Danish Energy Agency

dena Deutsche Energie-Agentur

CNREC 国家可再生能源中心 CHINA NATIONAL RENEWABLE ENERGY CENTRE

Distributed Wind and PV in Denmark and Germany

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1. Introduction

Over the last decade, China has experienced a significant increase in electricity demand, which is expected to continue in the coming years. Consequently, it is necessary to ensure that the power generation meets such electricity demand while also doing it in an environmentally sustainable and cost-effective way as partly highlighted by the Beautiful China targets. At the same time, securing an independent and stable food source has prompted the government to reserve land for agriculture. In order to achieve optimal use of the land, it is necessary to consider land use policies that facilitate achievement of targets both for food and energy production.

In such a setting, distributed energy resources (i.e., distributed onshore wind and solar photovoltaic (PV)) have gained strategic importance in the Chinese context. Specifically, they consist of low carbon solutions which are able to exploit local wind and solar resources in a cost-effective manner. Moreover, as these technologies are characterised by a low footprint in terms of area occupied, they allow the optimal combination of land usage and installation of distributed wind and solar power. Furthermore, by occupying a limited area, such technologies can be installed in sites which are close to the load centres (i.e., cities and industrial hubs), minimising the need for investing in transmission line expansion, as well as transmission losses and bottlenecks.

In order to develop an optimal strategy for distributed energy sources, it is useful for China to look at the development of such distributed systems in a global scale. In particular, Denmark and Germany are often described as a pioneers and forerunners in renewable energy (RE) policy and development, and have gained valuable experience in the development of distributed wind power and PV projects during the last decades. Not only have both countries increased the share of RE while de-fossilising their power system, but they have achieved that so while ensuring extremely high levels of security of supply. Understanding th Danish and German approach to site selection, approval process and legislative framework will provide inspiration for the future development of these distributed RE in China.

This report describes the current regulations in Denmark and Germany for land use and planning and siting of RE facilities, especially distributed onshore wind and free-field PV systems. In the first section, the status of both onshore wind power and PV in both countries is presented. Afterwards, the planning and siting processes as well as the approval processes for onshore wind farms and free-field PV systems are explained. In this context, it is important to note that, while Denmark is ruled by country-level regulation, in Germany the regulations for land use differ across the federal states, which have the power to issue own rules. The most important differences are briefly presented in this report. Afterwards, the public participation processes are discussed. Finally, lessons learned for China based on the Danish and German experiences with planning and siting onshore wind power plants and free-field PV systems are suggested.

1.1. Current status of Chinese distributed onshore wind

Since 2011, the Chinese National Energy Administration (NEA) has published several policy documents to promote the development of distributed wind projects. Until 2016, there were only 4.000 MW of distributed wind power installation in the whole country. The quantity of distributed wind projects in China is still very small compared with large-scale applications in “Three-North” regions. As the size of distributed wind project is much smaller than large-scale applications, larger power investors do not have big interests in this market. However, the smaller ones lack experience and sufficient financial support to invest distributed wind projects. In addition, the approval process of small projects is the same as large ones, and the risks are not well handled during the process, which leads to higher cost per kW. Last, the pricing scheme in China does not reflect the benefits of distributed generation on reducing net load. The development of distributed wind still requires a lot of efforts both on improving the investment environment as well as on enhancing the regulating framework with a focus on project quality.

In China, the administration process of wind projects also needs a consultation from relevant departments in local governments. An approval of land use, Environmental Impact Assessments (EIA) report and grid connection approval are the key documents before the project can start the construction. However, the assessment procedure may vary from one municipality to another, and some of the evaluation procedures and regulations are not well defined. Due to the lack of coordination and conflicts of interests among different departments in the local governments, the approval process gets very difficult in some cases.

Property rights of different types of land are undergoing a transition period, especially for land in villages. It is uncertain for farmers to invest on wind turbines in the land they have the utility rights. Due to the food security, usage of farm land as well as farm land capacity are both critical. Multiple usage of farm land is restricted to few types of activities, such as PV on greenhouses can be invested without changing the type of land. However, there is not a policy that clarifies that wind projects can share the same right. Therefore, a lot of potentials remain to be discovered.

Compared with Denmark and Germany, the landscape in China is complicated and the size is much bigger. Such conditions make the environment impact evaluation conditions different from one project to another, and one province to another. As environment protection becomes a priority for local governments, some of them terminate onshore wind approvals (or with hard criteria) to reduce the load of work. Such cases imply that the current regulation system lacks mandatory and binding policies to encourage both the local government and investing companies to provide a better development environment for renewable industry.

2. Status of onshore wind power in Denmark

In the 1970s, import prices of oil in Denmark quadrupled overnight, street lights were turned off and car driving became forbidden on Sundays. To achieve energy security, Denmark decided to become a pioneer in wind power development, installing wind turbines onshore to achieve energy independence. Nevertheless, Denmark is also a farming land: 61% of Denmark's total area is cultivated, and the agricultural cluster contributes by 25% to the total Danish export of goods. Denmark was therefore forced to combine agriculture and wind, and has successfully done so since the 1970's. Denmark will continue investing in wind energy, and its current target is to become independent of fossil fuels by 2050, in line with the Paris agreement to reduce global warming.

Nowadays, Denmark is the country with the highest share of wind energy in electricity demand. In 2018, wind power covered around 41% of the Danish electricity consumption. Besides the highest penetration of intermittent energy resources in the energy system, Denmark boasts one of the highest levels of security of power supply in Europe. Furthermore, Danish wind energy has a curtailment rate which is close to zero. From an economic perspective, wind power sector consists of an essential contribution to the Danish economy, contributing to the export of wind turbines and wind energy technology all over the world. An overview of existing wind turbines in the country is presented in Figure 1.

Fact box

In 2018, wind power covered around 41% of the Danish electricity consumption, with onshore wind producing 9,20 TWh, and offshore wind producing 4,65 TWh approximately.

Fact box

Wind power production in Denmark increased by 30% from 2012 to 2018. Specifically, offshore wind power production increased from 2013 to 2018 by 7% (i.e., from 4,35 to 4,65 TWh).

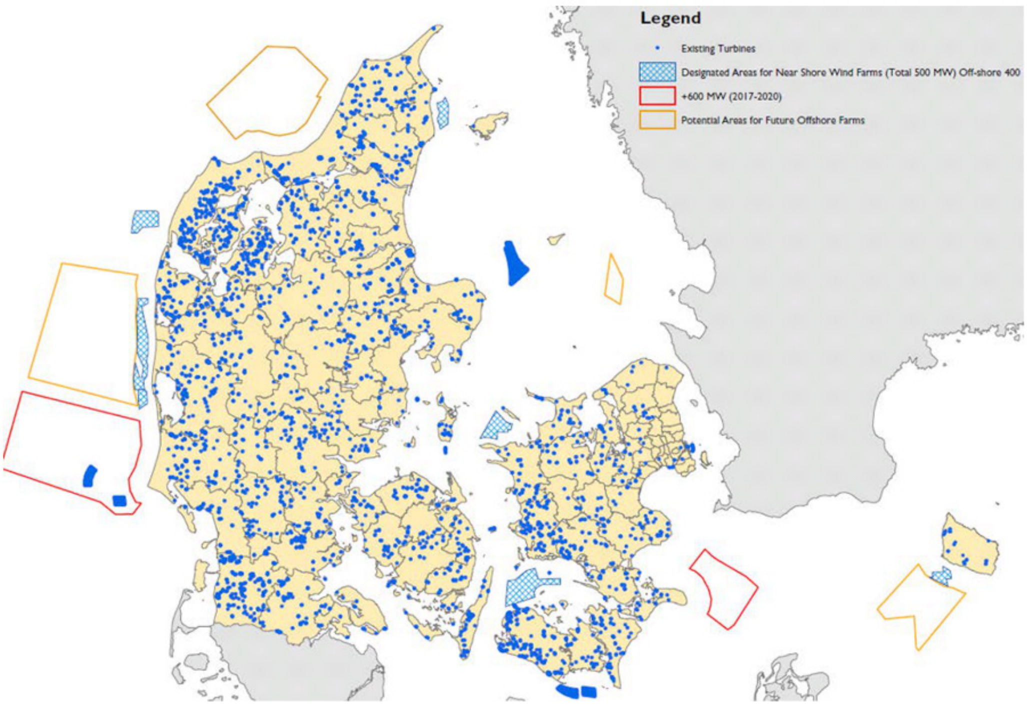

Figure 1: Onshore and offshore wind turbines in Denmark, 2017.

As an agricultural nation, farmland covers a significant area of Denmark. As such, a main concern is to ensure the safety and security of the national food production, and to achieve an expansion of the energy system that does not compromise or negatively affect farmland. As Figure 1 shows, wind turbines are distributed across the entirety of the Danish country. This distribution has proven very beneficial in minimising network constraints by siting turbines closer to demand areas, while providing valuable lessons in regards to the interaction between distributed wind and farmland. In particular, it has shown that the low area footprint of onshore wind turbines allows for power generation in farmland without compromising the security of agricultural production. As a matter of fact, there is an average of approximately 150 kW of installed wind capacity per km² in agricultural land.

In the future, Denmark expects that onshore wind energy will maintain its important role in the national energy portfolio. Consequently, the Danish Energy Agency (DEA), which is the main authority regarding administration and planning of the Danish energy system, investigated the overall potential of the Danish territory for future onshore wind power placement, by analysing which areas are affected by restrictions in that matter.

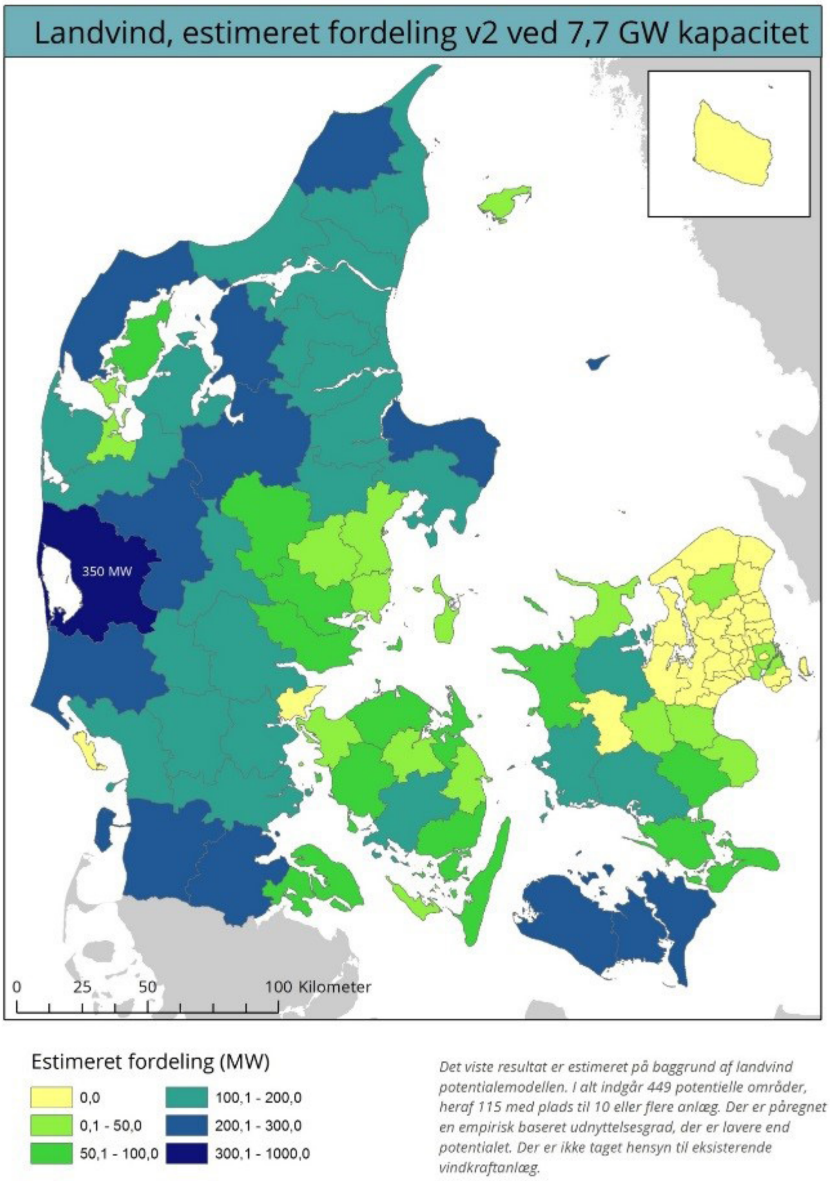

Figure 2: Scenarios of the future wind power capacity in Denmark.

To assess the future role of onshore wind power in Denmark, the DEA also carried out several scenarios of the onshore wind power capacity. From such studies, it emerged that, by assuming a relatively small smaller utilisation rate (i.e., number of annual full load hours) in the scenario modelling, the potential wind power capacity may reach 7,7 GW. However, if the number of installations set in all geographical areas is maximised, the potential capacity of onshore wind power in Denmark is expected to grow to 8 GW. It is important to keep in mind that the Chinese potential for onshore wind is close to 1700 GW, over 200 times greater. In Figure 2, the results of such scenarios are provided showing the different wind power capacity potential in different regions in Denmark.

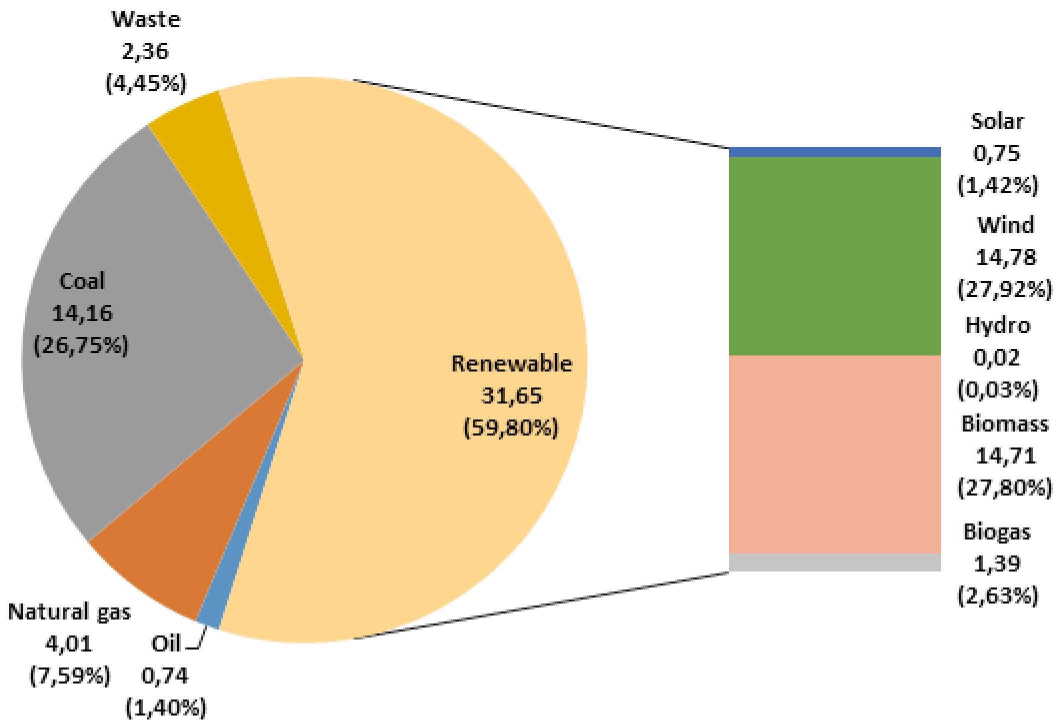

Figure 3: Share of fuel consumption for electricity production in Denmark in 2017 in TWh.

3. Status of onshore wind power and PV in Germany

In 2018, wind power contributed to around 17,3% of the German gross power production, with onshore wind producing 92,2 TWh (14,3%) and offshore wind producing 19,3 TWh (3%), as it can be seen in Figure 4. Onshore wind has currently the highest share in the electricity production among other RE. Wind energy is the second biggest source of electricity in Germany after lignite and ahead of hard coal and nuclear energy.

In 2018, Germany installed 2,402 MW of onshore wind capacity. 743 new wind turbines were erected. Compared to the record year of 2017, this represents a decline of around 55. Considering the dismantling of a combined capacity of 249 MW (205 wind turbines), the resulting net installed capacity in 2018 was 2,154 MW. With those additions, the recorded cumulative capacity of onshore wind increased to almost 53 GW by December, 31 2018.

In 2018, a part of the dismantled wind turbines was replaced by 111 wind turbines with an overall capacity of 363 MW (see Figure 5). Even though the repowering capacity dropped in comparison to the previous year, the repowering share of the gross additions was higher.

Fact box

Wind power production in Germany increased by 4% from 2017 to 2018, producing a total of 89,5 TWh of eletricity. The repowered capacity in 2018 has been of 0,36 GW. Additionally, the recorded cumulative capacity of onshore wind increased to almost 53 GW by December, 31 2018.

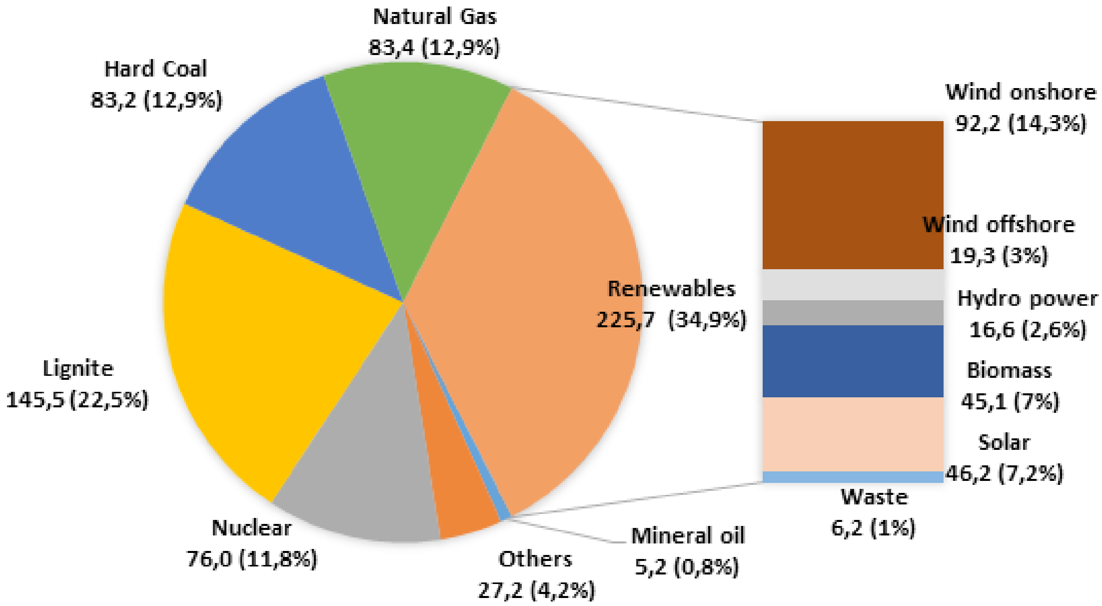

Figure 4: Share of energy sources in gross German electricity production in 2018 in TWh.

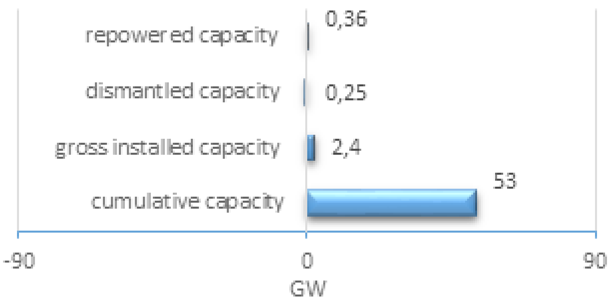

Figure 5: Onshore wind capacity in Germany in 2018 in GW.

Due to many different influence factors such as land and wind resource availability as well as different regional regulations for planning and siting of wind turbines, the distribution of installed and planned wind turbines differs across the federal states in Germany. In 2018, Lower Saxony had the largest gross additions, the largest newly and cumulative installed capacities and consequently the largest number of new and all installed wind turbines. North Rhine-Westphalia (NRW) and Brandenburg saw large volumes of additional installations in 2018. Berlin, Bremen and Hamburg were among those states with the lowest number of new wind turbine installations as well as the lowest cumulative capacity due to their mostly urban structure and not much opportunities to site wind turbines. Schleswig-Holstein was the state with the largest total portfolio of wind turbines in relation to the land area and with the second largest cumulative capacity after Lower Saxony.

When looking at PV, it can be seen that by the end of 2018 around 1,7 million PV systems were installed with a cumulative capacity of 45,4 GWp. That accounted for about 9% of the cumulative PV capacity installed worldwide (515 GWp). PV was the second largest source of renewable electricity behind onshore and offshore wind. In Germany, PV was the second largest source of renewable electricity behind onshore wind energy in 2017. Whereas roof-mounted PV systems have been generally the most common PV deployment form, the number of free-field PV systems is increasing as well. Those systems are usually medium to large-scale operated by commercial and institutional investors. This report focuses on the land use aspects of free-field PV systems, because systems mounted on private roofs do not cause any effects on land use. The information on status of PV in Germany below includes, however, both free-field and roof-mounted systems, because the most relevant statistics do not state different forms of PV construction separately.

In 2017, the newly installed capacity in Germany was about 1,75 GWp and therefore did not reach the annual national target. In 2018, 2,81 GWp of new PV capacity was added, which was more than the yearly growth corridor. In the same year, the federal government decided to reduce the annual target from 2,5 GW to 1,9 GW, which came into effect in the beginning of 2019. In accordance with the annual target, the amount of capacity to be awarded through auctions is 600 MW per year. In addition, for the years 2019 to 2021, a further 4 GW in total will be awarded through special tenders. However, in order to meet the target formulated in the government coalition agreement in March 2018 to reach the share of 65% RE in the gross electricity consumption, a higher PV growth is needed, about 5 GW to 10 GW per year.

4. Planning and siting of wind turbines in Denmark

One of the main factors that has allowed the successful development of wind energy in Denmark, particularly in a cost-efficient manner, has been the planning approach towards the development of wind farms. In this section, we provide an overview of the best practices and regulation associated to the planning process and siting of wind turbines in Denmark, particularly when considering the interaction between distributed wind and agricultural land.

4.1. Wind resources mapping

When dealing with wind power technology, the local availability of wind resources must be understood and quantified. In fact, having solid knowledge of the local wind availability can have a significant impact on the decisions related to the sizes and location of wind farm projects. For this reason, the assessment of wind resources has been the base of the planning process in Denmark.

Since the 1980s, wind resource mapping has been developed and included in the wind power planning both at national and municipal levels; since 1999, the Danish wind resources have been identified and reported in a wind atlas, now expanded to a global wind atlas available at https://globalwindatlas.info/. The project was carried out originally by the Technical University of Denmark, and continues today with support from the World Bank Group. The wind atlas can be used in the planning process to assess the wind resource potential in a given area. Moreover, it can be used to identify potential wind development zones in line with the strategic environmental framework or assessments studies. By providing wind speed predictions with known and traceable accuracy, the wind atlas is also useful to developers during the calculation of the potential yield of wind energy resources. Finally, it facilitates the Transmission System Operator (TSO) when handling variable wind resources and providing input data used in long-term grid planning. An example of the wind atlas of Denmark is provided in Figure 6.

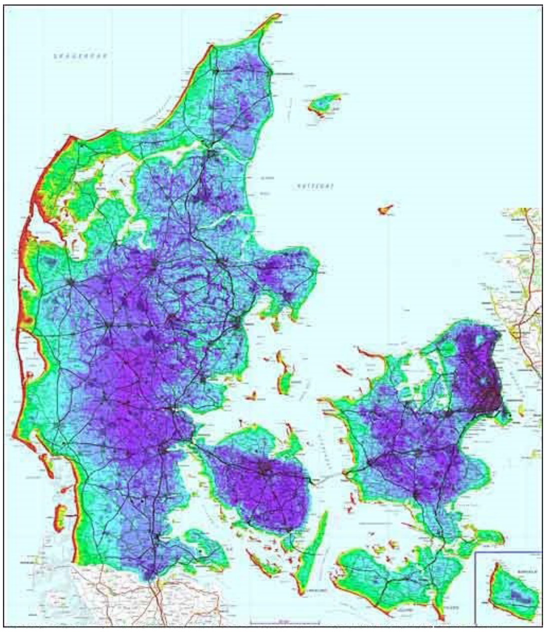

Figure 6: Wind atlas of Denmark.

4.2 Siting of wind turbines

Once the wind resource level is assessed and mapped, it is possible to look into the land use and definition of which areas in Denmark are suitable for the development of wind. The first macro-level planning is focused mainly on ensuring that wind turbines are built in areas that maximise available wind, while minimising the required grid expansion and reinforcements due to distance to demand centres and/or existing grid installations. Consequently, in Denmark the concentration of wind turbines is higher in the western part of the country and in the coastal regions, where wind is ample.

Municipal wind turbine planning is key to balance different land use interests when siting wind power onshore. Municipalities must take into account the planning of wind turbine locations - hence, consider access and designate areas suitable for wind turbines through municipal planning while ensuring that full consideration is given to neighbouring residences, nature, landscape, culture-historical values, etc. Such considerations must also be included into the municipal plan. The Danish landscape is divided into urban-zones and land-zones and any development in the land-zone including wind turbines needs a special land-zone permission.

Private and agricultural land

Few restrictions apply to siting wind turbines on private land, e.g., onshore wind turbines can be built in private land with a minimum distance to private owned forests of 300 m. Nevertheless, it is possible to site onshore wind turbines in private land, depending on the agreements between wind turbine owner/developer and the landowner. Moreover, contracts for renting the land are very common in Denmark. This means that often wind turbines are placed in farms, where it is possible to take advantage of the small footprint of wind turbines to generate power without compromising food production, as shown for example in Figure 7.

Figure 7: Distributed wind in farmland in Denmark (cc). Pablo Hevia-Koch

In order to facilitate the planning of wind turbines in Denmark, several tools and guidelines have been made available. The Danish Nature Agency (DNA) provided a guideline containing an overview of the process for the identification of new areas for wind turbines and a draft decree related to wind turbines planning. Although these guidelines are mainly supposed for municipal planners, they are publicly available and can be useful for interested citizens to understand how authorities work in wind turbine planning.

Moreover, in 2013, a joint initiative by the DEA, the Environmental Protection Agency (EPA), the Danish Nature Agency, the national TSO Energinet and the Transport Authority produced a web platform – Wind-Info. www.vindinfo.dk to compile information on wind turbines from all the relevant national authorities' websites to citizens, municipalities and wind turbine developers.

When looking at more specific micro-siting of new wind turbines, various factors and restrictions must be considered, such as wind speed, distance to the nearest neighbours, noise and shadow effects. Factors can also include cultural heritage, presence of other technical installations, agriculture, sailing, fishing as well as landscape and nature.

4.2.1. Distance requirements overview

According to the Nature Conservation Act, no changes can be made to the areas covered by dune dredging and under beach protection; in other words, no onshore wind turbines can be built in those areas. The law restricts the placement of onshore wind turbines to 300 m behind the shore. Protection lines are fixed and registered in the cadastral register and reported in the land register of the individual property. Protection lines may be defined close to the coast on a number of lines, where there are urban buildings. According to the Nature Protection Act, changes in landscape (such as installing wind turbines) cannot be done in proximity of lakes and the placement of wind turbines is forbidden within conservation areas, nature protection areas, forests, national heritage, gravel mining sites and airport safety zones.

Criteria related to existing infrastructures	Criteria related to nature conservation
• Private / agricultural land • Coastal zones • Air traffic • Sailing and fishing • Cultural heritage zones • Churches • Safety zones • Gravel mining sites • Overhead transmission lines / underg-round electricity cable / gas pipeline • Radio corridors • Road highways • Other technical installations	• Nature conservation • Forests • Breeding birds • Specific bird species • Protected landscape areas • Protected flora-fauna-habitat areas • Streams of water

Table 1: Designation criteria for wind turbines.

Special consideration must be given to the coastal zone, which is defined in the Danish Planning Act as a three-kilometre zone inwards from the coastline. If a municipality intends to install wind turbines onshore in the coastal zone, special planning and functional justification are required (such as exceptional favourable wind conditions along the municipality's coastline).

General minimum distance requirements are defined for certain land use interests which are summarised in Table 2.

Land interest use	Distance required
Shore	300 m
Lakes	150 m
Churches	300 m
Radio corridors	200 m
Overhead transmission lines	1 times the total height of the turbine plus 15 m to nearest phase
Underground electricity cable	50 m
Gas pipeline	2 times the total height of the turbine
Roads-highways-railroads	1-1,7 times the total height of the turbine
Residential buildings	4 times the total height of the turbine

Table 2: Distance required for wind turbine installation.

4.2.2. Visual impact guidelines

The Danish experience has shown that any location designated for the placement of wind turbines requires customized planning including tailored wind farm patterns.

In order to minimise the environmental impact of wind power, large and uniform landscapes are usually suitable for large wind turbines. Such landscapes can match the large dimensions of the turbines as they are characterised by flat or evenly sloping terrain with large and open spaces. Small-scale landscapes are generally less suitable for large wind turbines. These landscapes are characterised by small hills or gentle slopes with smaller and more confined spaces. In such areas, large wind turbines would dominate and have a high impact on the character of the landscape. Moreover, wind turbines shall not be placed within or close to vulnerable natural environments.

Furthermore, the specific placement of wind turbines should be completed in line with existing guidelines. Particularly, onshore turbines should be placed in groups uniformly and should be easy to recognise in relation to the landscape. For example, wind turbines usually lie in single straight lines with an even distance between each other. Furthermore, each group of turbines should have a distance of minimum 28 times the height of turbines. In order for groups of turbines to be placed closer, an assessment is required to document that the combined visual impact by the two groups is acceptable.

Aviation is handled as a special concern. All significant obstacles to aviation should be visible at an appropriate distance, allowing pilots to perform the necessary operational measures in due time. Therefore, airspace needs adequate marking and lightning and distance requirements, which are specified in the Regulations for Civil Aviation BL 3-11.

4.2.3. Noise and shadow effects

The location of new wind turbines must generally respect a distance from the nearest neighbours, which is at a minimum of 4 times the total height of the wind turbine. Such a distance reflects the visual impact of the wind turbines, and is normally sufficient to comply with noise and flicker effects regulation.

Wind turbines must comply with noise limits, which are part of a statutory order. The noise level must not exceed 44 dB (a) at any dwelling at 8 m/s wind velocity and 42 dB (a) at 6 m/s. These noise limits are to be kept out doors at a maximum distance of 15 m. from the dwelling. In housing areas and noise sensitive recreational areas e.g. camping sites, more restrictive noise levels are required. Furthermore, in 2012, an additional limit for the low frequency noise indoors was added of 20 dB at 6 and 8 m/s. The developer must demonstrate that such limits are met before wind turbines are set up.

After the installation of turbines, the owner must cover the cost for undertaking noise measurements and calculations, if demanded by the authorities. Noise levels are calculated based on the measured noise emission from the wind turbine and the distance to the dwellings and recreational areas. The measurement procedure and calculation method are part of the statutory order.

Finally, Denmark provides guidance to limit the impact of flickering for wind power. Shadow flicker is the effect caused by rotating turbines blades when brightness varies periodically at locations where solar rays are obscured, which can cause annoyance at residents located close to wind turbines. The Ministry of Environment recommends that the real case impact of shadow flicker on dwellings should not exceed 10 hours per year: if due to siting 10 hours of flickering are exceeded, an automatic control system shall be installed to limit the impact. The use of computer models can accurately predict the extent of shadow effects in the neighbouring areas and facilitate planning, as shown in Figure 8.

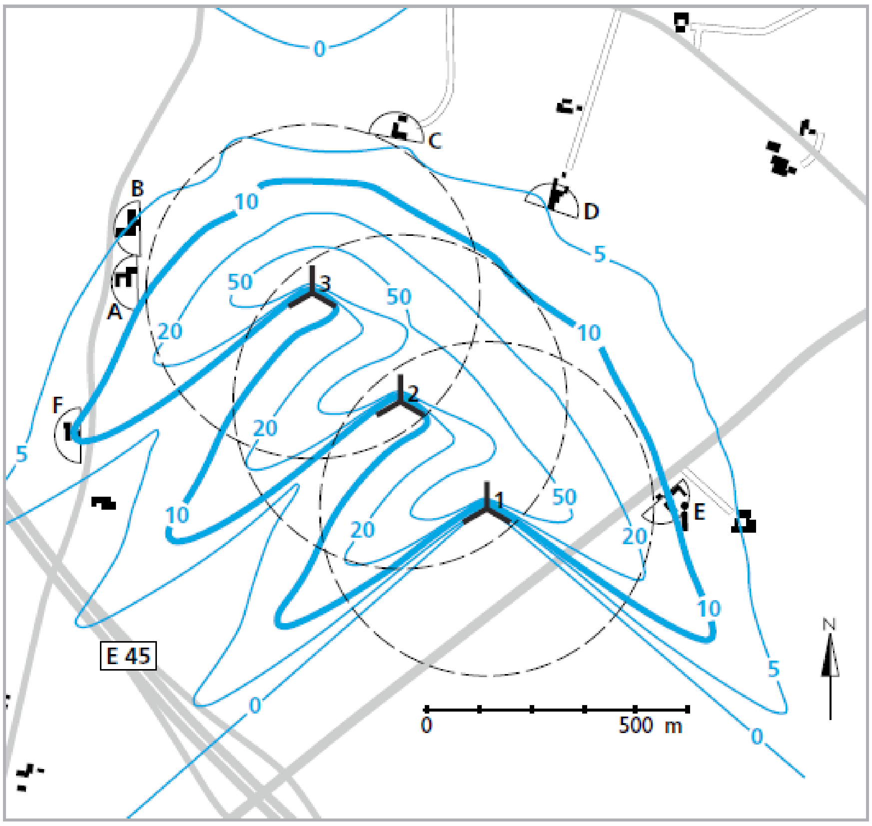

Figure 8: Isolines for shadow periods for 0.5. 10, 20 and 50 hours per year.

4.3. Environmental Impact Assessment

The Environmental Impact Assessment consists of an assessment required before decisions that can affect the environment are made. It provides an overview of the consequences of a certain proposed project. This also applies to the placement and replacement of wind turbines. The EIA operates with a broad environmental concept, including traditional pollution parameters, impact on nature protection areas, landscape and cultural heritage etc. The EIA process includes consultations with relevant authorities, i.e., neighbouring municipalities, region (county) and national bodies. These entities have to grant environmental approvals to allow implementation of the physical planning. Furthermore, local and regional supply companies shall be involved as their installations may be affected by the project.

In addition, the EIA is drafted in collaboration with the project developer and must be approved or rejected by the Municipality. Furthermore, the EIA provides realistic computer visualisations of the project from key points and at varying distances. Such computer visualisations are supposed to facilitate citizens in understanding the implications wind turbine projects on the landscape. Aiming to increase transparency and to streamline the process, the requirements for the process and contents of such an EIA are clearly defined in the Danish legislation.

Figure 9: Distributed wind in forest area in Torup, Denmark (cc). Øyvind Holmstad

4.4. Connection and integration to the grid

In Denmark, onshore wind turbines are connected to the power system by the local grid company or the TSO. To this matter, the local grid company assigns the connecting point to the grid and the voltage level. In addition, the grid company or the TSO cover the costs related to the expansion and strengthening of the grid. Finally, they establish grid connections up to the connection point on the boundary of specifically designated wind area laid out in the municipality plan. There must be sufficient certainty for the provision of wind turbines, with a total installed capacity of at least 1,5 MW.

The developer provides adequate security, such as a bank guarantee or equivalent collateral, and pays for the connection costs. Connection costs only include: wind turbine installation, low-voltage connection, low-voltage socket, the establishment of a local wind turbine transformer including meter, power cord to the power grid, grid connection including power factor correction, and the costs of the collective electricity supply company processing the request for grid connection. The costs related to power factor correction for uncompensated reactive power consumption are financed by the grid company or TSO and eventually paid by electricity consumers.

In order to achieve reliable penetration of wind power in the power system, new wind turbines must be successfully integrated into the existing grid infrastructure. Furthermore, new wind turbines must demonstrate to operate safely. To this matter, in Denmark all new turbines have to comply with the Danish Wind Turbine Certification Scheme (DWTCS). A Secretariat for such a scheme was set up and located at the Danish National Laboratory for Sustainable Energy, at the Technical University of Denmark (DTU).

An overview of the relevant authorities and principles ruling siting of wind turbines is presented in Table 3.

	Authority, principles and refereences
General planning	Danish Business Authority (DBA) and Municipalities
Natural reserve areas	Danish Nature Agency (DNA) as part of Ministry of Environment and Food (MEF)
Residential building	Four times the height of the wind turbine at wing tip
Noise	MEF and Environmental Protection Agency (EPA)
Shadow effect	DBA
Roads and railways	DBA and Ministry of Transport, Buildings and Housing (MTBH)
Airspace	Regulations for Civil Aviation BL 3-11, 2nd Edition of 2014, MTBH
Farm land	Municipalities and local development plans, DBA
Private land	Municipalities and local development plans, DBA
Government-owned land	Municipalities and Government Entities e.g. DNA Ministry of Defence
Recreational activities	Regulated accordingly like natural reserve areas and with regard to noise. DBA anf MEF

Table 3: Overview of requirements and authorities guiding siting of wind turbines.

4.5. Approval process for onshore wind farms

For projects regarding wind turbines lower than 150 m, the Municipalities are responsible for the planning. In case that wind turbines are higher than 150 m, the DNA needs to approve the placement location and an assessment toward aviation must be carried out in order to evaluate the potential visual impact on the surroundings. The Ministry of Environment handles the applications for infrastructural activities which have a potential impact on the substantial environmental. To this matter, the procedure is similar to the projects approved by municipalities, including public consultation and providing an EIA.

The process line for the project proposal is illustrated in Figure 10. First, the developer applies to the municipality by sending a draft plan. Afterwards, the municipality undertakes a public consultation of the draft plan for at least 2 weeks. The municipality is responsible for the EIA process and EIA report. However, the drafting of the EIA is often carried out in close collaboration with the project developer. Once the EIA is completed, it is sent in public consultation for at least 8 weeks. The EIA is then approved or rejected by the municipality. In case the project is approved, the wind turbines must be registered at the municipalities together with the noise-related documentation. Moreover, it must apply for a construction permit. Finally, the commissioning can take place.

4.6. Public acceptance schemes and possibility of profit sharing in Denmark

In order to facilitate the development and penetration of wind power, public perception of wind energy must also be taken into account in the planning. From the Danish case, population has been and still is at large positive towards the increasing use of wind power.

Public acceptance toward wind power in Denmark is the result of several actions to involve population in wind energy projects. During the 1980s and 1990s, many small investors were financially engaged in wind power. Such an engagement ensured local buy-in and a high degree of public acceptance.

Public acceptance is also achieved by involving several stakeholders in the planning process. They include national and local planning authorities, energy regulators, developers, grid operators and NGOs. Public participation in the decision making process led to a better public appreciation and higher accept rate. Specifically, public participation was achieved through public consultation procedures and meetings. In addition, the available administrative appeal procedures consist of an additional tool for the civil society to test a case in front of an appeal board, prior to the normal judicial possibilities through the courts.

In 2009, different schemes were introduced in Denmark to promote local population's acceptance and involvement in onshore wind power development. Such schemes are briefly summarised in the following section.

Option for shares

The first scheme concerns local citizens' option to purchase wind turbine shares, allowing local citizens to purchase a minimum of 20% of the wind project. The developer must advertise locally shares equal to the minimum 20% of project value (cost price). Any citizen who is at least 18 years old and live up to 4,5 km from new turbines is eligible to the shares and has priority entitlement to buy into local projects. A shareholder share revenues, risks and costs on an equal footing with the developer. Remaining shares that were not bought by citizens within 4,5 km radius are offered to permanent residents in the rest of the municipality.

Support for cooperatives

The second scheme intends to support local wind turbine cooperatives with preliminary investigations for new wind power projects, by providing loan guarantees: in case of project failure, the loan is reimbursed. Specifically, a dedicated fund provides a guarantee up to

500.000 DKK (approx. 500.000 RMB) for each project to undertake preliminary investigations, i.e., feasibility studies on technical and economic assessment of wind turbine locations as well as preparation of applications for authorities and EIAs. Eligible projects must consist of at least 10 participants, whose majority must have a permanent residence within a radius of 4,5 km from the planned wind or be permanent residents in the municipality.

Loss of value compensation

The third scheme refers to the compensation for loss of value to neighbouring real estate due to new wind turbines. The loss-of-value scheme gives eligible neighbours of new wind turbines compensation for value loss on their property. If a property is assessed to lose more than 1% of its real estate value as a result of the installation of new wind turbines, the developer is obliged to pay for such loss of value. The loss of value is determined by an impartial valuation authority.

The developer is required to visualise the project and prepare the relevant material with the view to inform concerned citizens at a public consultation meeting no later than 4 weeks before the municipal planning process ends. The TSO approves the announcement material to be used in conjunction with the meeting and explains at the meeting about the scheme. The owner of the property must notify their claim of loss of value on their property. For those having real estate further away than 6 times the total height of the turbine a 4.000 DKK fee (approx. 4.000 RMB) must be paid – subject to be refunded if the claim is found eligible. In the period from 2009 to 2012, around half of the claims made were found eligible to receive compensation while the other half were rejected or lapsed.

5. Planning and siting of onshore wind turbines in Germany

5.1. Spatial planning in the federal states, districts and municipalities

Designation criteria

In Germany, federal states and local governments/municipalities are responsible for creating guidelines or requirements determining wind turbines siting. They designate in their regional and land use plans the areas of suitability for wind power plants. Usually those locations encompass agricultural and forestry areas. At the moment, around 2% of the German territory are available for wind power plants.

In this process, different designation criteria have to be taken into account. It can be differentiated between the “exclusion” or “hard/restrictive” criteria and “soft” criteria. The hard criteria are anchored in the respective federal and state-level laws, executive orders, wind decrees (state-level) and recommendations, which altogether provide guidelines for the designation of wind energy areas by the federal states and municipalities (see also section 5.2 “Legal framework and approval process”). Soft criteria are in the discretion of the district planning authorities.

The following criteria need to be taken into account by designation of possible locations for wind power plants in the federal states and municipalities:

Criteria related to existing infrastructures	Criteria related to nature conservative
• Residential areas / individual houses	• Nature conservation
• Industrial areas	• Forests
• Directional radio lines	• Breeding birds
• High-voltage lines	• Specific bird species
• Traffic routes	• Protected landscape
• Air traffic	• Protected flora-fauna-habitat areas
	• Streams of water

Table 4: Designation criteria for wind turbines.

Due to the regionally different natural conditions and land use patterns, the laws and wind decrees of the individual federal states include different specifications concerning different designation criteria for wind power plants and their binding effect. In some federal states, which have only a small proportion of forest compared to the total land area, forest areas are classified as an exclusion criterion. In contrast, in federal states, which have a high proportion of forest, forest sites are included in the land use planning for wind power plants. There exist also differences between federal states concerning whether nature parks, protected areas, development zones of biosphere reservation or certain Natura 2000-sites are available or excluded as wind energy sites.

Options for the designation of possible locations

Overall, there are currently several options for the designation of possible locations for wind turbines. In the first step, areas of suitability for wind power plants are designated on the level of regional planning in the federal states. The sites can be designated as one of the following:

- priority sites,
- reserved sites,
- suitable sites,
- exclusion sites,

On priority sites, wind energy should be given precedence over other spatial uses and no use should be made that opposes the use of wind energy. Reserved sites are areas in which wind energy is to be given particular weight when compared to competing spatially significant uses. Suitable sites are areas in which wind turbines do not conflict with other space-relevant interests, whereby their construction is excluded elsewhere in the planning area. In the exclusion sites, location of wind turbines is not allowed.

The municipalities have the opportunity to concretize the identified wind energy areas within the scope of the regional planning or to identify larger areas (concentration zones) on the level of land use (or zoning) planning. For example, Mecklenburg-Vorpommern designates suitable sites for wind power plants and the municipalities can only concretize the locations within these areas. Baden-Württemberg designates priority areas for wind power plants, which means that their location is also possible outside of the priority areas, e.g., in the nature protection areas. This option for designation of wind power plants locations may lead to conflicts between project development and other spatially significant interests, such as planning of residential and industrial areas. From a nature protection and conservation point of view, the designation of exclusion sites is to be preferred, because they do not leave any legal scope for the possibility of setting up wind power plants in areas with relevance for nature protection and conservation.

Both the regional planning targets as well as targets mentioned within the zoning plan have to be adapted in the urban land use planning and local development plans.

5.2. Legal framework and approval process

Planning process from the perspective of a project developer

The planning and installation of wind power plants is complex and takes on approximately 4 to 5 years. At the beginning, suitable locations are analysed, based on a series of considerations, such as: regional and land use plans of the federal states and municipalities, wind conditions, availability of the grid connection, distances to residential areas and other infrastructural and natural elements according to the requirements of the federal state, nature protection and conservation aspects (e.g. existence of protected species in the planning area) or any other issues that may be hindering to the construction of wind power plants.

If a suitable location is identified, the implementation of the project begins. It consists of approval process including application for a building permit by the local building authority, preparation of the required expert opinions, such as environmental impact assessment and noise measurement surveys, public consultation, clarification of the ownership conditions (e.g. land lease agreements), financial planning, selection of the suitable plant type and access routes.

Another important step is the application for the grid connection by the responsible grid operator and clarification of the grid connection conditions. The grid connection costs are shared by the grid operator and the project developer. The grid operator determines the network connection point that is the most economically favorable connection point. The project developer is responsible for the connection of the plant below this point and covers its costs. All costs related to the optimisation, strengthening and expansion of the grid up to the connection point are covered by the responsible grid operator.

Construction can begin after all permits have been granted and all inconsistences clarified. The commissioning of the project needs to be reported to BNetzA , the Federal Network Agency.

Relevant legislation

For each of the planning steps mentioned above, legal regulations at the federal and state-level need to be taken into account. The following federal and state-level laws and plans set the most important legal framework for the building approval of wind power plants:

Legal framework for the approval of wind power plants:
Federal Immission Control Act
(Federal) Building Code German
(Federal) Construction Law
(Federal) Road Traffic Law
(Federal) Aviation Law
Federal Nature Conservation Law
State-level Planning Laws
State-level Development Plans)
State-level Nature Conservation Laws
State-level Wind Decrees
Regional Development Plans (federal states and municipalities)
Land Use Plans (municipalities)

Application for a building permit

Wind power plant developers must consider all the above mentioned regulations when applying for the building permit. The responsible building and nature protection authorities in the districts check the compliance of the planned wind power plants with all the regulations and issue the building permits. Often the permits are provided with constraints and additional requirements that need to be fulfilled in order to obtain the final building permit. Therefore, besides detailed information on construction design and planned electrical installations the applicants must provide detailed information about noise protection, shadows flicker effects, visibility and landscape effects as well as an environmental impact assessment of the project. Additionally, the building authorities investigates whether the project complies with the required distances to residential areas, traffic routes, nature protection areas, water and other infrastructure and natural elements. In the next sections, all those aspects of wind farm approval and regulation are shortly presented.

5.2.1. Noise and shadow effects

Noise protection

Wind turbines with a height of more than 50 m are subject to approval according to the German Federal Immission Control Act. They have to be built and operated in such a way that, according to the law, “does not involve harmful effects on the environment and other hazards, considerable disadvantages and considerable nuisance to the general public and the neighborhood”. The applicants are responsible for taking precautions “to prevent harmful effects on the environment, in particular by such emission control measures as are appropriate according to the state of the art”.

Besides the Federal Immission Control Act, there are two other elements of the legal regulation in Germany concerning noise abatement and limits for wind turbines: Technical Instructions of Noise Abatement – TA Noise and Recommendations on the Protection from Noise of Wind Turbines of the Federal/States’ Working Group for Immission Control. The instructions of TA Noise describe in detail the methods for the determination and the assessment of noise generated from industrial and commercial installations, including wind turbines. In particular, they contain binding immission limits for immission points in the areas outside buildings, which should ensure the function of these areas (see Table 5). When these limits are exceeded, measures to reduce noise immissions have to be implemented.

Types or areas	Day (6 a.m. - 10 p.m.)	Night (10 p.m. - 6 a.m)
Industrial areas	70 dB (A)	70 dB (A)
Commercial zones	65 dB (A)	50 dB (A)
Core areas, village areas and mixed-use zones	60 dB (A)	45 dB (A)
General residential areas and small residential etstate areas	55 dB (A)	40 dB (A)
Purely residential areas	50 dB (A)	35 dB (A)
Spa areas, areas where hospitalts and nursing homes are situated	45 dB (A)	35 dB (A)

Table 5: Binding immission limits according to TA noise.

According to TA Noise, individual short-term noise peaks may exceed binding immission limits during the day by not more than 30 dB(A), and at night by not more than 20 dB(A). The Immission Control Authority assesses whether the binding immission values are exceeded. In the planning phase, noise immissions are determined by computer-based forecasting. It has to take into account the influence of other noise sources and the natural environment conditions at the planned site. When the wind power plant is in operation, immissions should be checked by a measurement in operation mode that produces the maximum rating level.

For reasons of noise protection, municipalities may include in their urban land use plans higher distances to residential buildings than the legally prescribed minimum distances.

Possible shading duration

Besides noise, there are also regulations regarding shadow flicker effects. Depending on the time of a day, the position of a wind turbine, its navel height, rotor diameter and time in operation, the weather conditions and wind direction it throws a moving drop shadow. The calculation of the shadow flicker effects refers to the ”worst case” at significant locations of immissions (see below), which corresponds to the maximum astronomically possible shading duration. In addition, also shadow forecasts are made based on meteorologically probable shading period.

According to the Federal/States' Working Group for Immission Control (LAI) the astronomical maximum permissible shading period cannot exceed 30 hours per year or 30 minutes per day. Technical measures on the wind turbines can usually minimize the effects of shadows in order to comply with the limits. These measures include sensors that automatically shut down the wind turbine as soon as the limits are exceeded. If the sensors take into account metrological parameters (e.g. intensity of sunlight), they must automatically shut down the turbine if the shading period exceed 8 hours per year. Usually, the approval authorities do not refuse a permit due to shadow flicker effects, but they may impose technical obligations on the operators.

Significant locations of immissions include:

- **Protected spaces**
    - Residential buildings, flats
    - Dormitories, indcluding hotels, hospitals and sanatoriums
    - Classrooms ind schools, high schools and similar institutions
    - Officies, working rooms, meeting rooms and similar work spaces
- **Undeveloped land**
  at a reference level of 2 meters above ground on the most affected part of the land
- **Outside areas** at buildings (e.g. terraces and balconies) are protected areas during the day from 6 a.m. to 10 p.m.

5.2.2. Landscape and environmental impacts

Protection of landscape

At federal level, the protection of landscape is regulated in particular in the Federal Nature Conservation Law and in the nature conservation laws of the federal states. According to the federal law, significant impairments of the protected goods are to be avoided as far as possible. Unavoidable interventions must be compensated. There are different forms of compensatory measures, for example monetary compensation, dismantling of other, existing disruptive elements or plantation of additional natural elements such as forestry or avenues. The conservation laws of the federal states are complementary to the federal law. For example, they include specific forms of compensatory measures, which may be different from state to state.

The protection of the landscape is also included in the Building Code as one of the public concerns that may outweigh the benefits of a wind power plant on external undeveloped land. But there is a general rule that privileges wind power plants on external undeveloped land. Therefore, it is in principle not necessary to set up local development plans for wind power plants and the approval procedure takes place pursuant to the Federal Immission Control Act.

However, the way how the planned wind power plants may affect the landscape at the specific location need to be taken into consideration by the project developer in order to receive an approval. In particular, the effects on the landscape protection areas that are designated in the regional planning must be carefully analyzed, taking into account their visual vulnerability, the aesthetic significance of the planned wind farm and, in particular, the scope of compensatory measures or payments to be made.

The federal states use various methods for evaluating the landscape effects of wind power plants. This leads to different levels of compensatory payments or measures, which affects the overall project cost. Therefore, a standardized nationwide solution is under development. The Federal Compensation Ordinance, which is currently being drafted, will provide standardisation to the field.

Nature protection

The Building Code includes also restrictions for wind energy projects due to the nature protection. The nature protection concerns may also outweigh the benefits of a wind power plant on external undeveloped land. Further restrictions may result from species protection. According to the Federal Nature Conservation Law it is forbidden to kill, injure or disturb animals of the specially protected species as well as to damage or destroy their breeding sites and resting places. The construction and operation of wind turbines may affect especially the habitats of birds and bats. Therefore, both the planning authorities and wind project developers must examine the possible impacts of wind farms on environment. A detailed environmental impact assessment in accordance with the provisions of the Environmental Impact Assessment Act needs to be undertaken depending on the size of the wind power project:

< 3 wind turbines	3 to 5 wind turbines	6 to 19 wind turbines	> 19 wind turbines
No EIA	Site specific EIA	Preliminary EIA	Obligatory EIA

Table 6: Requirements for the environmental impact assessment of the wind farms.

In order to meet the wind power expansion targets of federal and state governments, the area required for wind power plants is increasing. In some cases, wind power projects have been already approved in protected areas. In addition, the expansion of wind power in forest areas is gaining importance in densely wooded federal states. This results in new legal and political questions of whether and how the existing regulation should be enhanced in order to enable more wind power projects.

5.2.3. Distances to residential and other areas

Specific requirements

The distances to residential areas, traffic routes, nature protection areas, water and other infrastructure and natural elements are subject of both federal and state laws. The federal law contains general requirements and the states may specify them within that legal framework by issuing non-binding recommendations for the designation of areas for wind power use and the distances of wind power projects to protected areas. They may also set absolute height limits for the wind power plants.

Based on the German Construction Law and jurisdiction disturbing optical effects associated with wind power plants, which may result from their height and rotational movement, are not allowed. Such effects do not occur when wind power plants are situated at a distance to residential areas corresponding to three times the height of the installation. This statutory interpretation provides a suitable solution to the planning and siting of increasingly bigger and higher wind power plants. With current average heights of the wind power plants, the distance to residential areas amounts nowadays to around 600 m.

Implicit distance requirements result also from the Federal Immission Control Act which includes a general rule for spatial separation of different kinds of constructions, buildings, installations and other usage forms, as well as prohibition of harmful environmental effects such as noise. The concretisation of noise limits is included in the subordinate regulations of TA Noise. This result in specific distance requirements. Pure residential areas enjoy higher protection than commercial and industrial areas, within which higher noise levels can be accepted (see section 5.2.1 “Noise and shadow effects”). If after the compliance with the distance requirements there remain impairments at certain times of the year e.g. by shadow effects, these are usually minimized through shutdown obligations.

State clause and 10H regulation of the Bavarian state

The federal regulation with the most far-reaching consequences for the planning and siting of wind power projects at federal level was the change of the Building Code in 2014. It gave the federal states the possibility to issue regulations to restrict the privileged treatment of wind energy projects on external undeveloped land, the so-called state clause. Based on this change, the federal states could adopt legislation with specific definitions of permissible distances between wind turbines and residential areas. This clause was used by the Bavarian state government, which issued a state law according to which wind power projects must keep a distance of ten times their height to existing residential areas (the so-called 10H regulation). This regulation limited the available areas for wind power projects significantly. The municipalities may include exemptions from this regulation in their individual land use planning but rarely do so. The 10H-regulation and the state clause have been criticized as massively restricting the further development of wind energy.

Figure 10: Distributed wind can be sited in mixed use areas, including residential (cc) Karsten Wuerth.

5.3. Public participation and acceptance

Infrastructural projects often face objection and resistance from the citizens in the affected municipalities. This is also the case for wind power projects. Taking into account the specific criticism and considering it in the process of planning and siting often enables a smoother process and more successful project development.

In Germany, the public generally has a very good attitude towards wind power. The surveys conducted by the Agency for Onshore Wind Energy (FA-Wind) in 2015, 2016, 2017 and 2018 show a stable approval level for the development of wind power in Germany. In each of those years, around 80% of about 1.000 respondents attributed wind power an important or very important role. Also the acceptance of wind power expansion in own living area is very high: 78% of the respondents in 2018, who have wind power plants in their surroundings, were in favor of them. 69% of respondents without wind power plants in their surroundings would have little (41%) or no concerns (28%) if wind power plants would be located in their direct vicinity.

The German society has generally also a positive attitude towards the energy transition (Energiewende) itself: 74% of respondents of the 2018 survey of FA-Wind would like to see more action to be taken by the federal government towards implementation of the energy transition. A total of 82% of respondents find that all federal states should make a relevant contribution to the development of onshore wind energy.

Nevertheless, in many places vehement resistance against wind farm emerges that leads to fierce conflicts in the affected communities. Some new surveys show also changes of the generally high acceptance of wind energy in the neighborhood as well as its significant decrease in some regions, for example in Mecklenburg-Western Pomerania (Northeast Germany).

Conflicts can be avoided and stronger public acceptance can be achieved by involving different stakeholders in the planning process and the operation of wind power plants. Both at the federal level and in the federal states, different measurers have been implemented to achieve this. Public participation is a formal element of every planning process of wind power plants. Also, project developers themselves may make attempts to involve the public through informal participation measures such as dialog formats with the aim to inform the public and exchange views and opinions about risks and benefits of wind power. This informal exchange can be enriching both for the community as well as for the project developers in order to recognize potential planning risks at an early stage and thus increase the acceptance of the project.

Citizens may also participate financially in wind energy projects. They can invest in wind energy with citizens' shares, although this possibility is rarely used by the project developers as it implies relatively high transactional cost. Citizens may also become entrepreneurs themselves by establishing energy cooperatives which act as main investor for a specific wind power project. Also passive forms of involving citizens financially are possible, e.g. special land lease agreements, citizen electricity offers, municipalities as wind parks operators etc. In addition, participating in the benefits of wind power is guaranteed in the tax regulation, according to which 70% of the trade tax revenues from a wind power plant remain in the municipality where the plant is built.

Unique regulation for the financial participation of citizens and municipalities in the wind power projects has been adopted by the federal government of Mecklenburg-Western Pomerania in 2016. It obliged the wind project developers to create a limited liability company and to offer shares of at least 20 percent of that company to the immediate neighbours of the wind park: local residents and municipalities. A share may cost a maximum of 500 € (approx. 3900 RMB). Project developers may also offer municipalities a yearly equalisation levy instead of shares. Citizens may choose between the possibility to obtain shares or a savings product. Such solutions are associated with lower financial risks than shares in a wind project company. The wind park operator may decide to transfer 10% of his profits into a bank, where the citizens may set up savings bonds or time deposits.

Wish of more financial participation

However, all these measures do not seem to be sufficient. According to the surveys of FA Wind (2015, 2017) there exist a constant and broad support for a stronger and earlier public participation in the development of wind power projects. A majority of respondents would also like to be involved in the planning process itself. Also, a further development of legal specifications for an increased public participation is widely wished. A great majority of the respondents of the FA-Wind survey 2018 (84%) considers different measures for financial participation in wind energy projects (directly or indirectly) as particularly well suited to increase the acceptance of new wind power plants. However, according to this survey, the majority of the respondents (53%) with wind turbines in their neighborhood value their contribution to the regional economic development and value chain as rather low or very low. Only 23% of the respondents assess this contribution as high or very high. Presumably, more opportunities for financial participation of citizens in wind power projects would increase the perception that wind power is an important contributor to the regional economic development. The federal states have recognized this wish and many of them are planning similar regulations as the one adopted in Mecklenburg-Western Pomerania.

A simplified overview of the process for onshore wind power proposals is presented in Figure 11. It contains the most relevant steps for both Germany and Denmark, clarifying where the process is different for both countries.

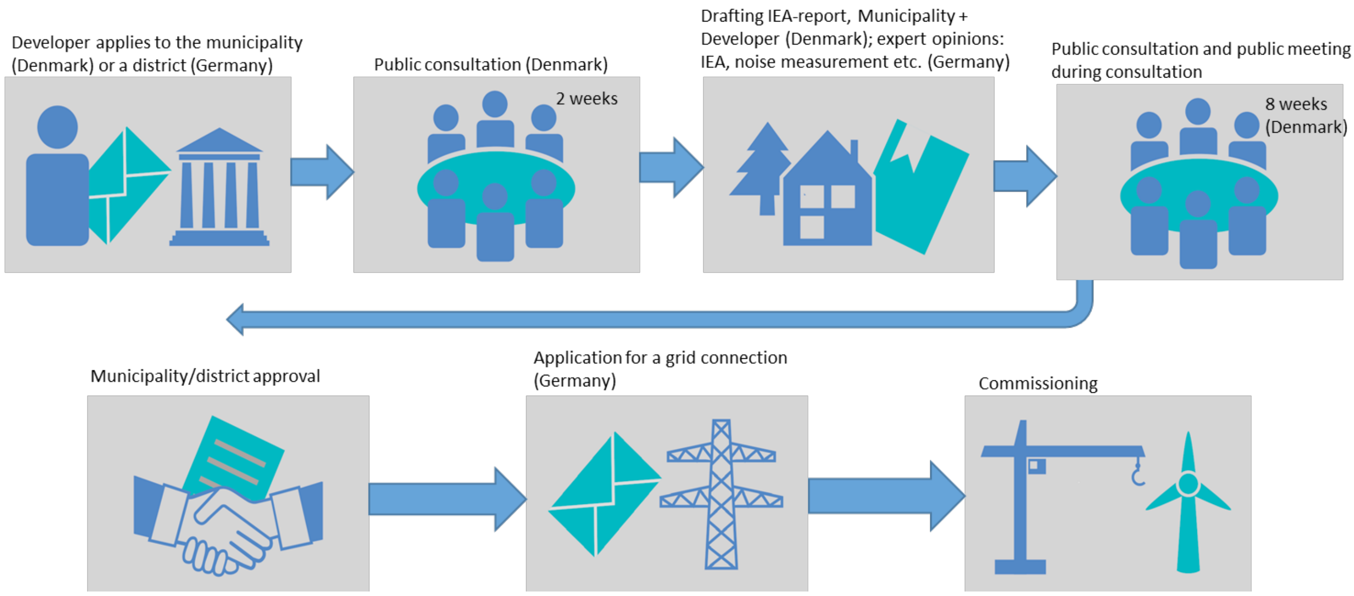

Figure 11: Process line for onshore wind power proposals.

6. Planning and siting of free-field PV power plants

Typical form construction

Generally, there exist three main types of PV power plants: roof-mounted, free-field and PV plants built on physical structures, e.g., on landfills sites, which are artificially poured or filled. Only the free-field PV power plants have to meet are-related eligibility requirements and therefore this section focus on them.

Free-field PV power plants are usually medium to large-scale systems operated by commercial investors. In most of the cases, the installations are just 2-3 m high. Tracked power plants that dynamically follow the course of the sun are usually higher but not common in Germany. Other forms of power plants that allow agriculture beneath them are also possible.

Suitable areas

Free-field PV power plants are often constructed along highways or railways. Other areas on external undeveloped land may be suitable, provided that they are free from shadow (e.g., by vegetation) and south facing in case the system is to be mounted on a slope and not on a flat surface. There are no other topographical restrictions that need to be taken into account when planning and siting PV power plants. There are, however, several legal restrictions with regard to their possible location. Generally, the following areas can be used for the installations of PV power plants according to the EEG:

Areas suitable for the installation of free-field PV systems:
Conversion areas
Areas along highways and railways
Commercial or industrial areas
Green areas or farmland

Conversion areas are areas that were previously used for military, transport, living or other economic purposes. These include, for example, soils with high pollutant load, former landfills or former military areas. In the areas along highway and railways, PV power plants can be located up to 110 m distance from highways and railways. In the green areas or farmland, PV power plants can be located to a limited extent in the so-called ”agriculturally disadvantaged areas” that do not represent high-quality land for agricultural purposes. The respective state government needs to approve the particular area for a PV power plants.

According to recommendations of the German nature protection association NABU, areas significant for nature protection should not be used for free-field PV, although this restriction is not a part of a formal regulation. However, if the size is bigger than 2 ha, PV power plants have to undertake a preliminary EIA, and if the size is bigger than 10 ha - a regular EIA.

Planning process at the level of municipalities

PV power plants are not privileged projects according to the Building Code. Therefore, they cannot be generally located on external undeveloped land. A general right for siting a PV power plants in certain area does not exist. Nevertheless, there are several circumstances that allow the construction of PV power plants on external underdeveloped land. The municipalities decide about these possibilities within their district and there they have much more freedom than in other building approval processes. For example, special areas for PV power plants can be designated in the local development plans. Another possibility is to undertake planning approval procedures for those areas. If a municipality has a land use plan, it must be checked whether local development plan with special areas for PV power plants can be derived from it. If this is not the case, the land use plan needs to be changed first. The parallel preparing and issuing of local development and land use plans by the municipalities is therefore the rule.

The municipal development plan may set specific provisions for PV power plants, such as the necessary compensation areas or measures. In practice, a so-called project-related local development plans is often issued for the individual case. In the implementation contract, municipalities can include additional project-related regulations. For example, they can charge the project developer with the entire planning and development costs or impose deadlines or obligations regarding the project life-cycle (e.g., decommissioning guarantees).

Generally, free-filed PV power plants do not meet as strong resistance in the local communities as wind energy projects.

Figure 12: Free-field PV in Germany (cc). Andreas Gucklhorn.

Building permit

In addition, project developers need to file applications for a building permit to the building authority in the district. As in case of the wind power plants, the authority checks the compliance of the planned PV power plant with all federal, state and local-level regulations with regard to, e.g., soil, species and nature protection. Generally, free-field PV power plants do not harm the environment. They may, however, affect the landscape so this potential influence needs to be investigated. Often the permits are provided with additional requirements (e.g., constructive measures to avoid blinding by sunlight reflection of drivers or pilots).

Grid connection

The electricity generated by the PV power plants is usually fed into either the medium-voltage (usually 10 or 30 kV) or the high-voltage grid (110 kV). The grid connection conditions must be therefore clarified and the connection itself approved and constructed by the respective grid operator. The costs of the grid connection are shared by the plant operator and the grid operator, as in case of the wind power plants (see section 5.2 “Legal framework and approval process”).

7. Perspectives for China

Based on the existing Chinese regulatory framework, and taking into account some of the experiences from Denmark and Germany, it is possible to identify some recommendations and suggestions to facilitate the development of distributed onshore wind in China.

While these recommendations are varied, they are based on three main concepts: de-risking through transparency and a long-term perspective, effective use of the Chinese wind resources, and increased public acceptance and participation.

Planning and land-use

The planning of onshore wind energy expansion can be a complex process, where many different factors have to be considered. Furthermore, a planning process that is carried out inadequately will at best produce a non-optimal development of wind energy; at worst will risk the complete development process. When planning the siting of future onshore wind projects, it is necessary to consider not only the total wind resource available, but also the economic optimality of the development. This means that all relevant aspects of developing and exploiting electricity from wind energy have to be accounted from the beginning of the planning process.

For this reason, it is strongly recommended that when planning future onshore wind development in China, the necessary grid reinforcement and connections are considered from the beginning, and that the related investments are carried out in a timely manner. This means that both transmission and distribution grids will have to be considered, and possibly reinforced, when developing new areas, and that the associated costs should be included in the analysis of where to site new wind energy developments. By doing this, not only will the sites selected reflect the total cost, but it will also reduce the risk of developers by ensuring proper infrastructure for the evacuation of the power generated by the wind turbines and reduce the possibilities for curtailment. China may develop a clear and balanced cost-sharing framework for the grid connection defining which costs for which elements of the grid connection are covered by the plant developer themselves and which by the grid operator. The grid operators could be made responsible for the reinforcement and expansion of the existing transmission and distribution grids in order to increase the wind and PV penetration in the Chinese energy system. The new framework would need to guarantee that the necessary investments are timely planned and aligned to the planning process of RE power plants.

This integrated planning framework will then balance the advantages of areas with high wind resource but away from load centres, versus areas closer to demand but with lower wind resource availability. In this case, it can be seen that the Danish approach of siting wind turbines in a distributed manner utilising farmland can be highly advantageous. These areas tend to be closer to demand centres, require less grid reinforcement than areas far away from population, and present possibilities for rural development. Furthermore, due to the extremely limited footprint of wind turbines compared to other power generating technologies (such as traditional fossil fuel plants or solar photovoltaic panels), it is possible to produce electricity from wind without jeopardising the food producing capabilities of the farms.

In case of PV power plants, it is crucial to decide which type of land may be generally used to site such projects, taking into account other alternative use purposes, such as agriculture. In both cases, it is important to define the framework conditions for these decisions: noise limits, levels and duration of shadow flicker effects, acceptable forms of unavoidable interventions in the landscape, permissible environmental consequences (for nature and species) as well as distances to different residential areas and other infrastructure and natural elements. Above that, wind and PV project developers apparently also need to consider the wind and insolation conditions in the particular area.

It is clear that the planning process should consider both national and local interests, and therefore local governments should have a significant role. Nonetheless, it would be extremely beneficial to consider establishing an entity at the national level that can support local authorities in the planning process. This national level authority would act as a wind turbines and planning task force, and be the source of best practices, knowledge, and support for local authorities that are engaged in the planning process which will be in charge of accounting for the particular conditions of the site, such as public acceptance, visual impact, and micro-siting.

The German experiences with regard to planning and siting of wind and PV power plants have shown, that many different approaches are possible. From this point of view, the German land use regulations that stretch out over federal, state and local levels seem to be quite complex and detailed. On the other hand, they provide a quite clear and transparent orientation on the possibilities and constraints for siting RE power plants. China could also work towards developing a clearer and more transparent set of rules for planning and siting of wind and PV power plants. The developers need a long-term planning security and legal certainty as to where they can locate their wind and PV power plants, which aspects of the land use they should take into account and what measures may be used for compensation.

Moreover, the division of responsibilities between different administrative units in Germany with regard to land use is clearly regulated. The most detailed specifications, such as preparing of local development and land use plans, are delegated to the lowest administrative level (municipalities), which have the best knowledge of local conditions. The federal and state levels formulate the legal framework and recommendations in order to guarantee that the decisions of municipalities are based on a clear set of rules and guidelines. China, which has currently different administrative levels, could learn from the German experience on what is the most effective way to divide the responsibilities with regard to land use planning.

Transparency in regulation

Wind turbines are extremely capital intensive, with a lifetimes of more than 20 years. As such, the business case is sensitive to long-term conditions while at the same time requiring significant investments up front. Danish experience has shown that for ensuring the successful development of wind energy, as well as maintaining competitive prices, it is necessary to reduce the risk as much as possible for project developers.

One of the main challenges for onshore wind existing today in China is the complicated permitting and planning process, and the many authorities involved. Today, it is hard for developers in China to have a clear understanding of the certainty of permits being given, and as such, there is significant risk associated to the permitting process. This also provides negative situations for regulators, with developers occasionally beginning construction of projects before all relevant permits have been obtained.

There are two main areas where China could focus on for de-risking onshore wind development: regulation and permitting, as well as grid connection of new projects, both of which could benefit from improved transparency and standardisation.

In terms of regulation, clear guidelines on requirements regarding land use, the permitting process and related authorities, as well as specific requirements on particular conditions of wind turbine farms (such as distance to houses and buildings, noise levels, etc.), would significantly minimise uncertainty from developers regarding the possibilities and timelines associated to obtaining permits for a development. Furthermore, if it was possible to improve coordination regarding the permit-issuing authorities, it would minimise the amount of interactions and steps needed for developers to obtain such permits. This would not only enable further wind development, but also to minimise costs associated to uncertainty in these projects. In addition, there has to be clarity regarding how to fulfil requirements such as noise: the Danish approach of utilising noise models before construction and on-site measurements afterwards, if requested, has proven quite effective for increasing transparency.

China could also set up standard measurement methods for noise, shadow flicker effects, landscape and environmental impacts as well as distances to residential and other areas. A proper and standardized measuring of those impacts and effects enable a transparent approval process and thus higher public acceptance for wind and PV power plants. Above all, a clear guidance regarding the approval procedure for the executing authorities in terms of definitions of administrative requirements, procedures and deadlines could be also introduced.

Environmental impact assessments deserve a special mention, since they also drive public acceptance. Danish experience has shown that standardising the contents and process associated to carrying out an environmental impact assessment allows not only for reduced risks and uncertainty for developers, but for increased trust from the public and less resistance from local population. As such, particular emphasis on the clarity and transparency of the regulation associated to these assessments is required.

Another source of uncertainty for developers is related to the availability and timeliness of grid connections and reinforcements. There needs to be clear guidelines regarding the responsibilities for such grid improvements, as well as timelines for a project, which will avoid the risk for developers of having a project finished but not having a connection to the grid that would allow for the utilisation of the power generated. Including grid connections in the general planning for onshore wind, as suggested above, would be a good way of addressing the issue.

Public and local participation

The final dimension for recommendations is related to public and local participation and benefits. The nature of distributed wind projects means that they will tend to be sited in proximity of the population, and therefore will have increased interaction with the public. It is important to note that these interactions can be both negative, such as opposition to noise and visual impact, and positive, e.g., embracing the development and actively participating in new projects. Policies should aim at minimising resistance while at the same time actively increasing approval and participation.

In terms of minimising public resistance, there are two main suggestions: the first one is the development of a transparent permitting and approval system for new projects (as suggested in the previous section), and the second one is the inclusion of local concerns during the planning process. If public resistance is to be minimised, there needs to be active accounting of the preferences of the local population, which will require a transparent and embracing framework for public participation in decision-making processes. For example, public hearings can be held during the planning process by the local authorities in charge of it, where citizens can voice their opinion and concerns regarding the use of certain areas for wind developments.

As both the German and the Danish cases show, involving the affected citizens at an early stage of a project proposal, providing broad information about the project, enabling exchange between public and project developers as well as possibilities for citizens to participate directly or indirectly in the projects in financial terms may increase and sustain public acceptance and allow the development of rural areas. For this reasons, China may consider introducing elements of public participation and try to involve the citizens more in the RE development.

Nonetheless, minimising resistance is not enough to ensure successful and widespread development of distributed onshore wind. As Denmark has experienced, there needs to be active approval from the public, for which several policy possibilities exist. The main recommendation for increasing acceptance of projects is to ensure that the local population feels benefited from such projects. While local content requirements are a common approach, extreme care must be taken when deciding the extent of local content mandated. High local content requirements will remove the possibility of taking advantage of economies of scale, and will slow down the development as well as significantly increase price.

Incentives for local communities have proven particularly effective in Denmark, not only for increasing acceptance, but also to further the development of rural areas. The possibility of having the option buy shares of a local wind turbine project has been one of the most successful policies for that effect. With such approach, the citizens not only accept the project, but also become active stakeholders that vie for the success of it.

The potential and possibilities for distributed onshore wind in China are clear and significant, to the point where it can be a technology that will play a central role in the energy transition for the country. The provided recommendations aim at ensuring that China develops its potential in an efficient, sustainable, and cost-effective manner.