Cooperation as a key to cost reductions for offshore wind

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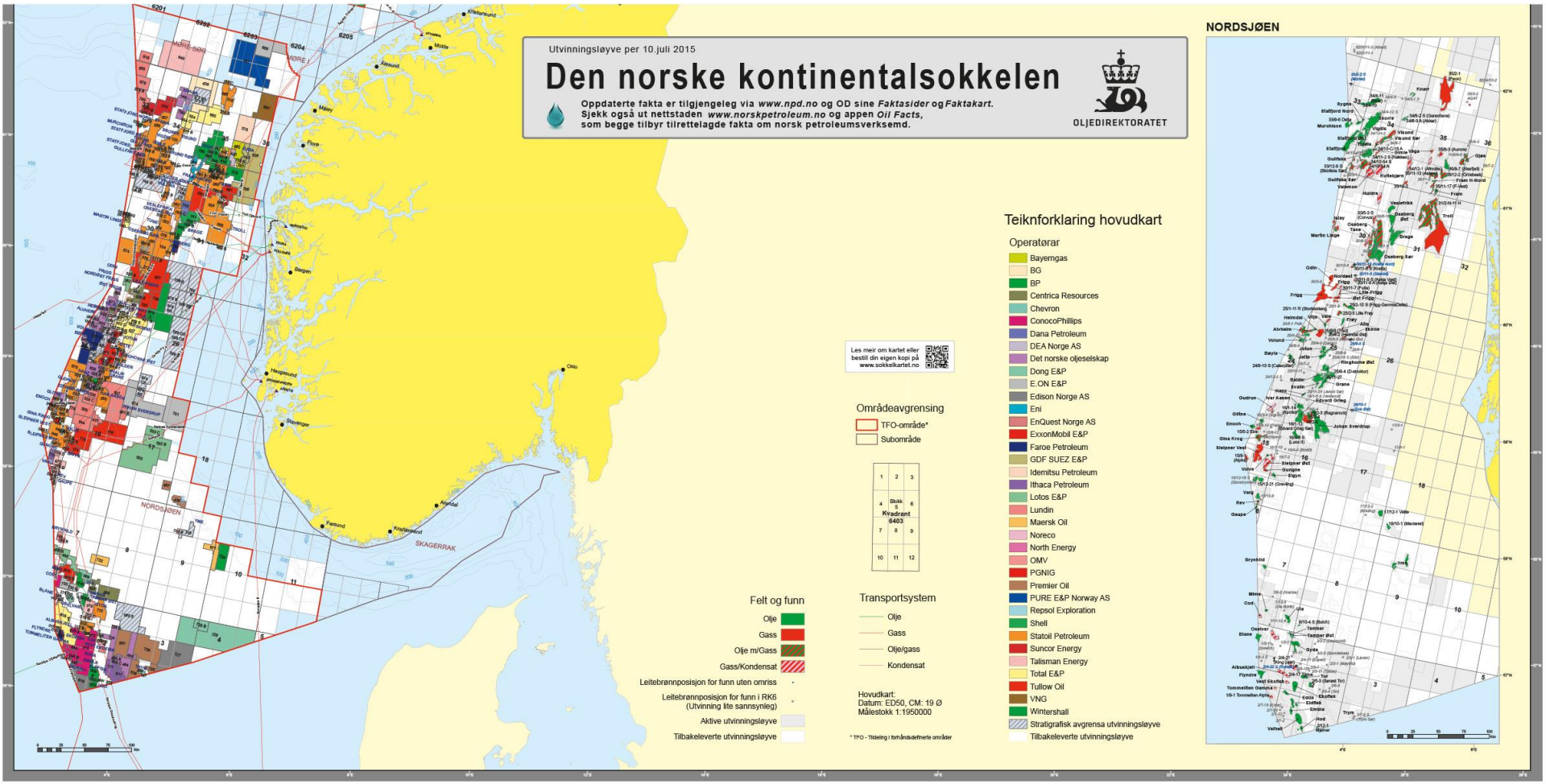
Outline

- Norwegian oil and gas industry
  - Cooperation
  - Govermental regulations
  - Support schemes for Norwegian research
- Examples from NORCOWE
  - OBLEX-F1
  - Improved understanding of turbulence
  - NORCOWE Reference Wind Farm
- 1+1=5!



Ownership of oil and gas licences
Statfjord as an example

Statoil	44,34 %
ExxonMobil	21,37 %
ConocoPhillips	15,17 %
Centrica Resources	9,69 %
Shell	8,55 %
Enterprise Oil	0,89 %
Norge	

Norwegian oil and gas industry

- Business sensitive information
  - Geological information
  - Interpretation of geological information
- Common interests in developing the oil&gas vendor industry
  - Close cooperation on development of the techical solutions, transperency between the vendor and the customer
  - Detailed technical information available to the oil&gas companies from the vendors
  - Use of JIP to mature the vendor industry
  - A development project is considered succesful when implemented in the vendor industry
-

Strong governmental involvement

- Oljedirektoratet founded in 1972 (first oil detected in August 1969)

NORWEGIAN PETROLEUM DIRECTORATE

- Petroleumstilsynet founded in 2004 (demerged from Oljedirektoratet)

PETROLEUM SAFETY AUTHORITY NORWAY

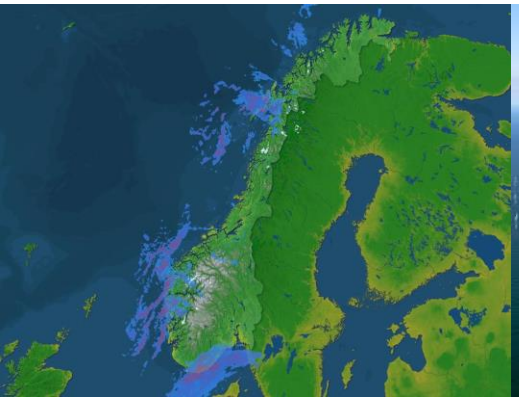
Investment in Norwegian research

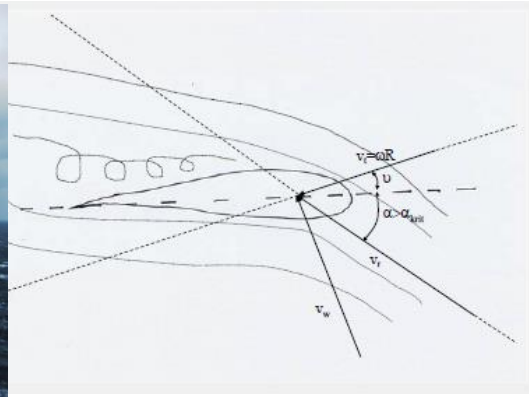
- Strong incentives to invest in Norwegian research by governmental regulations
- Norwegian authorities told the oil companies to install instruments on their offshore installations
- Norwegian Petroleum Directorate (OD) collected the data, and set up R&D programs to analyze the data. The analyses were paid by the oil companies
- OD still collects data from the Norwegian continental shelf
- Investment in R&D in Norway was important to get licences on the Norwegian continental shelf

Cooperation in the Norwegian oil and gas industry

- The Norwegian Oil and Gas association (Norsk olje og gass) consists of 54 oil/gas companies and 55 supplier companies. The companies represent about 35 000 employees.
- Founded in 1965 as Norsk Industriforening for Oljeselskapene
- Have organized joint projects to meet regulatory requirements
- An example of commercial cooperation: Turbinpool, a joint maintenance contract for 97 gas turbines from Norsk Hydro, Statoil and Exxcon Norge towards GE.

Why is scientific cooperation needed?



Mesoscale	Park scale	Rotor scale	Blade scale
10000 -10 km	10 -1 km	200 – 50 m	5 - .5 m
Days -Hours	20 min – 20 s	10 – 2 s	0.5 – 0.01 s

Factor of 10^6 in relevant length and time scales

By courtesy of Finn-Gunnar Nielsen

Examples from NORCOWE

- OBLEX-F1 – measurement campaign at FINO1
- LIMECS – Lidar measurement campaign at Sola (Stavanger)
- Improved understanding of turbulence and loads on offshore wind turbines
- NORCOWE Reference Wind Farm
- Validation of models with data from Sheringham Shoal
- Lysefjord bridge (UiS, NPRA, UiB, CMR, DTU)

FINO 1

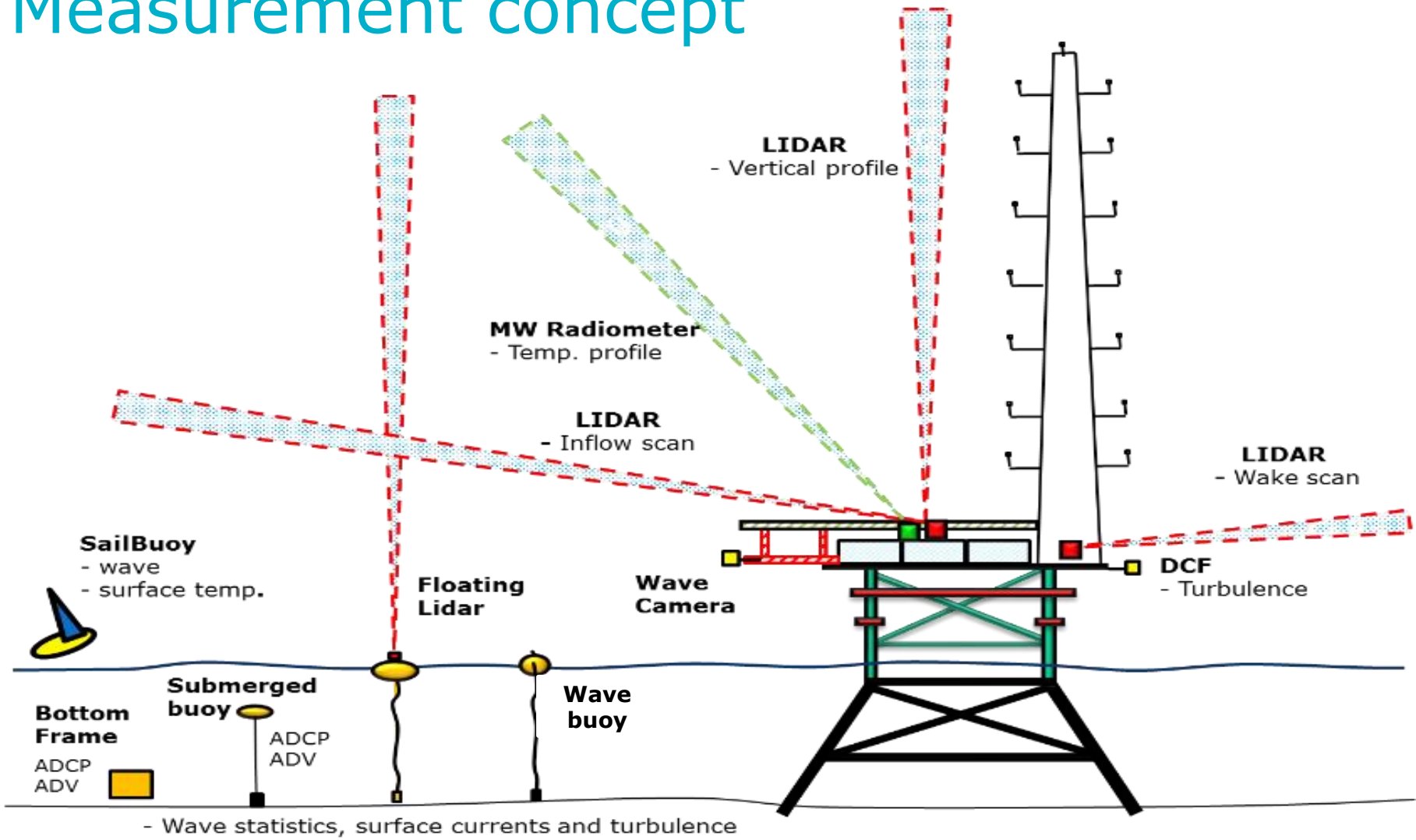
- Research platform
- Commissioned 2003

- Owner:
  Federal Ministry (BMWi)
- Administration:
  Projektträger Jülich

- Operator 2012-2017:
  FuE-Zentrum FH Kiel

- Public available data

Measurement concept

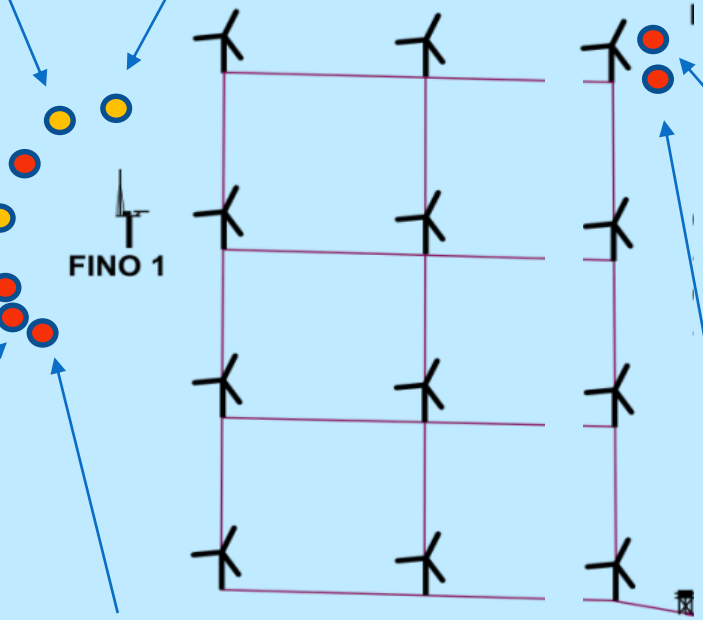


BSH
Wave buoy
Accelerometers, compass

IWES
2x LIDAR buoys

CMR
Sailbuoy
Wave sensor, temperature

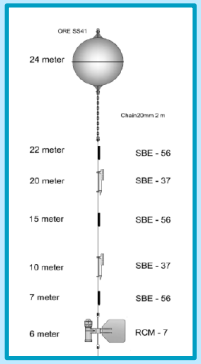
Axys
WindSentinel
LIDAR buoy

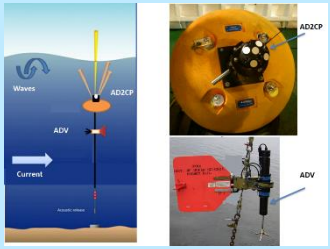


UIB/OBLO
Bottom frame
- ADCP, Aquadopp, ADV

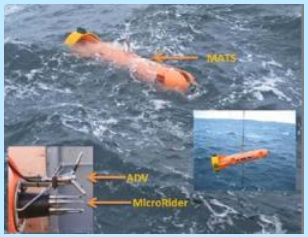
UIB/OBLO
Bottom frame
- ADCP, Aquadopp, ADV

UIB/OBLO
Submerged buoy
- Current meter

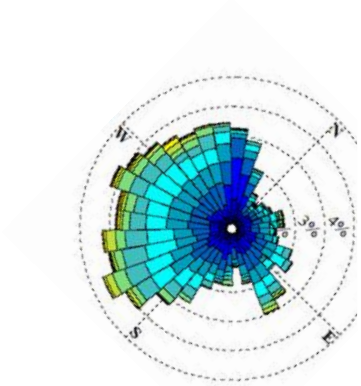




UIB/OBLO
Submerged buoy
- ADCP



UIB/OBLO MATS
Submerged buoy
- Microrider shear probes, Aquadopp



Wave camera

Microwave radiometer
RPG-HATPRO G4

Scanning lidar #2
Windcube 100s

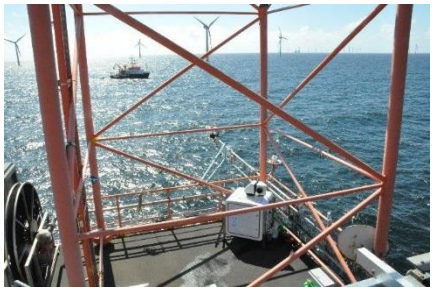
Scanning lidar #1
Windcube 100s

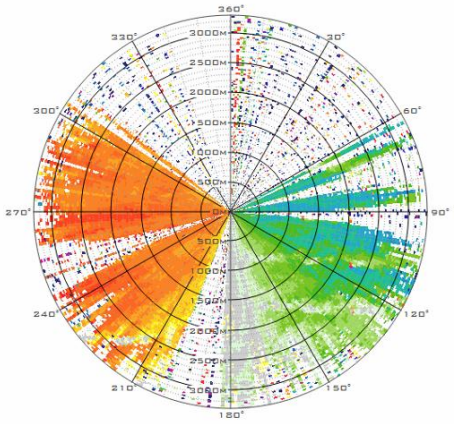
2x DCF
turbulence sensors

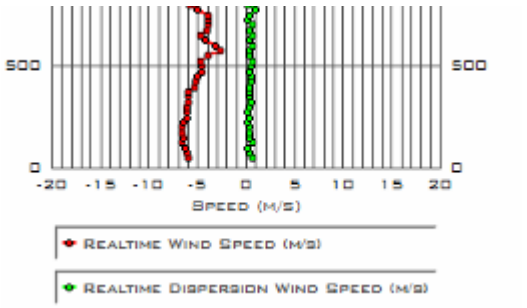
APLHA VENTUS, 405 m

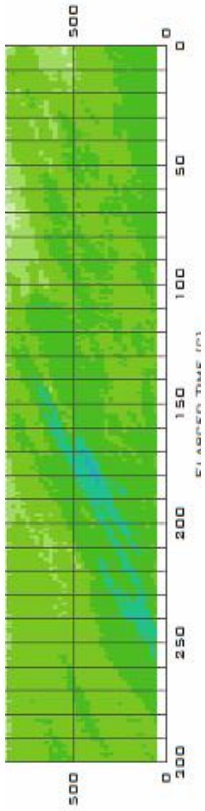
Scanning lidars

- Online instrument control and webcam monitoring
- Real-time access to wind profiles for inflow and wake









Workshop on OBLEX-F1 data

Validation of turbulence models

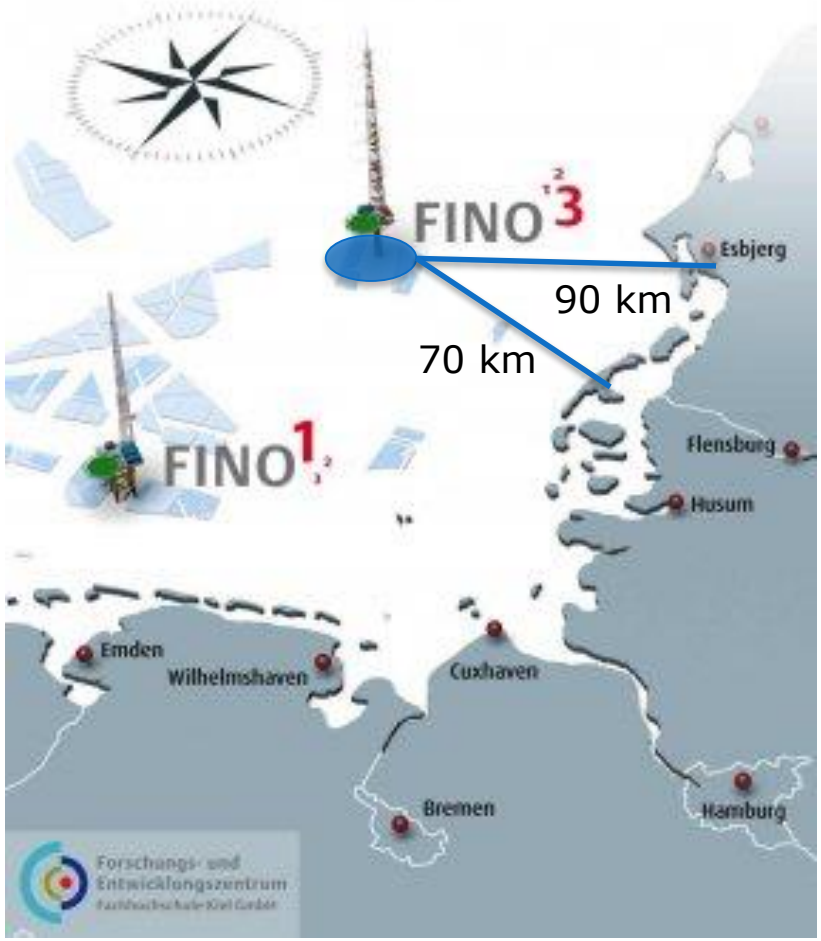
- Industrial motivation: accurate estimation of loads
- Validation of tubulence models, with a particular focus on applications to loads is a main focus area in NORCOWE in 2016-2017
- Coherence investigations of atmospheric turbulence as collaboration between UiB, UiS, UiA, CMR and Statoil
- Utilizing the OBLEX-F1 data to see if waves, atmospheric stability, wind and wave field influence the turbulence characteristics

Norcowe reference wind farm

Thomas Bak, Angus Graham, Alla Sapronova,
Zhen Chen, Torben Knudsen, John D Sørensen,
Mihai Florian, Peng Hou, Masoud Asgarpour

Key parameters

- Reference zone: FINO3
- Installed capacity: 800 MW
- Number of turbines: 80
- Turbine: DTU 10 MW turbine, rotor* 178m, hub height 119m
- Water depth / foundations is not in the initial focus – 22 meter, monopile



*Bak C, Zahle F, Bitsche R, Kim T, Yde A, Henriksen LC, Natarajan A, Hansen MH. Description of the DTU 10 MW Reference Wind Turbine. DTU Wind Energy Report-I-0092, 2013.

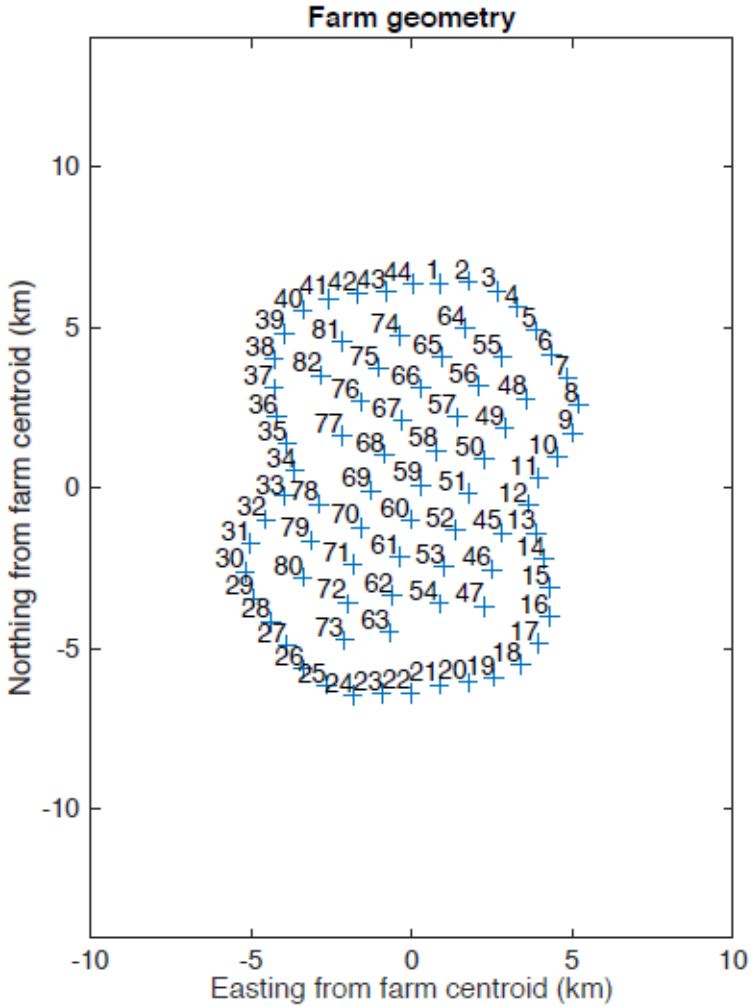
Baseline turbine layouts of the NORCOWE reference wind farm

Developmental work on Norcowe's reference wind farm (RWF) has taken place at Aalborg University and Uni Research.
The RWF comprises a fictitious 800 MW wind farm at the location of the FINO3 met mast, 80 km west of the island of Sylt at the Danish-German border.

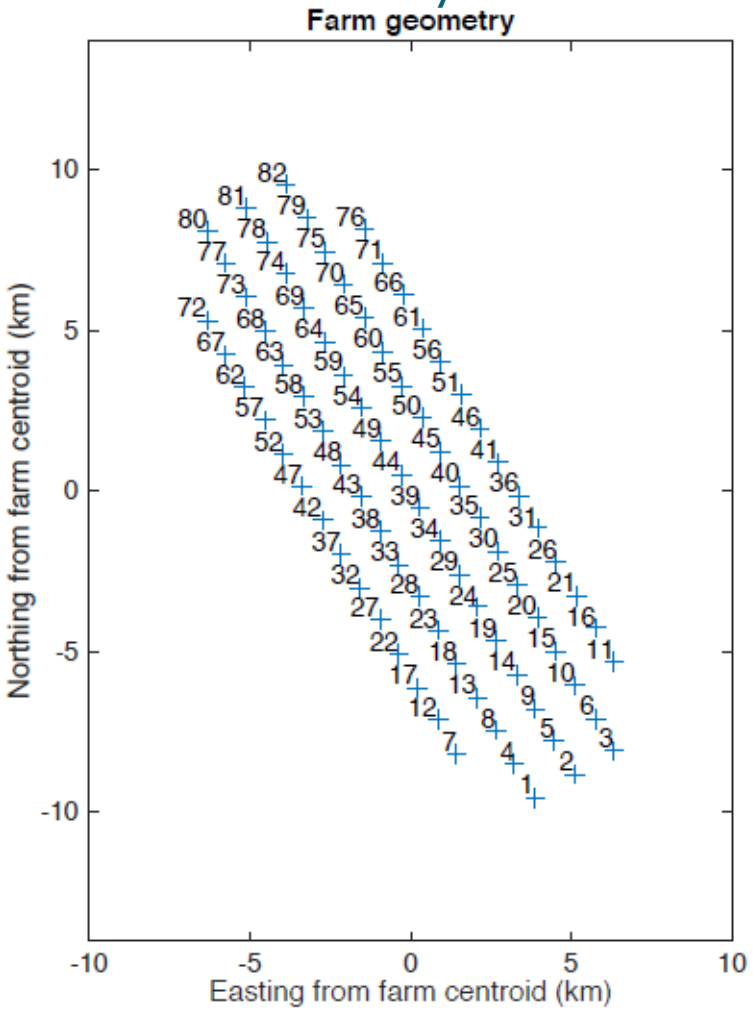
- The farm involves a set of 80 reference wind turbines and two substations.
- DTU's 10 MW reference wind turbine is the chosen turbine type, a variable-speed rotor of diameter 178 m and hub height 119 m.
- Foundations are monopiles: mean water depth at FINO3 is 22.5 m, soil type comprises medium dense to very dense sand deposits with gravel and silt constituents.
- There is a real wind farm at FINO3, DanTysk, owned by Vattenfall.

NORCOWE RWF

AALBORG UNIVERSITY



Alternative layout:



norcowe
Norwegian Centre for Offshore Wind Energy

How can 1+1=5?

- Common goals, joint effort
- Skilled people
- Clusters (industry, academia, education and public sector)
- Good management systems in the industry
- Govermental regulations
- Industrialization and standardization

It’s all about people!

Thank you for your attention!