ECN

Energy research Centre of the Netherlands

CWI, 11 november 2010

Ontwerpsoftware voor windenergietoepassingen

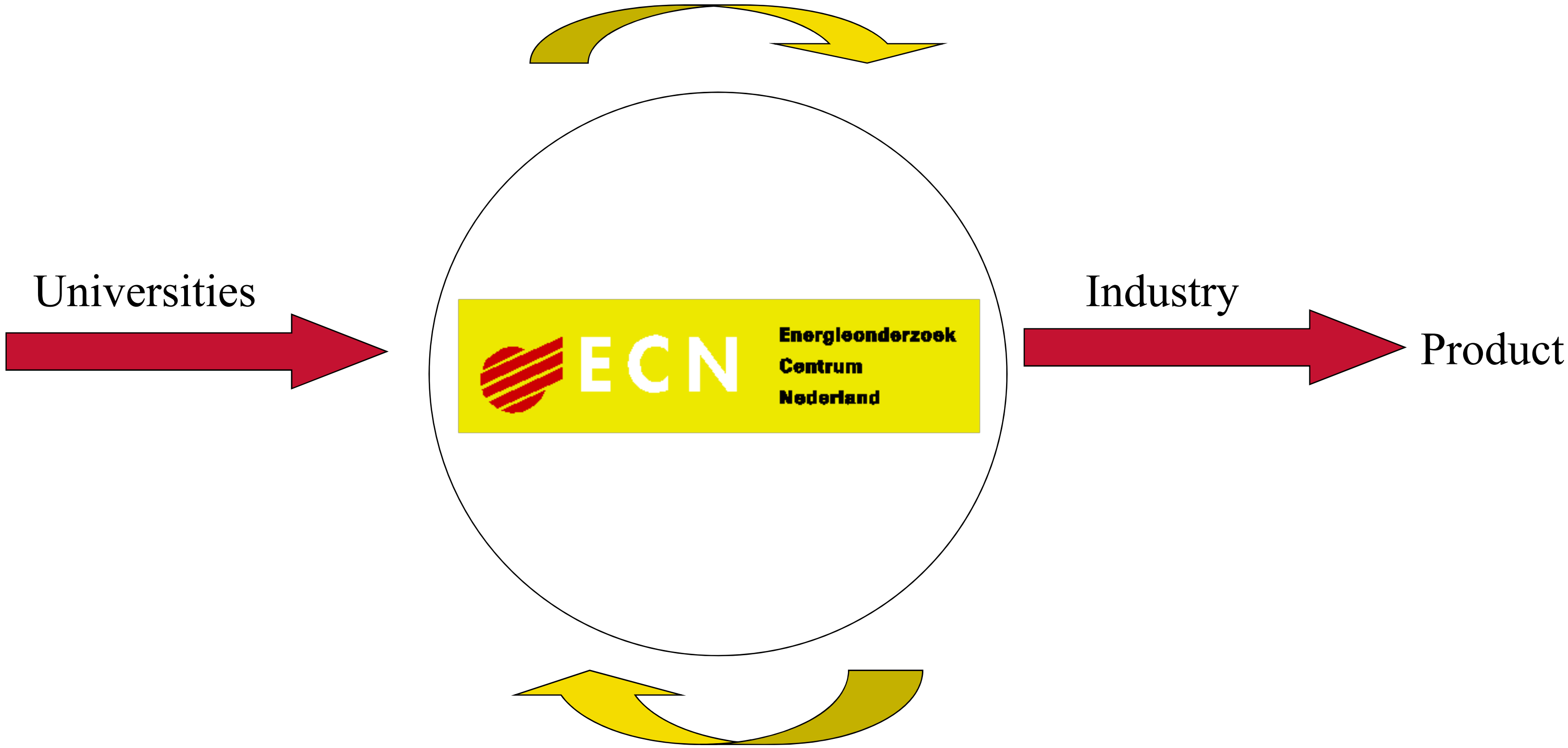
Peter Eecen

Outline

- Introduction to ECN
- Introduction to Wind Energy
- Examples of research activities
  - Rotor aerodynamics – dedicated codes
  - Wind farm aerodynamics CFD developments
  - Rotor aerodynamics – Ansys CFX

Petten: Energy research capital of Europe

ECN: Mission

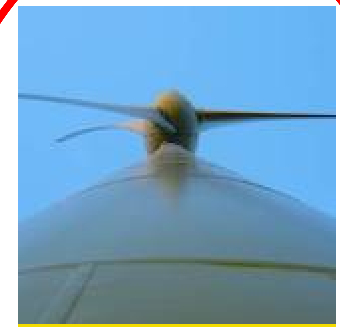


Mission: ECN develops and brings to market high-quality knowledge and technology for a sustainable energy system

ECN: Trias energetica

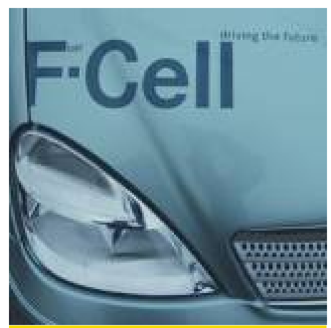
Solar Energy

Biomass



Wind Energy

Efficiency & Infrastructure

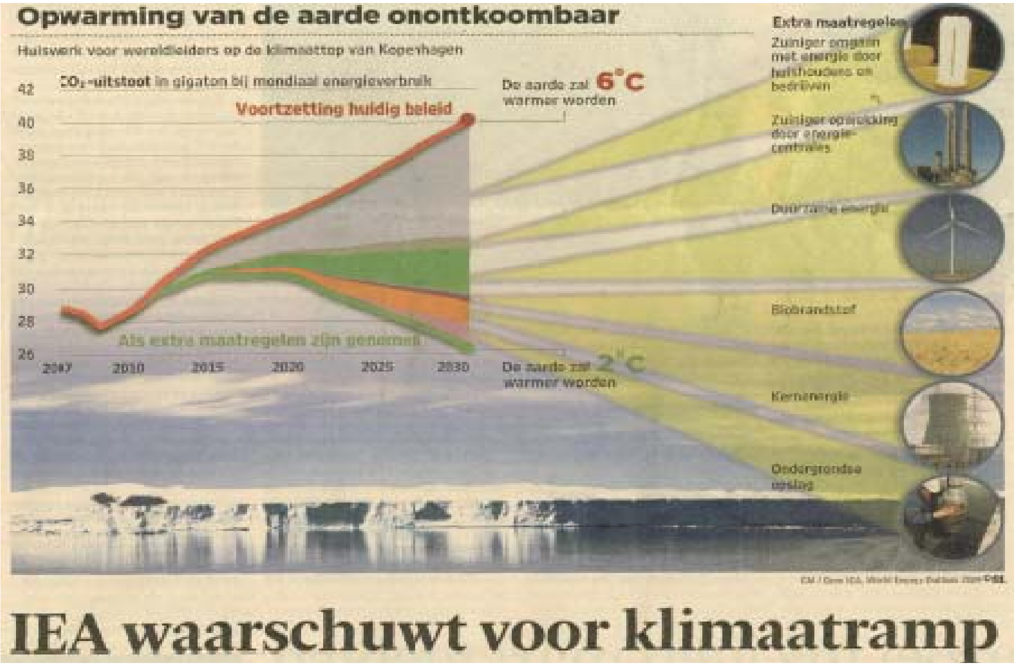


H2 & Clean Fossil Fuels

Policy Studies

Engineering & Services

Why Wind Energy ?



COP15
COPENHAGEN
UN CLIMATE CHANGE CONFERENCE 2009

Why Wind Energy ?

no geo-political risk
no external energy dependence
no energy imports
no fuel costs
no fuel price risk
no exploration
no extraction
no refining
no pipelines
no resource constraints
no CO_2 emissions

And……….

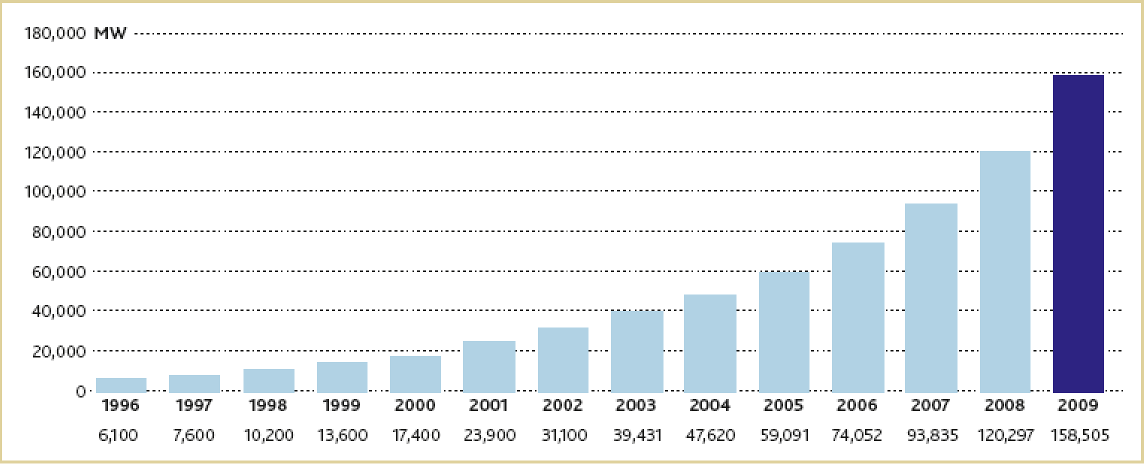
ECN

….because wind energy is beautiful

The Facts

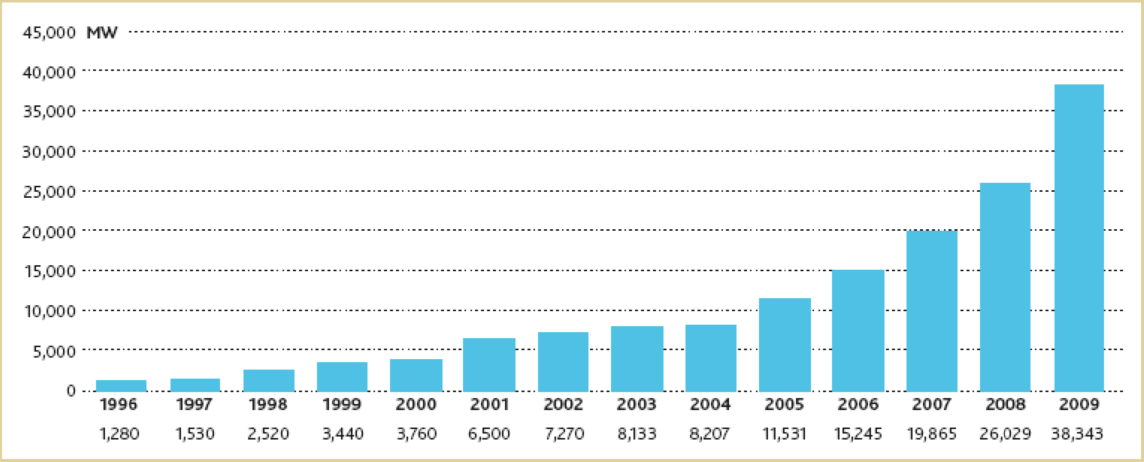
Global cumulative installed capacity

GLOBAL CUMULATIVE INSTALLED CAPACITY 1996-2009



Global annual installed capacity

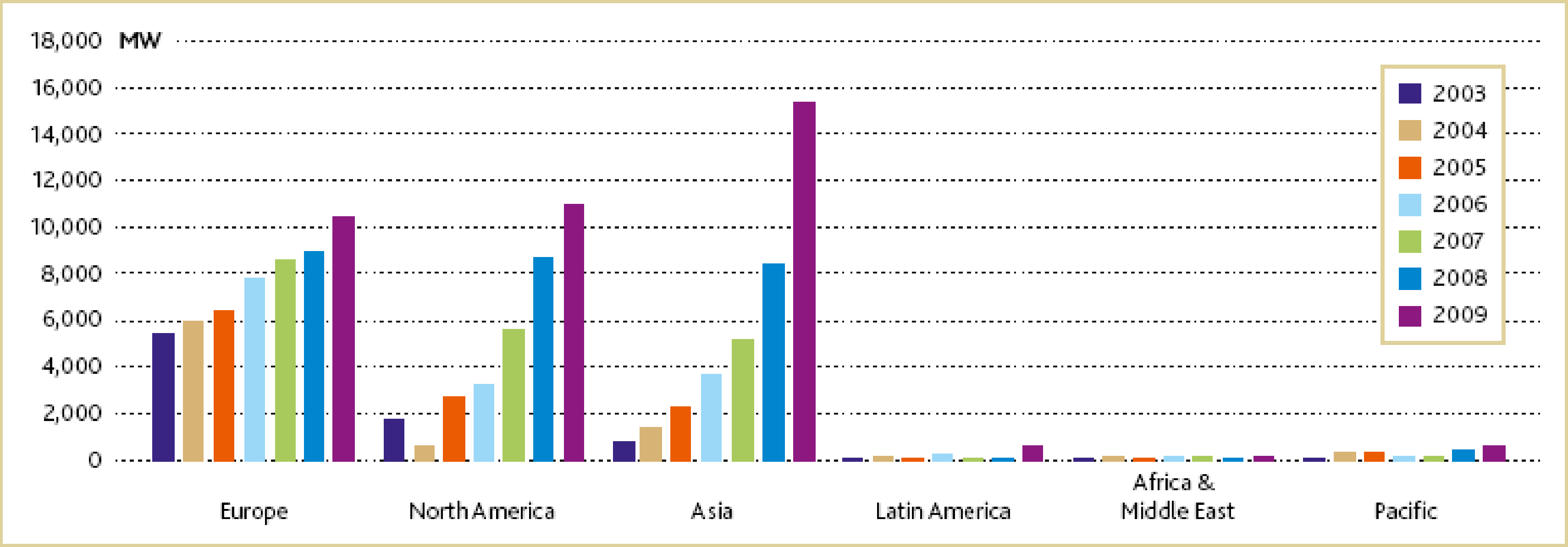
GLOBAL ANNUAL INSTALLED CAPACITY 1996-2009



From: GWEC –
Global Wind 2009 Report

The Facts

ANNUAL INSTALLED CAPACITY BY REGION 2003-2009



From: GWEC – Global Wind 2009 Report

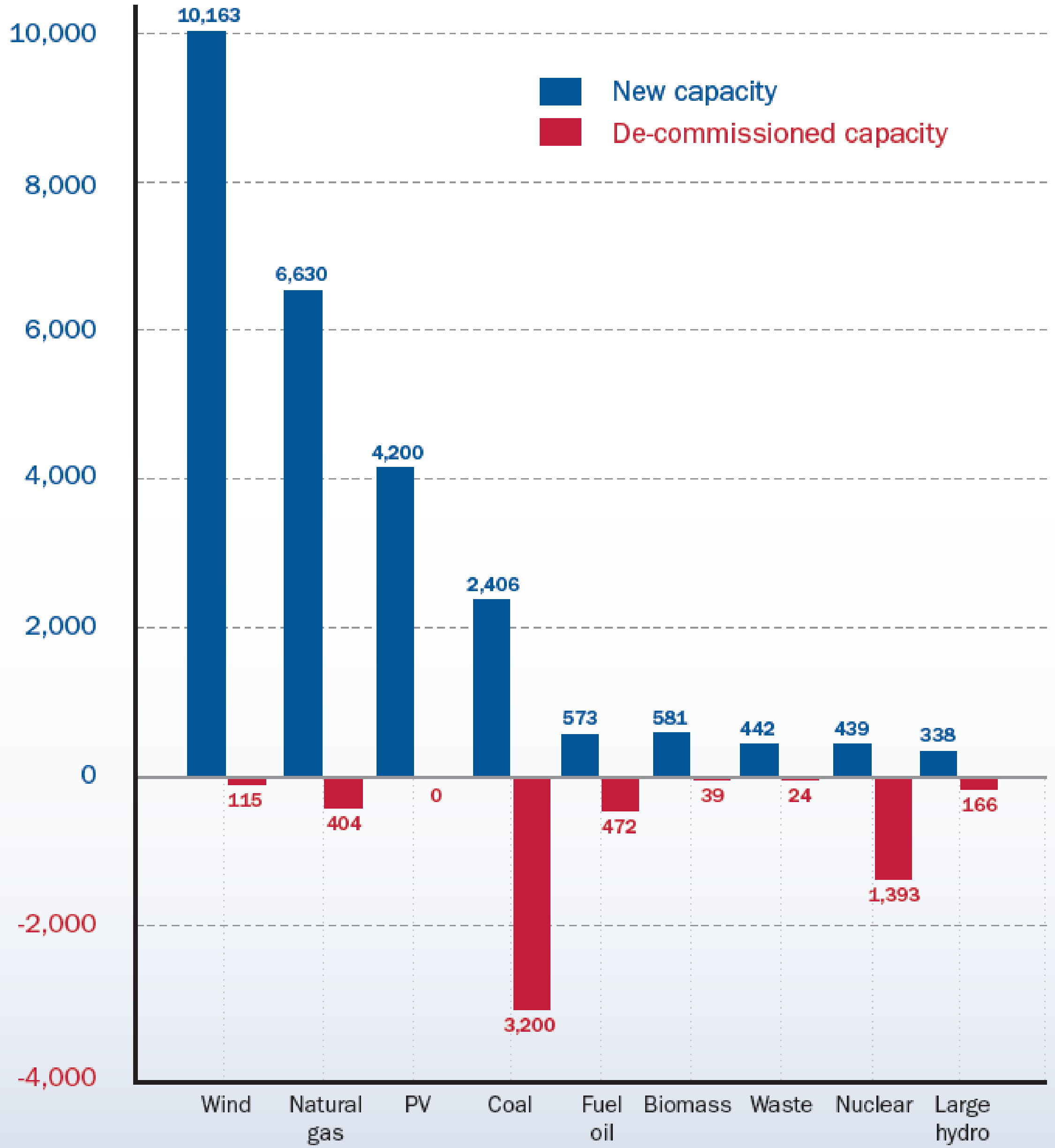
The Facts

- New installed capacity and de-commissioned capacity in EU 2009 in MW.
- Total 25,963 MW

From: Wind Energy Factsheets

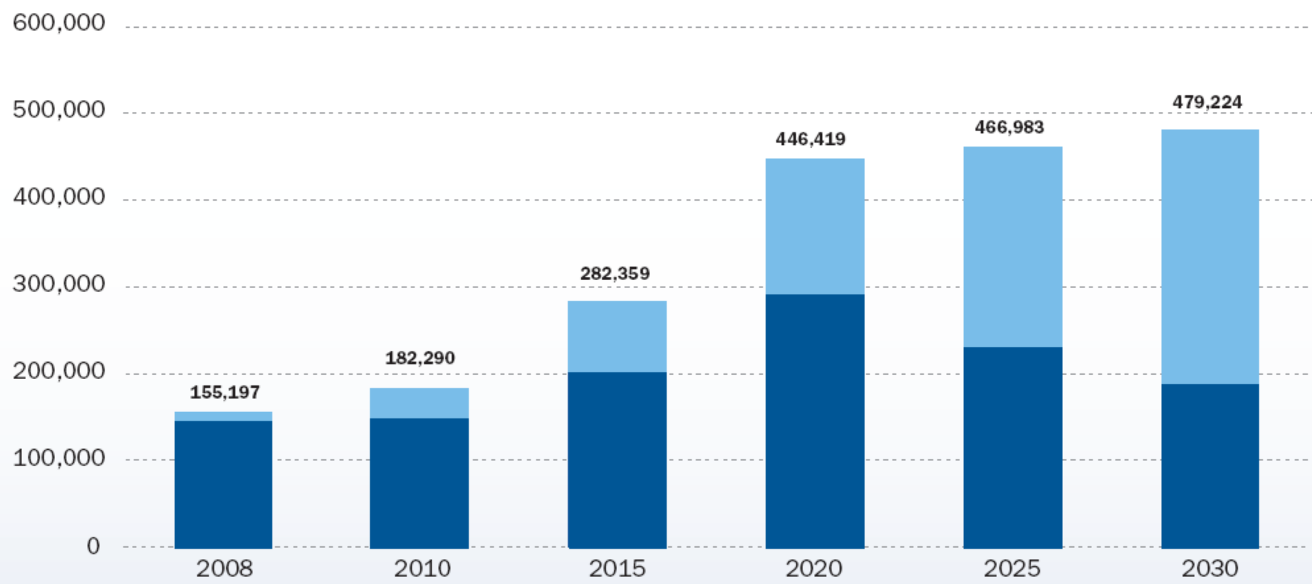
By the European Wind Energy Association – 2010

www.ewea.org



The Facts – employment

Wind energy sector employment (2008-2030)

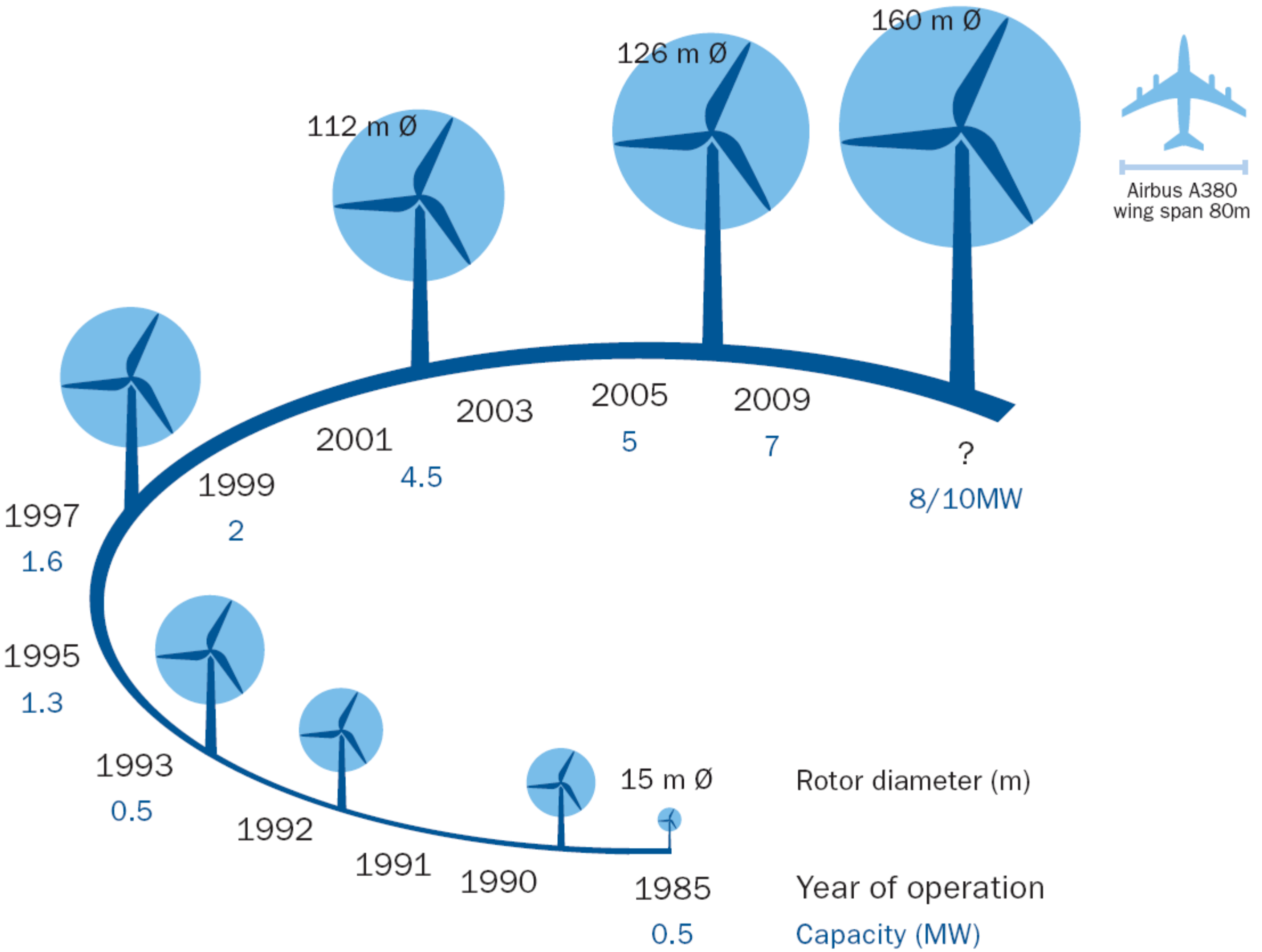


	2008	2010	2015	2020	2025	2030
Onshore	143,782	148,057	200,870	290,276	228,104	185,478
Offshore	11,415	34,232	81,489	156,143	238,879	293,746

Wind Energy Factsheets By the European Wind Energy Association – 2010, www.ewea.org

Size evolution of wind turbines over time

In 25 years wind energy technology has developed enormously. With more R&D investment it can continue to become even more efficient and high performing.



From: Wind Energy Factsheets
By the European Wind Energy Association – 2010
www.ewea.org

Blade sizes of today (61.5 m)

LM 61.5 P

Product specifications

Blade type	LM 61.5 P
Rotor diameter (max.)	126.3 m
Blade regulation	Pitch
Length	61.5 m
Max. chord	4,600 m
Profiled area	183.0 m^2
Weight	17,740 kg*
Number of bolts	128
Size of bolts	M36
Bolt circle diameter	3,200 mm

*Preliminary data

Research Programme

ECN
Energy research Centre of the Netherlands

Knowledge Centre WMC
Wind turbine Materials and Constructions

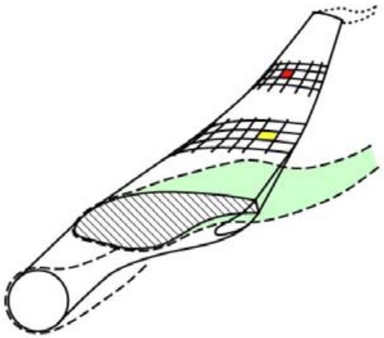
- Rotor- and Farm Aerodynamics
- Integrated Wind Turbine Design (software)
- Operation & Maintenance (Condition monitoring / O&M Tool)
- Material research (WMC)

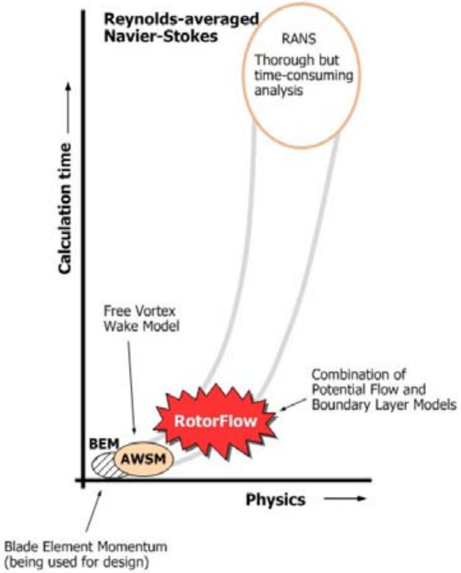
Research line: Rotor & Farm Aerodynamics

Rotor aerodynamics

- Theoretical and experimental research
- Use of CFD
- Development of industrial codes

RotorFlow
Aerodynamics



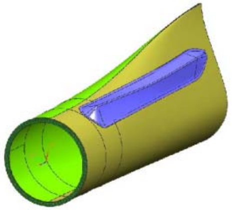


Wind farm aerodynamics

- Theoretical modelling
- Use of CFD
- Experiments (wind tunnels, scaled wind farm, full scale)

New ideas

- Strip on blade root
- Wind Farm control strategies
- Synthetic jets



Research infrastructure

The ECN AWSM code

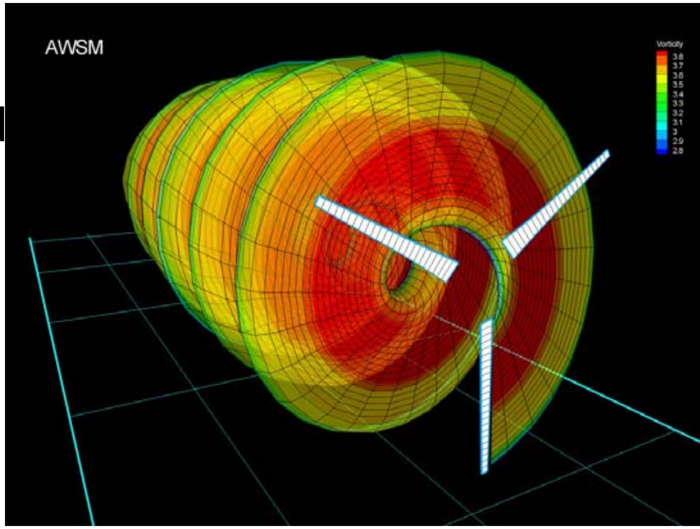
- Numerical code based on the Generalized Prandtl's Lifting Vortex Line Method

Able to include:

- Analysis of multi-body configurations
- General-shape geometries
- Steady and unsteady analysis
- Yaw, pitch misalignments
- Non uniform wind conditions (local gusts and wind shear)

Coupled to ECN Aeromodule

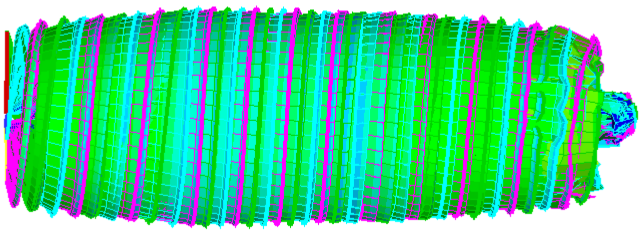
AWSM developed by: Arne van Garrel
Extended and used by: Francesco Grasso



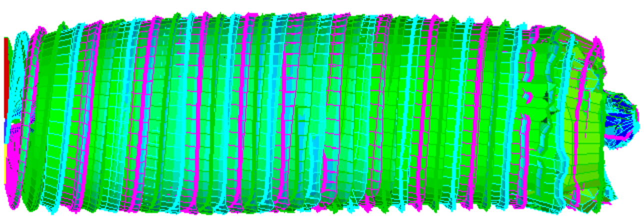
Arne van Garrel: Development of a wind turbine aerodynamics simulations tool, ECN report

Work by: Arne van Garrel
Francesco Grasso

Ground Effect

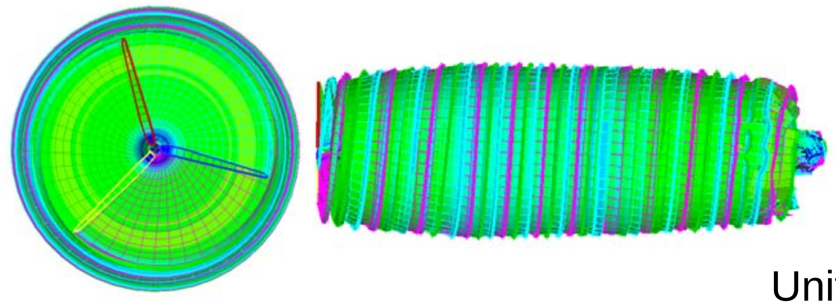


No ground

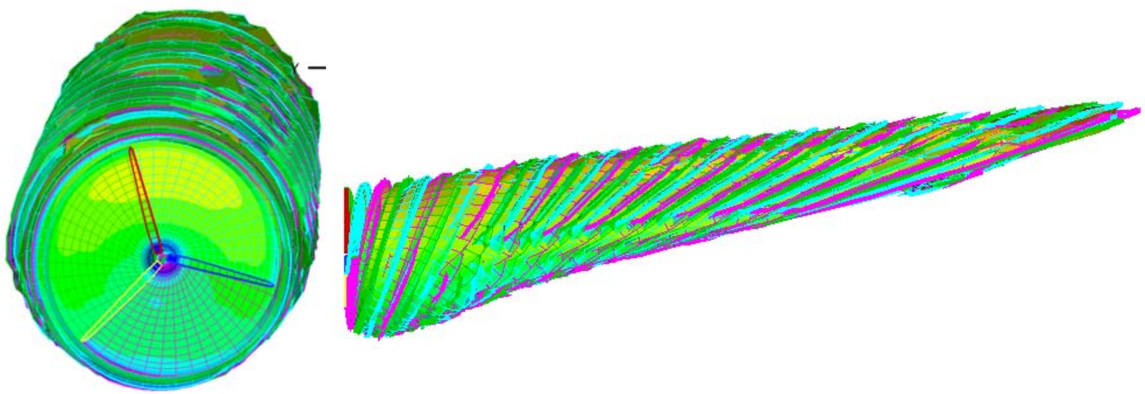


Ground

Shear Effect



Uniform wind

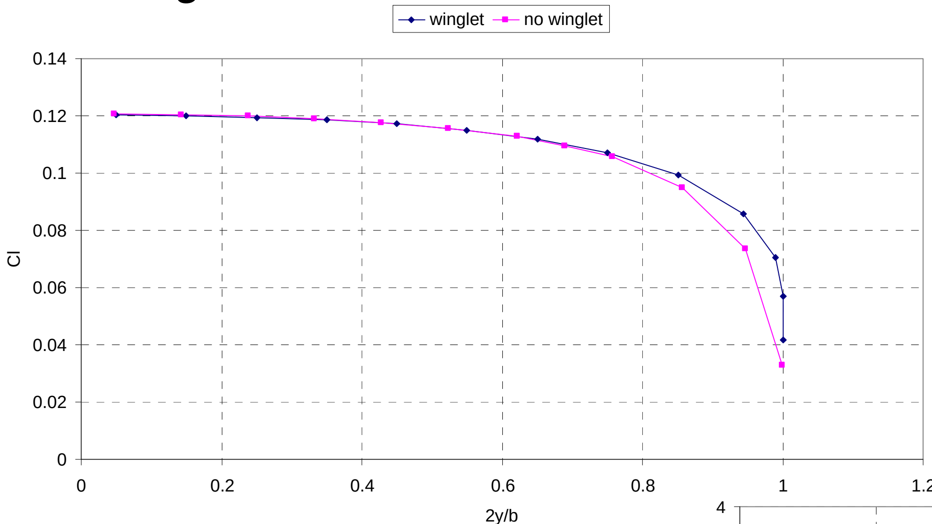


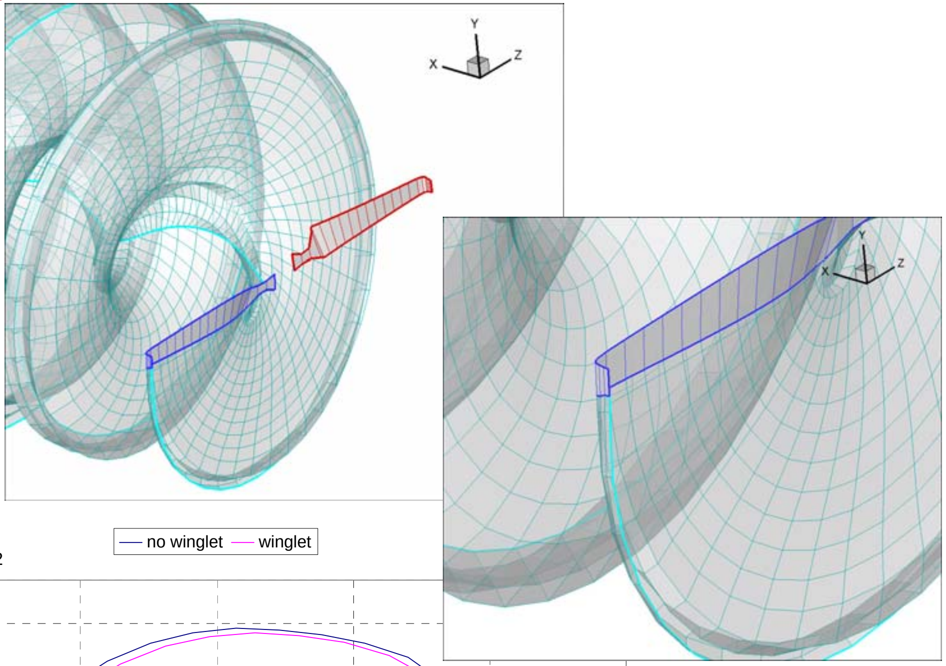
Wind shear

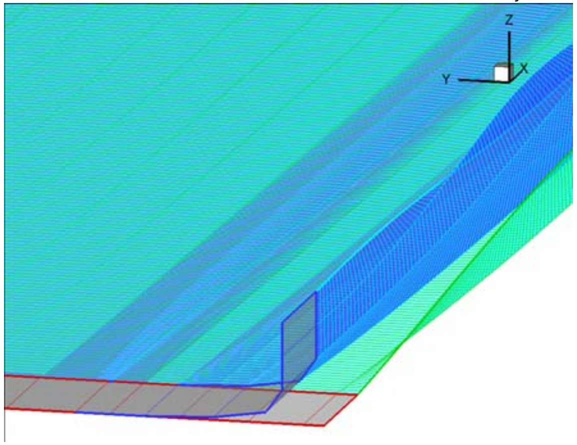
Work by: Arne van Garrel
Francesco Grasso

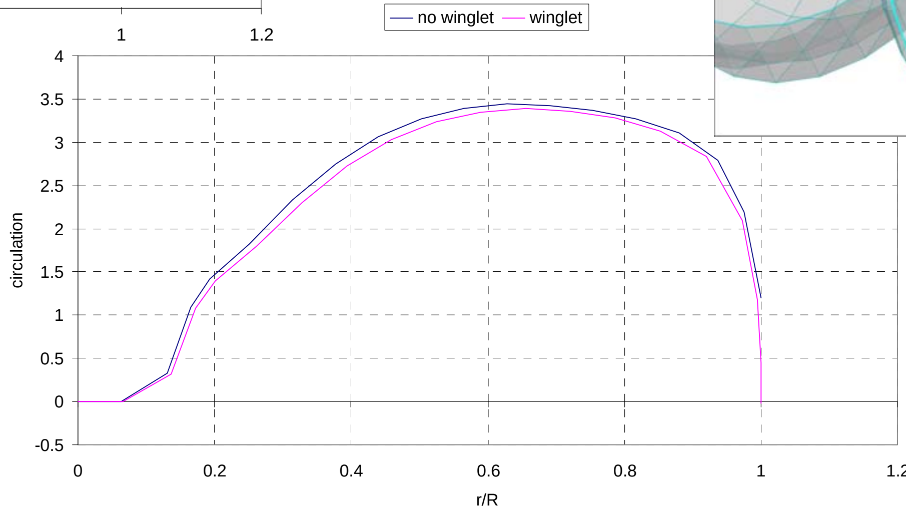
Non conventional configurations

Winglets





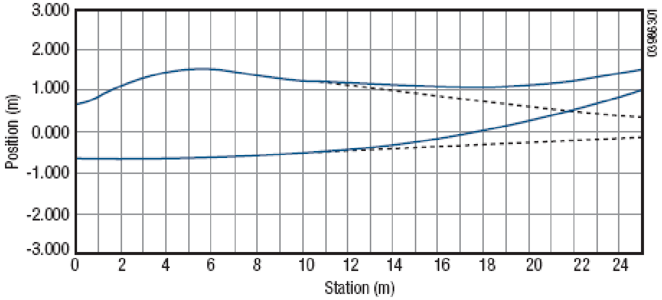


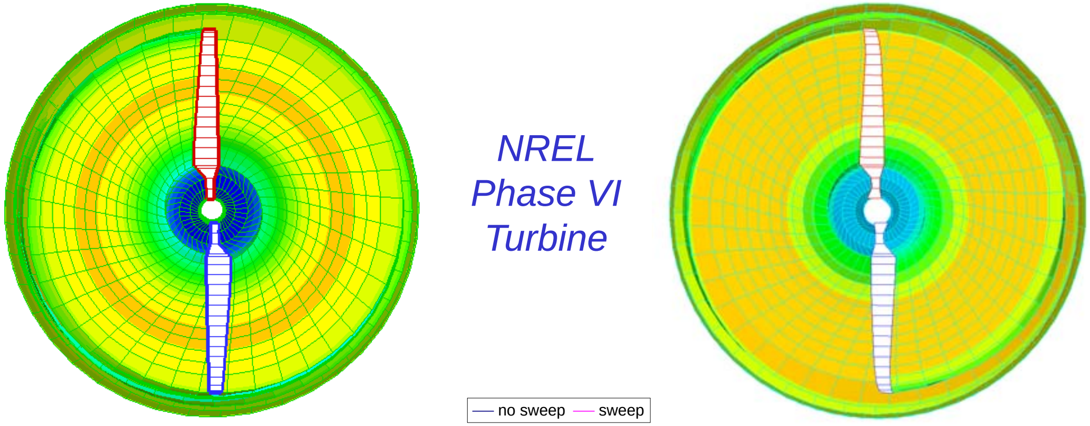


Work by: Arne van Garrel
Francesco Grasso

Non conventional configurations

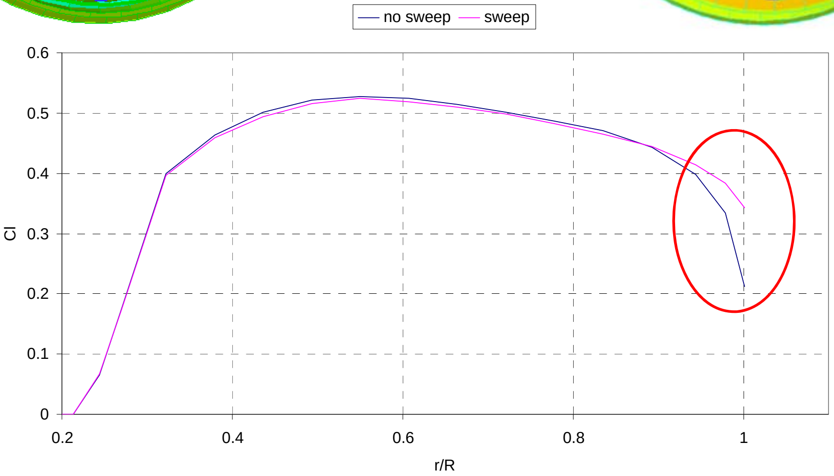
Swept blades





NREL
Phase VI
Turbine

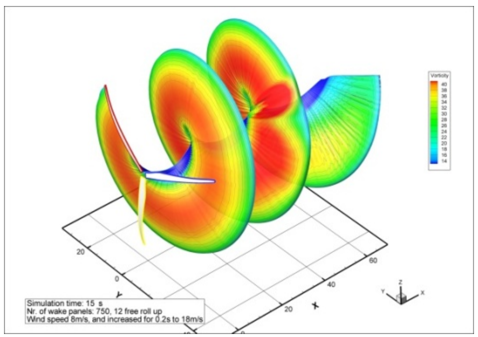
The initial mold fabrication for Knight and Carver's sweep twist blade.

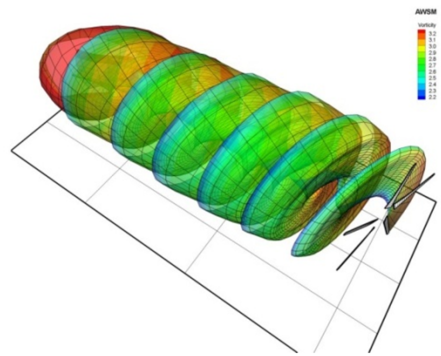


ROTORFLOW - development

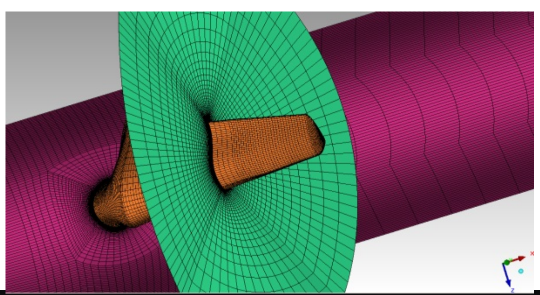
Work by: Hüseyin Özdemir
Arne van Garrel
Henny Bijleveld

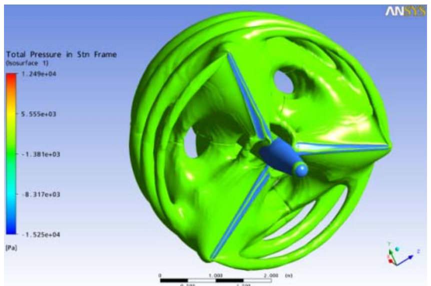
- Engineering tools: ***not accurate enough***
  - Blade Element Momentum (BEM), Vortex line method (AWSM), XFOIL, RFOIL

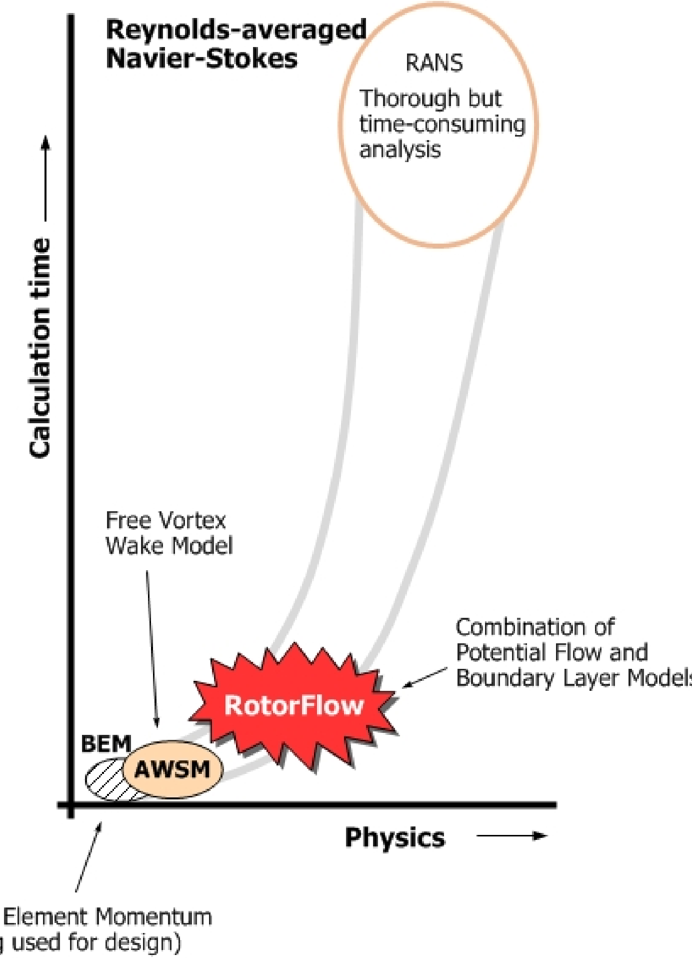




- CFD tools (CFX): ***too expensive, too much time***
  - Several weeks on cluster

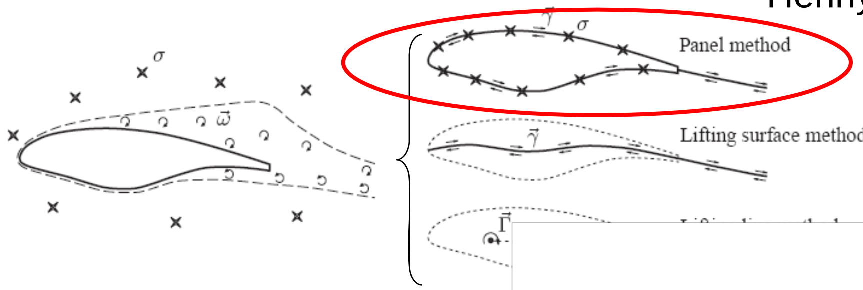




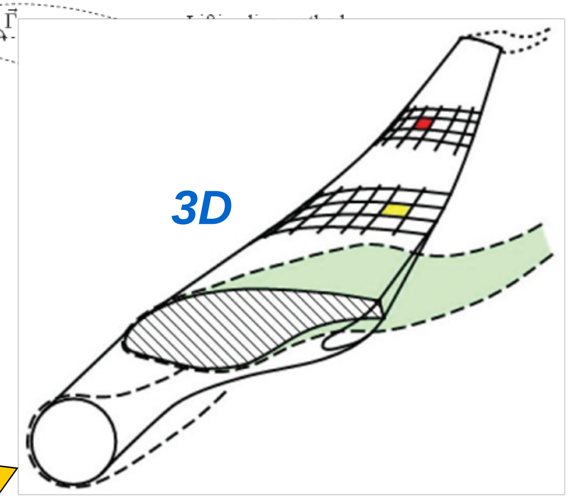


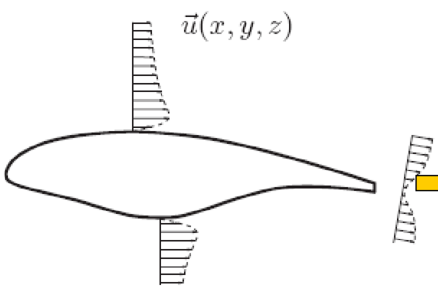
Work by: Hüseyin Özdemir
Arne van Garrel
Henny Bijleveld

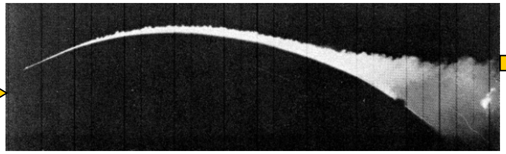
Development of RotorFlow code

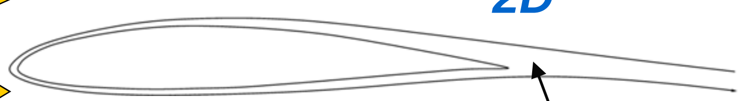


- ***Boundary Layer:***
  - ***Integral boundary layer method (IBL)***
- ***Potential outer layer:***
  - ***Panel method***
- ***Viscous – Inviscid Interaction (VII):***
  - ***Strong quasi-simultaneous interaction scheme***

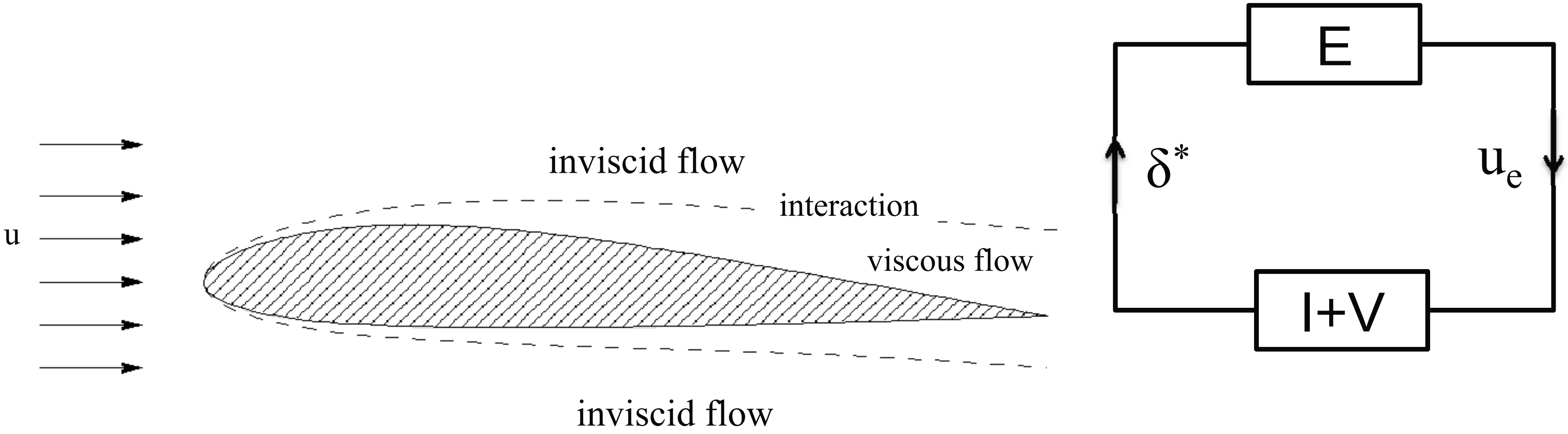






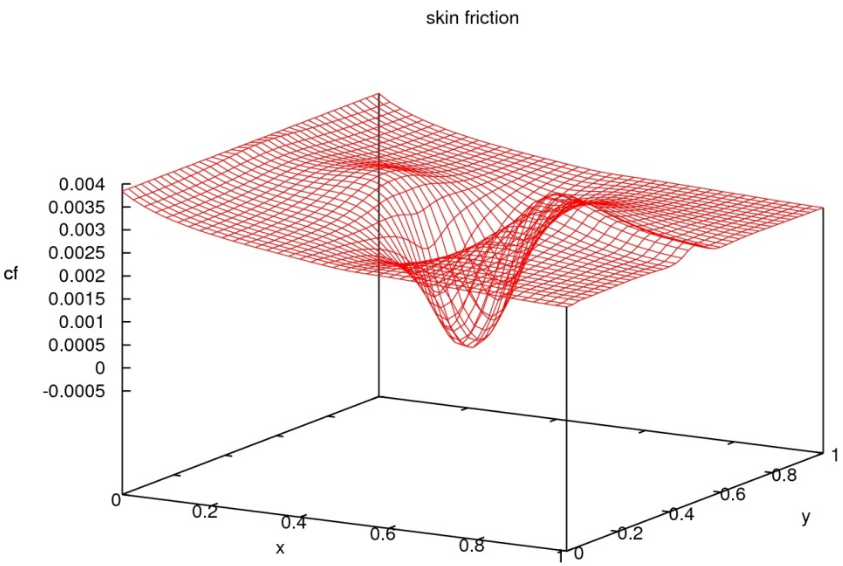


RotorFlow VII: Quasi-simultaneous interaction



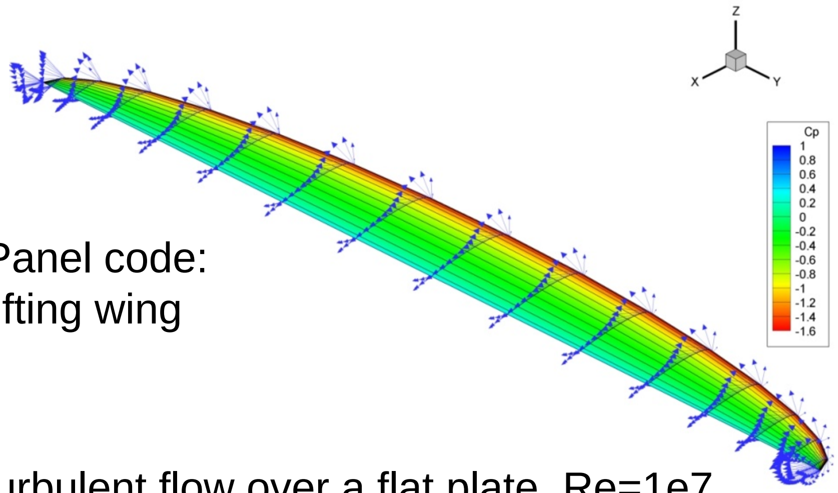
- Combines advantages of direct and simultaneous method
- Interaction law (I): approximation of inviscid flow (E) solved together with the boundary-layer equations (V)
- Interaction law is an algebraic equation

Preliminary results

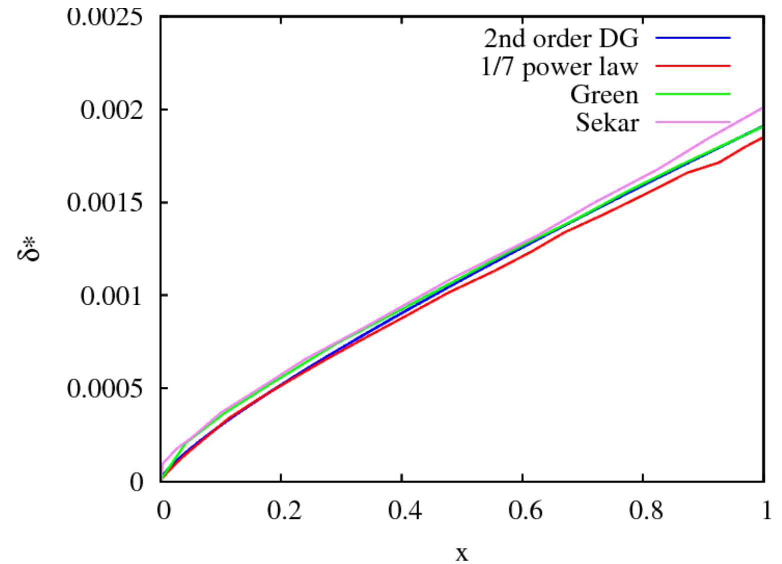


Flow over dented plate: Re = 11.5 10^6
Separation in middle of the dent

Panel code:
lifting wing



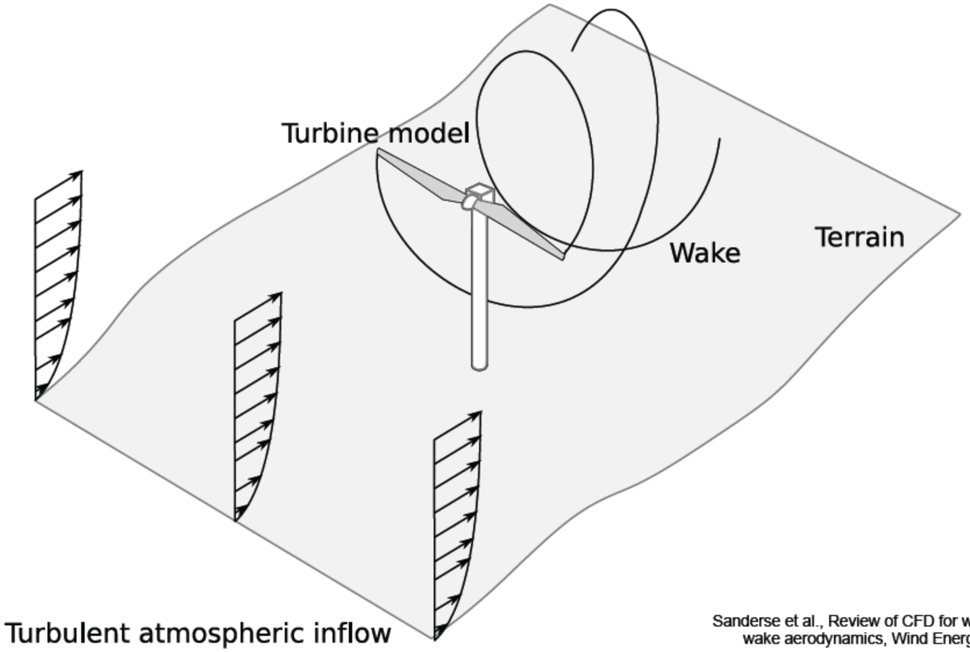
Turbulent flow over a flat plate, Re=1e7
2^{nd} order DG



Work by: Benjamin Sanderse

Development of a wind farm CFD code

Physical phenomenon	Numerical model
Wake model	Energy conserving discretization and Large Eddy Simulation
Turbine model	Actuator method
Atmospheric inflow	Precursor simulation
Terrain	Immersed boundary method

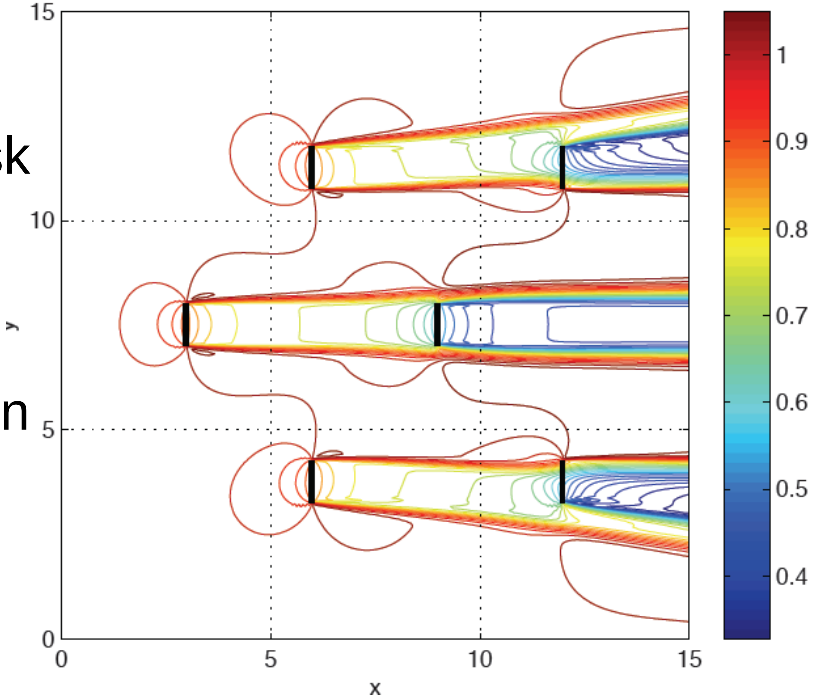


Sanderse et al., Review of CFD for wind- turbine wake aerodynamics, Wind Energy 2010

Energy conserving discretization of fluid flow

- Wakes are important to wind farm aerodynamics
- Dissipation must be limited to 'keep' the wakes

Code to be developed is dedicated to task
- Energy conserving discretization
- LES approach
- actuator method
- Atmospheric inflow: Precursor simulation
- Terrain by immersed boundary method



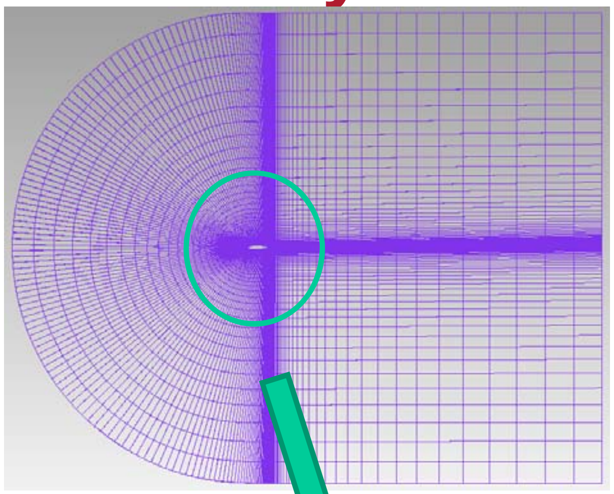
Wind farm aerodynamics CFD code

- Development CFD tool requires work in many areas:
  - Suitable discretization schemes
  - Turbulence models
  - Terrain modeling
  - Actuator modeling
- Atmospheric turbulent inflow, coupling with mesoscale model

To answer simple questions:

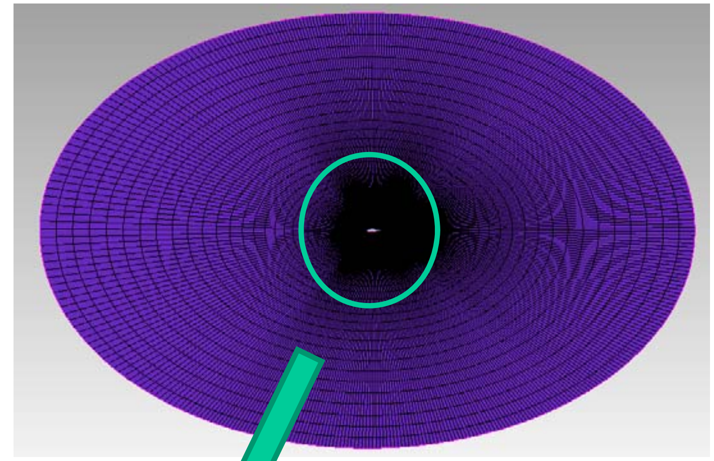
Optimum distance between turbines
Optimum wind farm lay-out
Influence of wind farm on local climate
Assessment of control strategies
Farm-Farm interaction
Design specifications (mechanical loads in farm)

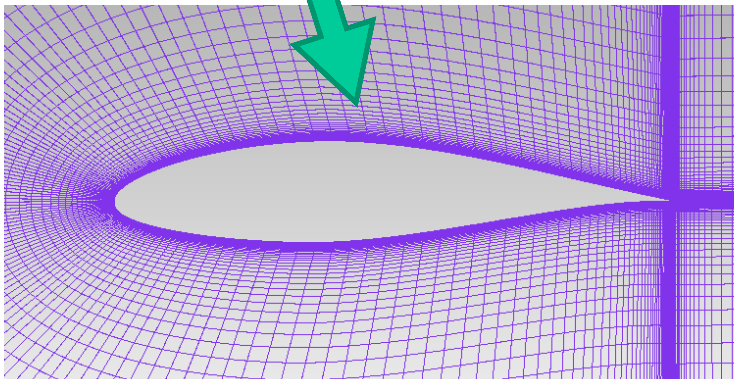
Use of commercial software Ansys-CFX
Analyses of 2D configurations



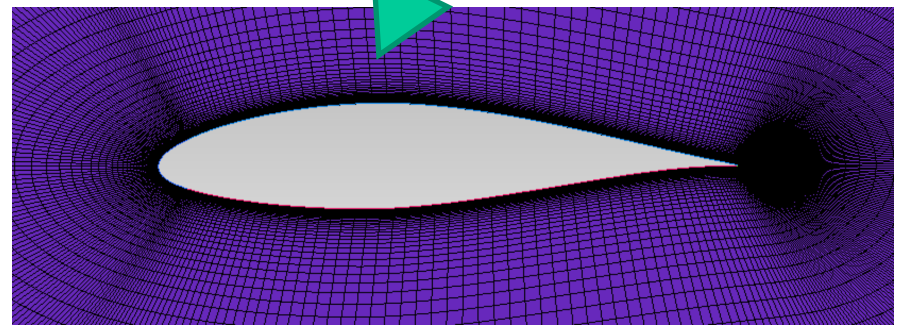
Reference airfoil

NACA 64_2418





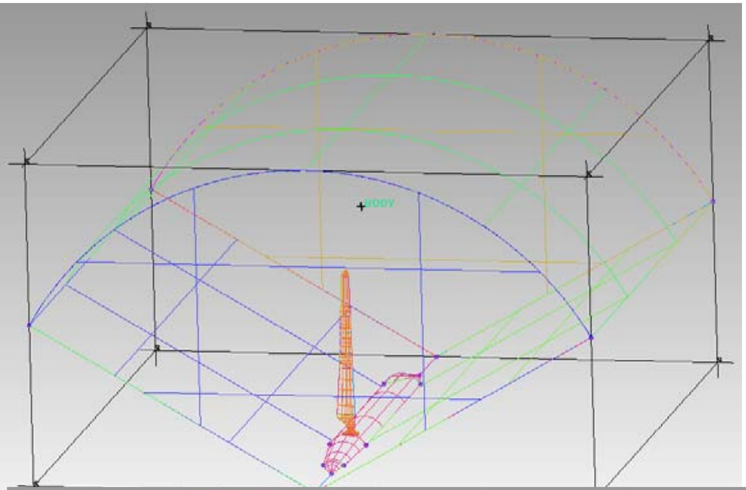
C-grid

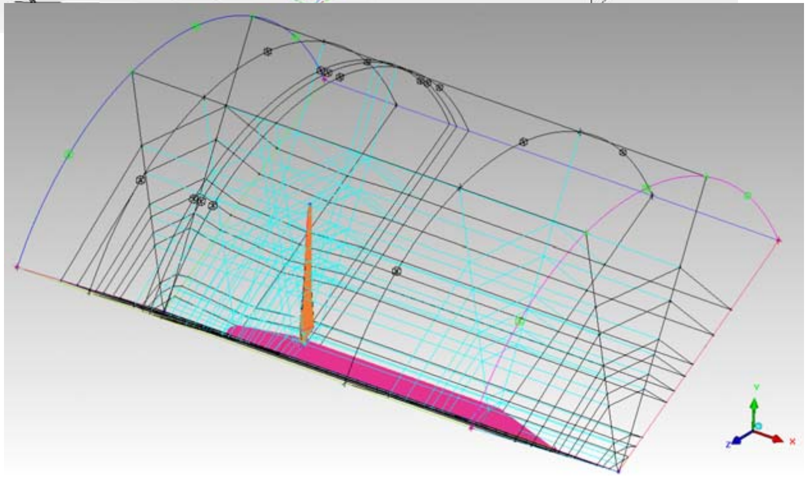


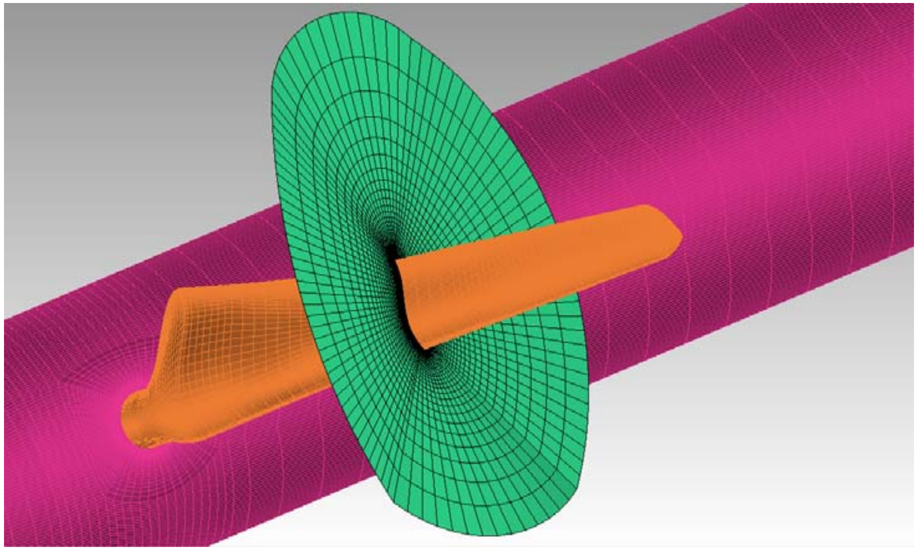
O-grid

Work by: Marc van Raalte

Use of commercial software Ansys-CFX
Analyses of 3D rotating configurations







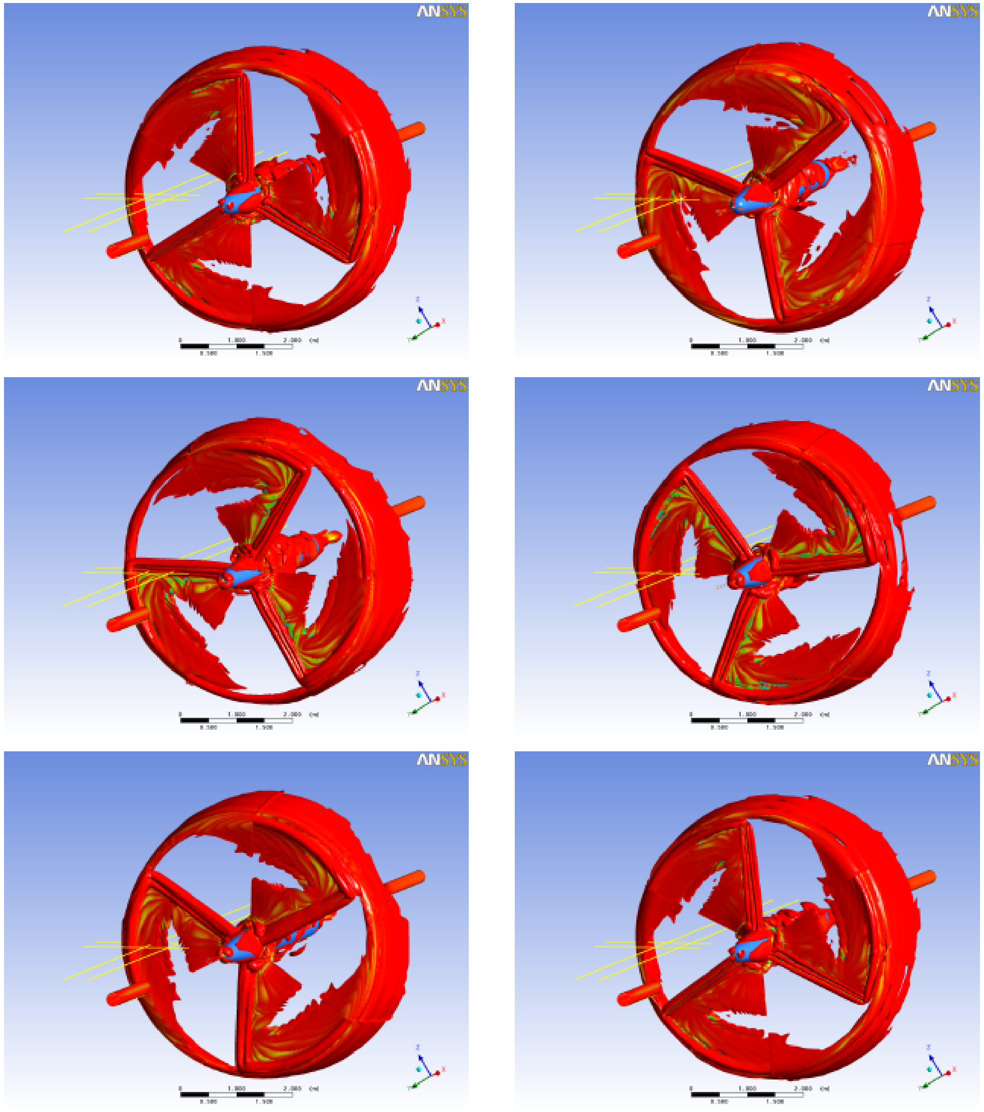
•First cell thickness : 1mm

- *MEXICO rotor – mesh setup*

	Inner wedge	Outer wedge	Total
Number of Nodes:	1997919	691875	2689794
Number of Elements:	1953406	671328	2624734
Wedges:	4305	9744	14049
Hexahedra:	1949101	661584	2610685

Visualisations – Ansys-CFX results

Work by: Marc van Raalte



Wind Energy contributes to CO_2 - reduction ambitions.

QUESTIONS?