

DTU



**Besøg
Folketingsudvalget
for
Landdistriker og Øer
og
Landdistikternes Fællesråd**

DTU

**Allan Vesth, Anders Ramsing Vestergaard, John Sarborg Pedersen
og Peter Hjuler Jensen**

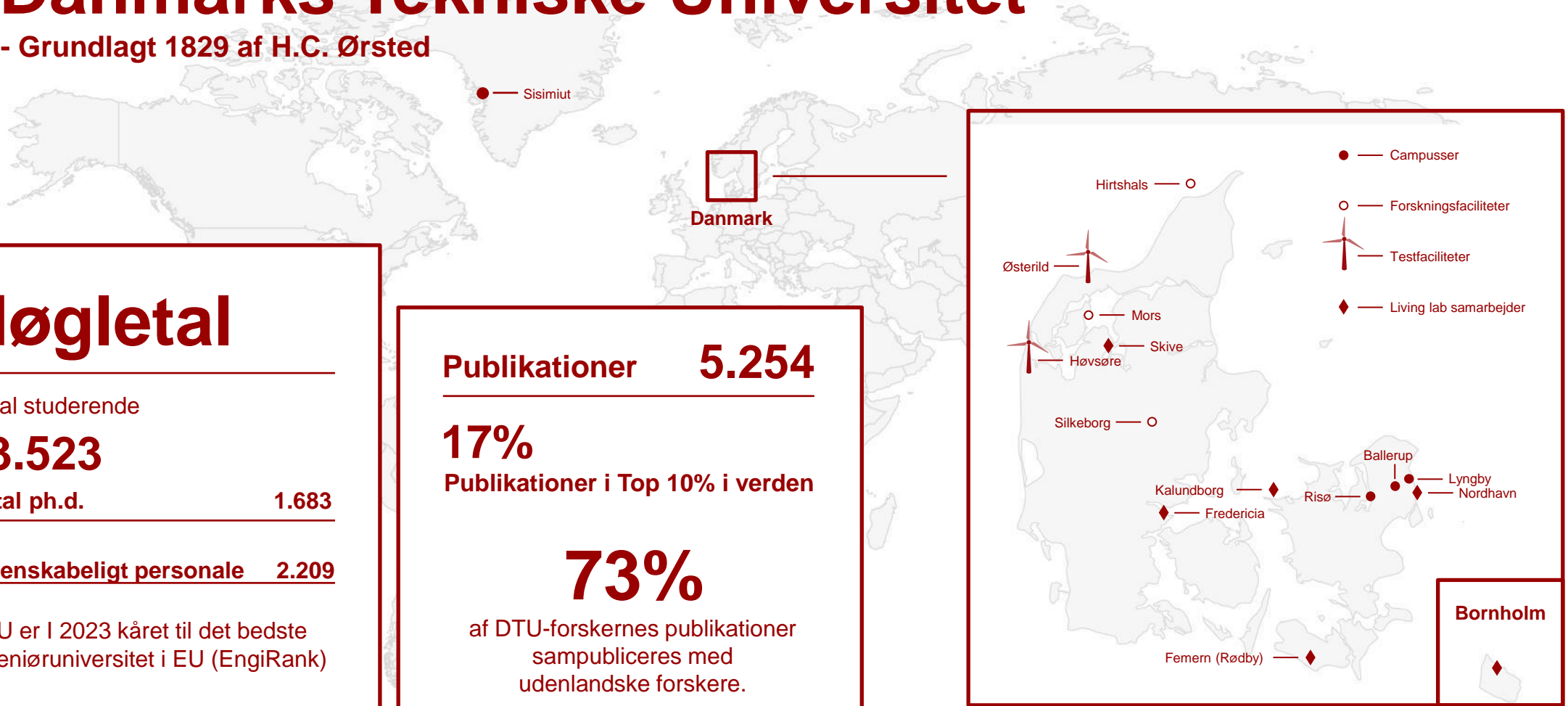
**Den 12. Januar 2024
Testcenter Høvsøre**

Program for DTU besøg

- 10.00** **Ankomst og velkomst**
- 10.10** **Præsentation af DTU, DTU Vind, vindmølleafprøvninger og Høvsøre**
- 11.00** **Tur langs møllerne – måske i bus.**
- 12.00** **Tilbage i mødelokale med spørgsmål mm**
- 12.15** **Frokost**

Danmarks Tekniske Universitet

- Grundlagt 1829 af H.C. Ørsted



Nøgletal

Antal studerende

13.523

Antal ph.d.

1.683

Videnskabeligt personale **2.209**

DTU er i 2023 kåret til det bedste ingeniøruniversitet i EU (EngiRank)

Publikationer

5.254

17%

Publikationer i Top 10% i verden

73%

af DTU-forskernes publikationer sampubliceres med udenlandske forskere.



DTU Wind and Energy Systems

DTU institut: Vind og Energisystemer

- **DTU institut med ca 400 ansatte, 85 % af omsætning eksterne indtægter, 65 % af medarbejdere ikke dansk baggrund**
- **Forskning, undervisning, innovation og myndighedsbistand,**
- **Global aktør: samarbejde med mange lande, virksomheder i hele verden, FN, Verdensbanken og meget aktive i internationale organisationer**
 - **Vindressourcer og vindforhold globalt**
 - **Design af vindmøller og fundamenter – aerodynamic, mekanik, dynamik, styrkeforhold**
 - **Vindenergi i elnet og elnet**
 - **Afprøvning: vindtunnel, måling af vindforhold, måling på vindmøller, måling på komponenter, materiale laboratorium mm.**
 - **Afprøvning af vindmøller Risø, Høvsøre og Østerild**
- **Myndighedsbistand til lande og international organisationer**

DTU Vind og Energisystemers forskningsområder

Visual overview Global perspectives for wind energy

Wind power provided 5% of the world's electricity output in 2019, almost exclusively in the form of onshore wind. By 2050, wind will provide 50% of electricity in Europe, 44% in North America and more than 30% of electricity in Greater China, Latin America and South East Asia. The share of offshore wind in total wind electricity generation will increase steadily, rising globally from 6% in 2019 to 40% in 2050, 15% of which is floating offshore (DNV, 2022).



Denmark a global leader in transforming the energy system
Denmark's goal is to get 55% renewable energy by 2030, equivalent to more than 100% renewable electricity, and to become independent of fossil energy by 2050.
In 2021, wind generated electricity was 43.0% or 16,082 TWh and this was even a poor wind year.

Trends in wind energy technology development

Lowest cost of energy continue to be an important driver for improvements of wind energy technologies but the total value of wind energy also requires a broader scope such as the technology mix, development of the whole energy system, supporting regulatory framework and citizens engagement.

Security of energy supply

Securing sustainable energy supply today and in the future is of utmost importance. Wind energy is a domestic source of energy as the wind resources are abundant and inexhaustible.

Designed for specific conditions

To lower the CoE, designers have tailored the turbines even more carefully to the conditions under which they operate.

Blades evolve

Many factors have added the move to lighter blades, of which the most important has been the development of blades that are much more slender and flexible than their predecessors.

Leading edge erosion on wind turbine blades causes loss in annual energy production and increases maintenance costs. New solutions are developed to predict, prevent and mitigate leading edge erosion.

Drive trains without gears

Conventional wind turbines use gears and are most often used for onshore wind, whereas offshore turbines use direct drive. These include direct drive based on the weaker ferrite magnets, direct drive based on superconducting coils or drive train based on a magnetic gearbox combined with an outer ring generator.

Support structures and foundations

Most installed offshore wind turbines presently rest on monopiles. In deeper waters, it is still used at low water depths, but the ease of manufacture and the scaling up of pile dimensions make them attractive solutions even at moderately deepwaters at 40-50 m.

Floating turbines

The cost of offshore wind increases with depth and distance from the shore. At larger depths, more materials and stronger piling into the sea bed are needed. At some depths, floating support structures become more cost-efficient (above 60m).

Wind power creates jobs

The Global Wind Energy Council estimates 3.3 million new wind energy related jobs worldwide over the next years. They come in addition to the 1.7 million jobs in 2019. In Denmark, the sector created 30,300 full-time jobs and indirectly additional 60,200 jobs, making the total of 90,500 full-time jobs.



Storage adds control capacity
Electrical storage can provide additional control capacity that could replace the need for flexible thermal power generation.

Power-to-X
Electrolysis of wind energy to hydrogen and other gases adds to the balancing and the indirect decarbonization of the energy system.

Balancing energy systems with high shares of wind

Balancing energy systems with very high shares of wind energy requires well-integrated grids with good interconnections. On the supply side, demand response will reduce balancing needs.

Wind energy policy and economics

The most important success factors in wind energy policy are 1) clarity on the design of the support scheme, 2) expression of long-term political commitment, and 3) sufficient level of remuneration, allowing an acceptable level of profits for investors. In the future, a vital part will also be needed in an enabling environment that allows wind energy to become an even more significant contributor to the energy transition.

Auxiliary services

Wind energy must take a larger responsibility for the stable operation of the energy system and provide system services, so called auxiliary services.

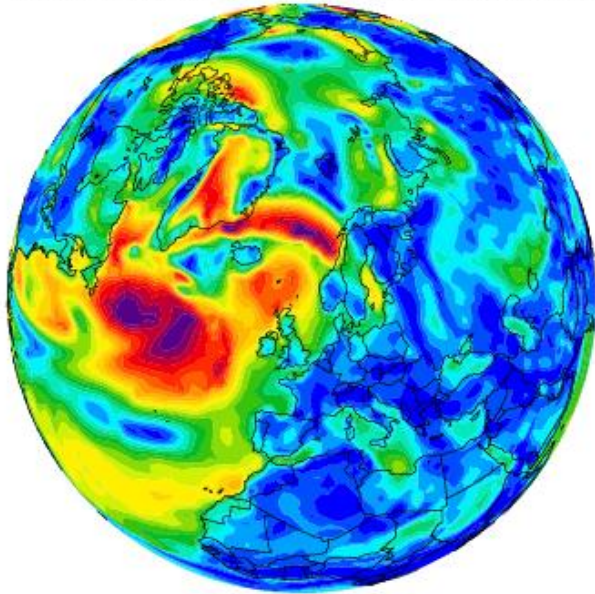
Environmental and social impacts of wind energy

Compliance of wind farms with local environmental requirements, and social acceptance, are both important if wind energy is to reach its ambitious targets.

Resource Assessment Modelling (RAM) Section

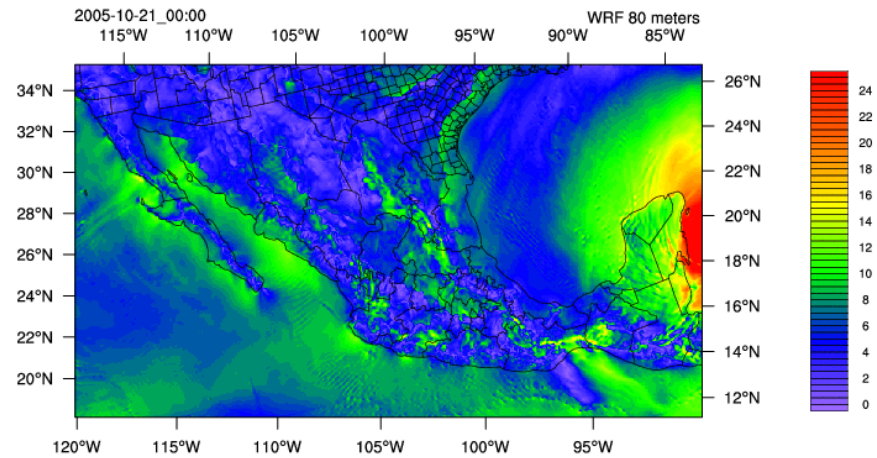
10-meter wind speed

01/01/1998 (00:00)



Global

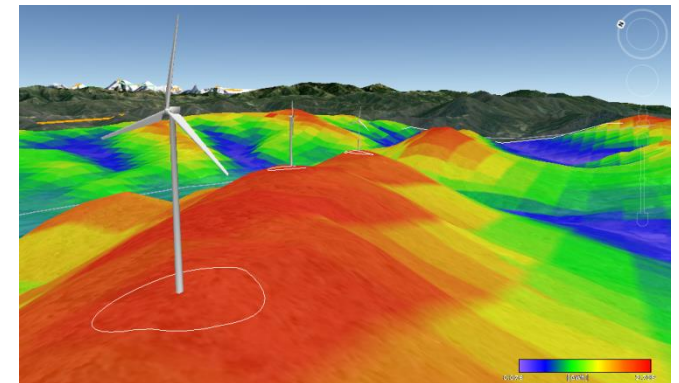
wind speed (m/s)



Regional

Downscaling

Site



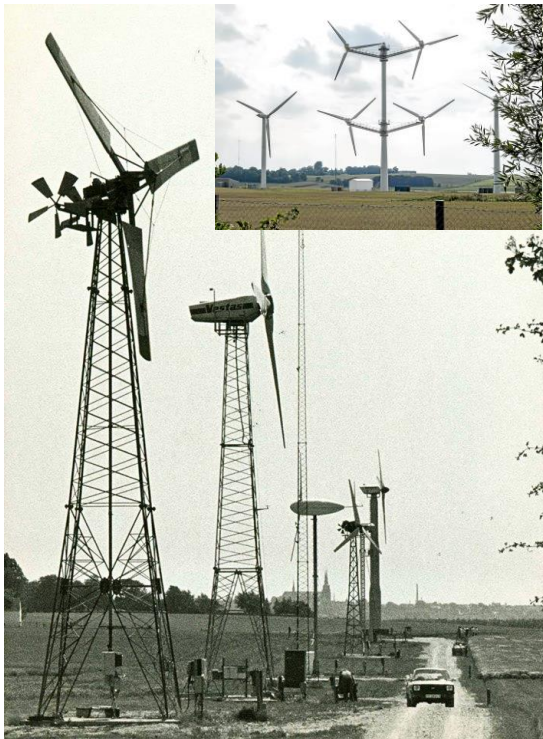
**Askov vindmølletestcenter
start 1890 Poul la Cour**

- **Forskning**
- **Test og udvikling**
- **Undervisning**
- **Konsulentbistand**



Afprøvning af vindmøller i Danmark fra 1980 til 2024

Forskningscenter Risø
1980 - 2024



Testcenter Høvsøre 2002 - 2024



Testcenter Østerild 2012 - 2024



Vindmølletestcentre i Danmark

Lov, Staten, DTU og industri

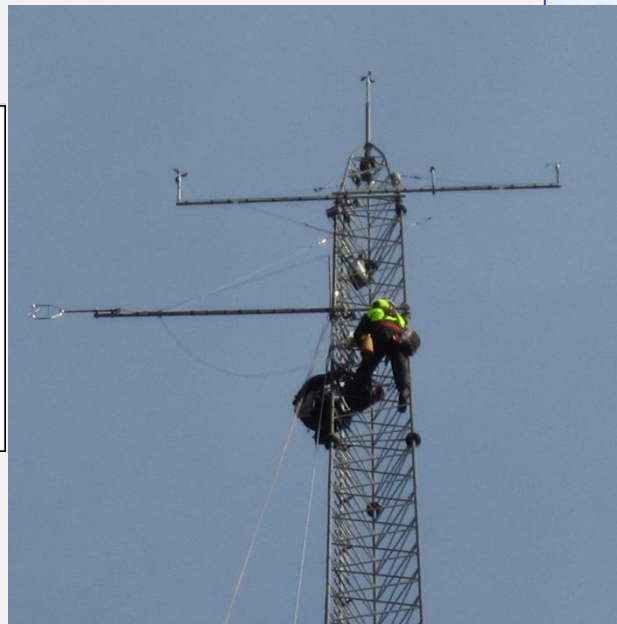
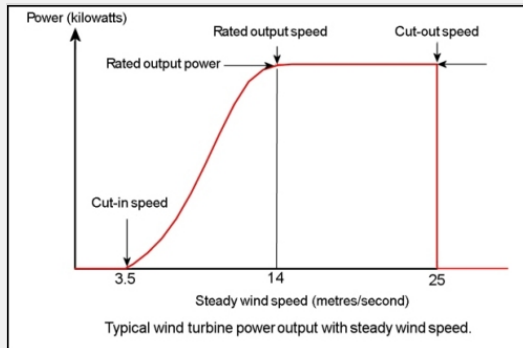
- **Landsplandirektiv muliggør etablering og drift af Testcenter Høvsøre (2000)**
- **Anlægslov muliggør etablering og drift af Testcenter Østerild (2010)**
- **Anlægslov ændres så både Testcentrene Høvsøre og Østerild omfattes af loven – styrelse administrerer loven/bekendtgørelsen (2018)**
- **Testcenter Høvsøre ejes af DTU – styregruppe – DTU udlejer pladser**
- **Testcenter Østerild: DTU lejeaftale med staten med økonomi, governance struktur – styre- og følgegruppe.**
- **Industrien betaler alle omkostninger ved etablering, drift og bortskaffelse af testcentrene**
- **DTU driftsherre og ansvarlig i forhold til drift af centeret i i forhold til lovgivning**

Lejere og ejere

- **Vestas og Siemens ejer hver to pladser på Testcenter Østerild**
- **De resterende 12 pladser udlejes af DTU ved udbud**
- **Udlejes normalt fra 6 til 15 år til en pris så investeringer tilbagebetales på 10 år.**
- **Der lejes et areal med infrastruktur. DTU har ikke privilegier i forhold til målinger på lejeres vindmøller**
- **DTU driftsherre og al myndighedskontakt går gennem DTU**
- **Styre- og projektfølgruppemøde drøfter og godkender løbende nyinvesteringer og driftsbudgetter og regnskaber for både Østerild og Høvsøre**

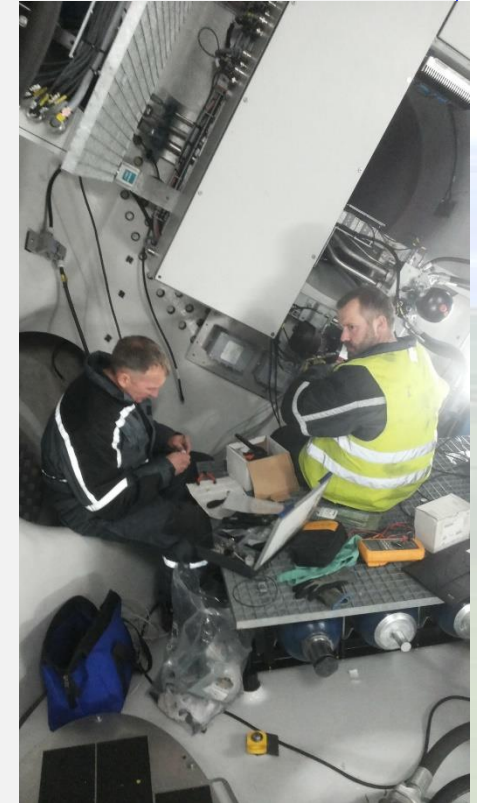
Power curve

- Power production
- Wind measurements (meteorological masts and lidars)

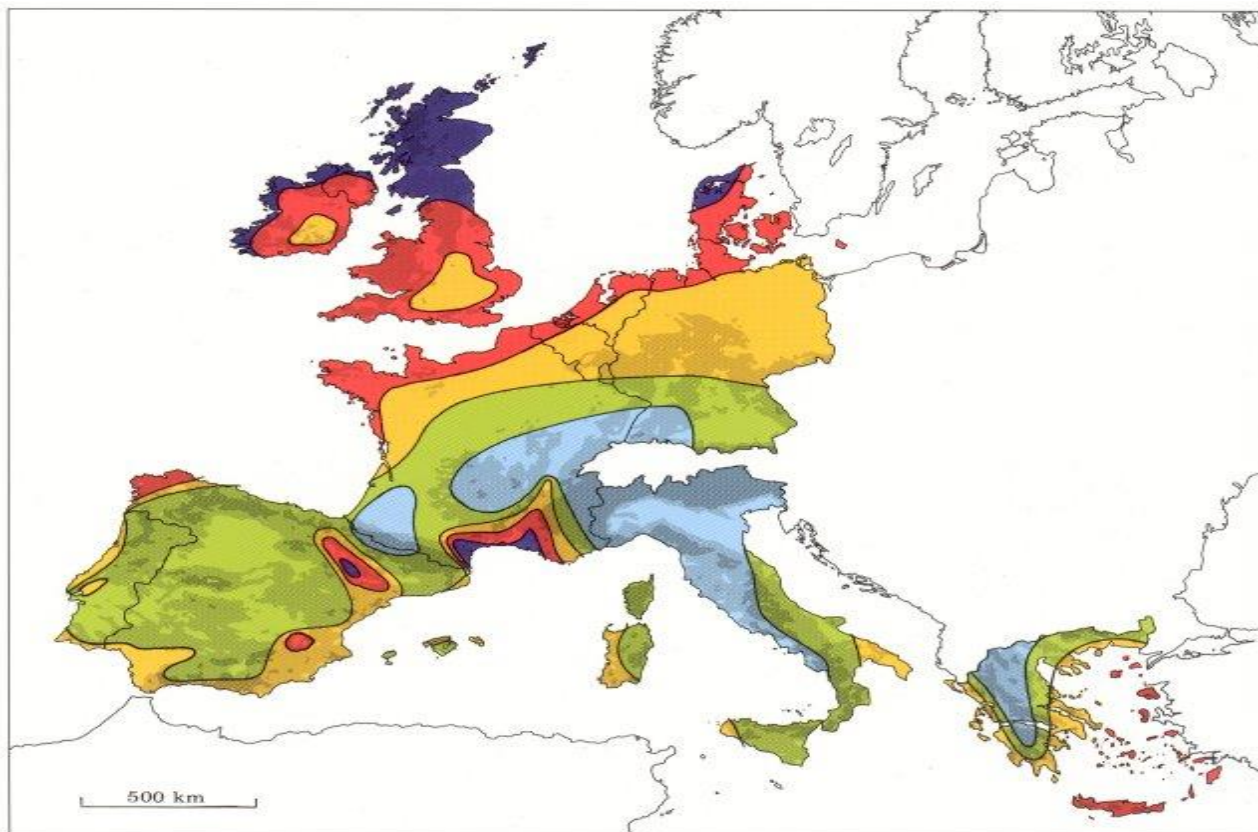


Mechanical loads

- Structural loads measurements
- Typically:
 - 200+ acquired signals
 - 70+ controller channels
 - 100+ post-proc. signals



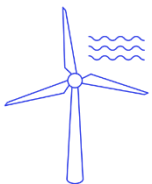
Noise measurements and Grid compliance tests



Wind resources¹ at 50 metres above ground level for five different topographic conditions

	Sheltered terrain ²		Open plain ³		At a sea coast ⁴		Open sea ⁵		Hills and ridges ⁶	
	$m s^{-1}$	Wm^{-2}	$m s^{-1}$	Wm^{-2}	$m s^{-1}$	Wm^{-2}	$m s^{-1}$	Wm^{-2}	$m s^{-1}$	Wm^{-2}
Dark Blue	> 6.0	> 250	> 7.5	> 500	> 8.5	> 700	> 9.0	> 800	> 11.5	> 1800
Red	5.0-6.0	150-250	6.5-7.5	300-500	7.0-8.5	400-700	8.0-9.0	600-800	10.0-11.5	1200-1800
Yellow	4.5-5.0	100-150	5.5-6.5	200-300	6.0-7.0	250-400	7.0-8.0	400-600	8.5-10.0	700-1200
Green	3.5-4.5	50-100	4.5-5.5	100-200	5.0-6.0	150-250	5.5-7.0	200-400	7.0- 8.5	400- 700
Light Blue	< 3.5	< 50	< 4.5	< 100	< 5.0	< 150	< 5.5	< 200	< 7.0	< 400

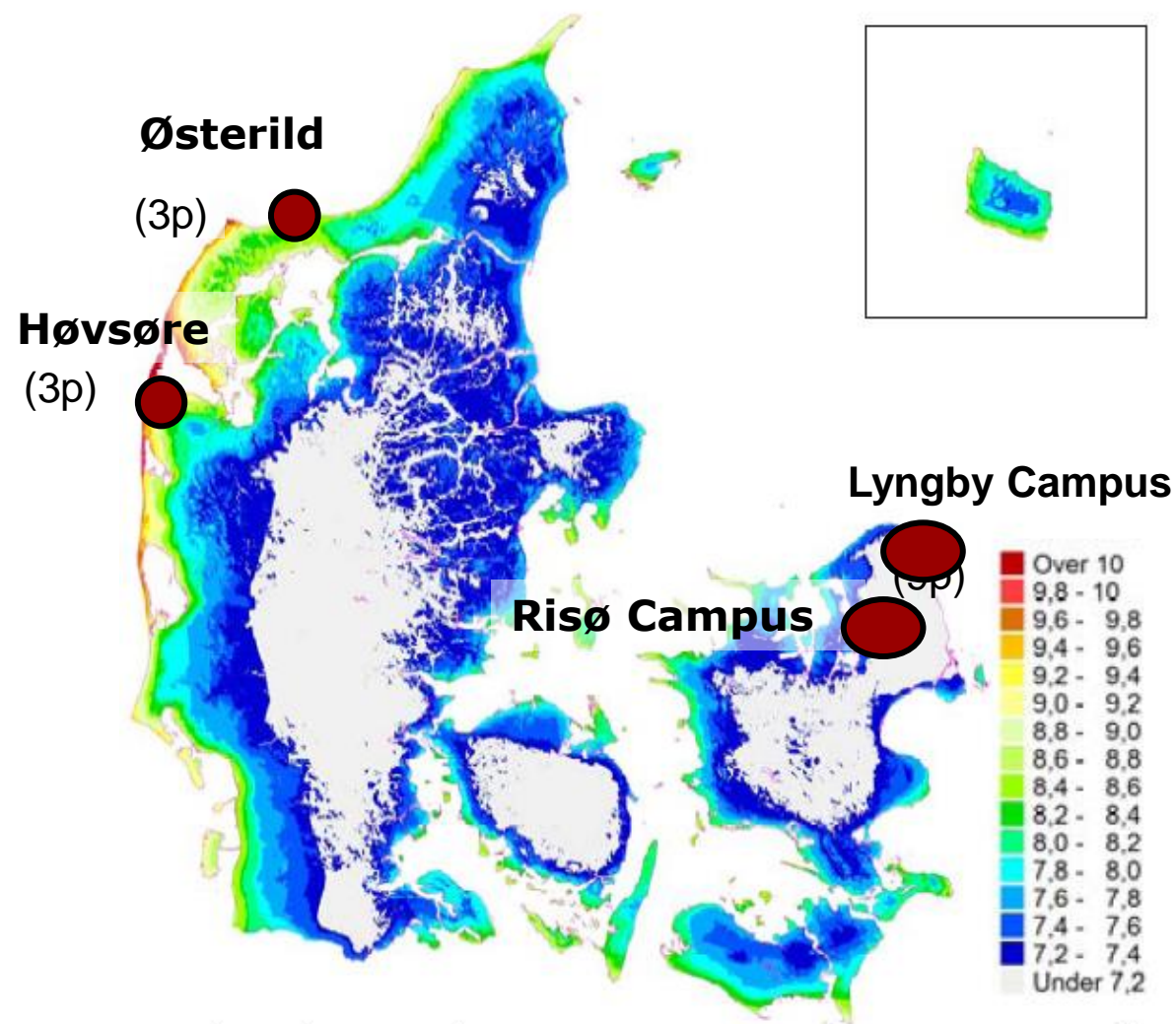
Where are we?



2 WTG test stations:
Høvsøre & Østerild



Lyngby Campus
Risø campus



Vindressourcekort over Danmark

Kilde: By- og Landskabsstyrelsen

21



State of the art test and measurement facilities & on-site DTU personnel

Østerild

National Test Center for very large Turbines

- 9 test pads
- Turbines up to 330 metres
- Rotordiameter 300 meter
- 3 technicians

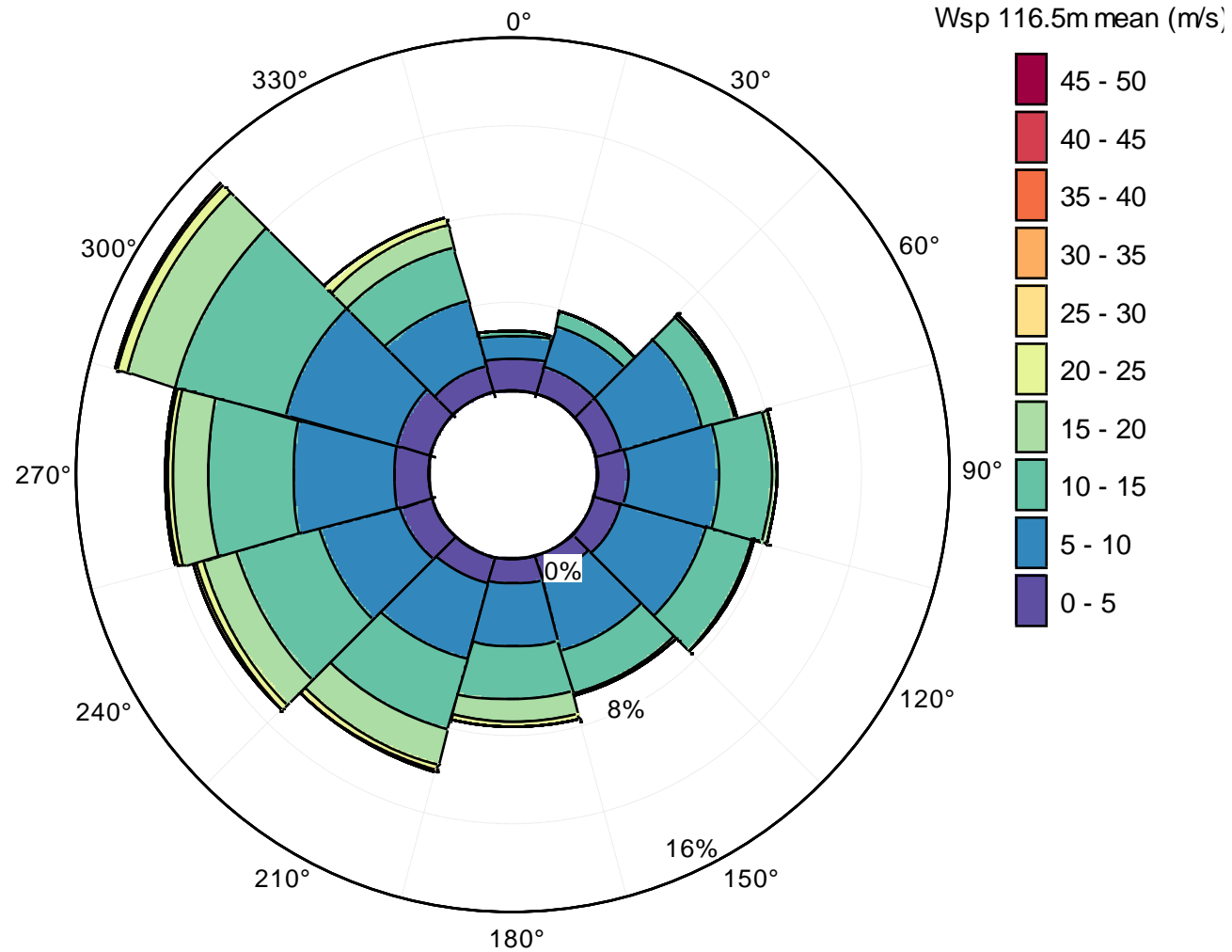
Høvsøre

- 7 test pads
- Turbines up to 200 metres
- Rotordiameter 150/175 meter
- 3 technicians

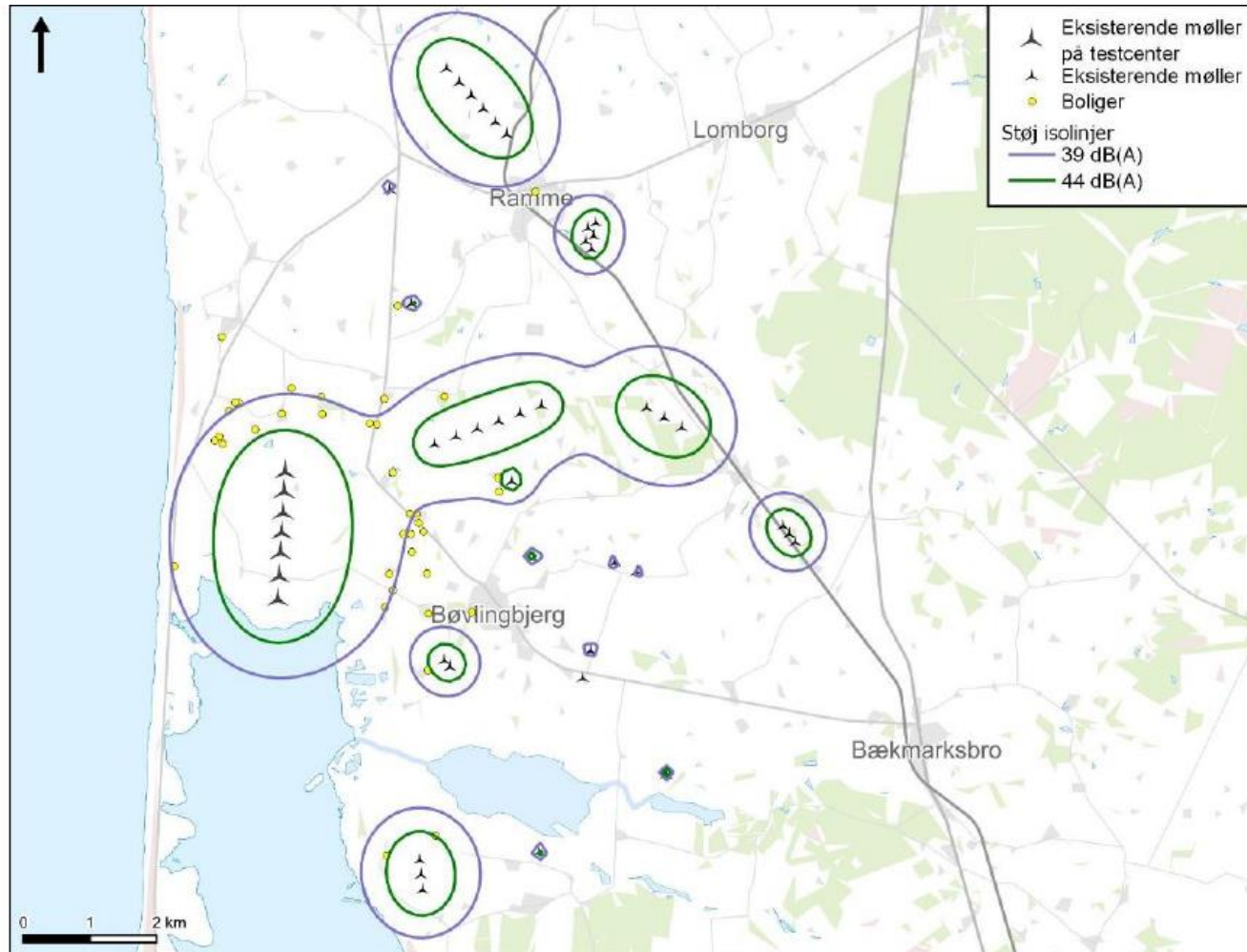




Wind Speed Distribution at Testcentre Høvsøre



Udbredelse af den samlede støj fra eksisterende vindmøller på testcenter Høvsøre



Vind 8 m/s

Teknik huse på testpladser



Metmast 2



Metmast 6



2 stk master 165 m med lysafmærkning for fly og helikopter

I dag er der ikke krav om f.eks. radarstyring



Studie af økonomiske effekter i området

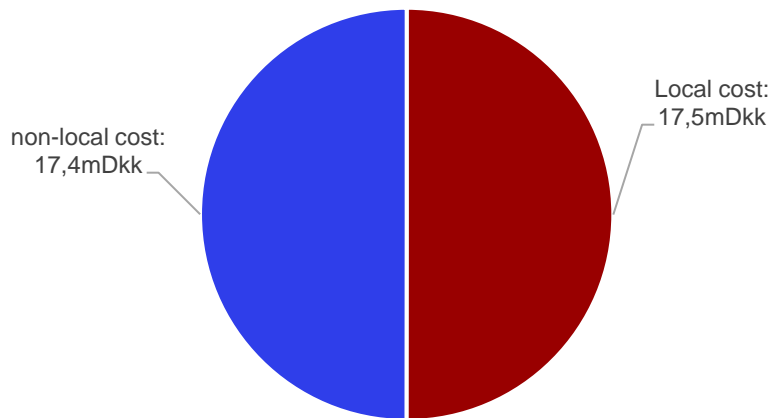
- Lokale økonomiske effekter i Lemvig kommune med fokus på virksomheder i nærheden af Testcenter Høvsøre
- Regional effekter i Midtjylland
- Nationale økonomiske effekter

- Forudsætninger
 - Alene udgifter Vestas, Siemens og DTU
 - Køb af jord ikke medtaget

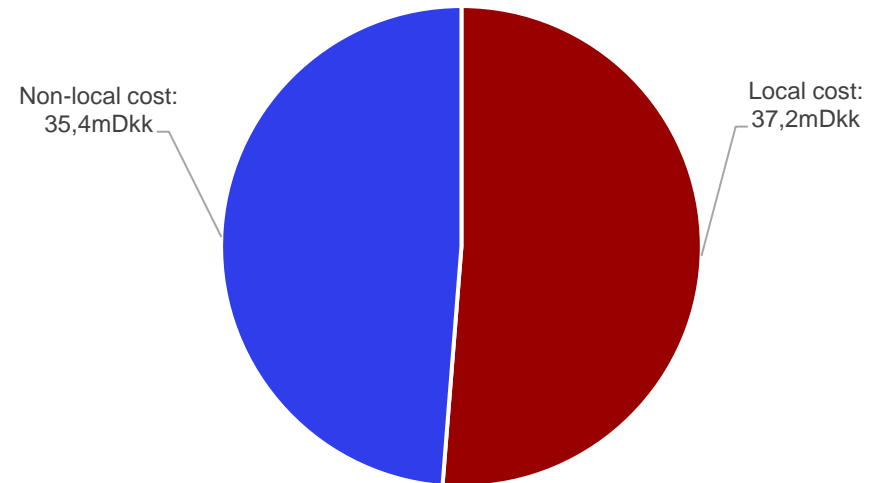
Primære økonomiske effekter

Årlig drift- og vedligeholdelsesomkostninger industri 35 mio kroner
Udvidelse af Testcenter Høvsøre 2018-22 budget 72,6 mio kroner

Total Yearly O&M Expenditure



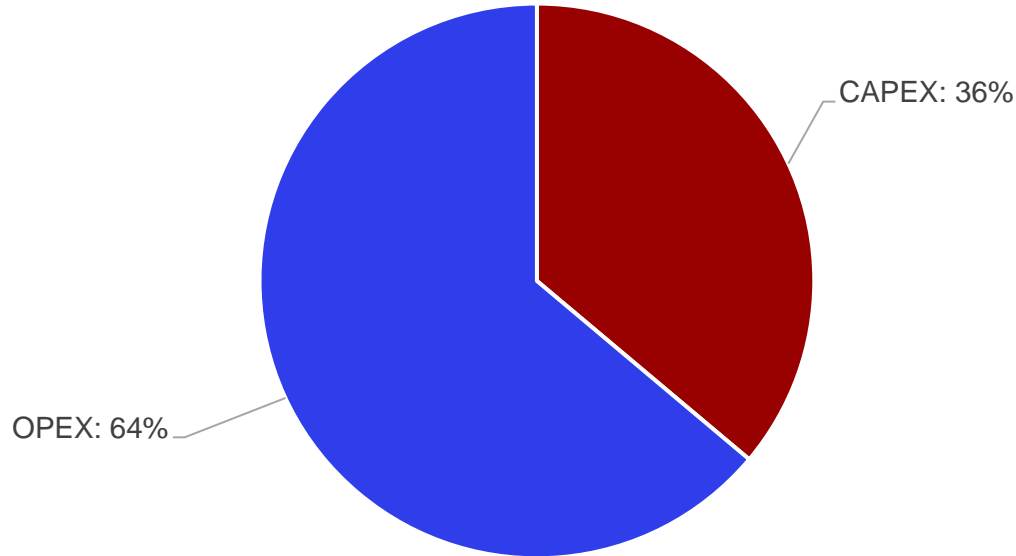
Rebuild 2023 DTU



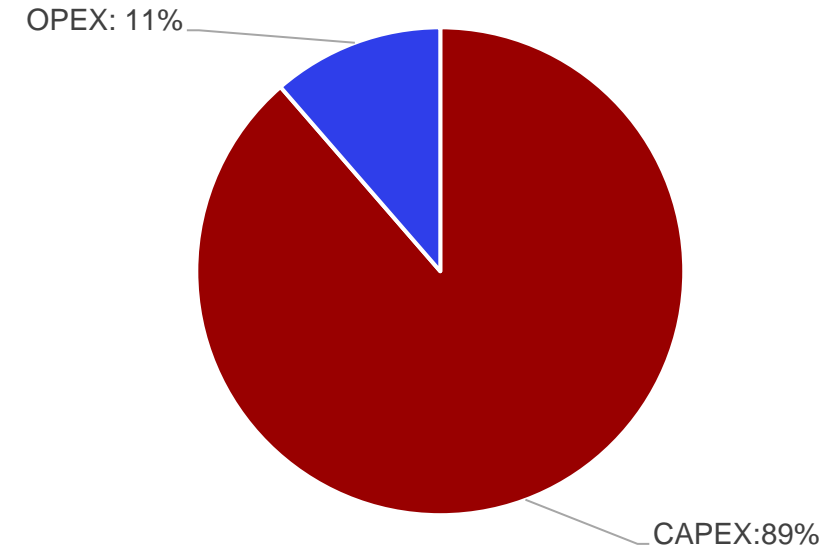
Omkostningsfordeling

Testcenter i forhold til almindelig vindmøllepark

OPEX/CAPEX fordeling Høvsøre 4 årig periode



OPEX/CAPEX fordeling 4 årig periode for almindelig vindmøllepark

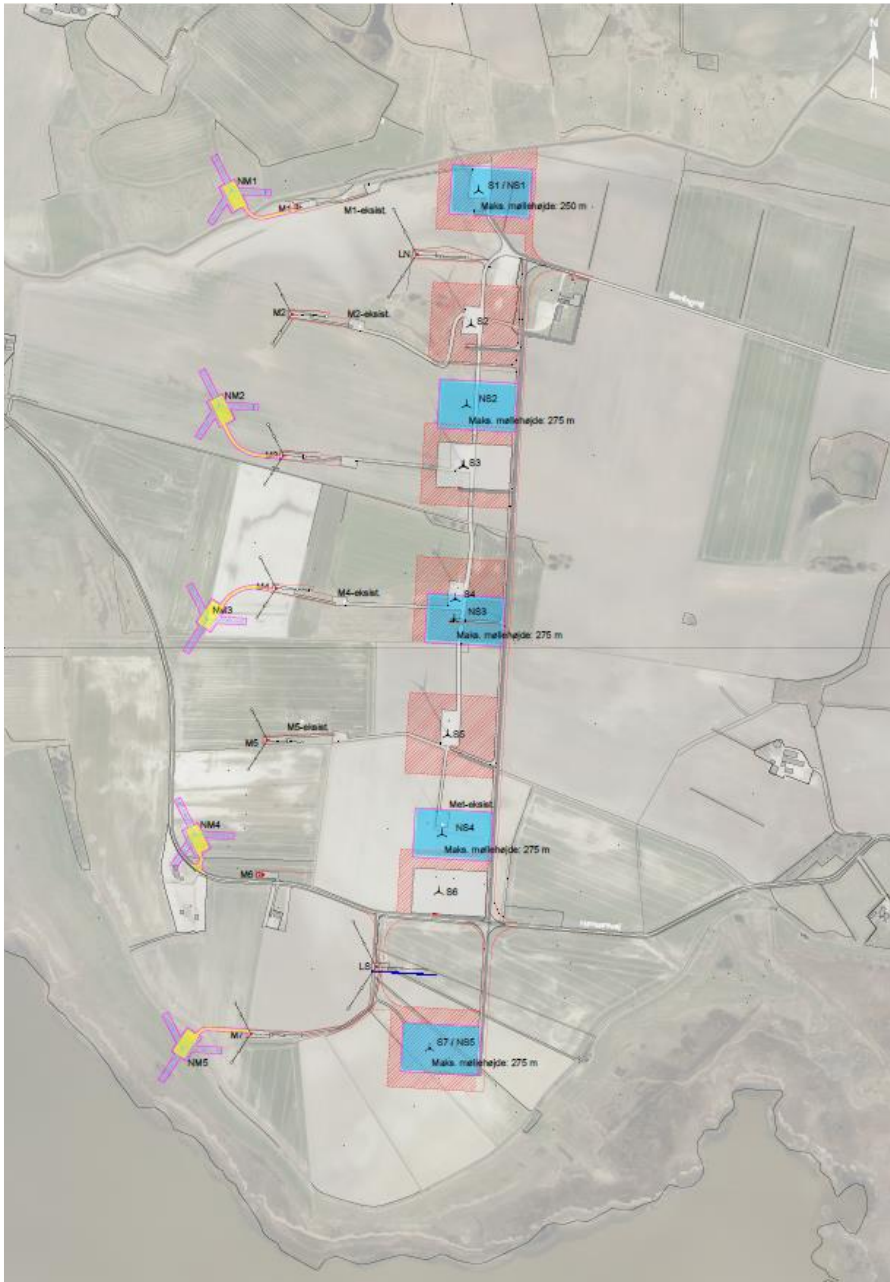


Konklusion: lokal økonomisk omsætning som følge af testcenter Høvsøre meget større end produktionsvindmøllepark

DTU's Testcenter Høvsøre



Stand	Manufacturer	Rated power[MW]	Rental period
1	Vestas	Unknown	01-10-2027
2	Vestas	2.0	30-09-2024
3	SGRE	5.0	31-10-2024
4	SGRE		21 -03-2029
5	-		
6	SGRE	6.0	28-02-2025
7	SGRE	6.0	31-07-2026



Forslag til opgradering af Testcenter Høvsøre

Maksimalhøjde 250, 275, 275, 275 og 275 meter

Afstand mellem prøvestande 475 meter

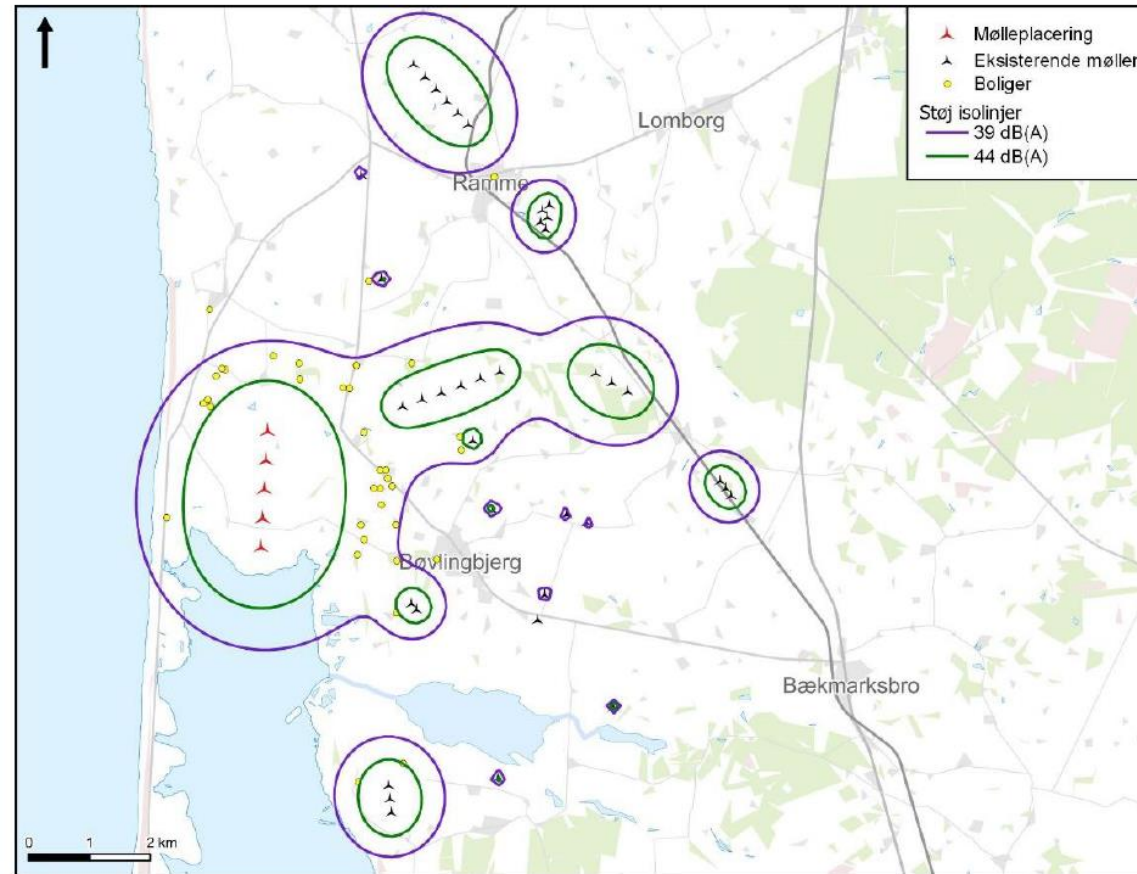
Nord og syd plads uændret placering

Målemaster længere mod vest

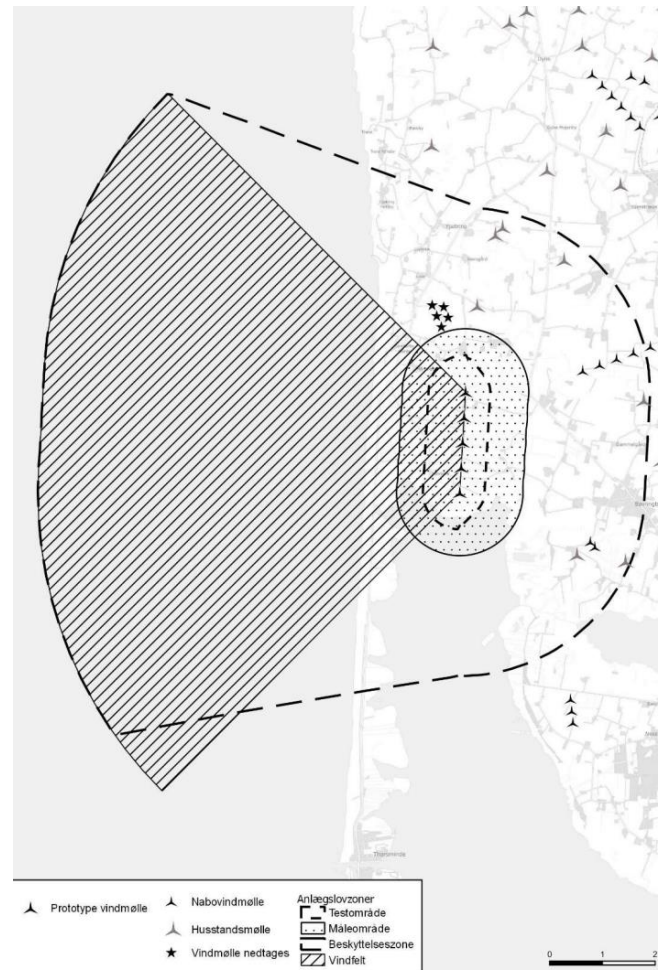
Større støjrummelighed

Større arbejdsarealer og mere vejareal

Udbredelse af den samlede støj i det nye forslag til tilpasning af Testcenter Høvsøre



Vindfelt opgraderede Testcenter Høvsøre



Wind Turbine Technology trends

- Digitalization
- Big data
- Disruption, incremental and revolution
- Globalization and specialization

- Upscaling 20 MW+
- Larger rotors relative to tower.
- Integrated complex design models with optimization and supercomputers
- Combined
 - Aeroelastic tailoring.
 - Distributed control.
 - Non-linear blade spar geometry
- Down wind turbines and 2-bladed WT
- Flexible towers
- Standard support structure.
- Advanced turbine and power plant control.







Thank you

Photo: P. F. Nielsen