AN OVERVIEW OF WIND ENERGY RESEARCH AT TU DELFT

Simon Watson

Professor of Wind Energy Systems

Director of DUWIND

TU Delft

OVERVIEW

- Wind Energy Section
- DUWIND
- Some research highlights
- The EUROS project
- Future initiatives
- Summary

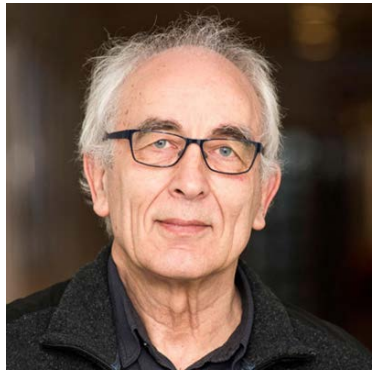
WIND ENERGY GROUP - ACADEMICS

4 professors
(one emeritus)

Simon Watson

Gerard van Bussel

Damiano Casalino



Gijs van Kuik

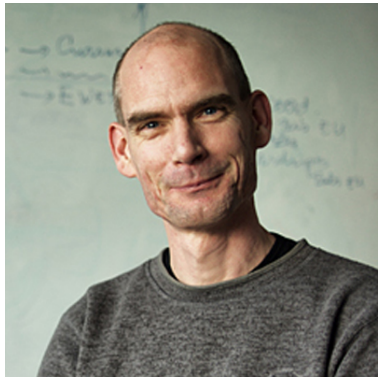
2 associate
professors

Carlos Ferreira

Roland Schmehl

6 assistant
professors

Francesco Avallone



Michiel Zaaijer

Nando Timmer

Wim Bierbooms

Axelle Viré

Daniele Ragni

WIND ENERGY GROUP – RESEARCHERS AND PHDS


Erik Quaeghebeur


Qingqing Ye


Johannes Oehler

3 research associates











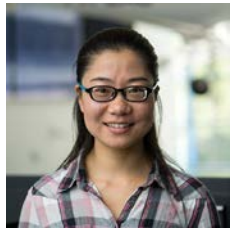


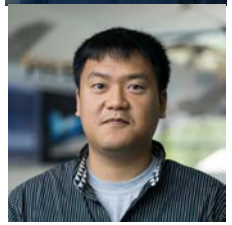
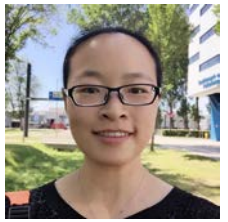





28 PhD candidates



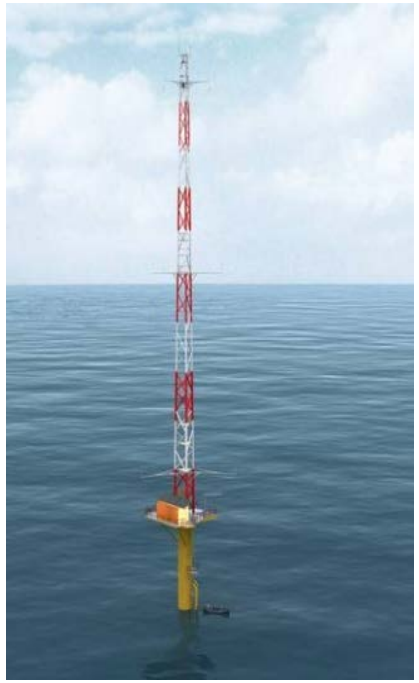

RESEARCH AREAS

- External conditions for wind turbine loading
- Wind turbine aerodynamics
  - rotor aerodynamics
  - load mitigation (adaptive) rotors
- Novel wind energy concepts
- Offshore wind farm optimisation
- Aeroacoustics

PROGRAMME 1: EXTERNAL CONDITIONS FOR WIND TURBINE LOADING

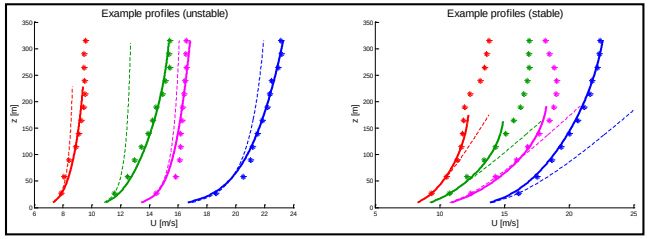
Objective:

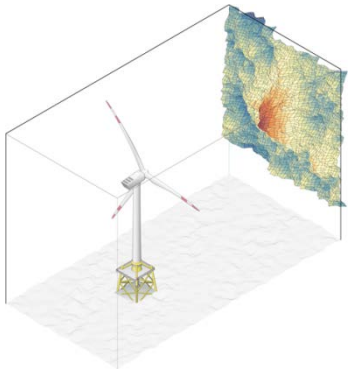
Characterisation of offshore wind environment for determination of its impact on wind turbine loads



Highlights:

- Method for constrained stochastic gust simulation
- Six-beam approach for lidar turbulence measurements.
- Novel momentum based extreme turbulent gust modeling





FLOW

meteo mast

PROGRAMME 2: WIND TURBINE AERODYNAMICS

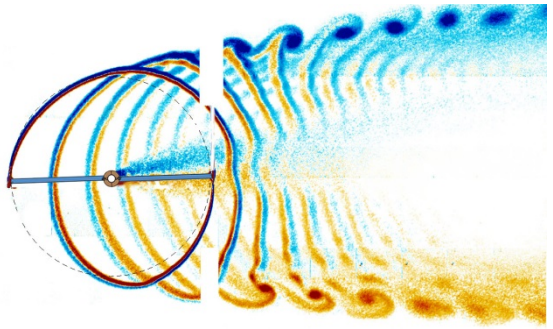
2a: Rotor aerodynamics

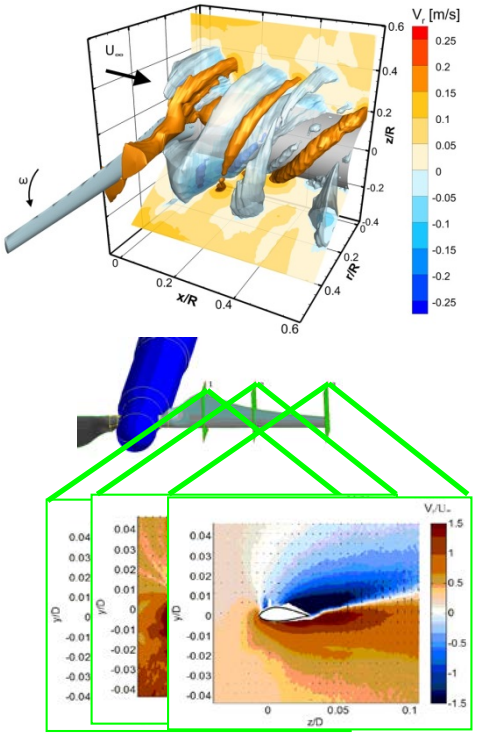
Objective:

Improvement of aerodynamic rotor performance of horizontal and vertical axis rotors in complex flows

Highlights:

- Hybrid Eulerian-Lagrangian code for 3D unsteady simulations
- New vertical axis rotor theory
  => thick airfoils lead to high rotor performance
- Validated high level CFD tool (open access)





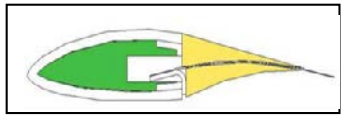
complex flows

PROGRAMME 2: WIND TURBINE AERODYNAMICS

2b: Load mitigating (adaptive) rotors

Objectives:

1. Innovative local blade aerodynamic control
   => mitigate load fluctuations
2. Alternatives for blade pitch control
   => lean robust rotor

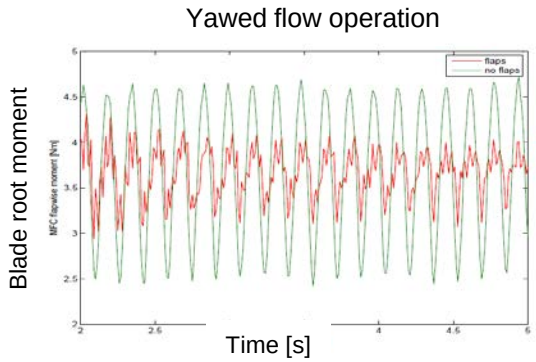


Highlights:

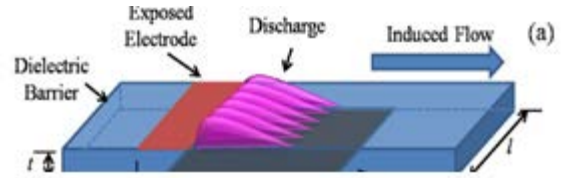
- Validated blade dynamics code with
  - integrated active flap control
  - non-linear structural dynamics
  - rotor aerodynamics

- Delft smart rotor technology
  => 5-10% load reduction on full scale wind turbines

- DBD (plasma) actuation methodology for load control and alleviation



TU Delft smart rotor



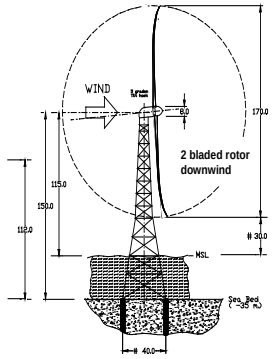
Programme 3: Novel Wind Energy Concepts

Objectives:

1. Cost reduction through lean design and
2. Reduction of material use

Three Concepts:

- 2 Bladed Downwind Rotor
  - lattice (truss) tower
  - passive load control



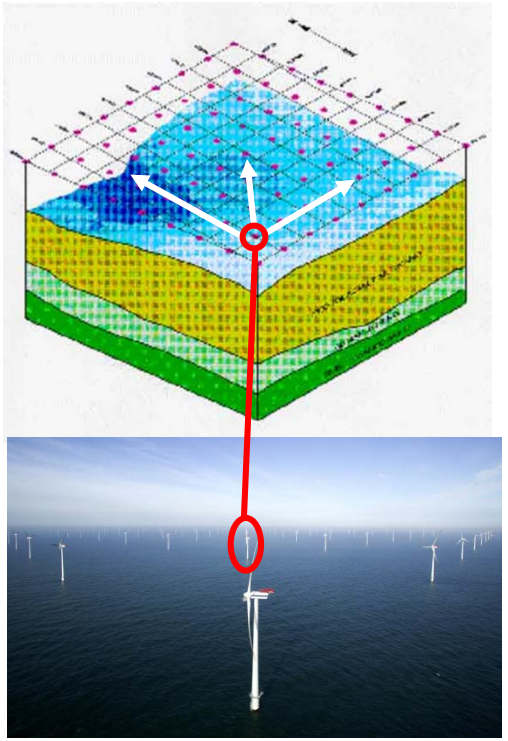
- Floating VAWT's
  - Advanced aero design with improved CP
  - Trifloater and spar buoy

- Airborne Wind Energy Concepts
  - automatic control of kite/wing
  - automated launch and retrieval using drone technology

PROGRAMME 4: OPTIMISATION OF (OFFSHORE) WIND FARMS

Objectives:

1. Multidisciplinary design optimisation for offshore wind farms
2. Optimisation of operation and maintenance

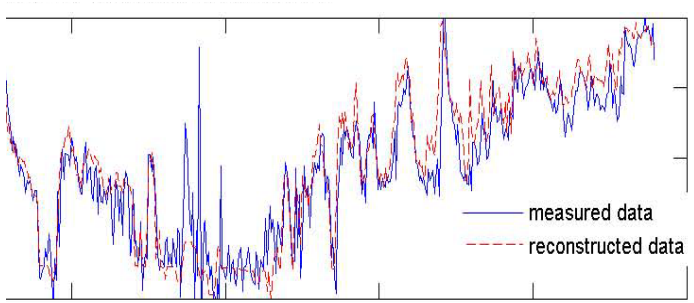


Highlights:

- Multi-agent scenario assessment tool
  => robust implementation paths for offshore wind farms in NL

- Offshore wind farm design emulator
  => efficient component trade-off studies.

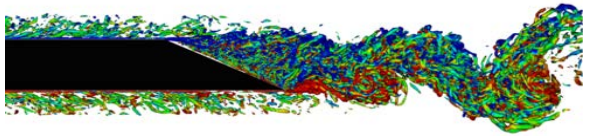
- MDO tool with dynamic simulations in the loop
  => up-scaling of offshore wind turbines

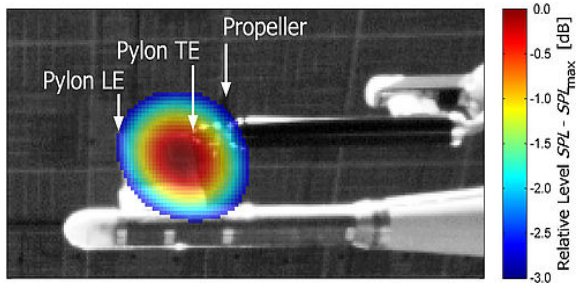


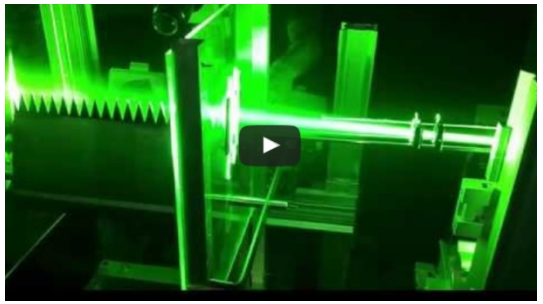
Programme 5: Aero-acoustics group

Objectives:

1. Facilitate noise reduction and noise mitigation rotors (both wind turbines and propellers)
2. Develop new concepts through combined numerical and experimental research







Highlights:

- New experimental aero acoustic wind tunnel to be inaugurated in 2017
- Novel design of serrated trailing edges (“flat iron” design)
- Development of tuned porous ceramics for noise mitigation on rotors and auxiliaries

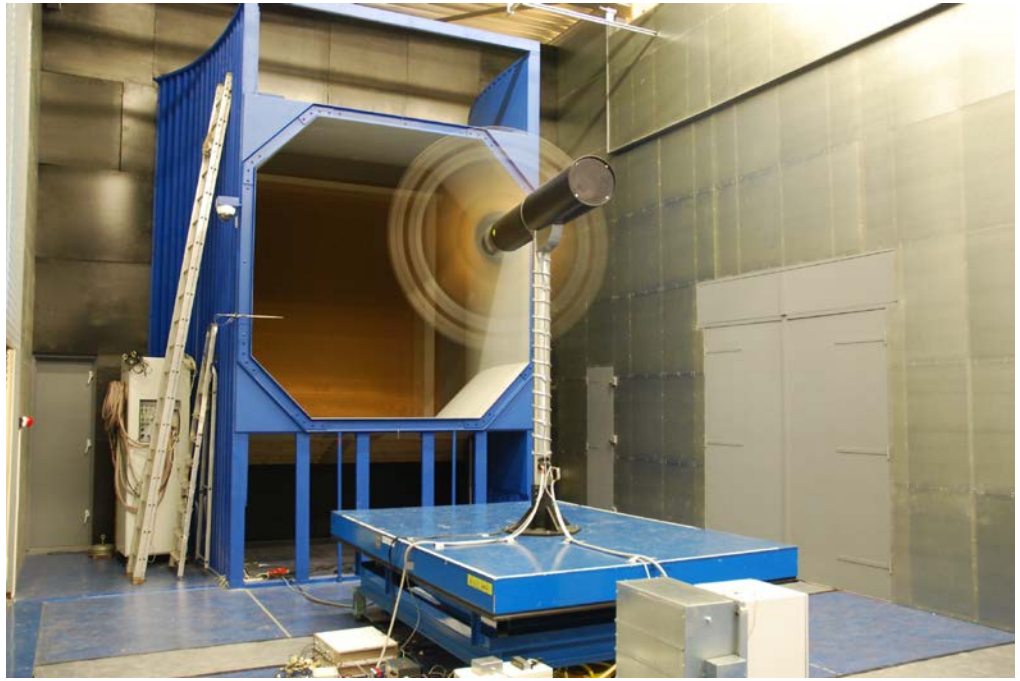
DUWIND - TU DELFT WIND ENERGY INSTITUTE

- Inter-faculty research organisation in Wind Energy
- Coordinates wind energy research activities across 5 faculties and 13 groups
- Works closely with external partners including Netherlands Energy Research Foundation ECN

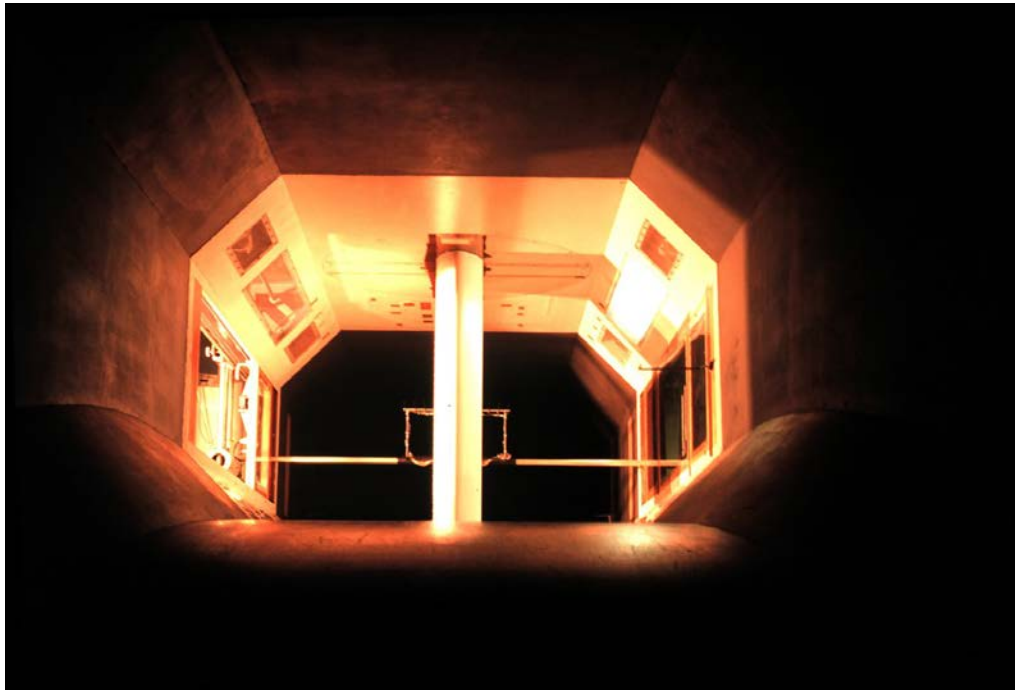
DUWIND PARTICIPANTS

- Aerospace Engineering (Wind Energy, Structural Integrity and Composites, Aerodynamics, Aerospace Structures)
- Civil Engineering and Geosciences (Offshore Wind)
- Electrical Engineering, Mathematics and Computer Science (Electrical Power Processing, Electrical Power Systems)
- Mechanical and Materials Engineering (Delft Center for Systems and Control (DCSC), Engineering Dynamics)
- Technology, Policy and Management (Economic of Infrastructures, Technology Dynamics & Sustainable Development)

WIND TUNNEL FACILITIES



Open Jet Facility

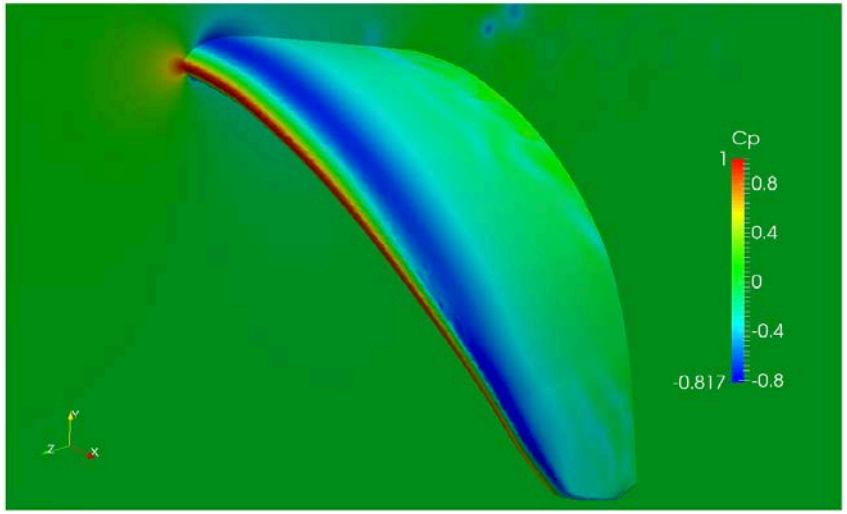


Low speed wind tunnel –
testing of DU blade section

HIGH-FIDELITY MODELLING OF FLUID-STRUCTURE INTERACTIONS

- Main team: Dr A. Vire, Dr R. Schmehl, N. Rajan, J. Brandsen, J. Dong, M. Folkersma
- CFD models: **Fluidity** (with Imperial College), **OpenFOAM**
- CSD models: in-house **Python codes** for flexible kites and NURBS-based rigid-body model

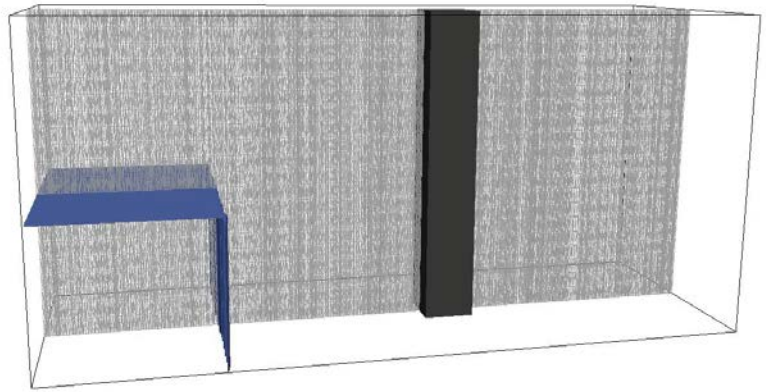
- Application to **airborne wind energy**: rigid and flexible kite wings
  - Aerodynamics of kite wings at high Re
  - Validation of RANS and LES models
  - Future work: Kite deformations
  - Funding:
    - EU Marie Curie CIG NUMIWING
    - EU ITN AWESCO



HIGH-FIDELITY MODELLING OF FLUID-STRUCTURE INTERACTIONS

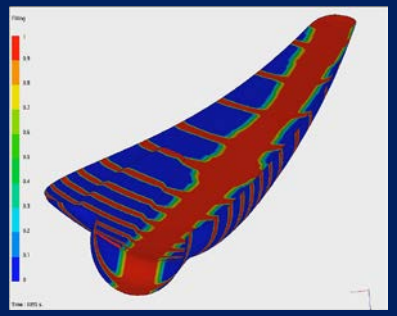
- Application to **fixed and floating offshore wind turbines**
  - Aero/hydro-dynamics problem
  - Accurate wave propagation and wave-structure interactions with air-water interface
  - Future work: wind turbine parameterisations
  - Funding: TU Delft cross-departmental scheme

- Application to **add-ons** for wind turbine blades (just started)
  - Partnership with 2B-Energy
  - Funding: Dutch research council

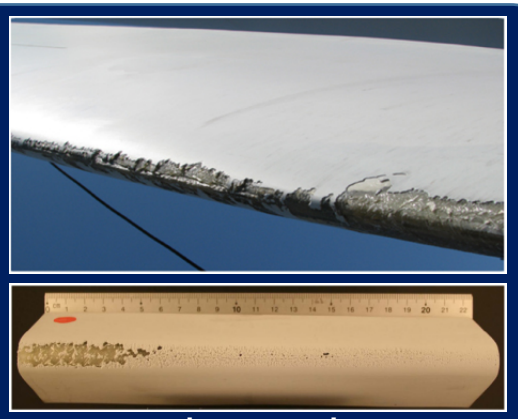


AEROSPACE STRUCTURE AND MATERIALS - BLADES

Reliable manufacturing with rapid throughput; Greener manufacturing processes

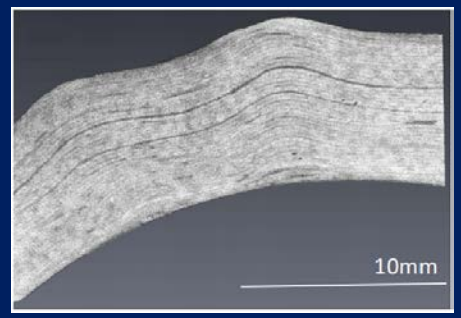


Process Simulation & Verification



Rain erosion

Processing new materials

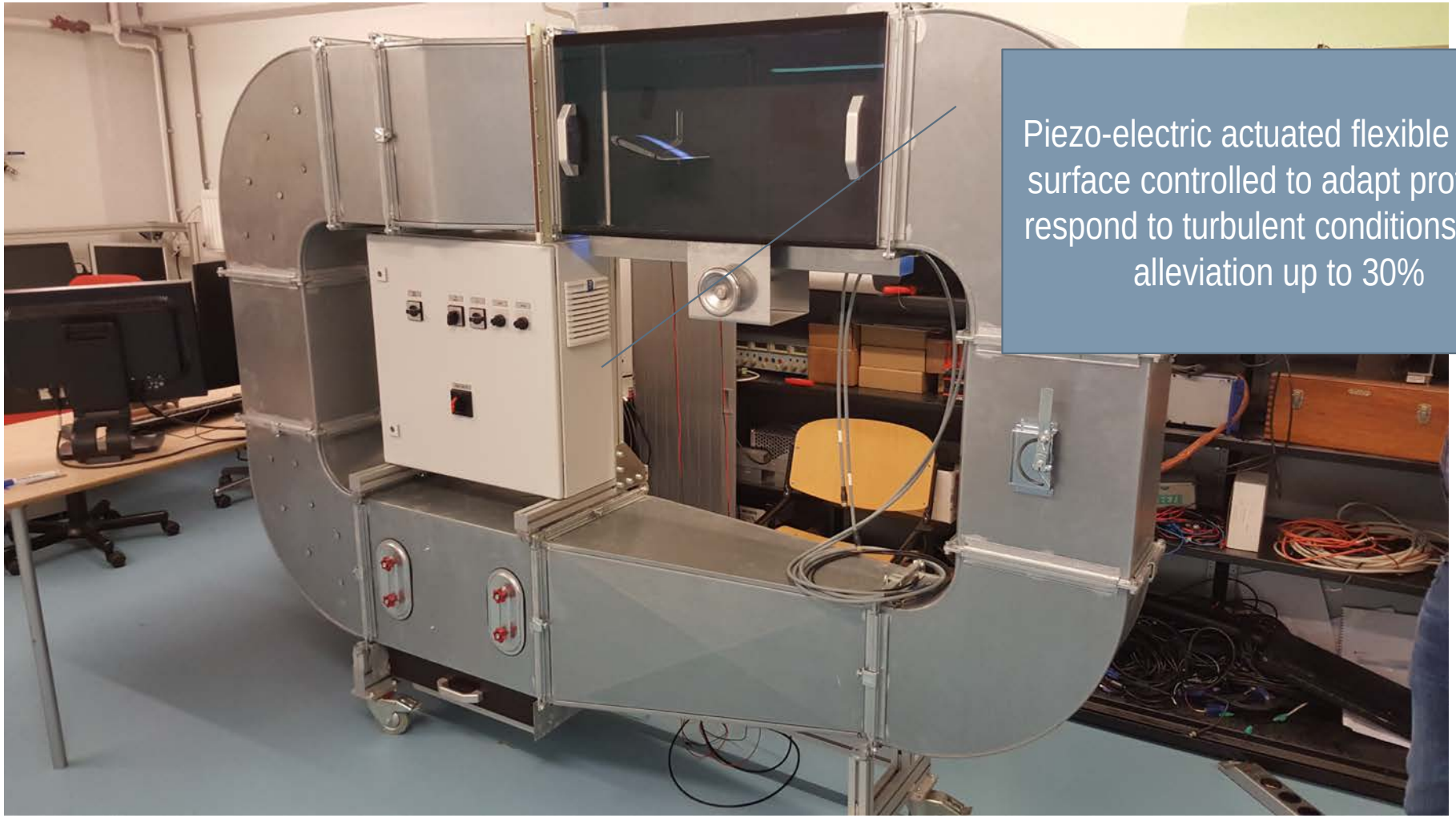


Effect of defects on lifetime

Smart manufacturing

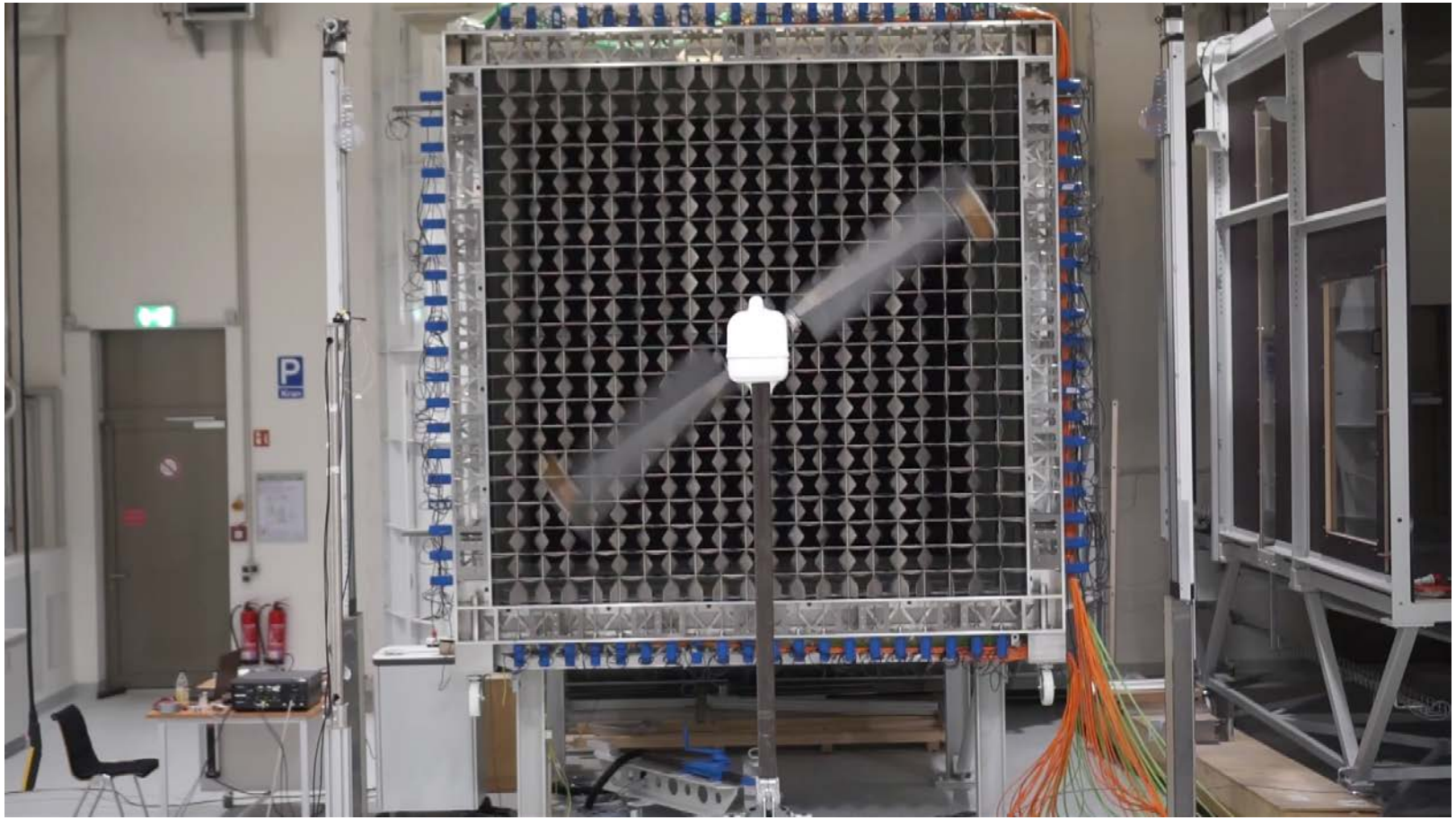
Sustainable processes

SMART ROTOR: MORPHING BLADES

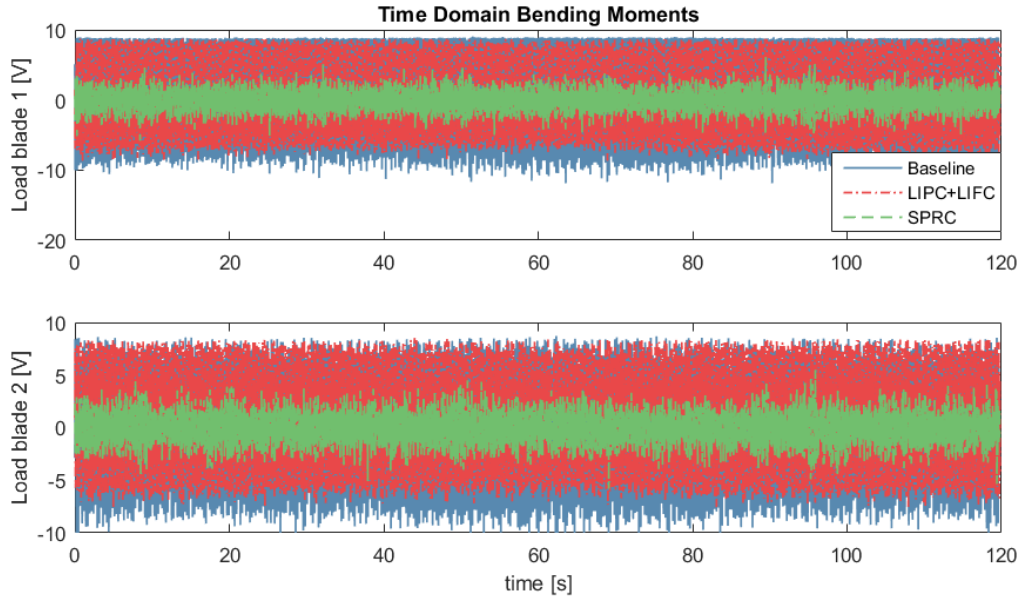


Piezo-electric actuated flexible blade surface controlled to adapt profile to respond to turbulent conditions: load alleviation up to 30%

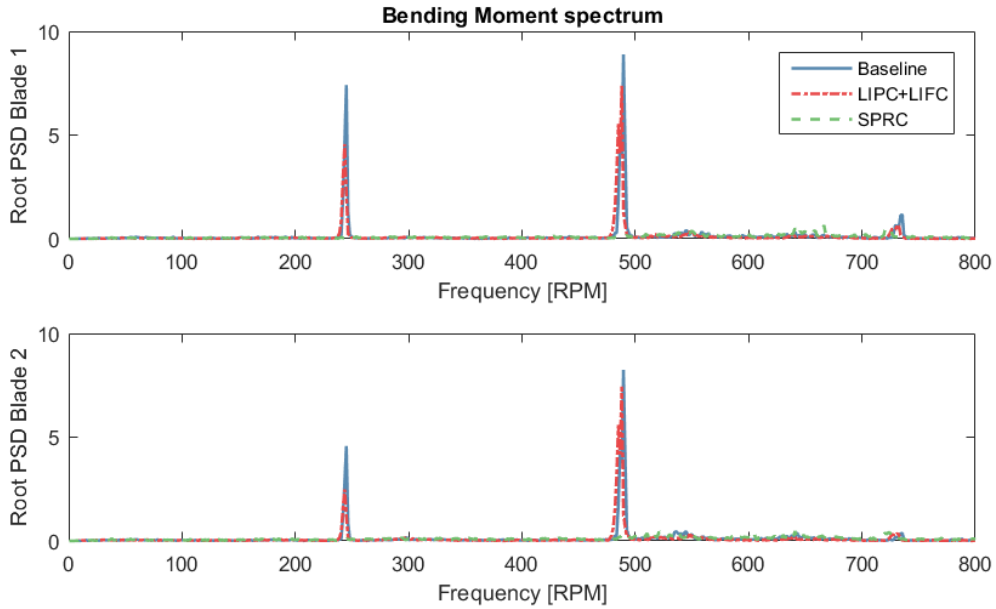
SMART ROTOR CONTROL



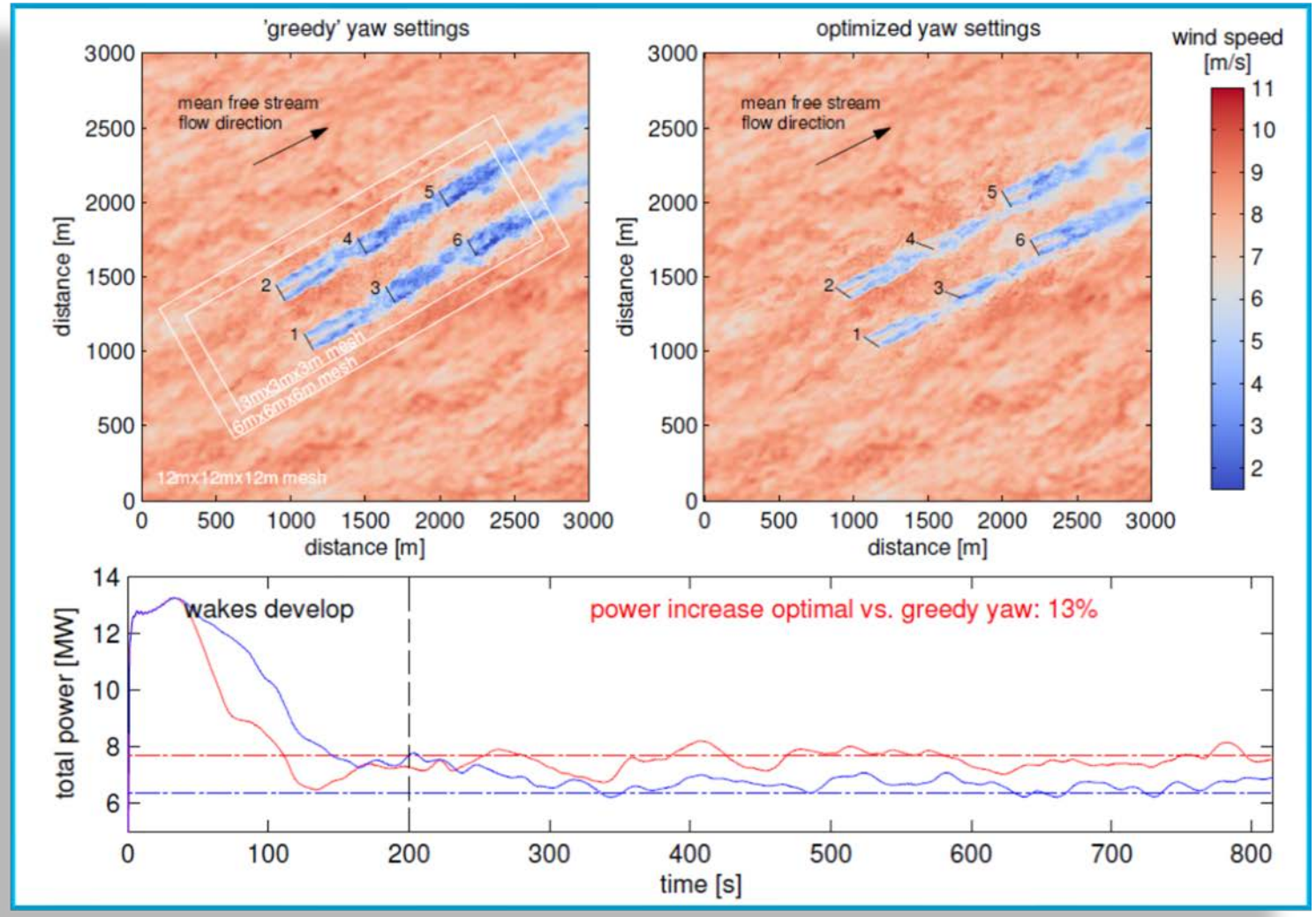
FATIGUE LOAD REDUCTION



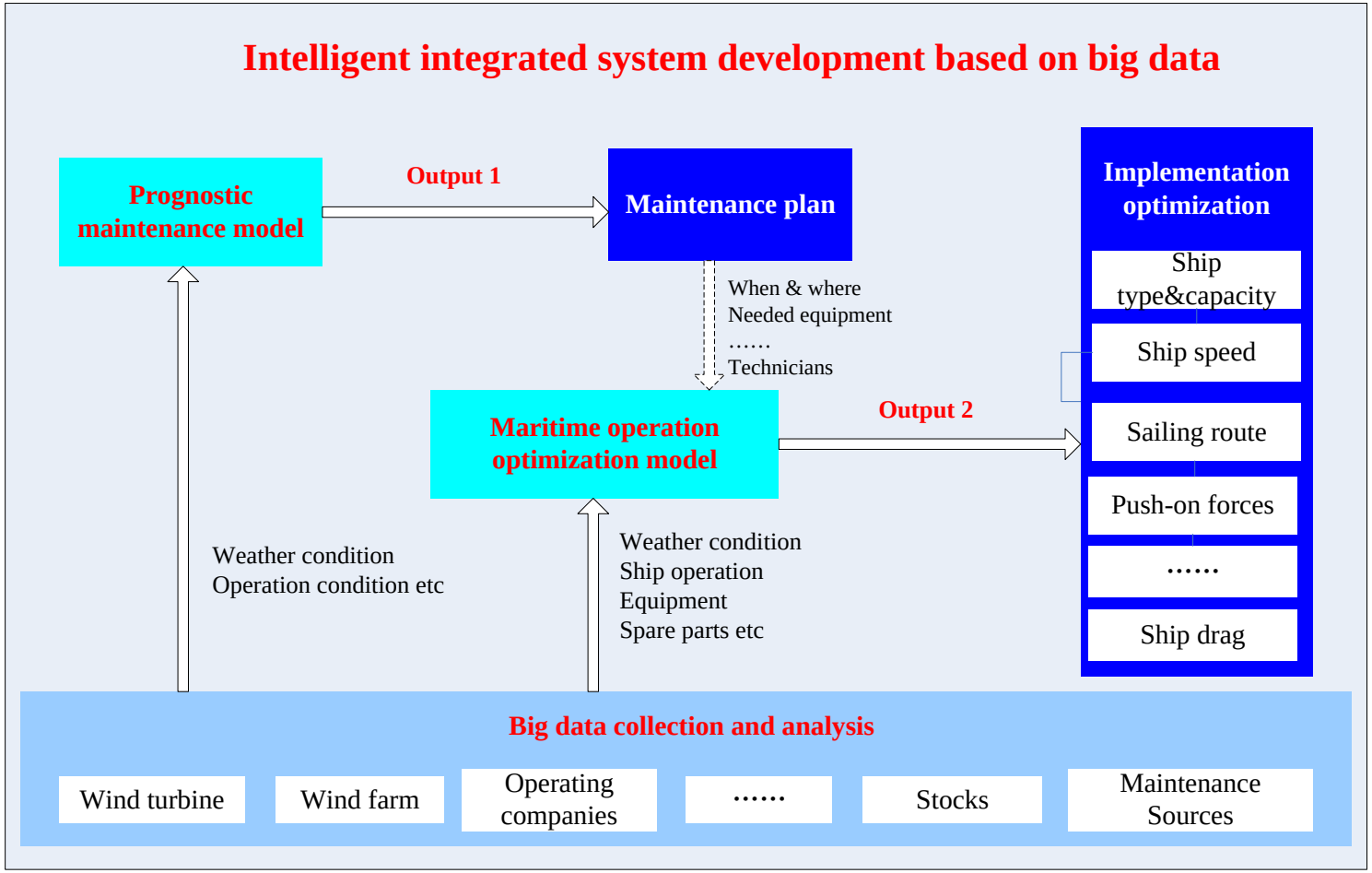
LIPC- Linear Individual Pitch Control
LIFC – Linear Individual Flap Control
SPRC- Subspace Predictive Repetitive Control



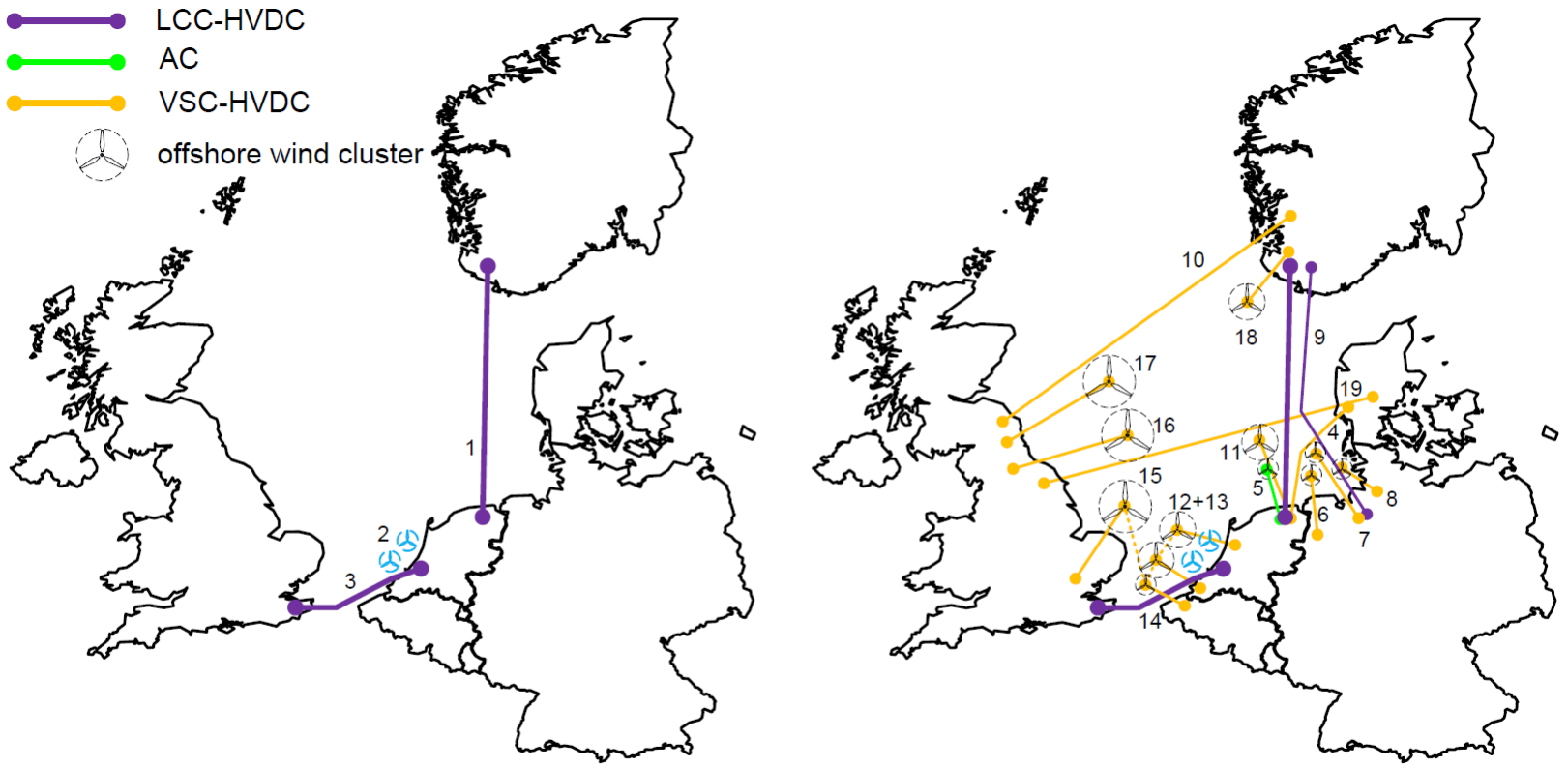
WIND FARM CONTROL – OPTIMISED YAW (NREL COLLABORATION USING SOWFA MODEL)



INTEGRATED O&M OPERATIONAL SYSTEM



ELECTRICAL POWER SYSTEMS – HVDC/HVAC MODELLING



(a) *2010* (b) *2025*

- Modelling impact of future offshore VSC-HVDC grids on AC transmission system stability

- Responsible innovation
- Social innovation
- Energy justice
- Wind energy faces public opposition:
  - How to engage with (local) communities in planning of wind parks?
  - (New) modes of participation in wind energy planning (e.g. financial participation, energy cooperatives)?
  - Design for values: how to incorporate public values in design of technology, institutions and planning procedures?

EUROS: EXCELLENCE IN UNCERTAINTY REDUCTION OF OFFSHORE WIND SYSTEMS

- Design
- Construction
- Logistics

- Over-conservative parameters increase costs
- Safety margins can be reduced by reducing uncertainties
- EUROS aims to lower costs by *reducing uncertainties* and *increasing efficiencies*

PARTNERS

Budget = €3.4M

Universities

TU Delft

TU/e

WAGENINGEN UR
For quality of life

Research Institutes

CWI
Centrum Wiskunde & Informatica

ECN
Your energy. Our passion.

Deltares
Enabling Delta Life

TNO innovation for life

Koninklijk Nederlands Meteorologisch Instituut
Ministerie van Infrastructuur en Milieu

Companies

DNV·GL

Eneco

FUGRO

MARINE CONTRACTORS

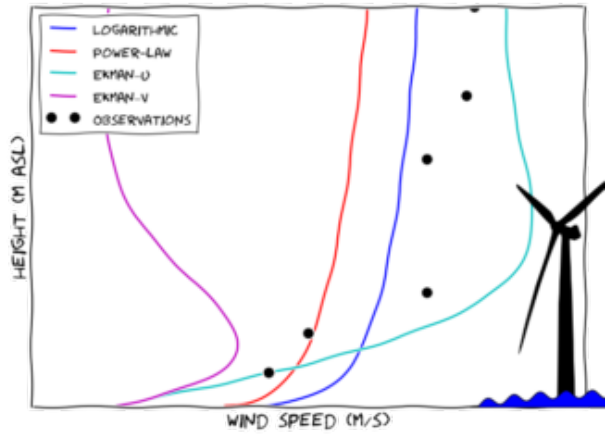
Van Oord
Marine ingenuity

IHC IQIP

SYSTEMS® NAVIGATOR

PROJECT 1: EXTERNAL CONDITIONS

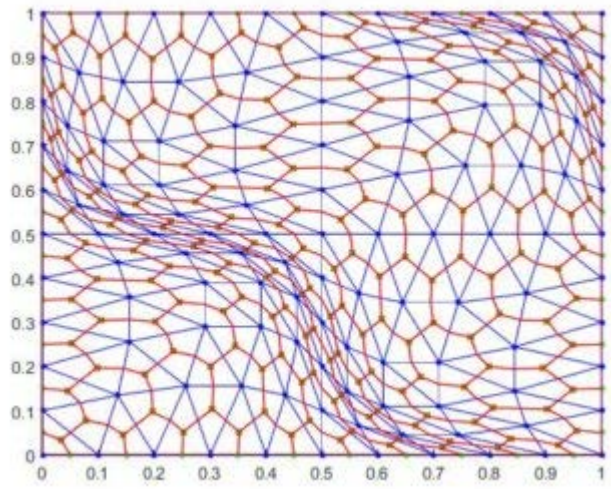
Wind Loads



Extended Weather Forecasts

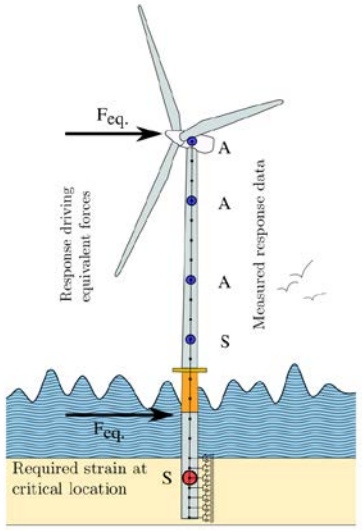
Uncertainty Quantification in Wind and Waves

Wind Farm Wake Effects



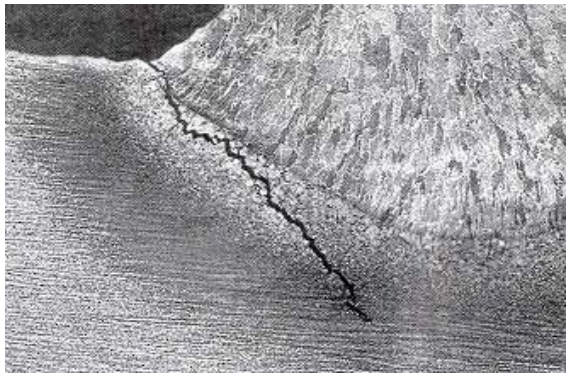
PROJECT 2: LOADS AND DAMAGE

Smart Monitoring and Damage Development



Physical Modelling of Service Life Consumption by Pile Driving

Physical Modelling of Crack Initiation and Propagation



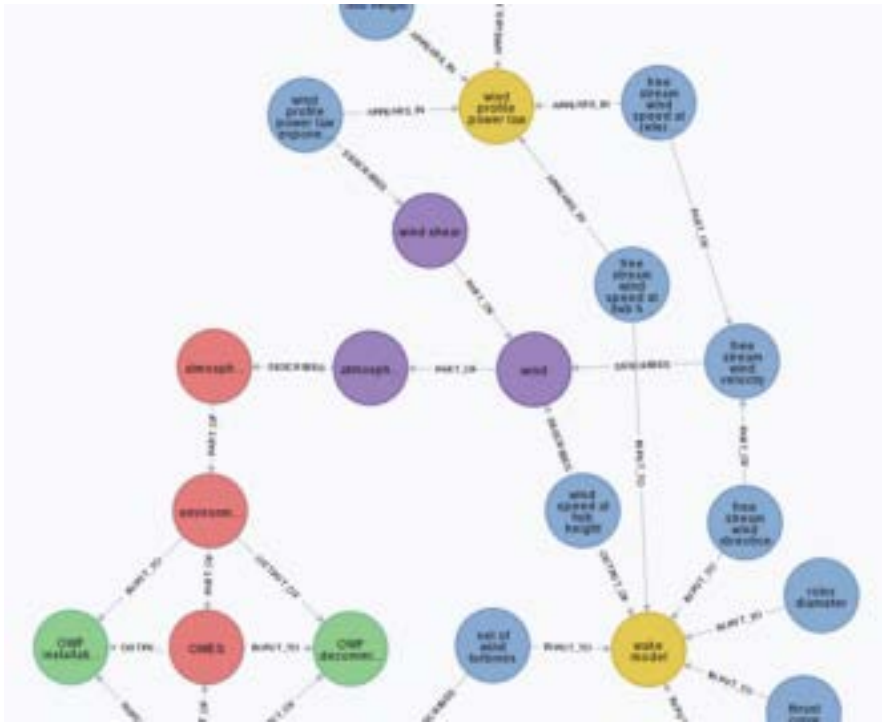
Physical Modelling of Scour and Seabed Variations

Uncertainty Propagation

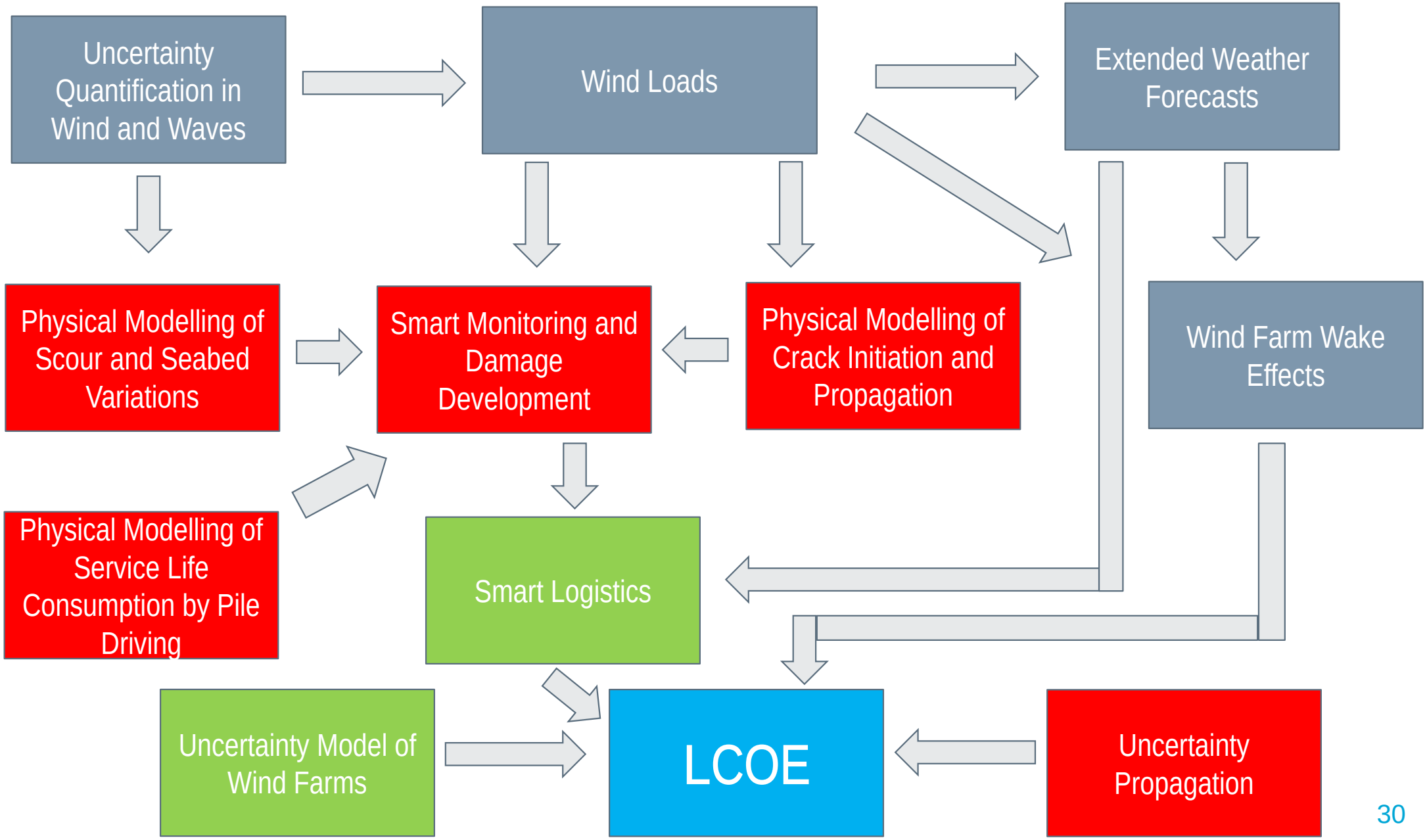
PROJECT 3: WIND FARM DESIGN OPTIMISATION

Smart Logistics

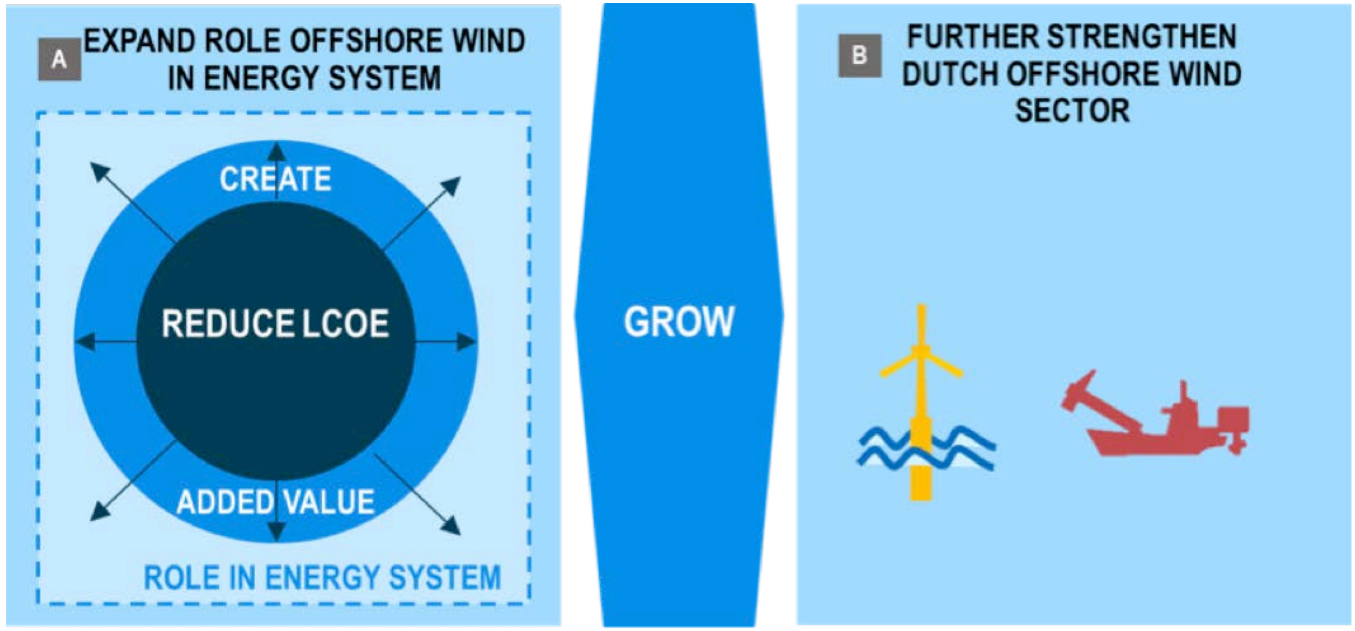
Uncertainty Model of Wind Farms



EUROS - THE BIG PICTURE



GROW: GROWTH THROUGH RESEARCH, DEVELOPMENT & DEMONSTRATION IN OFFSHORE WIND

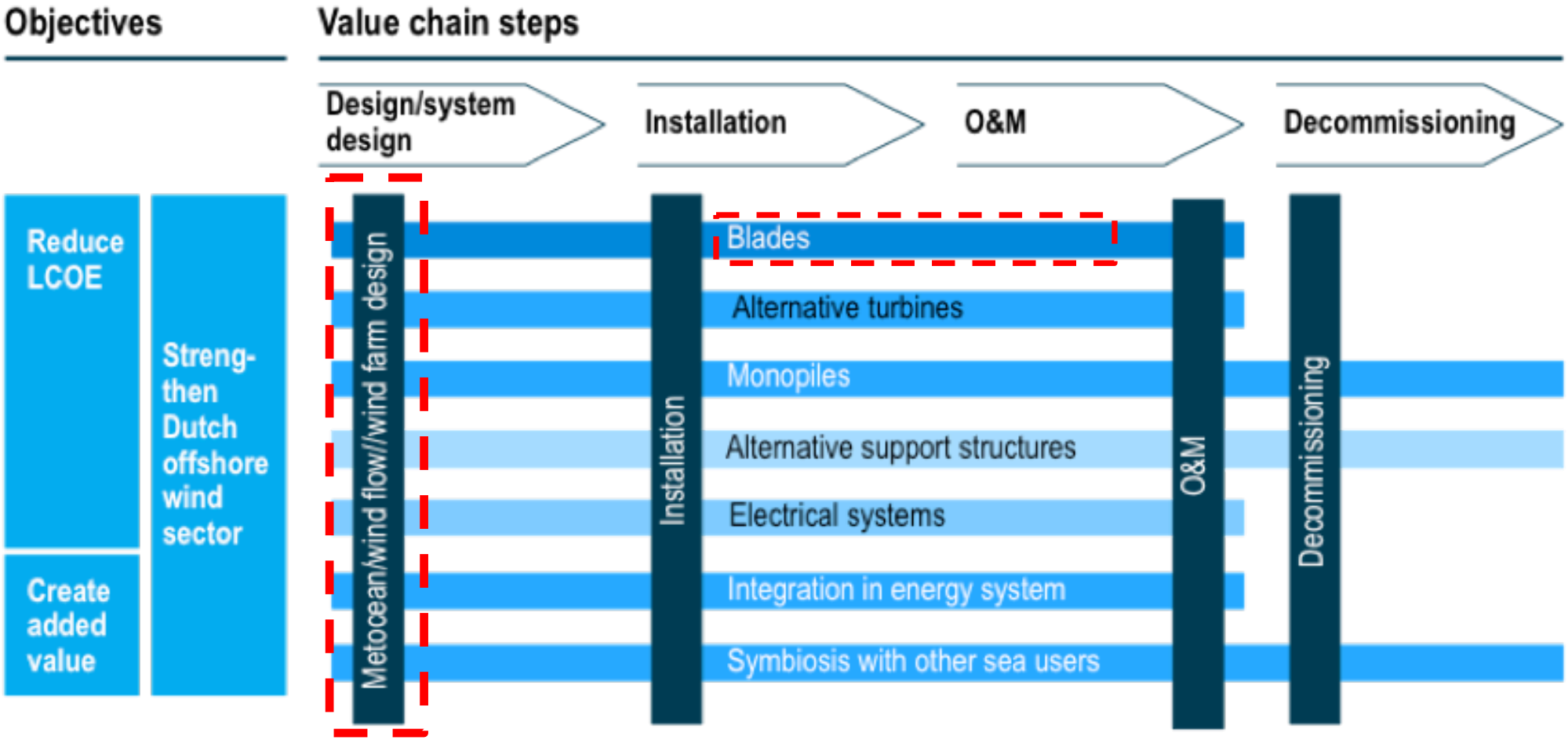


Budget: 100 Million Euros over five years

Public-private consortium of around 20 partners working to reduce the costs of offshore wind to a competitive level in the near future – successor to FLOW

GROW PARTNERS

PROGRAMME LINES



PHD@SEA

- GROW: higher TRL demonstrating short term LCOE gains
- Need for lower TRL research
- Dutch NWO planning to fund PhD programme on offshore renewable energy, primarily wind power
- PhD@Sea: Size and duration to be determined
- DUWIND planning to launch a Dutch ‘Doctoral College in Offshore Renewable Energy’ based on EU M-C ITNs and UK CDTs

SUMMARY

- TU Delft has the largest academic wind energy research activity in NL
- Strong connections with industry
- Dutch government keen to see research which lowers the LCOE of offshore wind and strengthens Dutch offshore wind sector
- Potentially large Dutch offshore renewable energy PhD programme to be rolled out
- Only a very small role for other marine renewables