Østerild Test Center: Lessons Learned in Setting up a Wind Test Center for Offshore Wind Energy

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Title: Østerild Test Center: Lessons Learned in Setting up a Wind Test Center for Offshore Wind Energy

Summary

This report has been developed as part of the Danish Energy Agency's global cooperation in assisting India in achieving its transition to green energy. It synthesizes the lessons learned from planning, constructing and operating the Danish national test center for large-scale wind power, the Test Center Østerild. It first describes the background to the Danish national center for large-scale wind turbines, the parliamentary decision-making process, starting with the screening of relevant sites, and the final selection of Østerild, including the environmental impact assessment, public hearings and the further expansion of the center. The business model is also presented. Secondly, it describes the construction and operation of the Test Center Østerild and its organisational and management arrangements. It briefly highlights the importance of certification as a Renewable Energy Test lab under the IECRE (IEC System for Certification to Standards relating to Equipment for use in Renewable Energy Applications), lists some of the many R&D projects that have benefited from these large-scale test facilities and concludes with a description of the visitor center. Lastly it summarises the lessons learned and the key features in the planning, design and operation of the Test Center Østerild.

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Contents

List of figures and tables

Abbreviations

DANAK	Danish Accreditation Fund
DKK	Danish krone
DSO	Distribution system operator
DTU	Technical University of Denmark
EIA	Environmental Impact Assessment
IEC	International Electrotechnical Commission
IECRE	IEC System for the Certification to Standards relating to Equipment for use in Renewable Energy Applications
MDKK	Million Danish krone
MW	Mega Watt
NEWA	New European Wind Atlas
NIWE	National Institute of Wind Energy
R&D	Research and Development
RE	Renewable
SEA	Strategic Environmental Assessment
TAC	Test and Calibration Section
WT	Wind Turbine

1. Introduction and background

India has set itself the very ambitious target of achieving 175 GW of renewable energy by 2022, the majority of which will come from solar (100 GW) and wind (60 GW) energy. The installed onshore wind-power capacity amounts to approximately 33 GW, and the remaining 27 GW was expected to be auctioned in March 2020.

In an effort to exceed its renewable energy targets for 2022, the Indian government has recently announced a new 5-GW target for offshore wind. Offshore wind power is promising for the Indian energy sector due to the benefits of higher capacity factors, more reliable wind speeds, less use of land, proximity to energy demand centers in coastal areas and reduced grid-evacuation issues. Kick-starting the development of offshore wind in India is expected to come at a premium in the initial phases, while the regulatory framework is being developed, major infrastructure is established, and the offshore value-chain in India reaches maturity.

The Danish-Indian cooperation programme on renewable energy and climate has the objective of assisting India in the green energy transition by increasing the share of renewable energy in its system. The knowledge acquired and lessons learned during the development of wind power in Denmark for more than 25 years, in particular offshore wind power, can be valuable to the Indian government in establishing and expanding the country's offshore wind sector and enabling it to achieve its renewable energy goals. Therefore, the National Institute of Wind energy (NIWE) has expressed a strong desire to learn from the Danish experience and draw lessons learned from the planning and operation of Denmark's Test Center Østerild.

This report aims at synthesizing the lessons learned from planning, constructing and operating the Danish national test center for large-scale wind power, the Test Center Østerild. The report is divided into three parts:

- The first part describes the background to the Danish national center for large-scale wind turbines, the parliamentary decision-making process, starting with the screening of relevant sites and the final selection of Østerild, the environmental impact assessment, public hearings and the further expansion of the center. The business model is also presented.
- The second part describes the construction and operation of the Test Center Østerild and its organizational and managerial arrangements. It briefly highlights the importance of certification as a Renewable Energy Test lab under the IECRE (IEC System for Certification to Standards relating to Equipment for use in Renewable Energy Applications), lists some of the many R&D projects that have benefited from the large-scale test facilities and concludes with a description of the visitor center.
- The third part sums up the lessons learned and key features from the planning, design and operation of the Test Center Østerild.

2. The Østerild Test Center

2.1 Description

The Test Center Østerild is located in north-west Denmark, close to the coast, and has very good wind resources and ideal wind conditions for testing purposes. In order to test large wind turbines, a mean wind speed of at least eight metres per second at a hundred metres high is a necessary and reasonable “simple” terrain that does not lead to complex wind conditions.

The Test Center Østerild came into operation in October 2012 with seven test sites for prototype wind turbines up to 250 meters in tip height. With the expansion of the Center in 2018, an additional two sites have been added, making it possible to test wind turbines up to 330 metres high in seven of the nine test sites.

The site consists of:

- Protection area
- Wind field
- Measurement area
- Test area

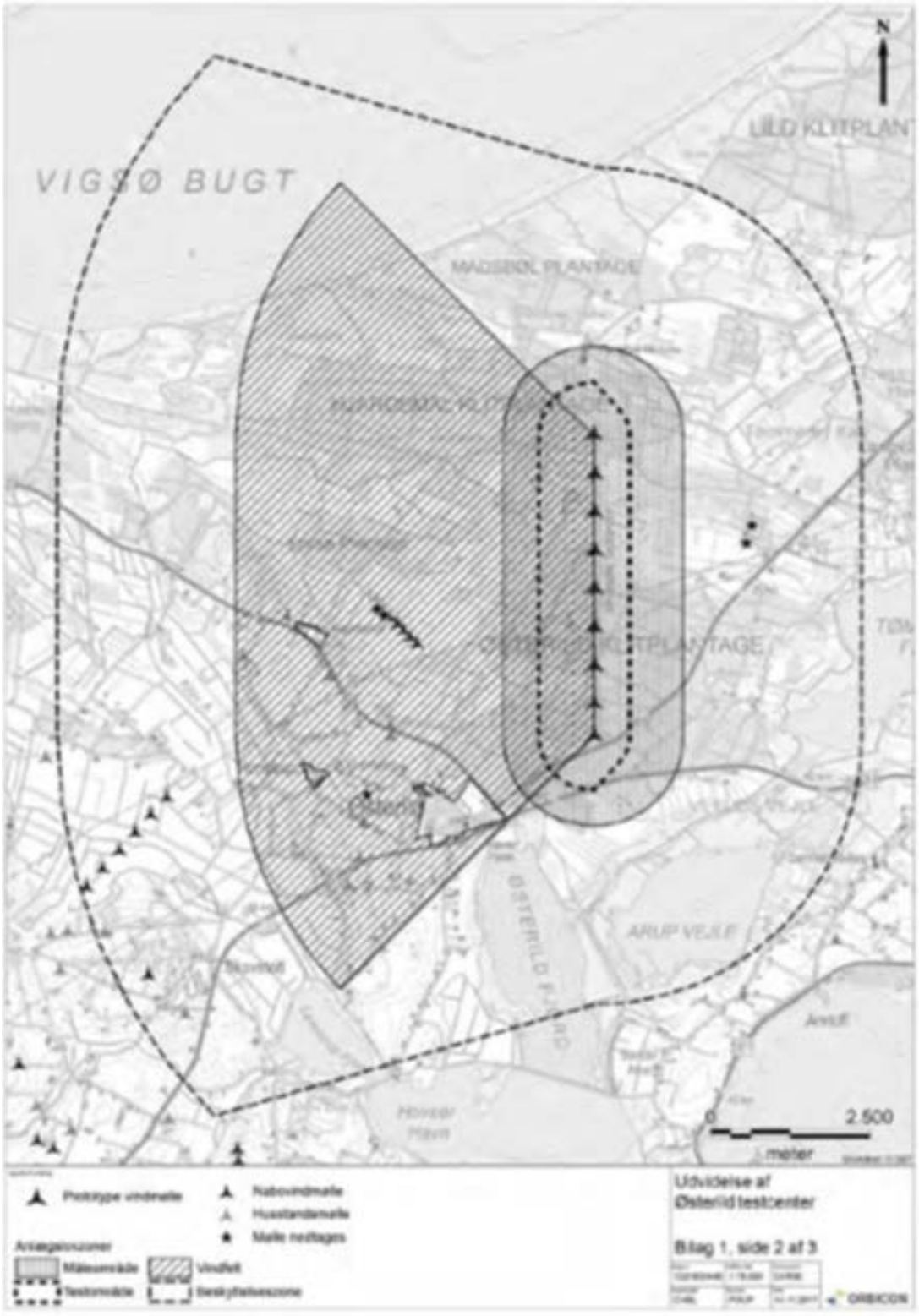

Figure 1. Overview of area

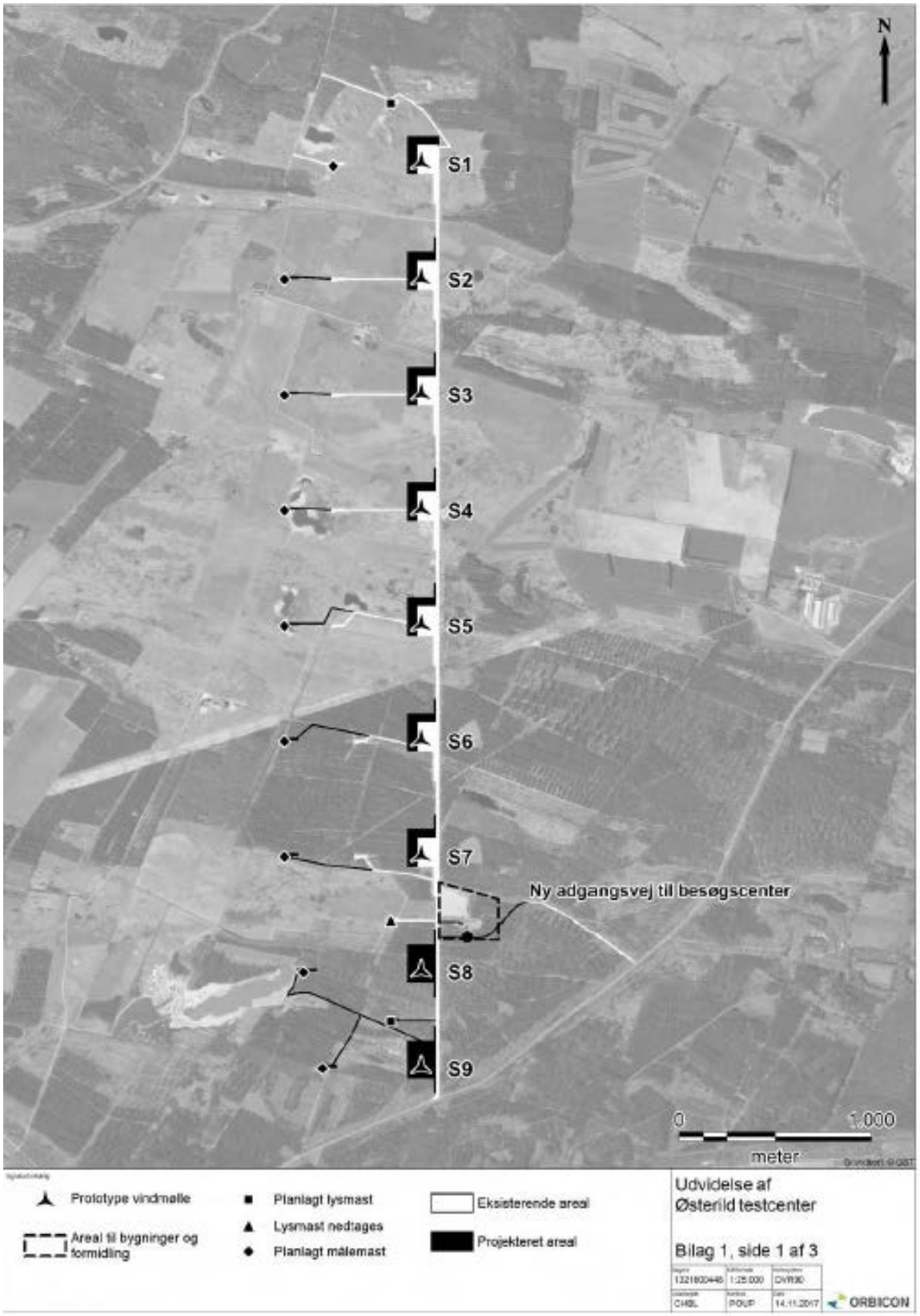

Figure 2. Siting of the 7-9 test stands

DTU Wind Energy is responsible for the operation and maintenance of the Center, including complying with the legal requirements. The test center is run in close cooperation with industry and the authorities.

An overview of companies using the test stands is given below.

Table 1. Overview of companies in the Test Center Østerild, 2020

	Company	WT type	MW	Rotor diameter (meters)	Hub height (meters)	Tip height (meters)
1	EDF RE	GE 150-6 MW	6.0	150	117	192
2	Vestas	V150	5.6	150	154	229
3	MHI Vestas	V174	9.5	174	130	217
4	Vestas	V150-4.2 MW	4.2	150	137	212
5	Envision Energy	EN-120/3.0 MW	3.0	120	90	150
6	Siemens Gamesa Renewable Energy	SG-DD-167	8.0	167	120	203,5
7	Siemens Gamesa Renewable Energy	SWT-7.0	7.0	154	120	197
8	Siemens Gamesa Renewable Energy	SG-DD-193	11.0	193	140	236.5
9	GE Renewable	Coming soon				

To mark the area for aviation traffic, two 250 m tall masts are located at each end of the row of wind turbines, equipped with white high-intensity blinking lights. At night the lights are controlled by a radar and only come on when an aircraft is approaching the area. The masts are also used as meteorology masts, as it can be seen in Figure 3 below.

Figure 3. The 250 m tall northern mast at Østerild Test Center. Photo Niels-Erik Clausen, 2019

The Municipality of Thisted runs a visitor center at the Østerild Test Center. It was inaugurated in 2017 and receives approximately 50,000 visitors annually. Next to the visitor center is an educational wind-turbine tower, a wind-turbine blade and a spinner where visitors can learn how a wind turbine works. There is also a charging station for cars where the transformer and breakers can be seen from the outside.

2.2 Planning the Østerild Test Center

Planning the establishment of the Test Center Østerild was a lengthy process ignited by the needs of the industry and DTU, who wanted to have better test facilities for larger wind turbines, as described in the Megavind partnership document of 2008.[1] Megavind recommended a new national test station with five to ten test pads for wind turbines (> 150 meters), a full-scale test of the integration of wind energy into the grid, associated R&D in meteorology, grid integration and solutions to stimulate local investment and public support.

The existing test station in Høvsøre was set up in 1999/2000, but further analysis by DTU, industry and independent consultants found that it could not be adapted to accommodate larger wind turbines (above 165 meters) that were expected to be erected close to the coast or offshore.

The government took note of this request and in June 2009 decided to create a national test center for wind turbines up to 250 meters high, also concluding that it should be introduced by means of a national law (*Anlægslov*). This was different from the decision to establish Test Center Høvsøre, which was taken administratively by the Ministry in the so-called *Landsplansdirektiv*, a national planning directive, which took more than seven years from planning to operation.[2] Using a parliamentary process, the decision would be reached more quickly and would allow thorough parliamentary decision-making, taking into account the involvement of the planning and other authorities, stakeholder hearings of both the environmental impact assessment of the selected location and the draft law, and most importantly ensuring broad political support.

Important steps were:

- Screening of feasible sites and site selection
- Environmental impact assessment of site
- Hearings
- Final parliamentary decision of the Law establishing the national test center for large-scale wind turbines in Østerild

2.2.1 Screening and selection of site

The Megavind partners, DTU and the industry, initially established a number of criteria for selecting sites for large-scale wind turbines close to the coast. The final criteria for screening feasible public and private areas were agreed together with the planning authorities, who also did the actual screening in 2009.

The agreed screening criteria were:

- An average wind speed of at least 8 meters a second based on DTU's wind resource map

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[1] Megavind, Afprøvning of demonstration af vindmøller, 2008. https://megavind.winddenmark.dk/publications/afprovning-demonstration-vindmoller-2008. Accessed 13 May 2020.

[2] Miljø- og Energiministeriet, National prøvestation for store vindmøller ved Høvsøre i Lemvig kommune Resumé af VVM-redegørelse Landsplandirektiv Kommuneplantillæg Lokalplan VVM-tilladelse, Juni 2000. https://planinfo.erhvervsstyrelsen.dk/sites/default/files/media/publikation/landsplandirektiv_nationalproevestation_hoevsoere2000.pdf

- An area of at least 346 ha, with space for 10 wind turbines (as requested by DTU and the industry)
- At least 1000 meters from households and summer cottages
- No bird protection area (in accordance with the Birds Directive 2009/147/EC).

A total of fourteen sites were identified based on data from SagaGIS, data on buildings and properties (BBR) and registers of residence (CPR). A further three sites were suggested by the industry, which did not take into account the EU Birds Directive. An inspection team of representatives from the Danish Ministry of Environment, the DTU and the industry visited eight of the sites, of which only two were deemed relevant:

- Østerild
- Kallesmæk Hede (suggested by the industry, but subject to the EU Birds Directive)

Further investigations were made into these two sites regarding infrastructure such as roads, harbour facilities etc. This was typically done in close cooperation with the local authorities, the distribution system operator (DSO), local harbours, the Danish Road Directorate and industry. Eventually, Østerild was chosen as the best feasible site for the national test center, the only one to fulfil all the criteria put forward.

2.2.2 Environmental impact assessment

As part of the parliamentary decision-making process, an environmental impact assessment of the area was made in accordance with the ordinary EIS framework (as requested in the 2011/92/EU/EIA Directive[3] and the 2001/42/EC Strategic Environmental Assessment (SEA) Directive[4]). The EIA assesses and lists the likely significant effects on the environment, and considers and suggests mitigation measures to prevent, reduce and offset the negative effects. SEA likewise streamlines environmental assessments of projects of common interest by involving the stakeholders while also meeting environmental legislation.

The Ministry of Environment assessed the environmental impact of the center as an integral aspect of drafting the law (*Anlægslov*). The Ministry, together with Miljøcenter Århus, with experience of conducting assessments of wind turbines larger than 150 meters, had the overall responsibility for this and was assisted in doing so by a consultancy firm (BirkNielsen/SWECO), its subcontractors Orbicon (nature and environment), EMD International (noise and flicker) and Nellemann & Bjørnkjær (regulation and planning).[5]

The EIA included:

- Project description
- EIA at the global, regional and national levels

[3] The 2011/92/EU EIA Directive sets out the procedure that must be followed before approval is granted for a range of plans and projects, defined in Annexes I and II of the Directive. The categorization of projects have been conducted as per a) characteristics of project, b) location of projects (i.e. environmental sensitivity of project locations), and c) significance of impacts.

[4] Directive 2001/42/EC SEA directive addresses the assessment of the effects of plans and programmes on the environment, including early environmental assessment and ensuring compliance with the applicable environmental legislation whilst considering stakeholder involvement.

[5] https://erst.w2ltest.dk/sites/default/files/testcenter-VVM-redegoerelse-dec-2009-samlet.pdf. Accessed 10 June 2020.

- EIA at the local level

2.2.3 The legislative process of drafting the law

In drafting a new law, the legislative process, follows a strict constitutional procedure allowing proper preparation of the law with decision-support materials such as analysis, EIA, hearings, and parliamentary and committee discussions before final approval.[6]

The draft legislation to set up a national test center was drafted by the Ministry of Environment and detailed the design and outline of the test center, the test sites, the measuring masts, the work areas, etc. It also covered noise restrictions, the limits on flicker (sun shadow that hits houses next to the test center) and restrictions on access and use during both installation and operation on site.

The draft legislation also outlined who is the responsible test-center manager (DTU) and emphasized a financial model involving payment by the users of the center, thereby ensuring it was cost-neutral in relation to the public budget. Although it allowed the state to sell or rent the site out to individual companies for wind-turbine tests, it did not interfere in the contractual relations between the state, DTU and the center's users.

No exceptions were to be made in the legislation regarding noise from the wind turbines, meaning that those houses that were exposed to noise above the limits would be purchased by the ministry. Further, the draft permitted forest clearance if this was deemed necessary for the establishment and operation of the center. Finally, the draft included procedures for expanding the test facilities until 2020.

As part of the parliamentary process, it was also agreed to consider other aspects related to the establishment of the national test center. This included the expansion and upgrade of Hanstholm harbor, which had drawn up a very ambitious development plan as a center for marine-energy technologies, including wave energy and six to eight wind turbines. The first two phases of this plan were already well underway with an investment of ~725 million DKK. The harbor also planned to apply for 20 million EUR from the EU regional development program.[7]

Legislative proposal L206 was finally approved by the Danish Parliament on 4th June 2010.[8] Law 647 of 15 June 2010 was signed into law by the Queen and published on 16 June 2010.[9]

As stated in the law of 2010, further development of the center and its test facilities was envisaged. The Megavind R&D strategy of January 2016 highlighted the need to establish additional prototype test sites to test the safety and reliability of wind turbines and also to facilitate R&D regarding new measurement methods, aerodynamics, meteorology and safety. Therefore, a request was made to allow turbines of up to 330 meters with an output of up to 32

[6] https://www.ft.dk/da/folkestyret/folketinget/lovgivningsprocessen-i-folketinget (in Danish)

[7] Memo 28 May 2010, Bilag. 2 Aftale om et nationalt testcenter for store vindmøller i Østerild som en del af en helhedsløsning for placering af testmøller frem mod 2020.

[8] The process and the underlying documents are available here (in Danish): ttps://www.ft.dk/samling/20091/lovforslag/l206/index.htm.

[9] The law text (in Danish): https://www.retsinformation.dk/eli/ACCN/A20100064730

MW. Because of these new requests, the law had to be revised and go through the parliamentary process again, as well as an environmental impact assessment and hearings. The new legislative proposal was finally approved by Parliament on 29 May 2018.[10] [11]

2.2.4 Hearings

The public and stakeholders were involved in two parallel hearing processes lasting eight weeks:

- The Environmental Impact Assessment (EIA) was made available to the public from 7/1 to 5/3 2010. A total of 140 responses, many of them from ordinary citizens, were sent to the planning authority and summarized for purposes of parliamentary decision-making.
- The legislative draft was made available to stakeholders from 7/1 to 5/3 2010 and summarized for purposes of parliamentary decision-making. A total of 155 responses were received by the Ministry of Environment, most of them from ordinary citizens.

The responses of both hearings addressed the following:

- **General remarks.** Many responses challenged the selection of Østerild as the location for the national test center, the selection criteria and the methodology used. In particular, the Danish Society for Nature Conservation was very critical of the plans and had also conducted its own investigation of alternative locations. The Ministry found that the Society's alternative analysis did not comply with the requirements of such test centers and concluded that Østerild was still the best location for testing large-scale wind turbines, including from the point of view of an environmental impact assessment.
- **Noise.** Some questions concerned the noise of the wind turbines and how that would be addressed. As the Test Center Østerild would not be exempt from the wind-turbine noise directive, noise measurements and noise limits were included as an annex to the law.
- **Visualisation.** The EIS followed the usual methods in assessing visualisation and used a worst-case scenario with maximum visualisation of wind turbines and the 250-meter light masts as a reference in sunny and clear weather.
- **Nature**. Some responses challenged the provision to clear some forest before the wind resource assessment had been finalised, but assurances were given that this would not happen. Also the certification of state forests and the implications for Østerild were analyzed by the company responsible for monitoring forest certification. Reforestation was included in the law and would happen at ratios of 1:2 for the test site itself and 1:1 for neighbouring areas in the form of wind shield etc., though the exact reforestation locations had yet to be identified. The areas subject to forest clearance were expected to develop into dune heartland, which was to be maintained in line with normal nature conservation principles.
- **Wildlife and birds.** Much concern was expressed regarding the impact on birds and wildlife. Would the wind turbines interfere with bird migration, and what was the risk of collisions with birds? The test center was located outside and at a distance from

[10] Parliamentary process re L198 (in Danish):
https://www.ft.dk/samling/20171/lovforslag/l198/20171_l198_som_vedtaget.htm

[11] The final revised law LBK 1069 of 21 August 2018 is available here: https://www.retsinformation.dk/eli/lta/2018/1069

NATURA 2000 areas,[12] and although birds do not recognize borders, the risk was deemed minimal. More generally, the center was expected to have minimum impact on wildlife, which was made up of various species. See map below.

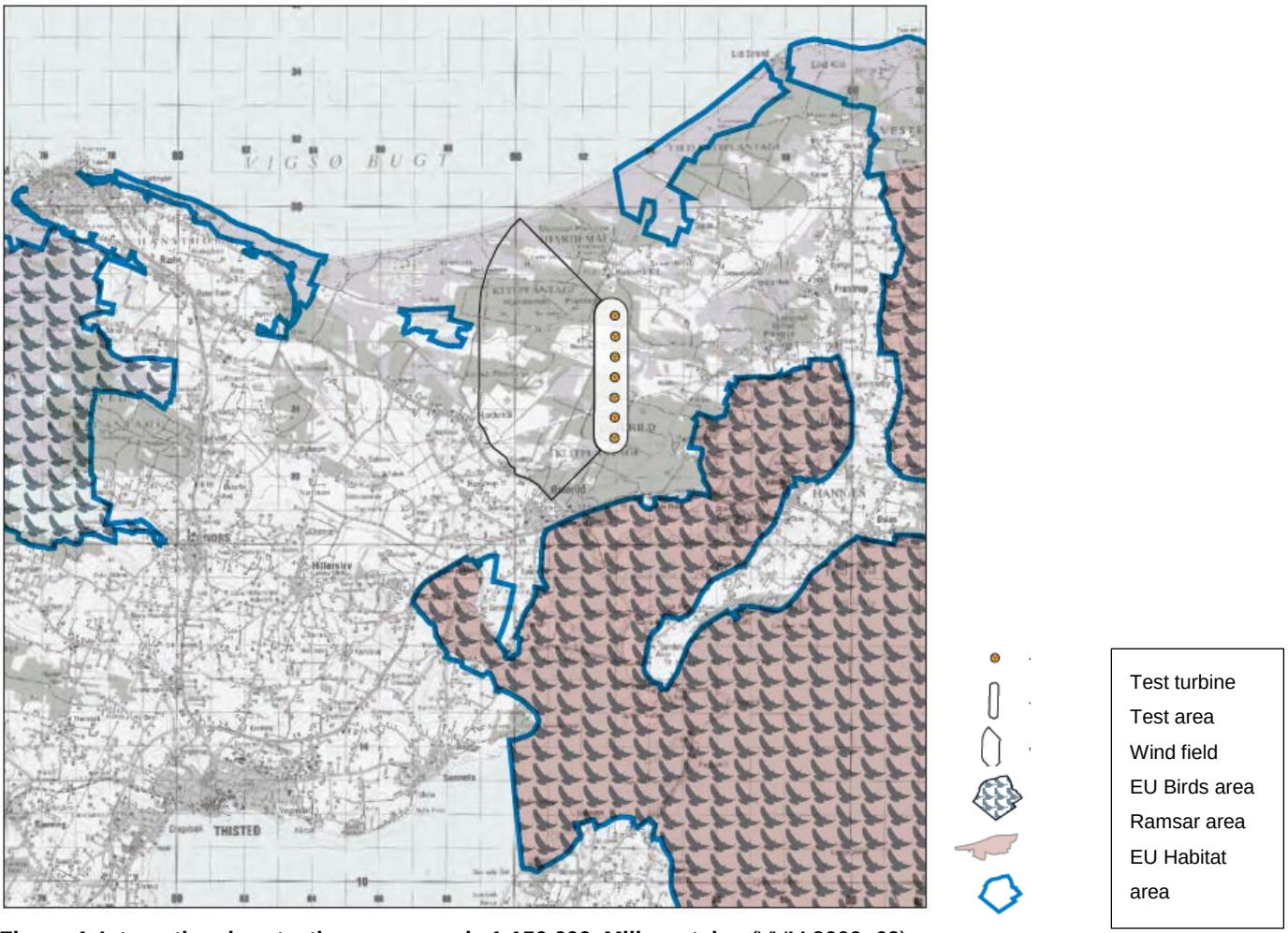

Figure 4. International protection areas, scale 1:150,000, Miljøportalen (VVM 2009: 63)

- **Water.** Due to concerns responses regarding the impact of forest clearance on groundwater, further analysis was made of the possibility of discharged pollutants seeping into the groundwater. Adequate measures would be established.
- **Use and public access.** Although forest and hedges were to be removed from the test site, the measurement area and the wind field, and hence were also subject to compulsory purchase, experience from Høvsøre and other places had shown that agriculture would have no major impact on the wind resources. It should be possible to raise wind measurement masts on private land, with financial compensation limited to documented damage.
- **Wind turbines: technical aspects.** The industry returned a response regarding the need for large-scale testing, some references being made to German tests being

[12] Natura 2000 is a network of nature protection areas in the EU, covering habitat, bird protection and RAMSAR sites. The areas preserve and protect habitat types, as well as wild animals and plants which are rare, endangered or characteristic for EU countries.

conducted offshore or right on the shore. The ideal site for testing wind turbines should have a simple topography, be a relatively non-complex terrain with, for example, buildings and trees, and be a good wind resource. The best site would have a roughness of from 1-1.3 or for some locations 1-2. Offshore sites offer zero roughness and are hence not ideal for testing the turbulence of large-scale wind turbines. Also it was emphasized that general access was important in order to construct and operate the test center. Although there was no Danish norm regarding sun shadow on neighboring houses (flicker), a limit of a maximum of ten hours of flicker from the wind turbines was included in the law.[13]

- **Socio-economic aspects.** The Municipality of Thisted was concerned about the economic consequences for local landowners and farmers. The establishment of the test center would require compulsory purchases of land with economic compensation, as laid down in the law. Further, provided that the center's activities were not impacted, agricultural activities could continue (see also above).

In addition to the written hearings, numerous town hall meetings, expert workshops and other meetings were organized. There were also protests and demonstrations by NGOs and concerned citizens opposing forest clearance, compulsory purchases and noise. While the local police managed both legal and illegal protests, DTU invited protesters outside DTU's Risø Campus to an open talk with the provost.

2.3 Business model

The business model was developed prior to drafting the law and rested on a public-private partnership approach, building on mutual trust and cooperation within the wind-energy sector, as well as the tradition of shared ownership and operation in major sectors of Danish society (agriculture, residential housing, banks, community wind-energy projects etc.). This has implications for both the organizational arrangements and the cost-sharing model.

2.3.1 A public-private partnership approach

Once the government had decided to plan a national test center for large-scale wind turbines, a Project Committee (*projektfølgegruppe*) was established with the key stakeholders involved, such as local public authorities, industry and DTU (lead). The group managed to address major uncertainties, obstacles and resistance regarding the project and actively influenced its final organizational and financial arrangements.

Once the law had been approved, the Project Committee was transformed into a project management group to oversee the construction and operation of the Center. The project management group was to be accountable to a Steering Committee on which representatives of owners and tenants sat. Each test stand was voted on, with DTU as the center's facility manager having a right of veto. A set of Rules of Conduct governs the Steering Committee's decision-making, including a gentleman's agreement regarding intellectual property and confidentiality the testing.

Those with roles, responsibilities and stakeholders' interests are:

[13] Sweden has a norm of a maximum of ten hours flicker a year: as shadows vary over the year, an annual norm has been adopted.

- **The national public authorities**, meaning the Ministry of Environment, which has the legislative responsibility, and the planning authority responsible for the environmental impact assessment, forest clearance, landscape maintenance and compulsory purchases, and was also the landlord and owner of most of the land.
- **The local authorities**, in this case the Municipality of Thisted, with responsibility for local roads, local planning (and thereby the impact on the test center's neighbours) and the harbour, and was deeply involved in the extension of Hanstholm harbour, close to Østerild. The municipality also had a strong interest in local job creation and in particular in tourism, also becoming the owner of the visitor centre.
- **Industry owners** are the two big wind-turbine manufacturers, Vestas and Siemens, which were among the parties that strongly requested long-term access to the necessary test facilities for wind turbines up to 250 meters. As a demonstration of their commitment, Vestas and Siemens have each bought the area for two test sites for thirty years and invested to an equal extent in the development of the center's infrastructure.
- **The main tenant and facility manager of the center** is DTU (similar to the arrangement in Høvsøre). DTU has rented the remaining area for thirty years, with the right to extend the rental period further, and is owner of the remaining three test sites (and after the expansion of 2018 also of the two newest test sites). As the facility's manager, DTU has responsibility for the construction of the center, access roads, internal power net etc., compliance with the legal requirements and the operation of the center. DTU has also drawn up an overall contingency plan for safety and a proper work environment, though each site owner or tenant is responsible for the safety and work environment of its own test pad. As well as carrying out testing as an R&D activity, DTU also has an interest in offering on-site accredited testing to companies (see also below).
- **Test-site tenants** (up to eight or twelve years, or in principle up to thirty years) are companies that, following a public tender call, are allowed to rent DTU's test sites. The final selection is done by DTU based on a combination of price (50%) and the company's R&D plan (50%), with minimum and maximum prices for the different characteristics of the test pads. Current tenants are Vestas, Siemens, Envision and, since the expansion in 2018, EDF, RE and GE.

2.3.2 Financial model

The national test center's financial model was negotiated between the Danish state, the industry and DTU. For the state, the center's cost neutrality is included in the law, while the contractual relations between the parties have been decided separately. The interests and thereby also the financial criteria of each of the parties are described below.

- **State (government).** The main criterion for the state is the cost-neutrality of the construction and operation of the center based on user payments so that users pay all the expenses related to the establishment of the center, such as the facilities, forest clearance and forest compensation (1:1), compulsory purchases, etc.
- **Industry owners.** The main criterion for the two industry owners is a cost-effective price giving them long-term rights to test sites. Cost-effectiveness is based on the economies of scale of the whole center and facility management, leaving the core part of the test to industry. Each company paid a market price for the area in 2010, together with a seventh of the construction costs per site (~25 MDKK per site – see table below).

The industry owners also contribute on an equal footing to the process of adapting the Test Center Østerild for larger wind turbines in 2018.

- **DTU.** The main criterion for DTU as a public self-governing institution, owner of the three (+2) sites and operator of the Center, is market fairness, meaning no major gains or losses. DTU has invested equally with industry, in the order of ~25 MDKK per site. The pay-back time of the investment in the three sites is ~12 years. This is reflected in the minimum price of renting out sites to other industries. The annual rent for the test pads per year ranges from 2.5 to 9 MDKK, depending on the test capacity of the test pad and the outcome of the tendering process.
- **Industry tenants.** the main criterion for other industry is to obtain access to a test site and the center's facilities at a reasonable price.

The original budget cost overview of the construction and operation of the center as presented during the parliamentary process in 2010 is given below.

Table 2. Budget costs for construction and operation of center, 2010

Million DKK	Total expenses	Expenses per test site
Total expenses	**171.8**	**24.8**
Construction of test center, excluding consultancy	73.1	
External consultancy/project management (EIA, infrastructure planning etc.)	7.1	
Compulsory purchases	28.1*	
Forest clearance	29.0	
Reforestation	28.6	
Prevention measures (birds, animals and nature)	5.0	
Legal assessment (*Kammeradvokaten*)	0.9	
Cost of area		0.3
Total annual operational costs	**3.9**	**0.6****
Annual cost of center operations	3.5	
Annual payment [to state] for maintenance of nature	0.4	

Source: L206, Annex 31 memo financial model 7 May 2010

* The costs of compulsory purchases were based on the market value of the property made by the tax authorities. These included five farms, legal and consultancy fees, demolition of buildings and compensation for area restrictions.

** The annual operational cost in 2019 was 0.5 MDKK per test, which is paid to DTU for each test pad (see also 3.2 Operations).

3. Construction and operation of Center

3.1 Construction phase

Roads, masts, electrical infrastructure, measurement systems etc. were developed by DTU in accordance with the required specifications, and tender documents were drawn up by Rambøll as consultant to DTU. Rambøll also assisted DTU in monitoring the work of private construction companies, the distribution network firm and the mast company following a public tendering process.

The same procedure was used in extending the test center in 2018, when wind turbines of up to 330 meters were allowed, and the output could go up to 32 MW on each test pad.

DTU also made a detailed assessment of the wind conditions at the site,[14] after which it was decided to remove only 245 ha of forest out of the 450 ha that had initially been allowed for.

Part of the construction extended beyond the test center and required alterations to the public road from Hanstholm harbor to the Test Center Østerild in order to accommodate the transport of large and heavy components that could not be transported over bridges or through tunnels due to their size and/or weight. This included the widening of a traffic circle and a crossroads.

3.2 Operations

3.2.1 Management

The Test Center Østerild is operated and maintained by DTU. The facility's management is headed by the deputy head of DTU Wind and includes an operations manager and two technicians on site and researchers from the Test and Calibration section (TAC) at DTU's Risø Campus. The unit also includes two technicians from the other test center in Høvsøre. The unit meets every second week to plan, monitor and follow up on the operation of the center, conduct measurements (commercial and R&D projects) and carry out other activities related to operating a national test center.

3.2.2 Day to day operations

The main responsibilities of the operations manager can be divided into two main groups:

- **Administrative tasks** related to notifying the authorities regarding the noise and groundwater implications of the erection and operation of wind turbines at each test pad. This is strictly confidential information which the operations manager handles for each company. He is also the contact point for other authorities, such as the local branch of the Planning Agency.
- **Practical tasks** such as maintenance of internal access roads, monitoring the electrical grid and the light masts.

[14] Hansen, B., Courtney, M., Mortensen, NG, Wind Resource Assessment of Østerild National Test Center for Large Scale Wind Turbines, DTU wind Energy, E-0052, 2014.
https://backend.orbit.dtu.dk/ws/portalfiles/portal/98593972/DTU_Wind_Energy_E_0052.pdf

In addition, the operations manager has an important role in facilitating the smooth running of the center by providing its users with whatever they need to make things work.

3.2.3 Transport and installation of turbine components

The transport and installation of wind-turbine prototypes are carried out and paid for by the individual company owing or renting the test pad. The transport of wind-turbine components and infrastructure needs careful preparation in coordination with external authorities and partners, as well as in aligning them with internal users at the center.

Below are some examples of the transport of large components such as the tower, nacelle and blades. These large components are shipped to Hanstholm harbor, from where they are trucked 21 km to the center. Other smaller components are trucked by road from the production facilities in Jutland to the center. The common denominator is that all these movements need careful planning and rigorous execution in close cooperation between the manufacturers, transport companies, authorities, local police and the center operator.

In November 2019, a 28-meter tall tower for Siemens' Gamesa 11 MW wind turbine was transported from Hanstholm harbor to Østerild Test Center – 21 km in total, at three km an hour). The transport was carried out by a transport company that had spent several months carefully planning the transport with due regard for the physical conditions, technical transport solutions and obtaining the necessary permits for this special transport to keep other traffic away. Along with the tower, a 400-ton nacelle was transported on a platform vehicle hauled by two trucks. The Home Guard (a voluntary military organization) managed the traffic and also notified the local population.[15]

[15] In 2016, the Haliade 150 transported three tower sections for GE from Northern Span to Hanstholm and further on to Østerild on platform vehicles. A video of the trip is available here: https://www.youtube.com/watch?v=HD3RUVxP3ZQ

Figure 5. Transportation of tower, from Hanstholm Habour to Østerild, November 2019. Photo: Peter Mørk, Nordjyske

Figure 6. Transport of nacelle from Hanstholm to Østerild, November 2019. Photo: Peter Mørk, Nordjyske

At the beginning of January 2020, the first of three blades was transported for the same wind turbine. The 94m and 0.5 tons B94 Integral Blade was produced in Aalborg, shipped to Hanstholm harbor, and from there transported on a 70-meter long platform vehicle.

Figure 7. Transport of blade. Photo: Lasse Dieckmann

The assembly of the wind turbine requires a special crane. The internal transport of the 800-ton, 50-meter long crane from one test pad to another is a demanding task in itself.[16]

The onsite assembly of the Siemens Gamesa 11 MW wind turbine is illustrated below.

[16] Video showing the internal transport of speciality crane – 600 tons and 50 meters high: https://www.youtube.com/watch?v=WwxligxBASo

Figure 8. Assembly of Siemens Gamesa 11 MW wind turbine. Photo: Siemens Gamesa

3.3 Accredited tests and certification

From the very beginning, DTU Wind Energy has contributed to the international standardization and certification of wind turbines and wind-energy systems as an important means of developing reliable and safe wind turbines and systems. Accredited tests and measurements in general, and certified test facilities and test stations in particular, are considered to be important ways of delivering internationally recognized, impartial and reliable tests and measurements. To maintain this recognition, laboratories are re-evaluated regularly by a recognized accreditation body to ensure their continued compliance with requirements, and to check or control that their standards of operation are being maintained.

DTU Wind Energy's Test and Calibration section (TAC) performs full-scale tests on wind turbines, mainly at the test centres in Høvsøre and Østerild, but also at other sites, including offshore measurements. The TAC mainly performs accredited power-curve measurement verifications and load measurements and lidar calibration for the industry. A commercial measurement test of a prototype wind turbine costs ~0.5-2.5 MDKK. An average measurement test costs ~0.8-1.0 million DKK and will typically include installation of lidars mv, 2-3 standard tests performed over ~6 months. The fact that DTU can offer such measurements at the Test Center Østerild, due to having technicians on site and thus saving significant amounts of time for the manufacturer, gives it a competitive advantage. However, there are also examples of competitors (German UL company) winning bids for industry testing at the Test Center Østerild.

The accreditation uses criteria and procedures specifically developed for determining technical competence in this context. Specialist technical assessors conduct a thorough evaluation of all factors in the laboratory that affect the production of test or calibration data, typically during a three-day on-site visit. The criteria are based on the internationally accepted and recognized

standards ISO/IEC 17025:2017. The accreditation is issued by the Danish Accreditation Fund (DANAK - http://english.danak.dk/) and the International Laboratory Accreditation Cooperation (ILAC - https://ilac.org/) and is audited approximately every fourteenth month.

Accreditations include:

- DTU accreditation of testing of wind turbines[17]
- DTU accreditation of calibration of anemometers[18]

In 2017, the Wind Turbine Test, Test and Measurements, DTU Wind Energy, was accepted as a Danish testing laboratory within the IECRE (IEC System for Certification to Standards relating to Equipment for use in Renewable Energy Applications - www.iecre.org), complying fully with the requirements of ISO/IEC 17025: 2005 and the Rules and Procedures of the IECRE System. This certification is re-issued by the IECRE Executive Secretary upon successful completion of the normally scheduled five-year Reassessment Programme.[19]

DTU Wind Energy is thus one of 27 RE test labs in wind energy globally to be certified by IECRE, covering China (5), Denmark (6), Germany (8), Korea (1), Spain (4), the UK (2) and USA (1).[20]

3.4 R&D

R&D has a central role in the whole set-up of the center for both each of the involved companies and DTU. The center offers excellent test facilities to accommodate the industry's need to test large-scale wind turbines in an area with good wind conditions and a thriving knowledge eco-system balanced carefully between the industry's quest for intellectual property and society's quest for publicly available research and knowledge. This foundation makes Denmark and the sector attractive for further investment by newcomers as well.

As described elsewhere, the assessment of new tenants of test sites (following a public call) is based on price (50%) and R&D plan (50%) and is made by DTU as the landlord.

Also, DTU Wind Energy makes good use of the facility in research projects, something which makes DTU a preferred and attractive partner in R&D projects for private and public institutions in Denmark and elsewhere. Examples of such R&D projects are listed below:

Project New European Wind Atlas: The Østerild Balconies Experiment (2016-17)
One of the main objectives of the New European Wind Atlas (NEWA) project is to carry out large-scale field experiments at high spatial and temporal resolutions and provide a significant upgrade to the experimental databases that are currently available. The aim of the Østerild Balconies Experiment is to collect measurements over a relatively flat and semi-forested terrain to quantify the effect of various terrain features on the mean wind field. The experiment was performed at the Østerild test station for large wind turbines in northern Denmark from April to August 2016.[21]

[17] http://published.danak.dk/showdata.asp?schema=proevningsdata&lang=e&akk=363

[18] http://published.danak.dk/showdata.asp?schema=kalibreringsdata&lang=e&akk=363

[19] https://www.iecre.org/members/testlabs/retl/dtu/)

[20] The whole list is available here: https://www.iecre.org/members/testlabs/

[21] https://orbit.dtu.dk/en/publications/new-european-wind-atlas-the-østerild-balconies-experiment

Project CORAL. Radar Controlled Obstruction Lights at the National Test Center in Østerild (2015-18). This project assessed the technical Radar Control of Obstruction Lights solution in Østerild. Based on generic system requirements, regulatory recommendations were drafted for Denmark's Obstruction Light Control (OLC). It also evaluated the social effects of introducing Radar Controlled Obstruction Lights for local residents and made suggestions for how OLC solutions could be installed in communities.[22]

3.5 Visitor center and local stakeholders

Already in the law of 2010, a visitor center was provided for to allow the public to learn about wind energy and the center. It was not financed by owners or tenants, as planned, but the private philanthropic association Realdania made a grant to the Municipality of Thisted to construct such a center. Today, it is run by the Municipality and has become one of the region's top attractions, with more than 50,000 visitors annually.

Visitors can take guided tours, which can be categorized in three groups:

- Tours for the general public, tourists and civil organizations are managed by the municipality for a small fee.
- Tours for technically informed lay persons are managed by the former operations manager of the Hanstholm Wave Center for a small fee.
- Tours for engineering students, engineer associations and high-level visits are managed by DTU and are free of charge.

Figure 9. The visitor center at Test Center Østerild 2017. Photo: Charlotte Hede Linde

The Test Center Østerild has a positive impact on the economic development of the area in terms of activities and thus also job creation. The center's site manager uses local firms for operational and maintenance tasks. In addition to the permanent technical staff living in the vicinity, DTU and companies regularly send technicians to the center, where they stay in local hotels and use local restaurants. To our knowledge, no thorough analysis has been made of their impact.

[22] https://orbit.dtu.dk/en/projects/radar-controlled-obstruction-lights-at-the-national-test-centre-i

4. Summary of lessons learned

The Test Center Østerild and its role in the further development of large-scale wind turbines are an integrated part of the Danish experience, expertise and innovation in transforming the energy system at an affordable and competitive price. The center has added to the creation of new, highly skilled jobs and also indirectly to new local jobs both during and after construction. Lessons learned from the planning and operations can be summarized as follows:

Multiple criteria assessment
The best location for a national test center must be guided by a number of criteria, which both fulfil the industry's and academia's requirements for adequate test facilities with easy access to components and people, and the responsibility of the authorities to protect the environment, citizens' concerns and local expectations regarding job creation.

Such criteria are:

- wind conditions
- sufficient space for the test site, including wind field and test area
- good infrastructure, such as roads, bridges, harbor and power lines
- access to a skilled workforce
- proximity to promising offshore sites, including also access to harbors
- minimum interference in nature and environment
- minimum impact on neighboring households

Public-private partnerships
A national test center for offshore wind is a costly long-term investment, which requires strong political support and economic willingness from both public and private stakeholders. To build a well-functioning partnership based on trust takes time and strong leadership, not least from partners with a strong interest in R&D to the benefit of society. This leadership must build support across various levels and must balance a variety of interests in a pragmatic way, finding common solutions that can be accepted by the key stakeholders.

Such interests include the following:

- Government authorities have an interest in transforming the energy system while also attracting investment and creating jobs.
- Industry expects fair and easy access to internationally excellent and certified test facilities at a competitive price, close to manufacturing facilities and promising offshore wind sites.
- Like industry, R&D institutions need excellent test facilities for both research and educational purposes, and also to be seen as attractive cooperation partners for industry and academic partners from around the world.

Robust and fair financial model and organizational arrangements
The financial model was not agreed from the very beginning but was developed during the process by the project group to accommodate the parties' different economic interests and risk

perceptions. The politicians and the public authorities wanted the model to be cost-neutral in respect of the public budget, making users pay for all major construction expenses.

DTU and the two industry owners shared the risks of the seven test sites by splitting the financial expenses into seven equal shares, excluding the acquisition or renting of land. The shared-burden model was also used for the center's operations.

The organizational arrangements facilitated the responsibilities and rights, the original project group being transformed into a project management group governed by a steering group once the law had been enacted.

Certification and R&D

Wind Turbine Test, Test and Measurements, DTU Wind Energy, is one of 27 global certified RE test centers, and the Test Center Østerild is an integral part of it. This means that all the measurements and tests performed at the center follow the highest international standards to the benefit of both industry and academic customers.

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