the expansion of renewable energies amongst the local population. Approaches exist for evaluating the sensitivity of landscapes to various forms of renewable energies. These must now be incorporated in the planning and decision-making processes. In addition, evaluation methods for landscape aesthetics are important for providing ways to promote acceptance through participatory processes and adjustments to the design of the measures.
- Landscapes with semi-natural characteristics and without technical infrastructure must be conserved. These areas are often particularly important for nature conservation and development objectives and for landscape management. Besides protected areas, these are e.g. woods and forests with stands of old trees and landscapes which are particularly valuable for recreational use or which have special aesthetic qualities.
- In order to protect open countryside and at the same time achieve the government's energy expansion goals, there is a pressing need to step up the development and use of solar energy in urban areas subject to construction law i.e. on sealed surfaces. Increasing expansion close to consumption also contributes to reducing the necessary high-voltage transmission grids and to improved acceptance. This also enables urban areas to make a significant contribution to the energy transition. Concepts such as the landlord-to-tenant electricity model in the EEG (Erneuerbare-Energien-Gesetz) [Renewable Energy Sources Act] support this development and also need to be further developed and expanded.

→ The overall aim of the National Strategy on Biological Diversity is to halt the decline in **biodiversity** and to achieve a positive trend in the development of species and habitat diversity. This must be borne in mind in the further expansion of renewable energies:

- Careful site selection is still the basis for avoiding conflicts between species protection/habitat conservation and RE plants or minimising these conflicts as far as possible. This requires ongoing research e.g. on species distribution, population developments and the migratory behaviour of birds and bats.
- More trials and accompanying research on the development and operation of RE plants should also be carried out on aspects of species conservation in order to collect practical experience e.g. on preventative measures or on the behaviour of species at RE plants, and to apply this to practice.
- Preventative measures must be used to improve the environmental compatibility of the plants and to minimise conflicts under species protection law. It is important to make use of proven measures and adapt these to specific sites. Further research needs to develop and test new measures and implement these in practice.

1 Nature Conservation and renewable energies: a balance of synergies and conflicts

The loss of biodiversity and climate change are challenges of global importance. Both issues are closely interlinked. And both developments are (partly) caused by human activities, so it is essential to reverse the trend in order to safeguard the systems that support life.

The status of many species is already extremely worrying, as demonstrated by the species protection report by the Federal Agency for Nature Conservation (BfN) (BfN 2015). A third of the animal and plant species in Germany are on the Red List, meaning that their populations are endangered. This reflects the status of our countryside, as species always represent habitats, ecosystems and the network of their relationships. According to Finck et al. (2017), two thirds of the biotopes which occur in Germany are now endangered. This is due to a variety of causes. The key drivers include changes in landuse with intensification of use, an increase in material and energy flows (fertiliser, pesticides, etc.) and advancing land take.

Climate change also plays an increasingly important role here due to its direct and indirect effects on biodiversity. Climate protection is therefore a major concern for protecting species and biotopes and for conserving our cultural landscapes. Worldwide 10 % of vegetation types are highly sensitive to climatic changes and almost 1,200 (approx. 4 %) of the world's threatened plant species on the IUCN Red List are endangered directly by climate change (Wills 2017). The report on the status of nature in Europe also shows that climate change is one of the threats to our species diversity (EEA 2015).

The energy sector can make an important contribution to climate protection by improving energy efficiency and expanding renewable energies (RE). The development and prioritising of renewable energies are necessary not only to limit climate change but also on account of the agreed withdrawal from nuclear power. This objective is also laid down in the Bundesnaturschutzgesetz (BNatSchG) [Federal Nature Conservation Act]: "the development of a sustainable energy supply, particularly through the increasing use of renewable energies, is of particular importance" (Section 1(3)(4) BNatSchG). However, renewable energies are not accorded a special role.

Obviously the expansion of renewable energies also involves conflicts with nature and the landscape. The cultural landscape is changing in a clearly perceptible way – the energy demand is becoming visible in the landscape due to the decentralised development and the extensive land take. This includes loss of land for habitats and species, and particular species and groups of species are affected due to qualitative changes to their habitats, or individuals can be directly endangered due to collisions with wind turbines, for instance. The development of renewable energies must therefore be planned in an environmentally compatible way.

Besides the provisions of Section 1 BNatSchG, the framework for this is defined by the objectives of the National Strategy on Biological Diversity, which was agreed by the German Federal Government in 2007 to implement the international Convention on Biological Diversity (CBD). This strategy formulates the objective that the generation and use of renewable energies must not take place at the expense of biological diversity. Achieving this objective requires the development of cooperative ideas and strategies to avoid/minimise conflicts between landuse requirements when expanding renewable energies, and support for synergy effects where possible. As an action programme to implement the biodiversity objectives by 2020, the Federal Government's nature protection campaign demonstrates ways to achieve these goals, e.g. locating environmentally compatible sites through the spatial management of RE plants while at the same time keeping priority areas for nature and the landscape free of development, or limiting the growing of energy plants in agriculture and forestry.

One of the main features of the energy transition that causes a profound change in the landscape is the increasing decentrality. Compared to centralised fossil or nuclear power plants, an energy supply using renewable energies requires a large

Figure 3:
Construction and operation of wind turbines impacts the cultural landscape and animal species that are sensitive to wind power (photo: Ulf Hauke)

number of smaller plants. Combined with the often huge visibility of the plants, this creates impacts over large areas.

Besides protecting the quality of landscape in accordance with Section 1(1)(3) BNatSchG, "land" is explicitly specified as one of the resources to be assessed under the German Federal Government's quantitative landsavings target and the environmental impact assessment (Section 2(1)(3) UVPG (German EIA law)). This aims to reduce the daily land take to only 30 ha by 2030. This value is currently running at around 66 ha per day, for example due to sealing off areas for buildings and industry or transport routes, mostly at the expense of agricultural land. However, there has been a positive overall development since the mid 1990s. At that point land take for housing and transport was still 120 ha/day (UBA 2017). Although renewable energy plants are not counted in the land consumption statistics, they are in fact responsible for making use of arable and pasture land and sealing it to a certain degree. The land-savings target therefore also needs to be applied here.

This energy report looks in more detail at the balance of synergies and conflicts between nature conservation and climate protection and demonstrates approaches to solutions based on current research by the BfN. The report does not include the range of topics associated with the expansion of the grid and offshore wind energy. The report also examines options for action which go beyond the primary nature conservation responsibilities but nevertheless have great relevance for protecting nature and the landscape.

Figure 4:
The large-scale growing of energy species such as maize for use in biogas plants contributes to a loss of biodiversity in the agricultural landscape (photo: Ulf Hauke)

Summary of Chapter 1

Climate protection is of key importance in conserving biological diversity and cultural landscapes. The expansion of renewable energies plays a major role in this. However, due to the decentral nature of the energy transition, it involves a fundamental change in the landscape and the risk of negatively impacting species and habitats.

This report therefore examines important discussion points and highlights the approaches required for an energy transition that is compatible with nature and the landscape.

2 Renewable energies: current status and expansion goals

2.1 Current numbers of RE plants and their spatial distribution

Renewable energies are very important for the energy transition in Germany. For electricity generation, the heating sector and transport they together currently make up around 16 % of final energy consumption. However, the different use pathways have very differing stages of development. Over half the renewable energy is accounted for by electricity generation. By 2018 the share in gross energy consumption had already risen to 37.8 %. The share in the heating and cooling sector was significantly lower at just 13.9 %, and in the transport sector only 5.6 % is currently provided by renewable energy sources (BMWI 2019). The different percentages of energy carriers in the renewable electricity generation sector are shown in Figure 5.

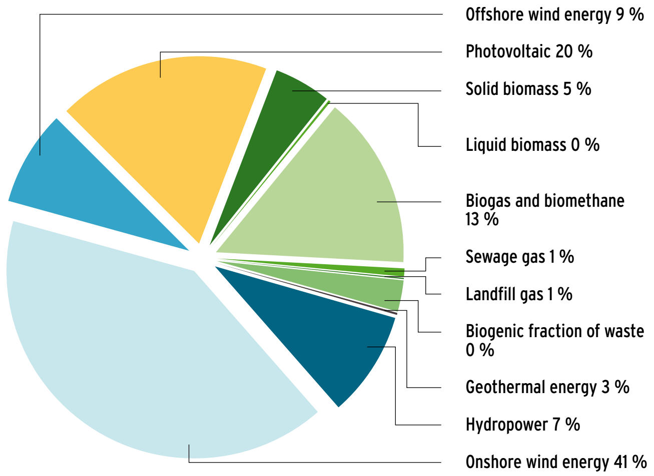


Figure 5:
Percentages of renewable energy carriers in electricity generation from RE in 2019 (own figure based on BMWI 2018)

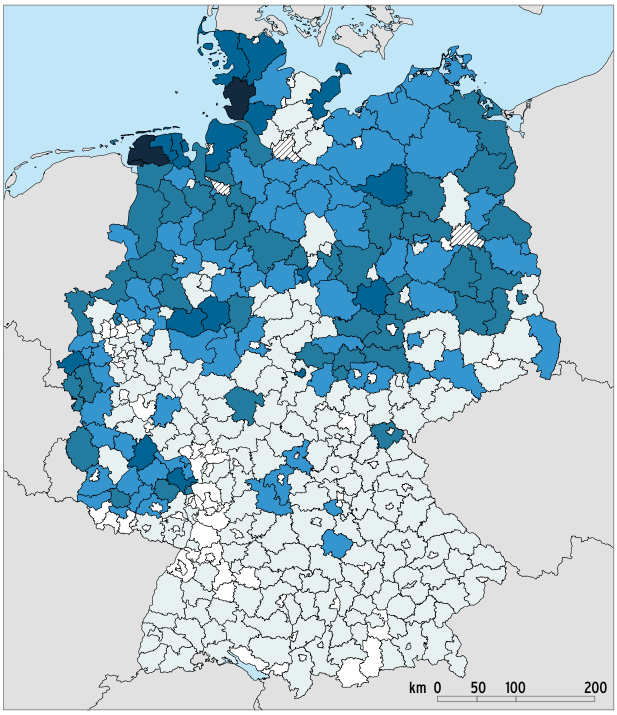
Mankind's traditional renewable energy source is wood. Bioenergy is now important both in the heating and power sectors as well as transport. The energy carriers of greatest importance are biogas from renewable raw materials in the electricity sector, wood burning in the heating sector and fuels based on plant oils (and ethanol) in the transport sector. There are currently around 8,700 biogas plants in Germany, over half of which are located in Lower Saxony, Bavaria and Baden-Württemberg (Daniel-Gromke et al. 2017). The exact number of biomass plants in the heating sector is unknown – the stock includes approx. 10 million stoves and fires in individual rooms, mainly for logs, and to a much lesser extent wood pellets, and just under 1 million biomass boilers (Lenz et al. 2015). Use of biomass in the transport sector is via admixtures of mainly biodiesel and bioethanol to fossil fuels. This use is therefore distributed across the entire transport sector.

Hydropower, like wind power, is a renewable energy source that mankind has used for centuries. While in the past hydropower was mainly used to drive machines directly, for a little over one hundred years it has been employed for electricity generation via turbines and generators. There are currently around 7,300 hydropower plants in operation throughout Germany. By far the greatest number of plants are located in the federal states of Bavaria and Baden-Württemberg. Smaller amounts of electricity are generated from hydropower in North Rhine-Westphalia, Saxony and Hesse (Keuneke et al. 2015). Approximately 3,500 of these plants are operated without any measures to take account of the environment. Almost 90 % of these plants have a power rating of < 100 kW, thus only making a very minor contribution to power generation.

Photovoltaics, at around 20 %, also makes an important contribution to renewable energy generation. Solar power is produced both from systems on roofs and façades and also through ground-mounted photovoltaic systems (GMPV), e.g. on fields, meadows and fallow land. There are estimated to be over 10,500 GMPV at present (Thrän et al., unpublished) (as at 2016).

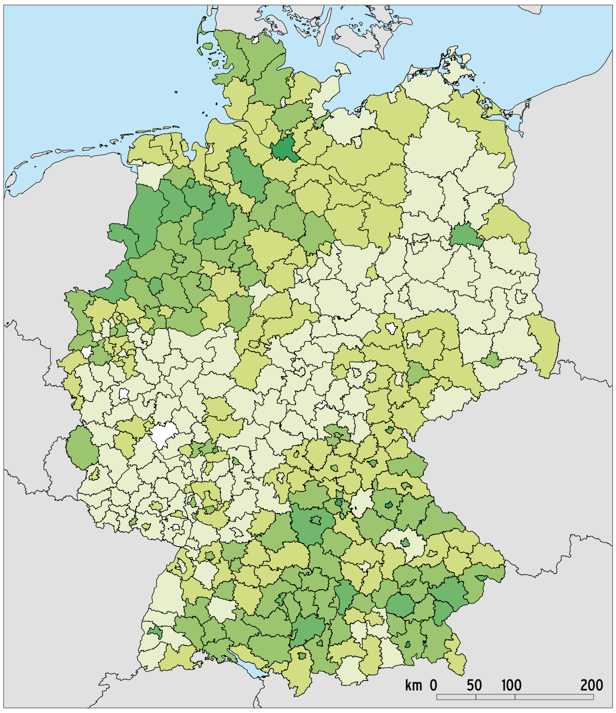
However, the largest share of the renewable energy supply by far is produced by onshore wind power with 41 %. Most of the total of around 29,200 wind turbines (as at 2018) are located in the windy regions of Germany in Lower Saxony, Brandenburg, Schleswig-Holstein and North Rhine-Westphalia (Deutsche Windguard 2019) (see also Figure 6).

Figure 6:
Geographical distribution of RE plants in Germany, as at 2015 (IE Leipzig 2018)



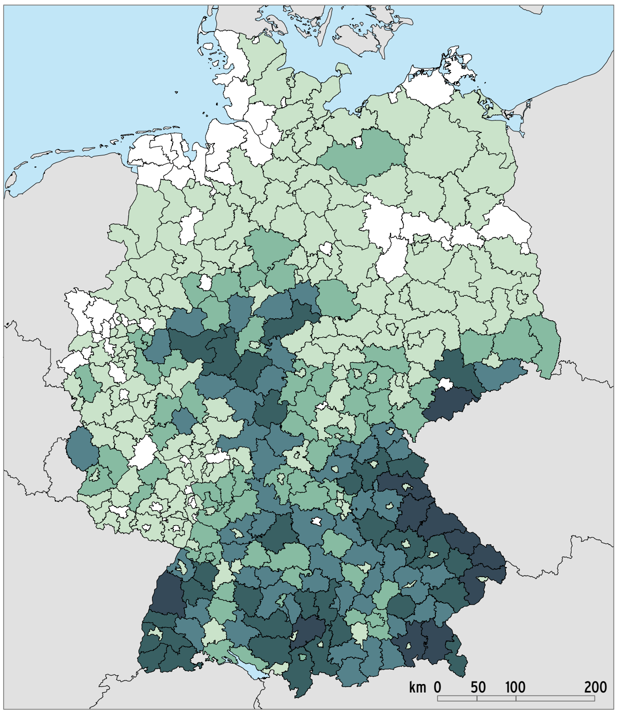
Number of wind turbines by district in 2015

0
1-5
6-10
11-20
21-40
41-80
no data



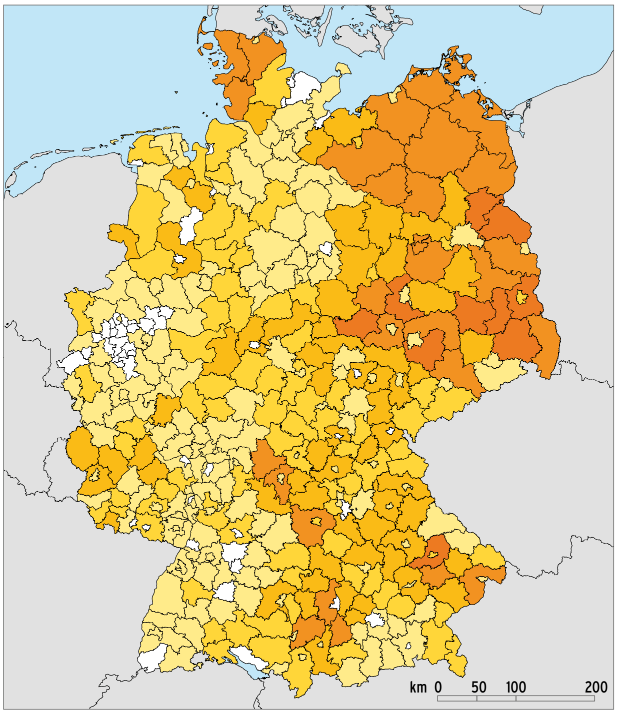
Densitiy of biogas plants by district in 2015 [n/100 km²]

0
1-3
4-5
6-10
11-20
21-40



Number of hydropower plants by district in 2015

0
1-10
11-25
26-50
51-100
101-160



Areas of ground-mounted photovoltaic by district in 2015 [km²]

0
0.1-0.2
0.3-0.5
0.6-1.5
1.6-3.0
3.1-9.0

2.2 Land use and land take by renewable energies

In order to assess the impact and spatial footprint of RE, the key factor besides the number of plants is land take. It is not just the actual area of land required that needs to be considered, but also the type of land and its features (grassland, woodland, nature reserve, species present, etc.) and the sensitivity of the resources affected in terms of the type of use, the impact of the plant and its operation.

In addition there are indirect effects, especially in the bioenergy sector, which can arise from e.g. the displacement of the original uses to other areas. Land uses which have been discontinued in favour of biomass production, such as e.g. the production of food and feed, have in part been transferred to other areas. The major expansion in the demand for land has also led to a clear increase in land values and lease prices, which in turn makes it more difficult to find land for implementing conservation requirements, e.g. in nature conservation agreements.

2.2.1 Land take by renewable energies

The different renewable energy carriers have very varying technology-related area requirements and energy yields per unit area. The land take for the production, processing and transport of energy carriers i.e. energy plants including their upstream chains, therefore vary greatly. To illustrate this, Figure 7 shows the energy yield which can be produced per m^2 per year. The simplified examples give an idea of the different area requirements to generate the same amount of energy. It should be noted for wind power that the total area of the wind park is taken into consideration, resulting in the relatively low values. With certain restrictions, the land between the wind turbines can continue to be used for other purposes.

For an evaluation from a nature conservation viewpoint, it is not simply which areas are used that is important, but also their qualitative characteristics and the type of use. This is obvious for something like ground-mounted photovoltaics (GMPV). Due to the EEG payment provisions, these have increasingly been installed on conversion areas and as marginal strips alongside infrastructure facilities. However, military conversion areas often provide valuable refuges for rare and threatened species, as these areas are generally less intensively used and can therefore develop with less disturbances. Fenced-off GMPV can act as barriers in habitats and migration corridors. In areas with intensive agriculture, power plant sites with more extensive management can in some cases provide habitats and stepping-stone biotopes for small mammals, insects, birds and various species of plants (Reich 2018).

Site quality is also crucial for making an evaluation from a nature conservation viewpoint in the case of wind power. Since 2011, wind turbines have been increasingly installed in woodland (see Figure 6). By the end of 2018 there were already around 2,000 wind turbines in operation in woodland throughout Germany. Due to the necessary infrastructure such as access routes, land for the crane pad etc., the land requirement (i.e. the area to be cleared and kept open) is usually larger than in open countryside. Different conflicts may arise with aspects of nature conservation than those on arable or grassland sites, as other species and habitat structures are involved.

The impact and visibility of the different renewable energy plants in the landscape are fundamentally different. Due to the vertical structure and energy conversion at height, wind power takes up very little land directly but is much more visible than, e.g. ground-mounted photovoltaic systems. The visibility of the turbines varies greatly depending on the

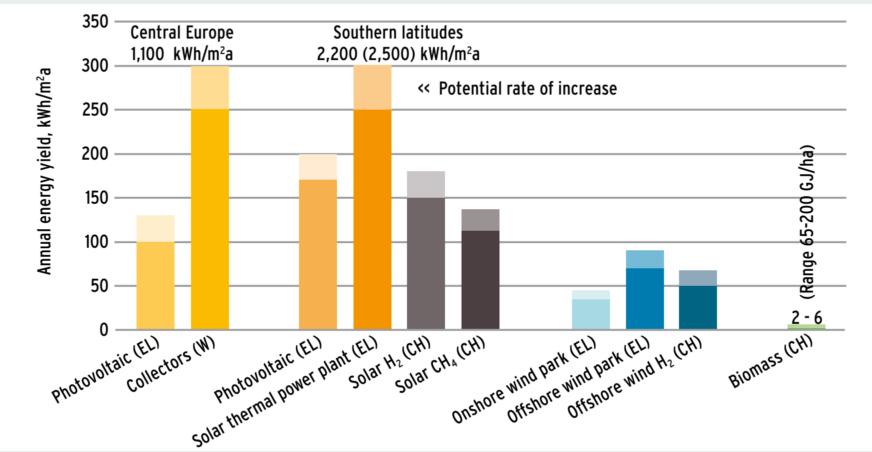


Figure 7:
Yields per hectare of different renewable energy carriers (DLR et al. 2012) (wind under German conditions, 5 MW plants, installation density 20 MW/km^2; related to total area; EL: electricity, H: heat, CH: chemical energy storage system; solar technology: two typical facilities for solar radiation, 2,500 kWh/m^{2}a for a solar thermal power plant)

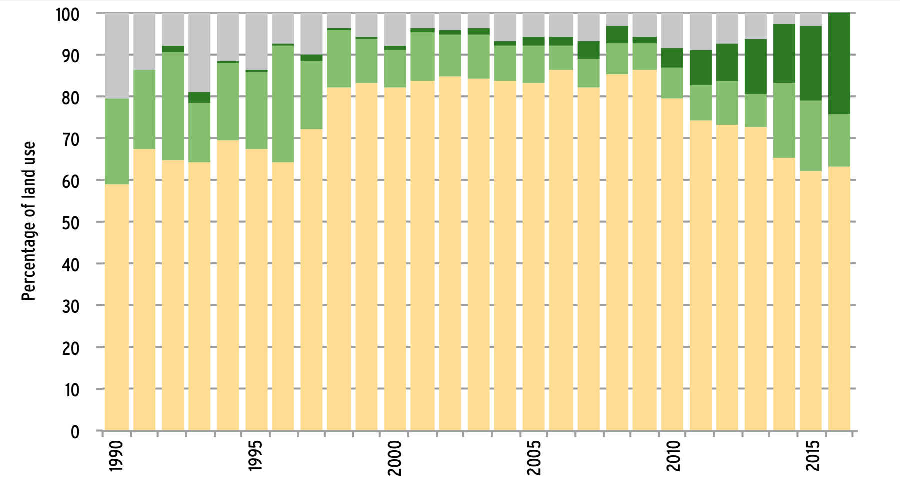


Figure 8:
Utilisation of various land use classes by yearly wind power expansion (own figure after Thrän et al., unpublished)

Other
Woodland/forest
Grassland
Arable

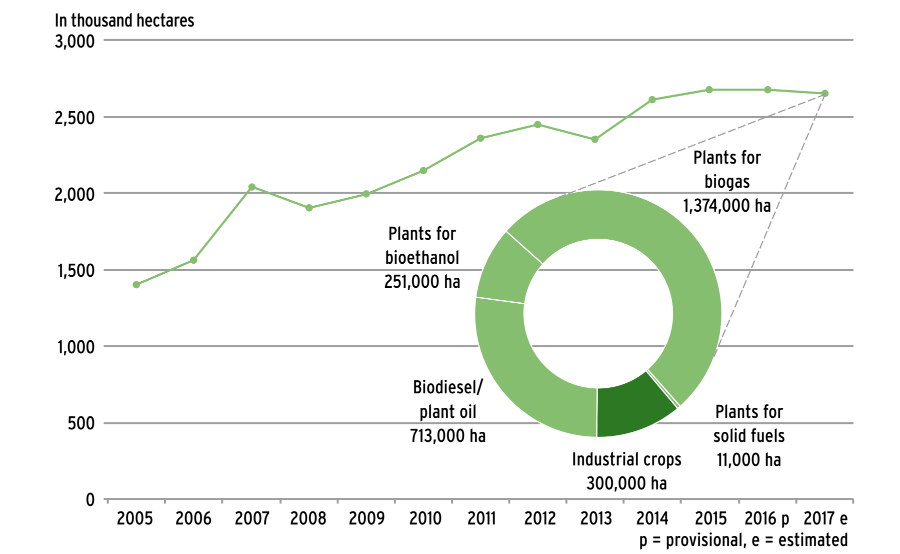


Figure 9:
Development of renewable raw material cultivation in Germany (FNR 2018, modified figure)

In thousand hectares
Biodiesel/plant oil 713,000 ha
Plants for bioethanol 251,000 ha
Plants for biogas 1,374,000 ha
Plants for solid fuels 11,000 ha
Industrial crops 300,000 ha
p = provisional
e = estimated

relief, position of the turbine and weather conditions, and can amount to several kilometres. The impact on the resource of landscape/scenery and landscape-related recreation depends on the distance and the visual relationships.

In contrast to the other renewable energy carriers, the land requirement for bioenergy and the impacts of this on natural resources are not related to the energy plant but arise from the production of biomass, particularly the growing or removal of renewable raw materials. As a result, the impacts and challenges are closely linked to nature conservation objectives in the agriculture and forestry sectors. Energy crops are currently grown on 2.4 million hectares of arable land amounting to around 20 % of the arable land in Germany. Over half of this is used for growing biogas substrates, a third for growing plants for biodiesel (mainly rapeseed) and smaller acreages for the production of bioethanol (cereals, sugar beet). Added to this is the land consumption abroad for the imported biomass. This has played a large role in recent years, particularly in the biofuel sector, involving e.g. rapeseed or palm oil. In 2016 for example, 442,000 tonnes of palm oil (equal to a growing area of around 115,000 ha) were used in Germany as fuel, imported mainly from Malaysia (BLE 2017).

Wood is the most used solid bioenergy carrier and is used primarily for heating. It is difficult to calculate the area requirement for solid biomass as a range of timbers are grown on the same area and the proportion of timber used in the energy sector depends on numerous factors. The quantity of timber used in the energy sector is higher nowadays than its use as a material.

2.2.2 Protected areas and renewable energies

The designation of protected areas is an important nature conservation instrument to preserve biodiversity and (cultural) landscapes. However, protected areas are also used for the expansion of renewable energies. Whether the installation of an RE plant is possible in individual cases depends on the category of the protected area and the particular conservation objective, and conforms with the statutory requirements of the Bundesnaturschutzgesetz [Federal Nature Conservation Act], the Landesnaturschutzgesetze [Nature Conservation Acts of the German Länder] and the relevant protected area regulations.

In Sections 21 ff. BNatSchG, the Federal Nature Conservation Act provides for various categories of protected areas which differ in their conservation purpose and stipulated targets. European site protection also plays a key role. The Habitat and Wild Birds Directives provide for the setting up of a European coordinated ecological network of special protection areas (the Natura 2000 sites). The Habitat and Wild Birds sites are subject to the strict protection regime of Sections 32 ff. BNatSchG. The various conservation objectives are binding.

Wind turbines in particular can have considerable impact on nature and the landscape when located in protected areas due to their inherent and operational effects, in some cases even if the site is outside the protected area. For example, they may cause impacts on bird or bat species living at the site. From a nature conservation viewpoint this requires a careful audit related to the protected area. Currently, wind turbines in Germany are located within all types of protected areas, except national parks. Table 1 shows the percentages of wind turbines which are located in different types of protected areas (note to Table 1: due to the overlapping of different types of protected areas, it is not possible to simply add up the percentages). Nature parks – which at around 28 % of the land area of Germany occupy the largest acreages of all types of protected site – are subject to the most use. Almost 12 % of all wind turbines are located in this type of protected site. Nature parks are only established by statutory instrument in some federal states. The scope of any established prohibition regimes also varies. In addition, they are not supported in full by other types of protected areas, such as landscape conservation areas (LSG) or nature conservation areas (NSG) and are therefore often subject to less strict protection regimes than other protected sites.

GMPV are also installed in protected areas. As with WT, these mainly make use of nature parks and landscape conservation areas. In total around 18 % of the total plant area is to be found in protected areas.

2.3 Impacts of the expansion on nature and landscape

The expansion of renewable energies and the conservation of nature and landscape are linked together in diverse ways. The technicalisation of the cultural landscape through the construction of renewable energy plants creates visible changes to the landscape and awakens people's awareness of the changes taking place. In addition, the installation and use of renewable energies has diverse impacts on natural resources as defined by the Federal Nature Conservation Act. The objectives of Section 1 BNatSchG aim to achieve the protection of biological diversity, the performance and functioning of the natural balance and the diversity, characteristic features and beauty of nature and landscape, as well as their recreational value. The use of the different renewable energies leads to specific impacts and potential conflicts with natural resources. Table 2 gives an overview of potential impacts whose intensity depends on the technical and site-specific conditions.

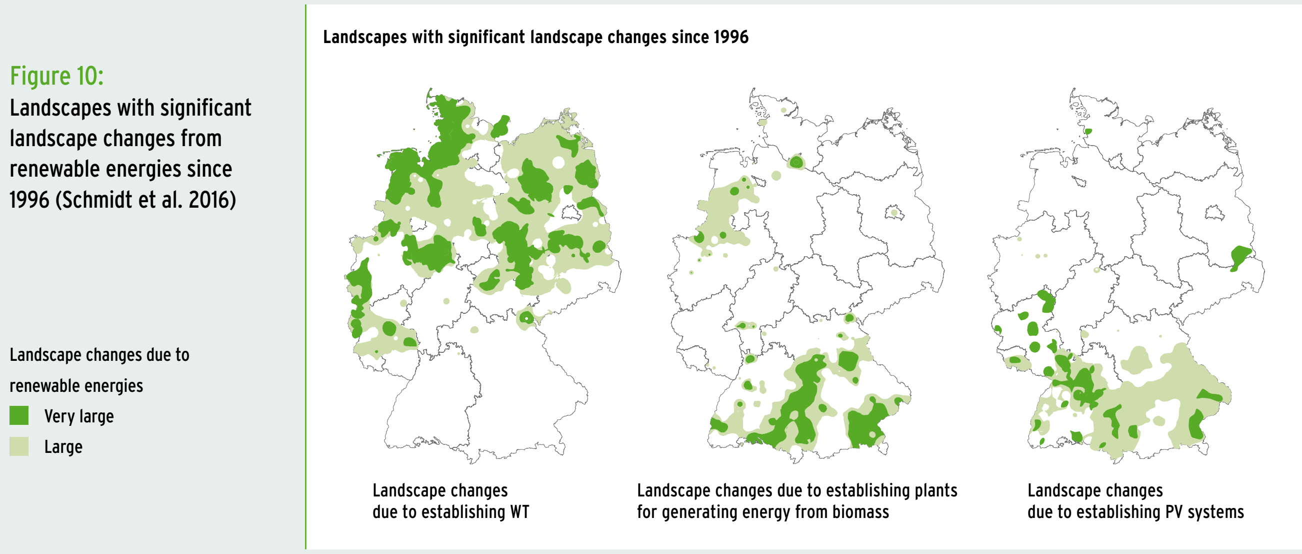
Type of protected area	Percentage of land area [%]	Percentage of WT in protected area [%]
Nature reserve	3.9	0.04
Landscape conservation area	27.9	5.7
National park	0.6	0.0
Nature park	27.9	11.9
Biosphere reserve	3.7	0.1
Bird sanctuary (SPA)	11.3	1.9
FFH site	9.4	0.3

Tabel 1 (left):
Percentage of wind turbines in the protected area categories (own calculation after Thrän et al. 2020)

Tabel 2 (right):
A non-exhaustive summary of potential impacts and conflicts of RE plants on species, habitats and the landscape (own compilation based on Peters et al. 2011 and Schmidt et al. 2018)

<table>
<tr><th rowspan="2">RE carrier</th><th colspan="3">Potential impacts/conflicts</th></tr>
<tr><th>Species</th><th>Habitats</th><th>Landscape</th></tr>
<tr><td>Onshore wind energy</td><td>• Risk of collision for birds and bats
• Barotrauma due to turbulence and pressure differences around the rotors, particularly affecting bats
• Disturbance or loss of habitat due to avoidance behaviour (e.g. golden plover, Montagu's harrier)</td><td>• Destruction and/or degradation of habitats due to turbine construction
• Barrier effect between partial habitats or to migration bats
• Disturbance to roosting and breeding sites</td><td>• Division, delimitation and fragmentation due to the vertical structure
• Changes to existing optical relationships
• Technicalisation of the landscape
• Casting shadows and disco effect</td></tr>
<tr><td>Ground-mounted photovoltaic plants</td><td>• Possible impacts on a few species of insects which react to the light spectrum, as they confuse the ground-mounted photovoltaic plants with water surfaces</td><td>• Marked changes in site conditions from partial covering all the way to loss of habitats
• Barrier effect and habitat fragmentation due to fencing
• More extensive use can create stepping stone biotopes and habitats for small mammals, birds, insects and plants</td><td>• Technicalisation of the landscape, particularly in hillside locations
• Strip effects from PV along infrastructure
• Possible light reflexes and reflections</td></tr>
<tr><td>Bioenergy</td><td>• Negative effects on plants and animals due to growing methods e.g. killing ground nesters due to earlier harvesting dates for the whole-plant harvest of cereals or frequent mowing
• The application of pesticides and fertilisers can harm insects and plant species diversity in particular.</td><td>• Loss of habitats and refuges due to substitution of more extensive land uses and agricultural intensification (e.g. ploughing up grassland and reactivation of set-aside)
• Intensive forest management can lead to the loss of dead wood as a habitat, for example through the removal of trunk sections or other tree parts.</td><td>• Impact primarily from the cultivation of energy plants and creating a monotonous and fragmented landscape
• Interruption to sight lines by tall crops such as maize or short-rotation plantations</td></tr>
<tr><td>Hydropower</td><td>• Increased risk of mortality for fish at hydropower plants
• Changes to the composition of aquatic flora and fauna due to changes in water flows and sedimentation
• e.g. decline in fish species typical of fast-flowing rivers and increase in standing water species
• Attraction of predators (fish/birds) which wait in the tailwater of the hydropower plant for prey fish species</td><td>• Inadequate passability for fish and other aquatic organisms during migratory movements
• Changes to habitat conditions and loss of habitat due to changes in water flows and sedimentation
• Changes to the sediment budget of running waters resulting in greater deepening of the river bed, particularly with dams in series, and consequent effects on groundwater levels
• Changes to the tree species composition in riparian forest</td><td>• Impact primarily from the cultivation of energy plants and creating a monotonous and fragmented landscape
• Interruption to sight lines by tall crops such as maize or short-rotation plantations</td></tr>
</table>

Figure 10:
Landscapes with significant landscape changes from renewable energies since 1996 (Schmidt et al. 2016)



The impacts of the expansion of renewable energies are not recorded in a standardised form so that the overall actual scale is not known. The development of a monitoring instrument which aims to provide a way of assessing the impacts of the different RE carriers through various indicators and measurands is currently being prepared within the R+D project "Monitoring of the expansion of renewable energies in the power sector with respect to nature conservation, and development of instruments to reduce the negative effects on nature and landscape" (FKZ 3515 82 2700), i.e. which measurands could be recorded or are already available as impact variables and to demonstrate the resulting status of nature and the landscape. This would then be used to derive indicators on the impacts of renewable energies and develop monitoring concepts for standardised data collection. It must be pointed out here that overlaps can always occur in the various effects e.g. from forestry or agriculture, making the results more difficult to interpret.

2.3.1 Landscape and renewable energies

Landscape has undergone changes from time immemorial, including due to various forms of energy generation. An important point here is the speed at which the landscape changes take place. If they progress gradually, they often remain unnoticed for a long time. However, over the last two decades, the effects of the energy transition in particular have produced a clearly visible change in the landscape. The objective of nature conservation in accordance with Section 1(3) BNatSchG includes the long-term safeguarding of diversity, uniqueness and beauty as well as the recreational value of nature and the landscape. This objective is defined in more detail in Section 1(4) BNatSchG. It follows that the changes to the landscape from the expansion of RE are not only of importance for socio-political reasons.

What marks out the energy transition is the extremely fast pace at which the renewable energy carriers with their spatial impacts gain in importance in the landscape. Some of Germany's landscapes are already characterised by scenery defined by modern technical elements (Schmidt et al. 2011). These kind of new "energy landscapes" are often perceived by the local population as a break in the development of the landscape, as a destruction of the familiar homeland, and viewed with corresponding scepticism.

Looked at nationally, there are considerable differences between the new energy landscapes (see also Figure 8). For instance, the landscape changes in Northern and Eastern Germany are characterised by the expansion of wind energy due to the wind conditions there. In addition, the changes are visible at increasing distances due to the construction of ever higher wind turbines. The main areas for energy generation from biomass are in the Northwest and South of Germany. These show an overlap with regions with a high density of cattle farming. The use of photovoltaic dominates the landscapes particularly in Southwestern Germany. In this region the density of roof-mounted photovoltaic systems is particularly high, whereas in Eastern Germany ground-mounted systems are the norm (Schmidt et al. 2018).

The interests of the resources of landscape and scenery are not currently adequately integrated in the planning and approval of RE plants. However, a proper debate on the development of the cultural landscape and scenery e.g. as part of landscape planning, is very important, particularly for the acceptance of the further expansion.

Figure 11:
Technicalisation of the landscape and historical townscape due to the dominance of wind turbines (photo: Ulf Hauke)

2.3.2 Species protection and renewable energies

A further objective of nature conservation is to "[protect] wild plants and animals, their communities, their living sites and their biotopes also with regard to their respective functions within the balance of nature" (Section 1(3)(5) BNatSchG).

Depending on the technology used, natural resources are affected by the construction work, land take and operation of the plant or, in some cases, from barrier impacts which lead to disturbance and/or loss of (partial) habitats and protected species. The species protection provisions of the Federal Nature Protection Act form the basis for assessing and managing the conflicts. The provisions of the protection for special species in Section 44 ff. BNatSchG are of particular relevance. Section 44(1) BNatSchG standardises prohibitions on taking of wild animals of specially and strictly protected species. Under Section 44(1)(1) BNatSchG it is forbidden to injure or kill wild animals of specially protected species (cf. Section 7(2)(13) BNatSchG). It is also forbidden to significantly disturb wild animals of strictly protected species (Section 7(2)(14) BNatSchG) and European bird species during their breeding, rearing, moulting, overwintering or hibernation, and migration periods (Section 44(1)(2) BNatSchG). In the case of unavoidable adverse effects under Section 15(1) BNatSchG, a violation of the killing and injuring prohibition, even for species under strict protection, is not applicable under the requirements of Section 44(5)(2)(1) BNatSchG if the interference caused by the intervention or project does not significantly increase the risk of killing or injury for individuals of the affected species and this interference cannot be avoided with the use of the necessary, professionally accepted protection measures.

The impacts on species and habitats vary greatly depending on the different renewable energy carriers. The main potential conflicts are summarised in Table 2. Besides land take and the changes to habitats associated with this, the construction and operation of wind turbines can lead to conflicts with bats and some species of birds. The danger of collisions with the turbines and possible interference or scaring effects are pertinent under species protection law. The Vogelschutzwarte Brandenburg (State Bird Conservancy Brandenburg) has provided information on the involvement of different species and groups of species in a central register which lists the finds of collision victims of birds and bats (Dürr 2018 and Dürr 2018a). Hydropower plants can likewise result in significant fish mortality, if the only corridor for migratory species consists of the passage through the turbines or fish end up in a dead end due to the lack of opportunities to get upstream.

The installation of ground-mounted photovoltaic systems and bioenergy use is particularly important in habitat changes. Due to the partial covering of the ground, GMPV causes significant changes in site conditions which can be positive or negative from a nature conservation viewpoint, depending on the initial situation and the site management. The key factor for assessing bioenergy use is the land use change caused by the increasing demand for biomass. In general this involves an intensification of use, particularly in the agricultural sector.

The expansion of the acreage for biomass production has often taken place on land which was previously farmed more extensively and had more valuable habitats. In the years of the biomass boom, inadequate protection of valuable grasslands led to many farms turning their grasslands into arable to grow fermentation substrate.

Figure 12:
Fencing off GMPV produces barriers in the landscape (photo: Ulf Hauke)

Figure 13:
Red kites frequently collide with wind turbines (photo: Nora Köcher)

The increase in the amount of organic fertiliser in regions where this cannot be utilised properly is also important. It can therefore be assumed that the high level of fermentation substrate production in regions which already have large quantities of farmyard manure has greatly increased the nitrogen problem. These considerations underline the importance of the high level of land take for bioenergy and its effect on land use.

2.4 Social aspects of the expansion of renewable energies

According to the expansion scenarios, the changes so far represent only the start of the transformation process that will continue to advance with the future expansion of renewable energies. Human beings, as part of nature, will be affected by the negative visual effects on the landscape, amongst other things.

Moreover, society‘s support for protecting biodiversity is very high at over 70 % (BfN 2018). There is therefore an urgent need for action to tackle the consequences of the energy transition for nature and the landscape, and to hold an ongoing public debate on the changes that this entails. This is also important in terms of social acceptability. Figure 14 shows over a number of years that, as at 2017, 61 % of interviewees are in favour of an energy supply mainly from renewable energies (BfN 2018). This value has remained largely constant with minor deviations since the first survey in 2011. However, acceptance of the energy transition proves to be very different if the various social milieus are considered. It varies between 79 % (for the “liberal intellectuals”) and only 48 % (for what are referred to as the “hedonists”).

The critical view of the energy transition is often a result of the change in the landscape which, being a direct impact, is perceived particularly strongly by society. Wind turbines in particular are at the centre of the debate due to their vertical dominance and impact on nature and the landscape. A study of 270 public campaigns also comes to the conclusion that the main argument put forward against wind energy is the protection of landscape and homeland (Figure 16) (Schmidt et al. 2018).

2.5 Outlook for future development

Besides the current status on the expansion of renewable energies, it is also important to consider future developments. This enables an evaluation of the possible effects on nature and the landscape, and the implementation of measures for a more compatible design.

The German Federal Government‘s climate protection and RE expansion targets envisage a widely greenhouse gas neutral energy supply by 2050 i.e. a saving of 80 to 95 % of greenhouse gases compared to 1990. 80 % of electricity and 60 % of the gross final energy consumption will then be supplied by RE (BMUB 2016). To achieve these targets, the German Federal Government plans to halve energy demand by

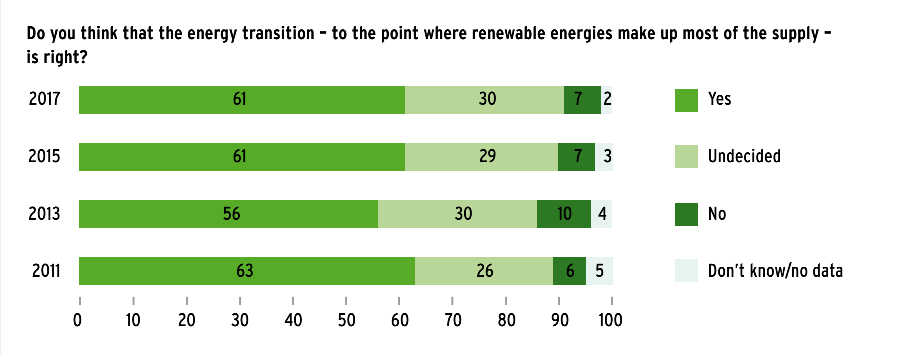


Figure 14: Acceptance of the energy transition over time (BfN 2018)

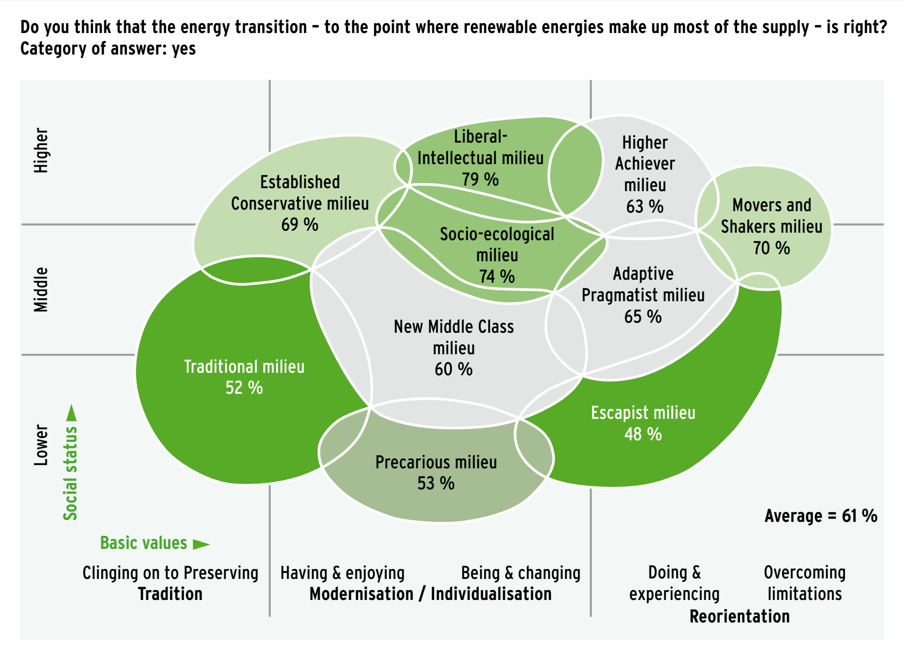


Figure 15: Acceptance of the energy transition according to milieu (Sinus modell) (BMU & BfN 2018)

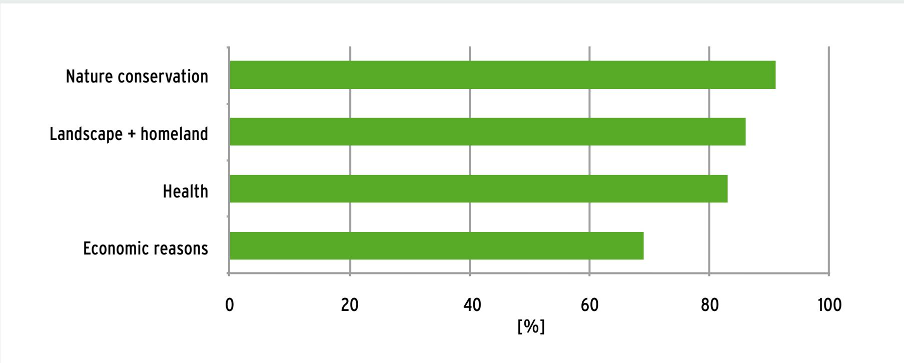


Figure 16: Main arguments from public campaigns against wind energy (Schmidt et al. 2018)

2050 by increasing energy efficiency and savings (CDU, CSU und SPD 2018). Electricity consumption in 2050 therefore needs to be reduced by 25 % compared to 2008. The annual refurbishment rate for buildings will be doubled from the current 1 % to 2 % and the final energy consumption in the transport sector needs to fall by 40 % compared to 2005 (Bundesregierung 2010).

The long-term scenarios (BMWI 2017) simulate these parameters in the difference scenarios. This clearly demonstrates that the expansion of renewable energies is a key element in the decarbonisation of electricity generation. Land-based wind energy forms the most important renewable source. The priority expansion in Northern Germany is more attractive from an economic viewpoint than a WT distribution close to the main consumption. Electricity will play a significantly larger role than at present. The renewable energy supply in the heating and transport sectors will also be electricity-based to a large degree. Efficiency is also a key factor in reaching the climate targets and in order not to waste the limited RE resources. Improved efficiency will in fact be one of the requirements for enabling the changeover to electricity and the substitution of fossil fuels (BMWI 2017).

There will be a significant increase in land take by RE. The following trends – which are always accompanied by (new) impacts on nature and the landscape – can already be observed:

- Construction of RE plants in semi-natural areas will probably continue to increase. There will be significantly more wind turbines in woodland and the pressure to install plants in or at the edge of protected areas will rise. One reason for this is the trend to construct turbines further away from residential areas.
- Development of wind turbines for repowering existing plants and for specific site conditions will go ahead. These include, e.g. low-wind turbines (normally higher and can use lower wind speeds) but also much shorter turbines with large rotor blades for windy regions.
- Construction of GMPV will increase as this is generally more cost-efficient than roof-mounted systems. The density of modules per hectare and therefore coverage of the ground will also rise. Solar thermal systems will also be increasingly built on open land, e.g. for the heating supply to new housing developments.
- Competition for renewable raw materials will presumably continue to rise in future as there will be a greater demand for using these as materials rather than for electricity generation.
- Future expansion will focus primarily on wind energy and photovoltaics, as some of the important technology pathways (biomass and hydropower) have already reached an environmentally compatible limit.

The expansion targets and current trends described here provide an outlook for the ongoing energy transition and its major importance for landscape changes, thus demonstrating the need for action for an environmentally compatible design of the energy transition.

Summary of Chapter 2

Renewable energies provide an increasing proportion of the power supply in Germany, particularly of electricity. Due to their decentral character they are associated with a significant land take and changes to the landscape. They can also create significant impacts on species and habitats.

The changes to the landscape to date are only the start of a major transformation, as the expansion of RE will need to speed up in order to reach the expansion targets set for 2030 and 2050. This will intensify the impacts on species noted so far and increase land take. Likewise, power generation will become even more visible in the landscape, driving the transformation towards energy landscapes.

Despite this, society's backing for the energy transition continues at a high level. To maintain this level of acceptance, the "landscape" element as a resource must be included to a greater degree in the planning and approval of RE plants

3 Potential solutions and future prospects

Based on research by the BfN, this chapter presents options for action to achieve an environmentally compatible design of the energy transition and the resolution of conflicts. However it must be stressed that the environmental compatibility of the energy transition cannot be based solely on an appropriate form of expansion. Efficient energy utilisation and reducing energy consumption are also crucial requirements.

Current R+D Projects

→ 1 | FKZ 3515 82 4300
Ecologically sustainable power supply from 100 % renewable energies 2050 (EE100)
Leibniz Universität Hannover, Institut für Umweltplanung

→ 2 | FKZ 3515 82 2900
Scenarios for the expansion of renewable energies from a nature conservation perspective
Hochschule Ostwestfalen-Lippe

→ 3 | FKZ 3516 83 0100
Acceptance-promoting factors of renewable energies (ACCEPT EE)
Martin-Luther-Universität Halle-Wittenberg

3.1 Future energy landscapes

Is an environmentally compatible energy transition aimed at a total energy supply from renewable energies possible? To answer this question it is helpful to make a picture of the future energy supply and the resulting "energy landscapes". Two research projects have looked at different scenarios for possible developments and derived important parameters and scope for action. So, for example – focusing on the requirements for nature conservation – preferred energy supply pathways were identified such as e.g. a significant increase in the amount of building-mounted photovoltaic in an "electricity dominated" future energy supply, always assuming progress in this technology. The studies also looked at different site options (close to demand, most cost-effective or most environmentally compatible) and indicate a large range of potential developments and scope for action.

The results show yet again that limitation of available land must be incorporated to a much greater degree in the decisions on the choice of pathway for achieving the energy transition. Looking at wind energy, for example, there is only a very limited amount of available site potential which is relatively conflict free, for example due to wind conditions, the distance to residential areas or species conservation considerations, and is often already being used.

3.1.1 Technical perspectives and challenges

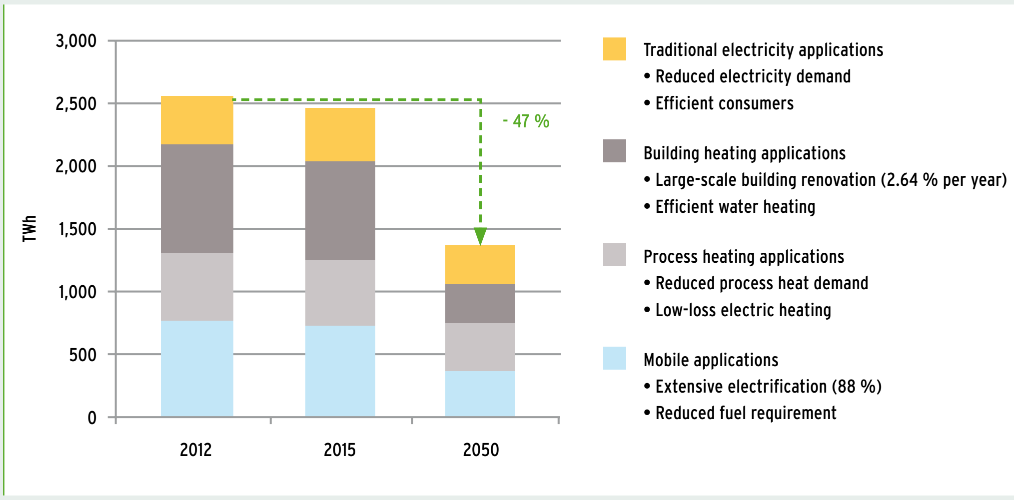
Most of the social challenges associated with the energy transition are still to come. With constant energy consumption, generation needs to be increased sevenfold in order to reach the required decarbonisation of the energy sector. However, a massive expansion of this kind could not be achieved in accordance with the objectives for the conservation and development of nature and the landscape.

So the important future tasks are the resolute pursuit of increases in energy efficiency and a reduction in energy consumption in order to guarantee the climate change objectives. The German Federal Government's energy plan formulates the objective of lowering the primary energy demand in 2050 by 50 % compared to 2008. Various scientific studies show that this is possible with the resolute pursuit and reinforcement of efforts (AEE 2014). One important contribution towards this is sector coupling, which can achieve a marked improvement in efficiency through the increased importance of renewably produced electricity in the heating and transport sectors. In the mobile sector this is based on the large-scale electrification of passenger and goods traffic on road and rail, accompanied by a significant increase in efficiency. This enables the final energy demand in this sector to be roughly halved. A significant decrease in the space heating requirement in the building heating sector can be achieved through a refurbishment rate of over 2 % annually and additional efficiency measures for the production of hot water. Boilers and stoves will be replaced by heat pumps which make use of the ambient heat. This will allow the final energy demand for building heating to be more than halved by 2050 compared to 2015.

The future renewable energy mix needs to take place through a large-scale expansion of photovoltaics, particularly in built-up areas, and wind energy, thus continuing the development of very efficient and compatible technologies (→1).

The further development of energy storage technologies is also important. Large amounts of storage will be required in order to compensate the differences between generation and consumption especially in the electricity sector, both in the short-term and over the course of the year. In addition to

Figure 17:
Ambitious targets for reducing energy demand by 2050 (Walter et al. 2018, modified figure)



developing additional cost reduction potential, there is a great need for research in the dimensioning and integration of storage systems at various network levels along with an intelligent networking of producers, consumers and energy transmission (Walter et al. 2018).

Besides these changes mainly linked to the system, achieving the targets also requires the further development of existing RE technologies and support for research to raise environmental compatibility, energy efficiency and storage capacity. For instance, there is a need to further develop ways to operate wind turbines in an environmentally compatible manner. There are already some positive examples, such as shutting down turbines at certain times to reduce collisions with bats (see Chapter 3.3).

Considering the limitation and scarcity of land and the premise of saving land, it is also essential to focus further expansion primarily on production pathways which use land very efficiently. Technical developments can be expected especially in the photovoltaic and wind energy sectors. Further significant increases in efficiency are possible in photovoltaics which will lead to additional useful application options. Besides further development using roof-mounted systems, there are future prospects here, for example through integration in the external envelope or transport routes. These sort of solutions also avoid conflicts with nature conservation as they do not have to be located “in the countryside” and so take pressure off the “unused” landscape. Continued technical and cost developments will be crucial in determining whether it will be possible to use the huge potential of photovoltaic in urban areas. This development needs to be supported by stipulations and incentives. Some possible approaches are funding for or even mandatory installation of PV on large flat roofs, or roofing over car parks and making use of the roof area this creates. The first district to do this, Tübin-

Figure 18:
Optically successful integration of photovoltaics in the building sector (photo: Ulf Hauke)

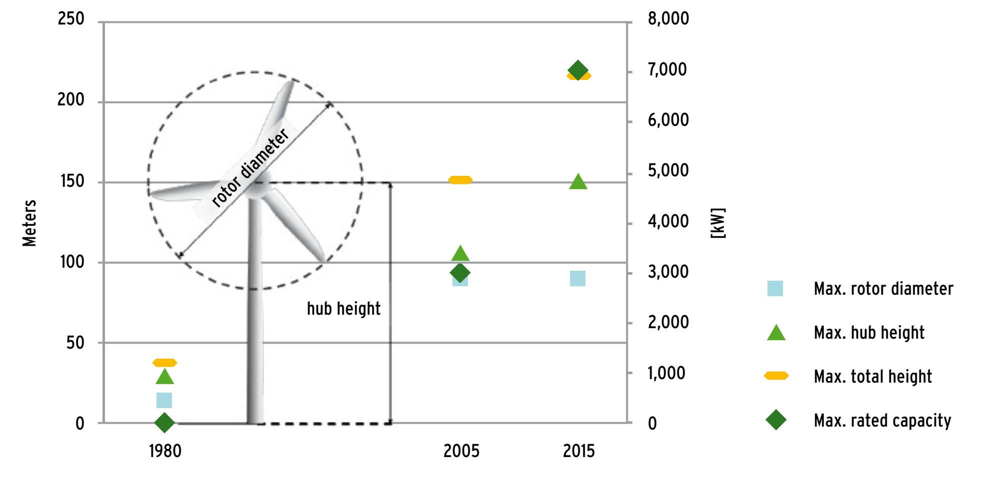


Figure 19:
Development in turbine height and maximum rated capacity of wind turbines (own diagram after BWE 2017)

gen, has for example stipulated that all new construction projects must be fitted with a PV system (Enkhardt 2018).

The trend in the wind energy sector of improving the efficiency of individual turbines by enlarging the rotor area and increasing the height of the turbine is continuing. These turbines can then produce more electricity than current standard turbines, so that fewer turbines are required for the same amount of electricity. Figure 17 shows the rapid development of turbine height and maximum rated capacity over recent decades. It is likely that the expansion will continue to be characterised by wind turbines with a horizontal axis and three rotor blades. Other types such as those with vertical axes and systems based on towing kites currently have no significant share of the market. Research in this area continues to be carried out, so that new types of model could certainly increase in importance over the next few decades. However, these systems need to be examined in more detail in terms of their environmental compatibility.

Biomass from renewable raw materials has no further development potential purely for power generation, mainly due to competition for other uses. The focus here is rather on the further development of existing bioenergy plants in terms of "quality not quantity". Sustainable concepts aim to provide benefits which cannot be achieved in a climate neutral manner by more efficient means in the medium to long term (e.g. biomethane for high-temperature processes). It is preferable to exploit more cost-effective residues and wastes rather than the large-scale use of agricultural biomass. In many cases a more extensive mode of operation of the plant would be desirable (creating flexibility by reducing the rated power).

For hydropower the existing utilisation potential taking into account an environmentally compatible use is largely exhausted and can only be developed by modernising and expanding existing hydropower plants of over 1 MW installed capacity. Due to the large impacts on nature conservation interests in comparison to the electricity yield, decommissioning of small hydropower plants (< 500 kW) should be the aim in the medium term.

3.1.2 Spatial distribution and number of RE plants

One unique feature of the scenarios developed from BfN projects → 1 and → 2 is the creation of a connection between the possible expansion and its relevance on the ground. Looking towards 2050, an area-related approach was adopted to allow the different requirements to be coordinated. Factors to be borne in mind were, e.g. distance to residential areas for wind energy expansion, safety distances to infrastructure (e.g. traffic), the objectives of the National Strategy on Biological Diversity and the sensitivity of the natural resources. The results underline the high spatial impact of RE expansion – and the concurrent scarcity of areas that really pose no conflicts.

Considering the expansion of photovoltaics, the studies revealed a very high potential with low conflicts in terms of other social objectives (→ 1). As a result, it was shown that very large amounts of electricity could be produced by using suitable roof and façade surfaces in urban areas.

The following can be stated for the spatial distribution of wind turbines (→ 1):

- The number of wind turbines required is smallest if they are constructed at sites with high wind speeds which therefore produce high electricity yields. This results in a concentration in Northern Germany where more sites with strong winds are available.
- On the other hand, optimising production close to consumption would require greater utilisation of Central and Southern Germany and locations with lower electricity

yields. More wind turbines are then needed to cover the electricity requirement.
- The calculated total conflict risk can be significantly reduced by optimising the turbine distribution in line with nature conservation criteria (e.g. for scenery and bird species sensitive to wind energy). Land take for forested areas would also be lower.
- High efficiency sites often lie in areas where there is significant conflict with nature conservation, such as on hilltops and ridges. If nature conservation considerations are to be optimised, then sites with low winds increasingly need to be used, which again increases the number of turbines required.

This demonstrates the difficulties and options for action which accompany turbine distribution in terms of proximity to or distance from consumption, and nature conservation optimisation (Riedl et al. 2018). The question of which version is preferable cannot at present be given a definitive answer. However, there are now evaluation methods (primarily from → 2) to incorporate these questions into strategic expansion factors.

3.1.3 Acceptance of landscape change

As the energy transition will be implemented via a large number of decentral plants, it is clearly seen as being the driver of a rapid and far-reaching change in the landscape. While there is a clear public majority in favour of a reform of the traditional energy supply, there are frequent controversial discussions and protests on whether and if so where specific projects should happen. However, broad public acceptance is the basis for the success of the expansion of renewable energies and the power grids.

A majority of the public supports the further expansion of renewable energies. Results from the BfN's Nature Awareness Studies (2011, 2013, 2015, 2017) show that members of the public basically support the energy transition and confirm a general acceptance of individual measures and technological implementation options. The studies (2013, 2015) show that approval for a supply mainly from renewable energies depends on the energy carrier and is highest for wind power and photovoltaic systems. Factors perceived as annoying in the case of wind turbines are mainly their visibility in the landscape and the background noise (Hübner 2015), not the much-debated distance from residential areas. In order to better address these demands, the requirements of nature and landscape conservation must be taken seriously during planning and be incorporated early and convincingly in decision-making. Local residents should not only be informed about the consequences of measures for the scenery and for the conservation of species and habitats but, where possible, also actively involved as "local experts", as part of a transparent procedure.

As the cooperation and agreement of the public is of crucial importance for the success of the energy transition, the project ACCEPT EE (→ 3) carried out an interdisciplinary analysis of factors which encourage acceptance of renewable energies in the context of nature, landscape and climate protection, as well as presenting synergies between nature conservation and the use of renewable energies. The aim of the project is to present synergies between nature conservation and the use of renewable energies and to promote acceptance of an environmentally compatible expansion. The key question is whether expansion which is compatible with nature and the landscape can lead to a higher level of acceptance of renewable energies.

Summary of Chapter 3.1

The energy transition is already producing a significant impact on the countryside. In view of the impending further expansion of renewable energies, (land) efficiency is one of the key aspects which must be incorporated to a greater degree than previously in strategic decision-making. However, it is already clear that great efforts are required in addition to this to reduce the energy demand so that the energy transition can develop in harmony with nature and the landscape. These efforts are of both a technical and social nature and require the creation of awareness and acceptance.

In order to minimise conflicts, expansion should occur on those sites most suitable from a nature conservation perspective. This includes a much higher use of roofs and façades i.e. sealed surfaces for the expansion of photovoltaics in urban areas, thus reducing the requirement for land in open countryside. Further discussion is needed on the optimum spatial distribution of RE systems, especially wind turbines, from nature conservation and efficiency perspectives.

3.2 Options for spatial control

The spatial distribution of RE plants is important for various reasons: protection of the landscape, biotopes and species, and social aspects (fair procedures and distribution, grid expansion requirements, general acceptance). However, options for the spatial control of renewable energies vary greatly, depending on the energy carrier.

In most federal states potential wind energy sites are controlled through regional planning (see e.g. BBSR 2015). In order to create adequate space for wind energy, designations are made in accordance with the federal state regulations via planning instruments for priority, suitable-for-development and/or reserved areas. Some federal states such as Rhineland-Palatinate, Baden-Württemberg and Saarland regulate spatial control in land use planning so that the overall and final planning of wind power sites is the remit of the municipality and the regional plans therefore have no preventative effect under Section 35(3)(3) of the Baugesetzbuch (BauGB) [Federal Building Code] (Schmidt et al. 2018).

In contrast to wind energy planning, site selection for ground-mounted photovoltaic systems occurs at local level, generally by drawing up a land-use plan or using existing land-use plans. The cultivation of biomass is not subject to planning permission or prior approval and is therefore practically impossible to control. In contrast, the legal framework for biogas plants is largely dependent on their size and the choice of location. Due to the high threshold values, biogas plants are rarely subject to the requirement for an EIA.

Approval for hydropower plants is guided by the Gewässerordnung [Water body order]. Responsibility for water bodies of order 1. lies with the Federal Waterways and federal authorities, whereas for water bodies of order 2. it is the local authorities. Application and approval are done on a case by case basis upon application. Depending on the size of the project, a spatial planning procedure and a planning approval procedure may be required, or only a planning approval procedure.

In addition to the traditional planning instruments, the Renewable Energy Sources Act (EEG) also has an influence on the spatial distribution of wind turbines through its compensation terms. There is a north-south divide in terms of the profitability of wind turbines and there are upper limits for the expansion of wind turbines in what are known as grid expansion areas. However, the EEG has no specific goal of restricting new developments to environmentally compatible sites.

Consideration must also be given to cumulative effects in land-use planning. These arise when several turbines are installed close together. Several negligible individual impacts can, through their combined effect, exceed a nuisance threshold and cause considerable interference. As part of the SEA and EIA as well as the FFH impact assessment, in addition to the individual impacts, the cumulate effects must be taken into account. For this reason, as part of the FFH impact assessment, Section 34(1)(1) BNatSchG specifically orders the inclusion of plans and projects with cumulative effects. The aim is to evaluate the overall impact on the affected Natura 2000 site at the time the plan is issued i.e. permission is granted. In the case of multiple use within different projects, de minimis thresholds must not lead to relevant impacts being ignored (Wulfert et al. 2018).

However, as there has been no method or standard for the survey and evaluation up until now, what happens in practice is still open to interpretation. The R+D project "Cumulative impacts of the expansion of renewable energies on nature and landscape" (→ 4) dealt with this issue and developed a methodology with which to monitor cumulative effects. This enables these impacts to be shown in specific areas on a map and therefore included better in the planning process. However, a comprehensive and final evaluation is not possible on this basis (Schuler et al. 2017).

Current R+D Projects

→ 4 | FKZ 3512 83 0200
Cumulative impacts of the expansion of renewable energies on nature and landscape
Leibniz-Zentrum für Agrarlandschaftsforschung (ZALF)

→ 5 | FKZ 3515 82 3400
Visible landscape and energy transition
TU Dresden

→ 6 | FKZ 3515 82 3100
Development of model regional and local energy policies from the viewpoint of nature conservation and landscape management
Technische Universität Berlin

3.2.1 Landscape and site selection

The landscape dimension of the energy transition (landscape and homeland) is a key argumentation pattern which also covers a study of public campaigns for and against wind energy (cf. Fig. 8). At the same time, an assessment of numerous planning and approval procedures showed that aesthetic aspects of the landscape were inadequately recorded, evaluated and taken into account in the decision-making process. Incorporating renewable energies in the landscape in the planning and approval procedures would allow a significant degree of control. Landscape aesthetics should be given greater attention when installing wind turbines, especially in the course of planning concentration zones when drawing up regional or land use plans and also as part of the environmental assessment and impact regulation.

Even though systems for the use of wind energy are privileged under Section 35(1)(5) BauGB, relevant projects for non-designated outlying areas are only permissible where there are no conflicting public interests. In particular, wind turbines must not contravene the representations of a landscape plan, be in conflict with the interests of nature conservation and the preservation of the countryside, detract from the natural character of the landscape or from its function as an area for recreation, or mar the overall appearance of the locality or of the landscape (Section 35(3)(1) Nos. 2 and 5 BauGB). High demands are placed on the incorporation of aesthetic aspects of landscape for planning wind turbines. Comprehensive and legally compliant statements must be supplied for a specific project area.

The incorporation of the aesthetic aspects of landscape in the planning and approval of **ground-mounted photovoltaic systems** takes place through the development of land-use plans (Section 1(6)(7) BauGB, Section 1a(3) and (4) BauGB) and within the framework of the environmental assessment and nature conservation impact regulation in accordance with Sections 14 ff. BNatSchG. The environmental assessment includes the determination, description and evaluation of the impacts of a project or plan on the landscape (Section 2(1)(3) UVPG) and therefore on the scenery. In current planning practice and approval of ground-mounted photovoltaic systems there is inadequate consideration of the scenery, both in land-use planning itself and in the environmental assessment and impact regulation (Schmidt et al. 2018). Greater attention to this is recommended. Guidelines on the matter are given in the information box.

Recommendations on including landscape and scenery when selecting sites for wind turbines (→ 5)

- For planning concentration zones the landscape framework plan or landscape plan must present detailed statements on the following criteria:
  - o Landscape characteristics such as hills, ridges and hillsides
  - o Forest in relationship to its function
  - o Natural landscapes without significant technical infrastructure
  - o Historically evolved cultural landscapes
  - o Cumulative negative visual impacts
- Selection of the following areas based on scientific criteria as part of preparatory planning and incorporation of these as "soft-taboo" zones in the concentration zone concept
  - o Historically evolved cultural landscapes
  - o Semi-natural landscapes
  - o Forest in relationship to its function
  - o Hills, ridges and hillsides
- Taking account of cumulative negative visual impacts in the evaluation of potential areas
- Use of scenarios in regional planning where additional criteria such as minimum area, distance criteria and requirements for the configuration of wind concentration zones can be explored via examples
- Establishing a standard comparative and transparent evaluation of the priority areas and concentration zones for wind energy in the environmental assessment to avoid negative impacts on landscape and scenery

(Schmidt et al. 2018a)

Recommendations on including the landscape and scenery when selecting sites for ground-mounted photovoltaic systems (→ 5)

- Drawing up of a viewshed analyses
  - o Detailed description of the viewshed of the planned ground-mounted photovoltaic system
  - o In relationship to existing landscape features – delimitation of different landscape units in the viewshed
  - o Previous impacts on the landscape need to be identified and taken into account in the evaluation
- Exploration of alternative designs when drawing up the land-use plan for a ground-mounted photovoltaic system
  - o Optimising the plant from a landscape aesthetics viewpoint
- Producing visualisations of the planned plant

(Schmidt et al. 2018a)

In bioenergy production, landscape aesthetics currently play a very minor role due to the limited possibility for control. But growing the substrate can produce significant changes to the agricultural use of whole regions and therefore the landscape and scenery there.

At present, a means of control for the construction of bioenergy plants to protect the landscape is only possible via the impact regulation e.g. in the emission protection approval and land-use planning procedures. Landscape aesthetics should be taken into account, including the landscape im-

Figure 20:
Alteration of historically evolved cultural landscapes by WT (photo: Ulf Hauke)

Figure 21 (below):
Recommendations on the landscape for planning practice for all energy carriers (based on Schmidt et al. 2018a)

pacts of growing the biomass, as part of the planning and approval process for biogas plants. At municipal level there is a considerable potential to have a precautionary influence on site selection for biogas plants and so take account of landscape sensibilities. For an informed choice of site it would be helpful for the landscape plan to contain a full evaluation of biogas plants in relation to landscape plus statements on the growing areas required for biogas substrate.

Another option for avoiding the negative impacts on the scenery from excessive monoculture of biomass exists in the development of clear recommendations for the inclusion or non-inclusion of biogas plants in the environmental assessment of regional or land-use plans. These should contain statements for the control of bioenergy plants that not only apply to existing conservation areas but also contain more far-reaching criteria on landscape aesthetics.

Recommendations on the landscape for planning practice for all energy carriers

Legislation

Formal planning

Regional plan
- More consideration for the interests of landscape aesthetics
- Assessment of the opportunities and limits of the different energy carriers in relation to the specific suitability and sensitivity of the sub-regions of a regional plan

Main recommendation:
overall concept for all energy carriers which promotes a balanced and sustainable overall spatial development of the region

Landscape framework plan and landscape plan
- Qualification in relation to the cultural landscape and scenery

Informal planning

Regional energy concept
- Development of a professional contribution on landscape to energy concepts
- Concept in which the natural environment and cultural landscape requirements and framework conditions for the use of renewable energies are presented in summary for all energy carriers.
- As an informal concept or part of a landscape framework plan

Control instruments

Impact regulation
- For a critical balancing procedure it must be noted that, as part of an overall balance, compensation must offset both the qualitative and quantitative negative impacts on the landscape and scenery.

Energy and climate protection concepts (→ 6) are an informal planning option to integrate nature conservation factors in the expansion of renewable energies from the start. These kinds of concepts can help in implementing the goal of the National Strategy on Biological Diversity, avoiding or minimising conflicts between land requirements in the expansion of renewable energies and making use of synergy effects.

Although energy concepts have frequently been produced at local and regional levels, nature conservation aspects are only considered in some of these. These concepts provide the opportunity to incorporate nature conservation strategies and guidelines for the planning and implementation of RE projects, thus enabling the potential land categories, for instance for ground-mounted photovoltaic systems, to be defined at regional or local level. This kind of information can then be used as a basis for formal planning in regional or landuse plans.

3.2.2 Species conservation and site selection

Site selection is the basis for avoiding or minimising conflicts between species conservation and RE plants, especially for wind energy and ground-mounted photovoltaic systems. Identification and assessment of sites with populations of potentially endangered species must therefore be carried out properly and as early as possible at the planning level, also in terms of legal and planning certainty.

This requirement is also a result of the fact that the specific species protection law must not contravene planning provisions. This applies, for example, to wind energy concentration zones in regional plans which require a guarantee that sufficient land is placed at the disposal of wind energy and no insurmountable hurdles in terms of species protection law will undermine the planning. However, it must also be stated that the species conservation issues within the different levels of the planning processes can only be tiered to a limited extent, i.e. transferred to the next planning level. The more binding and specific the planning at the various levels, the more thorough the required checks. Operationalisation of the duty of inspection cannot be inferred from the species protection provisions but is developed through case law (→ 7). Appropriate advice and guidelines can be developed from this at regional level.

Amongst the most important standards are distance recommendations from wind turbines to important bird habitats as well as nesting sites of selected bird species (LAG VSW 2015) – what is referred to as the Heligoland Paper. In the case of non-compliance, it is necessary to carry out a thorough investigation of the facts. The project "Avifaunistic metho-dology standards for wind energy approvals" (→ 8), is currently developing a proposal for a nationally concerted expert recommendation on a suitable methodology. This will be further developed in cooperation with representatives of the Länderarbeitsgemeinschaft der Vogelschutzwarten (German Inter-State Working Group of Bird Conservation Observatories) and contains detailed methodological guidelines.

Current R+D Projects

→ 7 | FKZ 3515 82 0100
Species and site protection at preceding planning levels
Bosch & Partner GmbH

→ 8 | FKZ 3514 82 3800
Avifaunistic methodology standards for wind energy approvals
Ökotop GbR – Büro für angewandte Landschaftsökologie

→ 9 | FKZ 3512 84 0200
Before and after studies at forest wind turbines to determine the effects on bat distribution
Freiburger Institut für angewandte Tierökologie (FRINAT) GmbH

→ 10 | FKZ 3512 86 0200
Identifying bat migration routes and corridors
PAN Planungsbüro für angewandten Naturschutz GmbH

Research has been carried out to provide greater detail of the site selection requirements for different species and groups of species. For example, the use of woodlands by bats and the function of woodlands as habitats was studied in order to be able to make deductions for site selection for wind turbines in forests (→ 9).

Research was also conducted into the spring and autumn migrations of species of migratory bats to see whether these take place in specific corridors or as a broad front (→ 10). As these species can be particularly at risk from wind turbines, information on seasonal migration and migratory routes is very important. The results show that a high likelihood of a broad front migration must be assumed, and that bats do not avoid minor mountain ranges. High levels of activity were detected along river banks, which are presumably used for hunting and for mating that takes place in autumn in the resting areas, and which mask the migratory movements.

Besides the wide-scale planning of sites for RE utilisation, the small-scale management is also very important in order to reduce the impacts of individual turbines or turbine parks. At the level of planning a specific project, the arrangement of turbines e.g. in a windpark, can be important. When considering raptors at risk of collision, a compact arrangement of the wind turbines is appropriate, as the collision risk is generally higher for the outer turbines.

Bats and wind energy in woodland (→ 9)

The following exclusion zones for wind turbine sites in woodlands are recommended to protect bats:

- old deciduous and mixed woodlands with tree stands > 100 years old,
- semi-natural coniferous woodland with potential for bat roosts,
- woodland with a good supply of dead wood,
- woodlands in Natura 2000 sites,
- 200 m buffer, with no interference, around known roosts or roosting centres and avoidance of potential roosts and hunting habitats.

There should be as great as possible a distance from the lower rotor tips to the top edge of the woodland, as current research indicates an increasing collision risk with decreasing distance to the rotor tips. A distance of at least 50 m between the canopy and lower rotor tips is therefore recommended.

The most suitable compensatory measures for possible loss of habitat which cannot be avoided due to the choice of site are:

- Discontinuation of use of forest stands,
- Semi-natural management with retention of sufficient habitat trees and future habitat trees,
- Habitat networking.

(Hurst et al. 2017)

Figure 22:
The noctule is one of the bat species that are sensitive to wind energy (photo: Hendrik Reers)

Figure 23:
WT arranged in a line can present barriers between partial habitats or for migration movements (photo: Ulf Hauke)

A barrier effect caused by the RE plants should be avoided at sites with regular migration movements. This applies for example to wind turbines which can create barriers for migratory birds. They can be arranged in parallel to the main migratory direction or, for species such as cranes, there is the option of increasing the distance between the WT to reduce the risk of collision should the birds fly through the wind park. Due to their ring fences, ground-mounted photovoltaic systems can also create barriers for roaming large mammals. In such cases broad corridors between the PV sites are recommended to allow the animals unrestricted movement.

3.2.3 The controlling effect of conservation areas

Site protection under the Federal Nature Conservation Act is one of the traditional nature conservation instruments. Due to its exclusionary effects it provides the possibility of the regulatory control of RE plants. Protected areas can make an important contribution to the spatial management of renewable energies. The configuration of requirements and prohibitions in the reserve declarations (often protected area regulations) permits the complete exclusion or a qualification of the uses and RE plants, where they are principally compatible with the protected area e.g. via stipulations on the plant design or for land-based uses.

The following approaches provide a spatially controlled effect via protected areas:
- New designation of protected areas,
- Changes to or adaptation of existing protected area declarations including zoning,
- The use of existing reserve declarations,
- Use of existing or newly designated protected areas as a background (e.g. in the regional plan).

Due to the statutory purposes, the protected area declarations for nature reserves (Section 23 BNatSchG), national parks and national natural monuments (Section 24 BNatSchG) and the core and buffer zones of biosphere reserves (Section 25 BNatSchG) are designed in such a way that they have a particularly restrictive effect on renewable energies. For landscape protection areas (Section 26 BNatSchG) it depends a great deal on the specific protection aims and the character of the site.

Protected area regulations generally provide good and varied opportunities for developing stipulations for renewable energy. This applies not only to the actual plant construction, but also regulations for agricultural and forestry management. However, these options have been used very cautiously in practice so far (→ 11).

An individual strategy needs to be developed for each protected area with its specific qualities and sensitivities. This can contain an exclusion of renewable energies, but also an active promotion of a decentral environmentally compatible use and design. Detailed recommendations for the renewable energy carriers in different protected area categories have been formulated in the projects → 11 and → 12. Some of these are presented as examples for wind energy in the information box.

Current R+D Projects

→ 11 | FKZ 3513 82 0100
National Natural Landscapes (NNL) and the use of renewable energies
Institut für Ländliche Strukturforschung (IfLS)
an der Goethe-Universität Frankfurt/Main

→ 12 | FKZ 3515 81 1000
Management potential under nature conservation law for site protection, particularly for landscape protection areas with particular reference to renewable energies
Universität Kassel, Fachgebiet für Landschaftsentwicklung/Umwelt- und Planungsrecht

Figure 24:
Uninterrupted natural and cultural landscapes have a special value, for example for recreational use, and can be conserved by such means as the protected areas instruments (photo: Asja Weber)

Recommendations for wind energy (→ 11, → 12)

- Biosphere reserves (→ 11) (Gehrlein et al. 2017a, p. 489 ff.)
  - o Core and buffer zones of biosphere reserves plus appropriate separation areas to these zones must be kept free of wind energy.
  - o In the transition zones, wind turbines should only be installed in less sensitive areas and in compliance with high standards after a careful examination of each case. This requires the development of an overall planning concept. Transition zones which have so far been (largely) free of WT and which have not been endorsed by the biosphere reserve administration for WT, should continue to remain without WT.
- Nature parks (→ 11) (Gehrlein et al. 2017a, p. 489 ff.):
  - o Individual nature parks of high landscape value must be excluded from wind energy development.
  - o Zoning plans must be developed and applied to the remaining nature parks. Examples of this are such areas as the Altmühl Valley Nature Park and the Franconian Heights Nature Park.
  - o If there is no competent planning concept for WT use, then there should be no development in the meantime.
- Landscape protection areas (→ 12) (Mengel et al., unpub., p. 382 ff.)
  - o As the resource of landscape is usually part of the conservation aim and WT can generally be assumed to cause a negative impact on the scenery on account of their size and longdistance effect, the following control options are conceivable via the protected area regulations:
    - Complete exclusion of wind turbines,
    - Drawing up a zoning concept and embodiment in the protected area regulation,
    - Admission of the construction of WT in the protected area regulation, subject to approval.

Summary of Chapter 3.2

The large- and small-scale distribution of RE plants has a significant impact on their environmental compatibility. Species protection is already included in site planning, but the actual form of the criteria to be taken into account must be continually updated in line with current research and the developing state of knowledge.
Landscape and scenery have not been adequately integrated in the spatial controls up to now. Much better attention should be given to this aspect, as a soft criterion but one of major relevance for acceptance. Approaches now exist for evaluating the sensitivity of landscapes to various types of RE plants. However, further research is needed, both to establish professional standards and to achieve a suitable integration in the planning processes.

Site protection offers the option of spatial control of renewable energies. For example, the qualification of protected area regulations can be used to create management approaches and conserve the special nature conservation value of the protected areas.

3.3 Environmentally compatible planning and design of RE plants

Even when RE plants are implemented, there are still numerous possibilities for minimising the negative impacts on nature and the landscape. Particular attention must be paid to the preventative requirements for projects and measures defined in the official nature conservation instruments, and to the possibility for incidental provisions in the approvals.

The main control instrument of the nature conservation intervention provisions (Section 13 ff. BNatSchG) prescribe that the intervener must refrain from avoidable adverse effects (Section 15(1)(1) BNatSchG). It is therefore very important to reduce the effects associated with the resources and measures. On the one hand, plant design can lead to better environmental compatibility (e.g. design of the base of the wind turbine, GMPV site management). On the other, through appropriate preventative measures, operation of the plant can be adapted to the specific conditions in order to reduce conflicts.

At **wind turbines** measures such as these can, for example, help to reduce the collision risk of bat and bird species which are sensitive to wind energy. Methods for preventing bat casualties at wind turbines have been developed in the national RENEBAT I to III research projects. The software ProBat enables a simple implementation of the results by calculating a site specific bat-friendly operating algorithm for the WT. The calculation is based on activity data from an acoustic recording around the nacelle plus wind speed and temperature data for the turbine. Information from users and new research results will be integrated in software updates to ProBat.

In addition to the spectrum of prevention and reduction measures, there is also a high level of variability in the sites, the range of species and the behaviour of the different species and individuals. The protection concept therefore needs to be assessed in each case in the course of project approval, and adapted to the site conditions and prescribed in the incidental provisions in accordance with the requirements of the relevant instruments (species protection assessment, nature conservation impact regulation, site and biotope conservation).

There are widely accepted research-based measures contained in the guidelines of the federal states and in the species protection recommendations. The measures include shutting down the turbine on certain days for or after agricultural management operations, establishing distraction feeding plots, temporary shutting down for migratory movements (e.g. the main or mass migration days of cranes) and bat-friendly operating algorithms.

Other types of measures have not been adequately tested so far. To improve our state of knowledge about the efficacy of additional preventative measures at wind turbines (distraction feeding plots, shutting down for agricultural operations) a further research project will carry out field studies to be able to provide recommendations on the necessary design of things like area sizes and time frames (→ 13, → 14).

Current R+D Projects

→ 13 | FKZ 3516 8227 00
Method development for species protection studies on the effectiveness of prevention and mitigation measures to reduce the impact of wind turbines on avifauna
BioConsult SH GmbH & Co. KG

→ 14 | FKZ 3517 86 0200
Field tests to assess the effectiveness of prevention measures to reduce the risk of killing in wind turbines
FöA Landschaftsplanung GmbH

→ 15 | FKZ 3517 86 1600
Development of a concept for nature conservation accompanying research within the framework of the WindForS wind energy test field Swabian Alb
Zentrum für Sonnenenergie- und Wasserstoff-Forschung Baden-Württemberg

→ 16 | FKZ 3515 83 0200
Taking account of species‘ protection interests when installing small wind turbines
Michael-Otto-Institut im NABU

→ 17 | FKZ 3515 83 0100
Evaluation of measures to reestablish free movement: Section 35 Wasserhaushaltsgesetz (WHG) [Federal Water Act]
Ingenieurbüro Floecksmühle GmbH

→ 18 | FKZ 3515 82 3300
Nature conservation issues arising from the expansion of renewable energies on regional transport routes and its effects on the reconnection of habitats
Leibniz Universität Hannover

→ 19 | FKZ 3512 83 0700
Energy transition and biodiversity in forests
Hochschule Weihenstephan-Triesdorf

→ 20 | FKZ 3511 82 1500
Biomass cultures of the future from a conservation point of view
Universität Hohenheim

Figure 25:
Raptors are attracted by operations on agricultural land. Neighbouring WT should therefore be shut down at certain times. (photo: Nora Köcher)

A wind test site set up specifically to research various operating parameters will test and evaluate species protection measures, particularly for bats and birds, in addition to economic and technical issues (→ 15). The wind test site will enable experimental testing which is not possible on commercially operated wind farms. The study will examine where, when and why bats and birds gather around wind turbines and how environmental parameters and the operation of the turbine affect their activity and risk of collision. Following on from this, research will focus on preventative measures which could effectively reduce these risks. These include the technical feasibility and nature conservation requirements for species-specific recording, and implementation rules for the responses (shutdown, deterrence).

While not new, there is currently great interest from both the operator side and nature conservation angle in technical preventative measures which use a detection/identification of individuals approaching the turbine to emit a deterrent signal or initiate a shutdown of the WT (e.g. DT-Bird). A scientifically-backed trial of the turbine operation aims to investigate the feasibility of technical preventative measures, amongst other things. The objective is to significantly reduce the collision risk. This raises a large number of questions which need to be answered before a general recommendation can be given to practice, such as:

- The technical feasibility and requirements for reliable species-specific recognition,
- Effectiveness of the deterrence:
  - o Targeted/species-specific deterrence possible?
  - o Are there other impacts such as habitat loss, scaring, habituation effects,
  - o Compatibility with the prohibition on disturbance,
  - o Acceptance of additional emission sources (sound, light),
- Can experts and authorities verify the systems and their effectiveness?
- Limits of technical and economic acceptability, particularly in view of the frequency and length of shutdowns.

Preventative measures can also be used to reduce the impacts on the landscape and scenery. The following should be assessed as part of the planning and approval process (→ 15) (Schmidt et al. 2018a):

- Potential use of night-time lighting when needed,
- Adaptation to existing structures/textures by means of colour design,
- Micrositing: rational design of turbine placement based on the conditions at the site,
- Harmonious overall effect when expanding a wind farm

Other aspects may arise at **small wind turbines** which must be taken into account when they are built. The following recommendations for birds can be derived from current research (→ 16):

- The important impact of SWT on birds manifests as relatively frequent collisions, in comparison to the quantity of electricity generated. The collision risk has a clear relationship to the type of turbine and the site. Small wind turbines which provide opportunities for perching and even nesting produce an increased collision risk and should be modified. Types of wind turbine with tensioning cables create an additional source of hazard.
- The collision risk can be estimated relatively accurately from the site parameters of the surroundings. It is increased by large amounts of structures which attract urban and woodland birds, such as buildings, farms, gardens, shrubs and hedges as well as nesting boxes and bird feeders and the proximity to livestock farms.
- All the options for site selection should therefore be investigated before installing SWT. The necessary data can be determined comparatively easily from aerial photographs and a site visit.

Measures at **hydropower plants** affect both fish conservation, upstream and downstream fish movements, structural management of water bodies and also the linking of riparian areas to safeguard biodiversity in semi-natural river and water meadow ecosystems. As part of the project "Evaluation of measures to reestablish free movement: Section 35 Federal Water Act (→ 17) a research concept is being developed to establish and evaluate fish conservation and fish bypass facilities at the Eddersheim and Griesheim am Main hydropower sites (> 50 m^3/s turbine flow rate). The sites are being set up as research locations to study gaps in knowledge on the harm i.e. behaviour at weirs and hydropower passes, the effectiveness and guiding influence of mechanical barriers and bypasses plus clarification of technical issues at hydropower sites with flow rates > 50 m³/s.

Recommendations for the environmentally compatible design of hydropower plants (i.a. → 17)

The following requirements should be applied to hydropower plants from a nature conservation perspective:

- Guarantee of upstream and downstream free movement for fish and other aquatic organisms using migration aids,
- Reservoir drawdown at times of increased migration such as e.g. eels in the Main,
- Installation of mechanical barriers (fine screens) and bypass systems to protect fish from turbine damage, taking account of species-specific requirements (e.g. size, swimming speed and behaviour) of the target species and diverting them into the tailwater,
- Connection and preservation of adjacent riparian areas and backwaters with the main water body and its discharge dynamics, including the water level fluctuations and cycles which are typical and characteristic of these areas,
- Morphological measures to increase the habitat diversity of the riverbed and the bank,
- Safeguarding semi-natural groundwater relationships above and below the transverse structure,
- Ensuring the free movement of flotsam (floating debris) and bed load,
- Compliance with seasonal and species' ecology criteria when determining the minimum water discharge in the diverted river reach.

Photovoltaic systems should preferably only be installed on roofs and areas which are already sealed in order to minimise the amount of open space they consume. New technical developments enable a wide range of design options.

Recommendations for the environmentally compatible design of ground-mounted PV

If GMPV systems are erected on open areas, they can still have a positive effect on species numbers and structural diversity e.g. on arable land using appropriate design. The following requirements apply to GMPV (e.g. → 18):

- Exclusion of areas with varied structure and grassland sites,
- Reducing the barrier effects through opportunities for large mammals to cross and appropriate design so that these opportunities are also used (50 m wide, should not end directly at a road as this can cause more frequent wild animal casualties)
- PV plant design taking account of landscape aesthetics e.g. by integrating elements characteristic of the locality or screening using appropriate planting,
- Avoidance of additional sealing of the ground as far as possible,
- Extensive land management e.g. only mowing once or twice or extensive grazing, permitting natural succession on suitable parts,
- Compensation of unavoidable disturbances through appropriate compensatory and replacement measures.

The **bioenergy sector** offers options for a sustainable operation e.g. using an environmentally compatible biomass supply. The substrate composition for biogas plants in particular must be improved from the present situation.

The current context must be borne in mind: bioenergy is a comparatively expensive pathway and is under a high transformation pressure at present. One element in this is the large area required for the production of renewable raw materials. In addition, many substrates which are more desirable from a nature conservation perspective come from more extensive management and therefore use even more land and are more expensive to produce. Replacing agricultural biomass (particularly maize) by extensively grown substrates is a course of action with a very limited scope for the future energy transition.

From a nature conservation perspective, the continued operation of biomass plants makes sense if the plant in question can exploit cheap residues and materials which do not create much competition with other (more valuable) land uses. However, it must be noted that the use of residues can also involve risks if these residues serve a function in the agricultural and forestry systems (e.g. in their nutrient cycle).

Contrary to the "sustainable" potentials of forest residues described in some studies, an R+D project was able to determine that any use which exceeds the current level is only possible at the expense of material uses and/or biological diversity (→ 19). Even expanding the use of straw brings risks, if incentives are created but there are no clear conditions and criteria for environmentally compatible use. For this reason there is also a limit to the availability of residues.

However, there are some materials whose use and processing in bioenergy plants is also appropriate from a nature conservation point of view, such as materials from carefully designed environmental priority areas (i.e. for example perennial energy plants instead of catch crops) or from landscape management. However, this is less sound if the key driver is substrate-based energy production and the real benefit is not viable in the context of sustainable land use.

Figure 26:
Fish ladder (photo: Friedhelm Igel)

Summary of Chapter 3.3

Research has led to the development of a range of measures which can reduce conflicts with RE plants under species protection regulations, as optimum site selection for nature conservation is not always possible. For instance, appropriate design and planning of GMPV and extensive land management can reduce negative impacts on nature conservation interests.
It is crucial to adapt the measures to the specific site and its conditions and to the potential impacts of the RE plant. In addition, only tried and tested preventative measures should be used and their effectiveness monitored. New measures need to be developed and existing ones improved and implemented in practice as part of continuing research.
For bioenergy, in contrast, it is the choice of raw materials that is important. Points to note here are the intensity of land use and competition with the use of biomass as a material. Synergies with nature conservation, such as the recycling of landscape management material, are possible to a certain extent. Wood fuel can continue to be used at the current level. However, this does not provide any environmentally compatible expansion options for the future design of the energy transition.

4 Conclusions and recommendations for an environmentally compatible expansion of renewable energies

The implementation of both the nature conservation goals and the energy transition is a major economic, environmental, social and political challenge. However, broad sections of the public support the energy transition as well as the conservation of biodiversity (BfN 2018) and view them as a top priority for German society.

The high spatial impact and the shortage of “conflict free” areas require the aspect of nature and landscape compatibility to be strengthened and incorporated at an early point in the continued expansion of renewable energies. The reasons for this are conflict minimisation and legal compliance, but also acceptance amongst the public. Nature conservation concerns cannot be taken into account for the first time when planning specific areas and projects but must be thought about at the strategic level (e.g. development pathways, choice of technology, etc.).

4.1 Measures for short-term implementation

Even if the energy transition needs to be planned and implemented in the long-term, there are some measures which can be put in place now or in short time frames. This is all the more important, because RE plants are designed for a service life of around 20 years, while hydropower plants have even a service life of 60-80 years on average. The impacts of the current expansion are also crucial indicators for the accompanying infrastructure e.g. for the expansion of the grid, the development of heating networks, etc.

The following areas for action must therefore be addressed:

→ Optimising site selection for nature conservation at all levels of planning and approval:

- There is only limited availability of sites with few or no conflicts. A careful use of land and resources must therefore be given consideration even for the basic strategic direction of the energy transition (e.g. development pathways of individual energy carriers). This can for example be developed and implemented via energy and climate protection concepts which include nature conservation.
- Expansion of renewable energies must be specifically aimed at sites which have no or minor conflict potential with nature conservation. This includes a much greater use of roof surfaces and previously sealed areas for photovoltaic plants. This potential has not been exploited nearly enough, especially in urban areas. The current statutory regulations such as the EEG landlord-to-tenant regulation can and must make a contribution to this. Additional incentives could be incorporated in the legislation via a separate tendering for/funding of roof-mounted PV systems.
- Areas of particular importance for the protection and development goals of nature conservation and landscape management must be excluded from the site selection process. These include specially protected areas (Natura 2000, nature reserves, national parks, national natural monuments, core and buffer zones of biosphere reserves), legally protected biotopes, protection forests, nest protection zones, semi-natural woodlands with multi-storey or selectively harvested stands, woodlands with stands of ancient trees, woodlands with a soil protection function and those with tree stands of importance for cultural history or landscape character, woodland edges and areas which are to be used for semi-natural or natural woodland growth, recreational areas with qualitatively valuable landscape and scenery, bird and bat migration corridors and sites with populations of endangered species or those sensitive to disturbance.
- When open areas are used, e.g. for GMPV, then upgrading measures should be undertaken on these areas (e.g. in terms of stepping stones to network the habitats).
- The expansion in renewable energies is creating ever greater changes in our landscapes. Nevertheless, aspects of the experience of landscape and scenery are given scarcely any attention in the pertinent planning and approval procedures. Their inclusion is very important in the opinion of a majority of the population and one of the decisive factors in the public‘s acceptance of the energy transition. Aspects of the experience of landscape and scenery should therefore play a larger part in the planning and approval of RE plants in future and be accompanied by a greater involvement of the public.
- It would be useful to have a national standardisation of the research methods and procedures as well as the qualification and certification of experts and planners to evaluate the research results with the aim of improving the quality of the impact assessments, and the concomitant higher legal compliance of the plans.

→ Environmentally compatible design of RE plants and their operation

- Preventative measures must be used to minimise site-related conflicts with species protection. This applies equally to preventative options under the scope of the species protection assessment or the environmental protection impact regulation as well as preven-

Figure 27:
Even small roof surfaces can be used for generating solar power (photo: Ulf Hauke)

tative options which minimise impacts on the landscape through appropriate site selection and design. Examples of the relevant measures are described in Chapter 3.3.

- For new systems, such as technical identification systems (e.g. cameras) in combination with needs-based shutdown, proof of their effectiveness is still needed. This is why they are still not in common use.
- The more potential conflicts at a site (e.g. in terms of the collision risk at WT), the more costly conflict prevention becomes, with sites even becoming uneconomical, for instance due to long shutdown periods. Site selection is therefore crucial and must be given appropriate consideration at earlier planning and decision-making stages.

→ Improve knowledge and data bases

- The actual effects of the expansion of renewable energies on species and habitats are not fully known at present. Monitoring of the energy transition from a nature conservation perspective therefore needs to be set up to document the effects of the different renewable energy carriers. One option for this is the monitoring report for the EEG.
- Based on current information, a better understanding of the interactions is needed. The intense research effort over recent years shows that innovative proposals for solutions can be found. This research must therefore be continued and in particular should consider current developments such as improved recording systems at wind turbines and monitor their introduction in practice. Surveys on population dynamics and analyses of the causes of threats to target species are also required. Continued research on the migratory behaviour of bats and birds is another important topic.
- The proposed solutions from the many research projects on the subject of an environmentally compatible plant design must be made available and applied in practice. Close links are essential between research and practice in order to identify overarching topic areas, synergies and research needs, process research results and transfer these into practice. These links must therefore be continued.
- A method needs to be developed to evaluate the cumulative impacts from the expansion of RE which will enable a comparative and practicable use in the field. Improved representation of cumulative impact assessments in land use planning and environmental assessment is also needed due to the increasing density of RE plants.
- More trials and accompanying research on RE plants are required. Scientific support e.g. at test sites or as part of the normal plant operation can enable the evaluation of environmental compatibility. An example is the evaluation of the effectiveness of preventative measures.

→ Monitoring and supporting technical developments

- The technical development of RE plants must be continued in terms of their environmental compatibility and technical preventative measures (e.g. automatic turbine shutdown). New systems need to be tested for their environmental compatibility before being used.
- Ambitious measures to reduce the energy demand must also be addressed in the near future. This applies particularly to sectors where investments are made with a long-term commitment such as the building heating sector. But action is also needed in the mobility sector, such as fleet targets for new passenger cars and the further development of electromobility. From a nature conservation perspective, this is more important than, for example, the development and funding of advanced biofuels which involve the risk of creating new utilisation competition.

4.2 Criteria for the future design of an environmentally compatible energy transition

Expanding renewable energies is not enough on its own for an environmentally compatible energy transition and climate protection. For the long-term prospects, more fundamental changes in the energy supply system are required in order to achieve the goals of both nature conservation and climate protection. The following aspects are important:

→ Ambitious implementation of energy efficiency and energy savings goals

- Improving the efficiency of the entire energy supply system is essential. This can be achieved via measures such as the expansion of sector coupling and electrification in the transport and heating sectors.
- The use of bioenergy is accompanied by high land requirements and competition for the use of resources. From a nature conservation point of view, the areas under intensive cultivation for biogas production need to be reduced.
- Bioenergy can also lead to synergies from various areas, for example from landscape management. The degree to which funding by the energy sector is appropriate for actually developing these kind of synergies and at the same time supporting an affordable contribution to the energy system is doubtful.

→ Choosing sustainable technologies and making environmentally compatible options the norm

- The objectives for the further expansion of RE must be formulated in such a way that expansion pathways with a low impact on the land are given a significant boost. Urban areas subject to construction planning law must be used for modern technologies suited to buildings, such as photovoltaics, solar thermal energy and ambient/geothermal heat which go beyond the traditional roof-mounted systems. The EEG needs to be amended in line with this. The higher investment costs associated with this must be balanced against the overall social costs e.g. for further surface sealing.
- The aim is for a landscape- and site-specific mix of efficient RE plants with the lowest possible impacts on nature and the landscape. This requires new directions, such as the combination of large and small wind turbines at some sites.
- The incorporation of storage technologies in Germany‘s overall energy concept is essential for creating an energy supply mainly from renewables.

→ Improving the integration of nature conservation goals in legislation related to the expansion of RE

- Laws and (funding) instruments must be further developed, in particular with respect to aspects of environmental compatibility, in order to avoid conflicts before they arise (e.g. EEG, EEWärmeG Erneuerbare-Energien-Wärmegesetz) [Renewable Energies Heat Act].
- The different protection categories in the nature conservation legislation provide a range of instruments for site protection and can also be used for the spatial control of RE. The funding under the EEG should also be linked to the eligible areas in future.
- Nature conservation goals for species and landscape protection must always be kept fully in view and reconciled in planning further RE expansion. The goals of the National Strategy on Biological Diversity include, for example, natural woodland development on 5 % of the forested area, the expansion of the protected area network and the safeguarding of populations of endangered species. Discussion is needed on a higher-level of spatial control at national level (e.g. via regional tendering quantities linked to aspects of nature conservation), one which is suited to coordinating these interests in a professional manner and of establishing a spatial balance to the planned amount of expansion nationally.

→ Making better use of public involvement as a requirement for success in increasing acceptance

- Without public acceptance, the environmentally compatible expansion of renewable energies and the power grid is at risk. Even if aspects such as species protection and preserving landscape and scenery only account for part of the reason for protest, these are presented very succinctly and often have a particularly strong effect on the public, which is why this part in particular needs to be taken into account to a greater degree in planning processes. There are also the following further research needs:
    - Ongoing evaluation of previous participatory approaches and success should be encouraged in the context of the expansion of wind energy and grid expansion taking nature and landscape protection into account.
    - Research on the impact (positive, negative) of renewable energies on people must be expanded, e.g. in the form of long-term acceptance analyses.
    - Development and validation of methodological standards i.e. an empirical basis for evaluation procedures on the subject of renewable energies, landscape change and acceptance should take place.
    - Positive examples of RE projects with added value for nature conservation and landscape planning need to be analysed, evaluated and compiled into a collection of best-practice examples. Evaluation of the effectiveness of public relations work (especially new media) and acceptance-enhancing measures for the (re)design of RE projects must be carried out.

5 Bibliography

Agentur für Erneuerbare Energien (AEE) (2014): Metaanalyse vergleicht Prognosen zum Energieverbrauch in Deutschland. (https://www.unendlich-viel-energie.de/metaanalyse-vergleicht-prognosen-zum-energieverbrauch-in-deutschland, retrieved 13 June 2018)

Behr, Oliver et al. (2015). Reduktion des Kollisionsrisikos von Fledermäusen an Onshore-Windenergieanlagen (RENEBAT II). Umwelt und Raum Bd. 7, 368 S., Institut für Umweltplanung, Hannover.

Brinkmann et al. (2018): Unveröffentlichte Ergebnisse aus dem F+E-Vorhaben am Bundesamt für Naturschutz „Berücksichtigung von Artenschutzbelangen bei der Errichtung von KWEA II (in Süddeutschland)". FKZ 3517 86 0600.

Bundesanstalt für Landwirtschaft und Ernährung (BLE) (2017): Evaluations- und Erfahrungsbericht für das Jahr 2016. Biomassestrom-Nachhaltigkeitsverordnung, Biomassekraftstoff-Nachhaltigkeitsverordnung. Bonn.

Bundesamt für Naturschutz (BfN) (2015): Artenschutz-Report 2015. Tiere und Pflanzen in Deutschland. Bonn.

Bundesamt für Naturschutz (BfN) (2016): Daten zur Natur 2016. Bonn - Bad Godesberg.

Bundesinstitut für Bau-, Stadt- und Raumforschung (BBSR) (Hrsg.) (2015): Steuerung der Windenergie durch die Regionalplanung – gestern, heute, morgen. In: BBSR-Analysen KOMPAKT 09/2015. Bonn.

Bundesministerium für Umwelt, Naturschutz und Reaktorsicherheit (BMU) (2007): Nationale Strategie zur Biologischen Vielfalt. Berlin. Bonn.

Bundesministerium für Umwelt, Naturschutz, Bau und Reaktorsicherheit (BMUB) (2016): Klimaschutzplan 2050. Klimaschutzpolitische Grundsätze und Ziele der Bundesregierung. Berlin.

Bundesministerium für Umwelt, Naturschutz und nukleare Sicherheit und Bundesamt für Naturschutz / BMU & BfN (2018): Naturbewusstsein 2017. Bevölkerungsumfrage zu Natur und biologischer Vielfalt. Berlin und Bonn.

Bundesministerium für Wirtschaft und Energie (BMWI) (2018): Zeitreihen zur Entwicklung der Erneuerbaren Energien in Deutschland unter Verwendung von Daten der Arbeitsgruppe Erneuerbare Energien-Statistik (AGEE-STAT). Stand Februar 2018.

Bundesministerium für Wirtschaft und Energie (BMWI) (2017): Langfristszenarien für die Transformation des Energiesystems in Deutschland. Modul 0: Zentrale Ergebnisse und Schlussfolgerungen. Studie im Auftrag des Bundesministeriums für Wirtschaft und Energie. Karlsruhe, Aachen, Heidelberg.

Bundesregierung (2010): Energiekonzept für eine umweltschonende, zuverlässige und bezahlbare Energieversorgung. Berlin.

Bundesverband Windenergie (BWE) (2018): Themen – Technik. Technische Entwicklung. (https://www.wind-energie.de/themen/technikanlagen)

CDU, CSU und SPD (2018): Ein neuer Aufbruch für Europa. Eine neue Dynamik für Deutschland. Ein neuer Zusammenhalt für unser Land. Koalitionsvertrag zwischen CDU, CSU und SPD. Berlin.

Daniel-Gromke, Jaqueline et al. (2017): Anlagenbestand Biogas und Biomethan – Biogaserzeugung und -nutzung in Deutschland. DBFZ Report Nr. 30. Leipzig.

Deutsche Windguard (2018): Status des Windenergieausbaus an Land in Deutschland.

DLR, Fraunhofer IWES, IFNE (2012): Langfristszenarien und Strategien für den Ausbau der erneuerbaren Energien in Deutschland bei der Berücksichtigung der Entwicklung in Europa und global. Schlussbericht BMU-FKZ 03MAP146.

Dürr, Tobias (2018): Vogelverluste an Windenergieanlagen. Daten aus der zentralen Fundkartei der Staatlichen Vogelschutzwarte Brandenburg im Landesamt für Umwelt Brandenburg. (http://www.lugv.brandenburg.de/cms/media.php/lbm1.a.3310.de/wka_voegel_de.xls)

Dürr, Tobias (2018a): Fledermausverluste an Windenergieanlagen. Daten aus der zentralen Fundkartei der Staatlichen Vogelschutzwarte Brandenburg im Landesamt für Umwelt Brandenburg.
(https://lfu.brandenburg.de/cms/media.php/lbm1.a.3310.de/wka_fmaus_de.xls, abgerufen am 11.04.2018)

Enkhardt, Sandra (2018): Tübingen führt Photovoltaik-Pflicht ein. In: PV-Magazin. (https://www.pv-magazine.de/2018/07/05/tuebingen-fuehrt-photovoltaik-pflicht-ein/, retrieved 31 July 2018)

European Energy Agency (EEA) (2015): State of nature in the EU. Results from reporting under the nature directives 2007–2012. Luxembourg.

Fachagentur Nachwachsende Rohstoffe (FNR) (2017): Massebezogener Substrateinsatz in Biogasanlagen. (https://mediathek.fnr.de/grafiken/daten-und-fakten/bioenergie/biogas/massebezogener-substrateinsatz-in-biogasanlagen.html, retrieved 12 April 2018)

Fachagentur Nachwachsende Rohstoffe (FNR) (2017a): Massebezogener Substrateinsatz Nachwachsender Rohstoffe in Biogasanlagen 2015. (https://mediathek.fnr.de/grafiken/daten-und-fakten/bioenergie/biogas/massebezogener-substrateinsatz-nachwachsender-rohstoffe-in-biogasanlagen.html, retrieved 12 April 2018)

Fachagentur Nachwachsende Rohstoffe (FNR) (2018): Anbau nachwachsender Rohstoffe in Deutschland. (https://mediathek.fnr.de/grafiken/daten-und-fakten/anbau/anbauflache-fur-nachwachsende-rohstoffe.html, retrieved 9 April 2018)

Fachagentur Windenergie an Land (FAW) (2018): Entwicklung der Windenergie im Wald. Ausbau, planerische Vorgaben und Empfehlungen für Windenergiestandorte auf Waldflächen in den Bundesländern. Berlin.

Finck, Peter et al. (2017): Rote Liste der gefährdeten Biotoptypen in Deutschland. Dritte fortgeschriebene Fassung 2017.

Gehrlein, Ulrich et al. (2017): Nationale Naturlandschaften (NNL) und erneuerbare Energien. Gesamtbericht zum gleichnamigen F+E-Vorhaben. Band 1. BfN-Skript 482, Bonn - Bad Godesberg.

Gehrlein, Ulrich et al. (2017a): Nationale Naturlandschaften (NNL) und erneuerbare Energien. Gesamtbericht zum gleichnamigen F+E-Vorhaben. Band 2. BfN-Skript 483, Bonn - Bad Godesberg.

Haaren, Christina v. et al. (2018): Naturverträgliche Energieversorgung aus 100 % erneuerbaren Energien 2050. BfN-Skript 501, Bonn - Bad Godesberg.

Hübner, G., Pohl, J. (2015): Mehr Abstand – mehr Akzeptanz? Ein umweltpsychologischer Studienvergleich. Berlin.

Hurst, Johanna et al. (2016): Fledermäuse und Windkraft im Wald. – Naturschutz und Biologische Vielfalt 153, Bonn - Bad Godesberg.

Keuneke et al. (2015): Marktanalyse zur Vorbereitung von Ausschreibungen. Vorhaben IId, Wasserkraft. Im Auftrag des BMWI. (https://www.erneuerbare-energien.de/EE/Redaktion/DE/Downloads/bmwi_de/marktanalysen-studie-wasserkraft.pdf?__blob=publicationFile&v=4, retrieved 11 April 2018)

Länderarbeitsgemeinschaft der Vogelschutzwarten (LAG VSW) (2015): Abstandsempfehlungen für Windenergieanlagen zu bedeutsamen Vogellebensräumen sowie Brutplätzen ausgewählter Vogelarten (Stand April 2015).

Lenz, Volker et al. (2015): Effiziente Wärme aus Biomasse – Stand, Herausforderungen und Perspektiven (http://www.fvee.de/fileadmin/publikationen/Themenhefte/th2015/th2015_07_03.pdf, retrieved 12 July 2018)

Mengel, A. et al. (2018): Naturschutzrechtliche Steuerungspotenziale des Gebietsschutzes – Schwerpunkt Landschaftsschutzgebiete. Naturschutz und Biologische Vielfalt 166, Bonn - Bad Godesberg.

Ministerium für Umwelt, Gesundheit und Verbraucherschutz (MUGV Brandenburg) (2014): Leitfaden des Landes Brandenburg für Planung, Genehmigung und Betrieb von Windkraftanlagen im Wald. Potsdam.

Ministerium für Umwelt, Klima und Energiewirtschaft (UM) (2018): Welchen Flächenbedarf haben Windenergieanlagen? (https://um.baden-wuerttemberg.de/de/energie/erneuerbare-energien/windenergie/faq-windenergie/welchen-flaechenbedarf-haben-windenergieanlagen/, retrieved 5 April 2018)

Meschede, Angelika et al. (2017): Wanderrouten der Fledermäuse. BfN-Skript 453, Bonn - Bad Godesberg.

Ministeriums für Umwelt, Landwirtschaft, Ernährung, Weinbau und Forsten Rheinland-Pfalz (MULEFW) (2012): Naturschutzfachlicher Rahmen zum Ausbau der Windenergienutzung in Rheinland-Pfalz. Artenschutz (Vögel, Fledermäuse) und NATURA 2000-Gebiete.

Peters, Wolfgang et al. (2011): Naturschutzstandards Erneuerbarer Energien. Schlussbericht (http://www.naturschutzstandards-erneuerbarer-energien.de/index.php/infodatenbank, retrieved 14 May 2018)

Reich, Michael et al. (2018): Unveröffentlichte Ergebnisse aus dem F+E-Vorhaben am Bundesamt für Naturschutz „Naturschutzfachliche Fragen des Ausbaus der erneuerbaren Energien an überörtlichen Verkehrswegen und dessen Auswirkungen auf die Wiedervernetzung von Lebensräumen“. FKZ 3515 82 3300.

Riedl, Ulrich et al. (2018): Unveröffentlichte Ergebnisse aus dem F+E-Vorhaben am Bundesamt für Naturschutz „Szenarien für den Ausbau der erneuerbaren Energien aus Naturschutzsicht“. FKZ 3515 82 2900.

Schmidt, Catrin et al. (2011): Kulturlandschaften gestalten! Dresden.

Schmidt, Catrin et al. (2016): Monitoring Deutschland. (https://tu-dresden.de/bu/architektur/ila/lp/forschung/forschungsprojekte/abgeschlossene-forschungsprojekte/monitoring-kulturlandschaft-deutschland, retrieved 23 May 2018)

Schmidt, Catrin et al. (2018): Landschaftsbild und Energiewende. Ergebnisse des gleichnamigen Forschungsvorhabens FKZ 3515 82 3400 im Auftrag des Bundesamtes für Naturschutz. Band 1: Grundlagen. Dresden, Rottenburg (Neckar), Tübingen, Kassel.

Schmidt, Catrin et al. (2018a): Landschaftsbild und Energiewende. Ergebnisse des gleichnamigen Forschungsvorhabens FKZ 3515 82 3400 im Auftrag des Bundesamtes für Naturschutz. Band 2: Handlungsempfehlungen. Dresden, Rottenburg (Neckar), Tübingen, Kassel.

Schuler, Johannes et al. (2017): Kumulative Wirkungen des Ausbaus erneuerbarer Energien auf Natur und Landschaft. BfN-Skript 463, Bonn - Bad Godesberg.

Schliep, Rainer et al. (2017): Indikatorensystem zur Darstellung direkter und indirekter Auswirkungen des Klimawandels auf die biologische Vielfalt. BfN-Skript 470, Bonn - Bad Godesberg.

Thrän, Daniela et al. (2020): Naturschutzfachliches Monitoring des Ausbaus der erneuerbaren Energien im Strombereich und Entwicklung von Instrumenten zur Verminderung der Beeinträchtigung von Natur und Landschaft („EE-Monitor“). BfN-Skript 562, Bonn - Bad Godesberg.

Umweltbundesamt (UBA) (2017): Flächensparen – Boden und Landschaft erhalten. (https://www.umweltbundesamt.de/themen/boden-landwirtschaft/flaechensparen-boeden-landschaften-erhalten#textpart-1, retrieved 4 April 2018)

Walter, Anna et al. (2018): Naturverträgliche Energieversorgung aus 100 % erneuerbaren Energien 2050. BfN-Skript 501, Bonn - Bad Godesberg.

Willis, Katherine J. (Hrsg.) (2017): State of the World’s Plants 2017. Report. Royal Botanic Gardens, Kew.

Wulfert, Katrin et al. (2018): Arten und Gebietsschutz auf vorgelagerten Planungsebenen. BfN-Skript 507, Bonn - Bad Godesberg.

6 List of figures

7 List of tables

8 List of abbreviations

BauGB	Baugesetzbuch [Federal Building Code]
BfN	Bundesamt für Naturschutz [Federal Agency for Nature Conservation]
BNatSchG	Bundesnaturschutzgesetz [Federal Nature Conservation Act]
EEG	Erneuerbare-Energien-Gesetz [Renewable Energy Sources Act]
EEWärmeG	Erneuerbare-Energien-Wärmegesetz [Act to Promote Renewable Energy for Heating Purposes]
e.g.	for example
EIA	Environmental impact assessment
FFH	Flora Fauna Habitat
FKZ	Forschungskennzeichen [Research code number]
GMPV	Ground-mounted photovoltaic system
i.e.	in other words
IUCN	International Union for Conservation of Nature
LSG	Landscape conservation area
NBS	National Strategy on Biological Diversity
NSG	Naturschutzgebiet [Nature reserve]
RE	Renewable energies
R+D	Research and development
SEA	Strategic environmental assessment
SPA	Special Protection Area
UVPG	Gesetz über die Umweltverträglichkeitsprüfung [Federal Environmental Impact Assessment Act]
WT	Wind turbine