Offshore Wind Energy in Norway

http://www.nowitech.no

transatlantic science week

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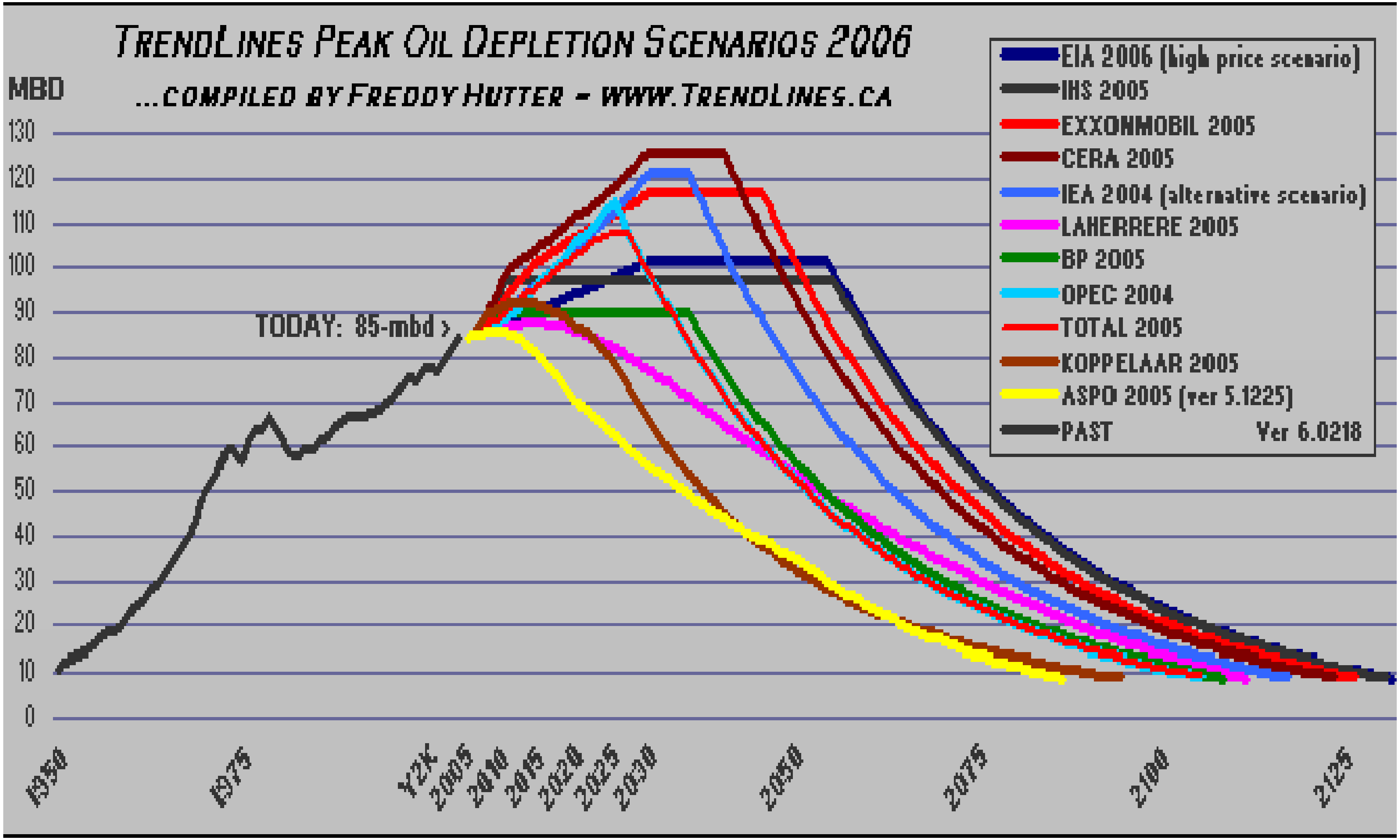
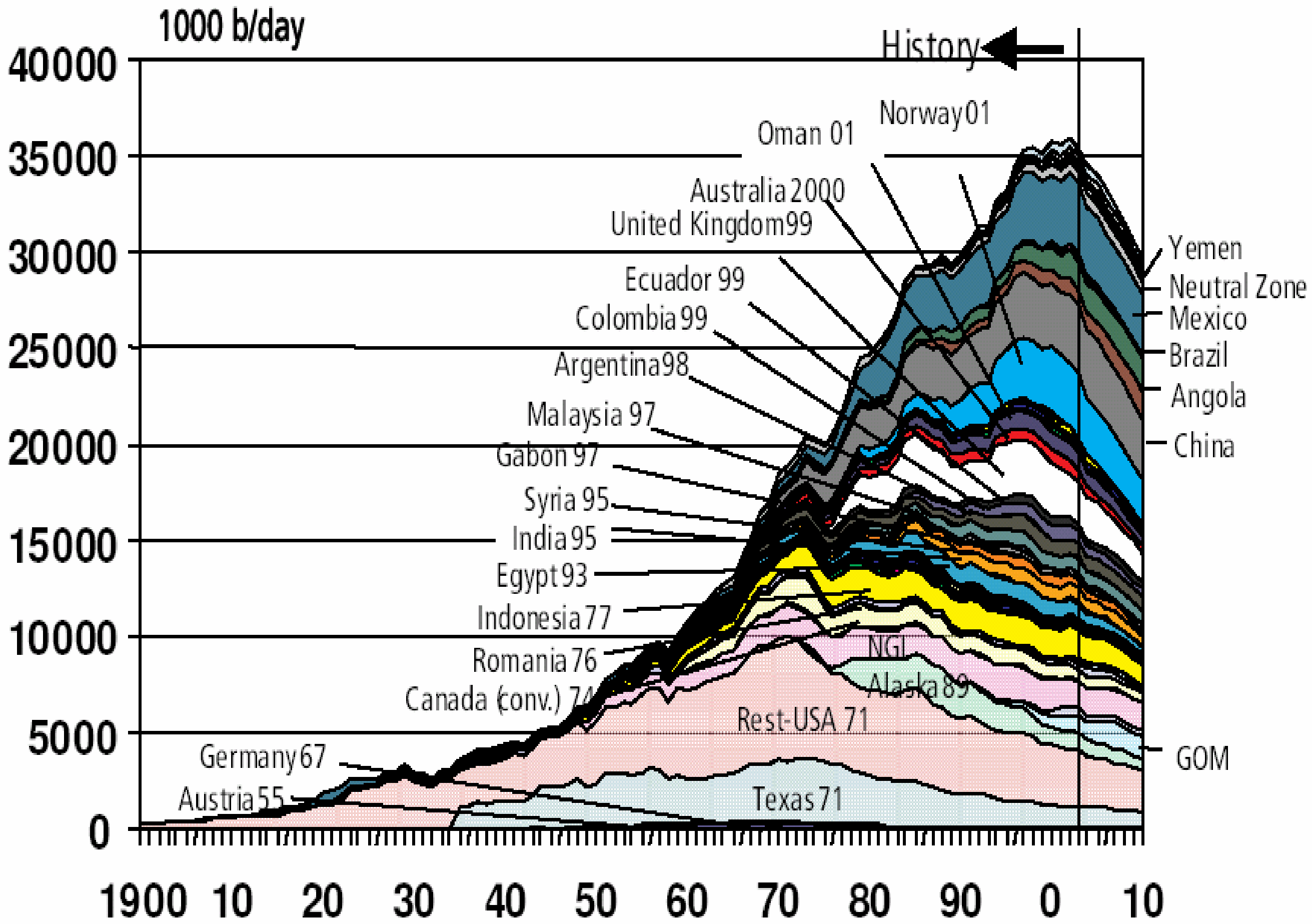


TRENDLINES PEAK OIL DEPLETION SCENARIOS 2006
...COMPILED BY FREDDY HUTTER - WWW.TRENDLINES.CA
MBD
130
120
110
100
90
80
70
60
50
40
30
20
10
0
TODAY: 85-mbd >
1950
1975
Y2K
2005
2010
2015
2020
2025
2030
2050
2075
2100
2125
EIA 2006 (high price scenario)
IHS 2005
EXXONMOBIL 2005
CERA 2005
IEA 2004 (alternative scenario)
LAHERRERE 2005
BP 2005
OPEC 2004
TOTAL 2005
KOPPELAAR 2005
ASPO 2005 (ver 5.1225)
PAST
Ver 6.0218

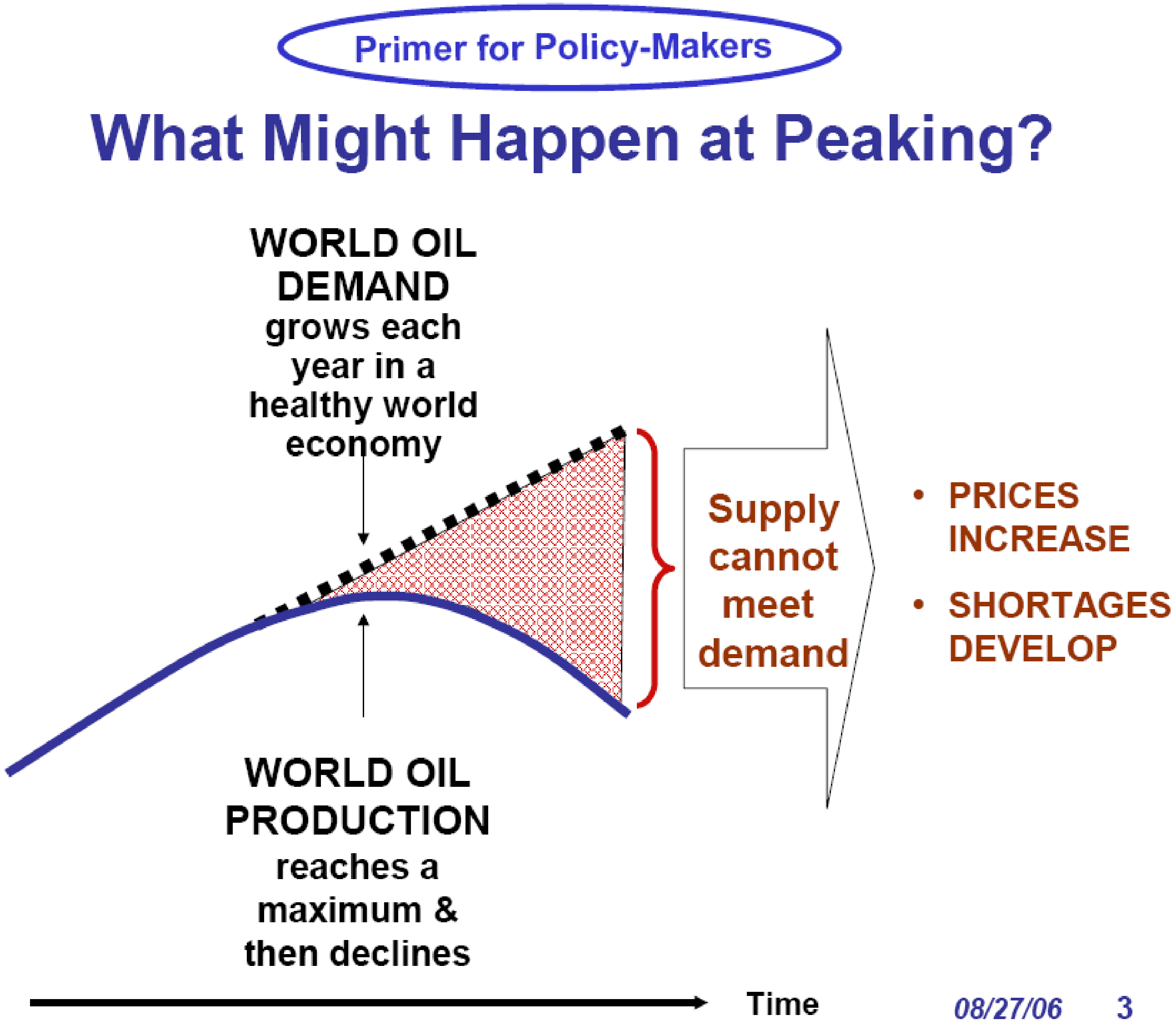
Oil production outside OPEC and FSU



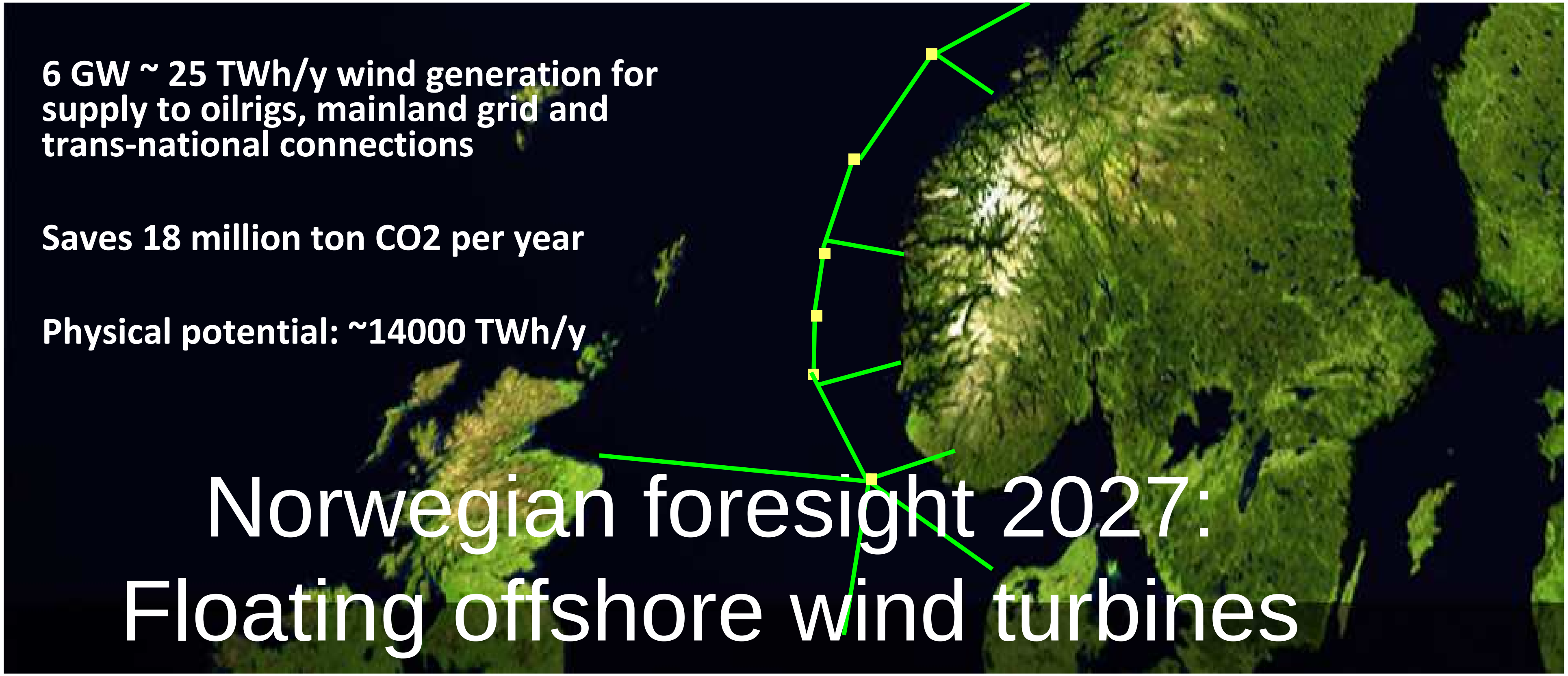
Source: Industry database, 2003 (IHS 2003)
OGJ, 9 Feb 2004 (Jan-Nov 2003)

Historic peak	
Austria	1955
Germany	1967
Texas	1971
USA Low. 48	1971
Canada (conventional)	1974
Romania	1976
Indonesia	1977
Alaska	1989
Egypt	1993
India	1995
Syria	1995
Gabon	1997
Malaysia	1997
Argentina 1998	1998
Colombia	1999
Equador	1999
UK	1999
Australia	2000
Oman	2001
Norway	2001

What happens at ”Peaking”?



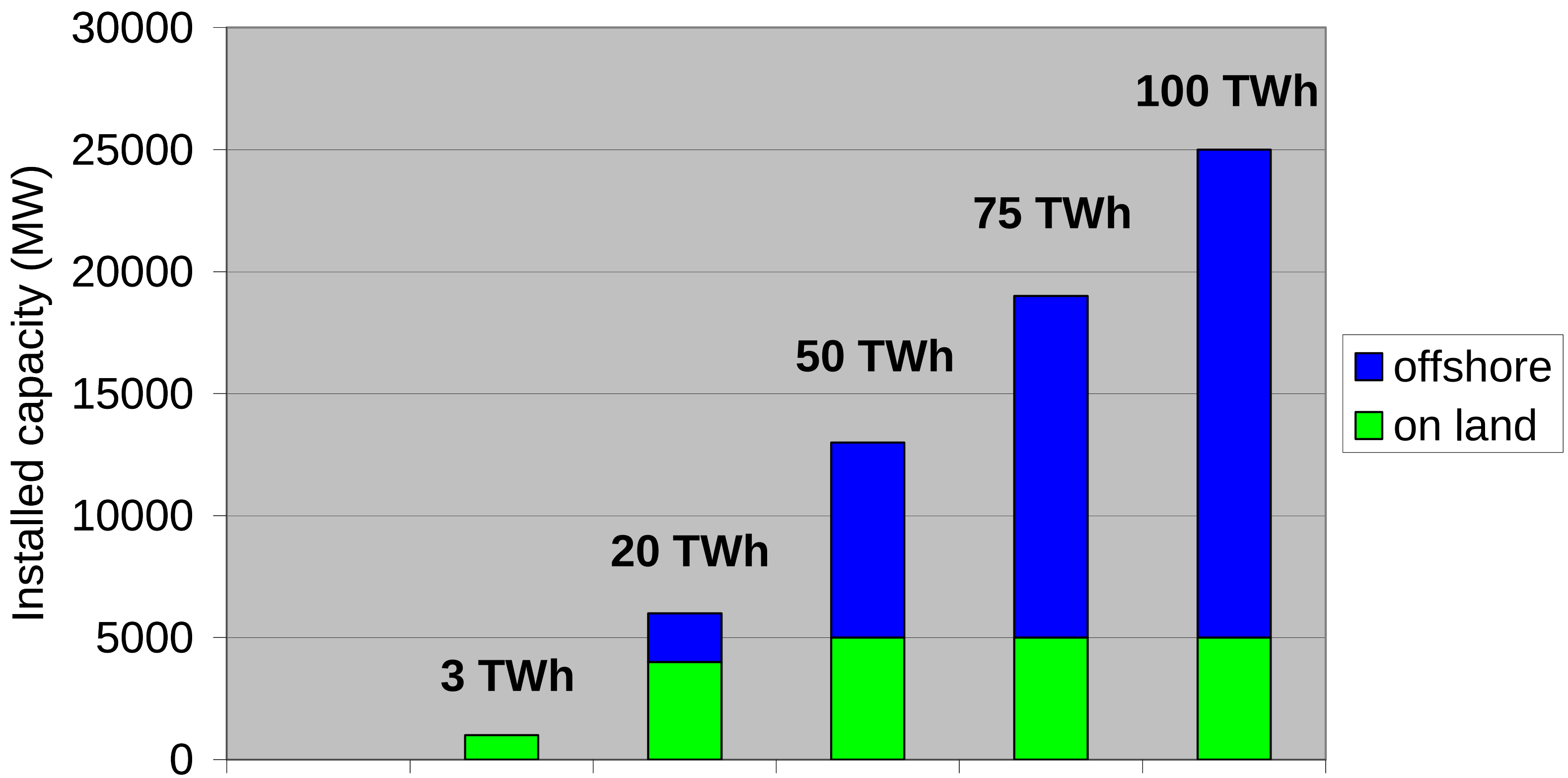
The European Offshore Supergrid



Norwegian foresight 2027: Floating offshore wind turbines

- **Tremendous physical potential**
  0-30 m: 125 TWh/y; 30-60 m: 871 TWh/y; 60-300 m: 12970 TWh/y
  (Norwegian hydro 125 TWh/y; oil and gas export 2500 TWh/y)
- **Norwegian industry and energy companies are active combining offshore and energy expertise to develop sound technology**
- **Global market – a unique possibility for developing new industry**
- **SINTEF, IFE and NTNU is heading R&D with key actors as participants**

Wind Energy in Norway: 2000 - 2050



Ballpark numbers!

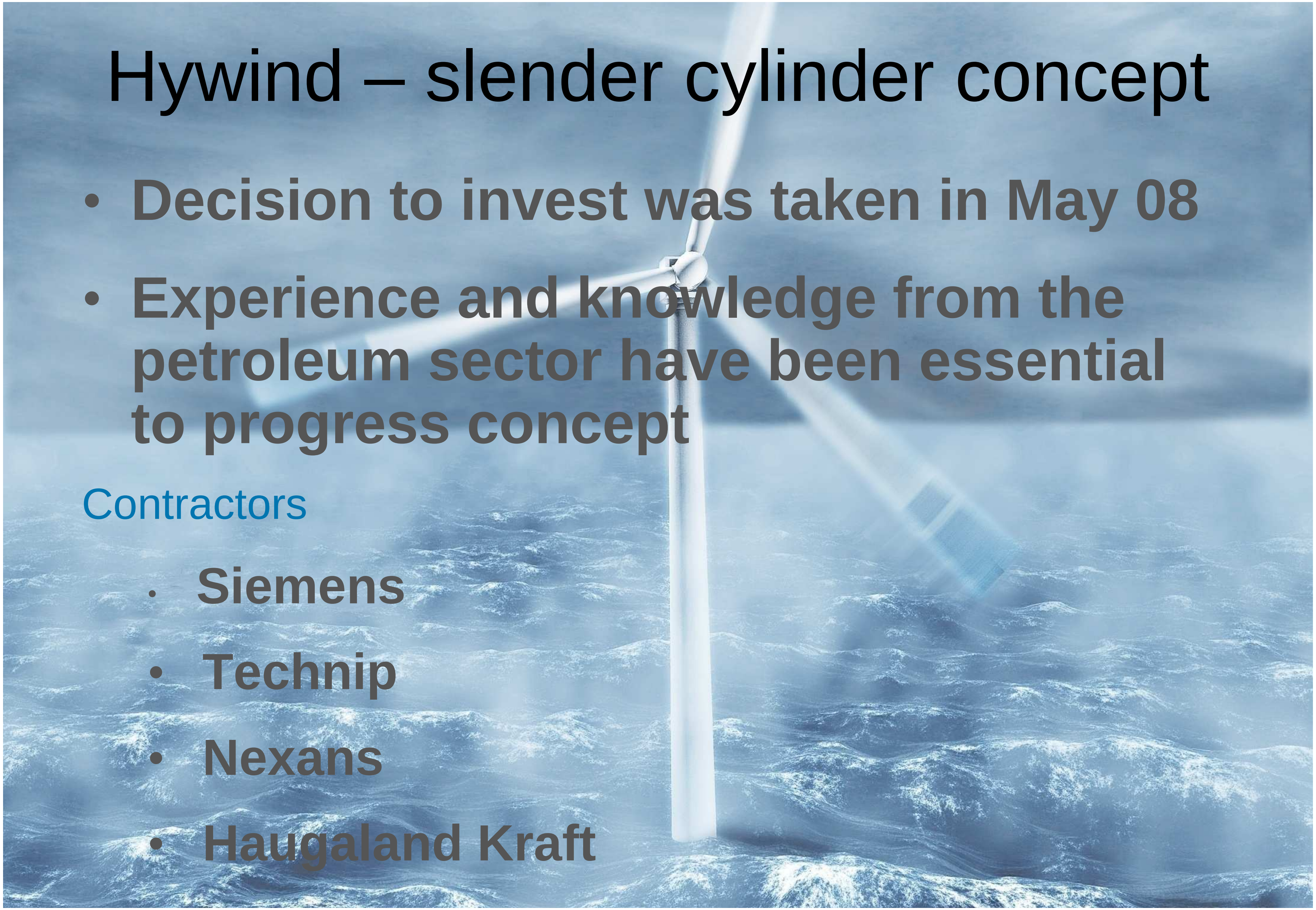
	2000	2010	2020	2030	2040	2050
CO_2 saving (Mt/y)	0	2	15	37	56	76
Investment (GNOK)	0	15	90	195	285	375
Area (km2)	0	100	600	1300	1900	2500

Norway land area 304 280 km2 + offshore; CO_2 emissions (2006); 53,5 million tons

Increase in 2008

EU	Plats 2008	Land/Region	Totalt Installerat slutet 2008 MW	Nytt installerat 2008 MW
-	1	USA	**25170,0**	8351,2
1	2	Tyskland	**23902,8**	1655,4
2	3	Spanien	**16740,3**	1595,2
-	4	Kina	**12210,0**	6298,0
-	5	Indien	**9587,0**	1737,0
3	6	Italien	**3736,0**	1009,9
4	7	Frankrike	**3404,0**	949,0
5	8	Storbritannien	**3287,9**	898,9
6	9	Danmark	**3160,0**	35,0
7	10	Portugal	**2862,0**	732,0
-	11	Kanada	**2369,0**	523,0
8	12	Holland	**2225,0**	478,0
-	13	Japan	**1880,0**	352,0
-	14	Australien	**1494,0**	676,7
9	15	Irland	**1244,7**	439,7
10	**16**	**Sverige**	**1066,9**	**235,9**
11	17	Österrike	**994,9**	13,4
12	18	Grekland	**989,7**	116,5
13	19	Polen	**472,0**	196,0
-	20	Norge	**428,0**	95,1

http://www.svensk-vindkraft.org



Hywind – slender cylinder concept

- **Decision to invest was taken in May 08**
- **Experience and knowledge from the petroleum sector have been essential to progress concept**

Contractors

- **Siemens**
- **Technip**
- **Nexans**
- **Haugaland Kraft**
- **Enova**

Key data and characteristics of demo concept

Main Data

- **WTG:** **2.3 MW**
- **Turbine weight:** **138 tons**
- **Draft:** **100 m**
- **Displacement:** **5300 m^3**
- **Diameter at water line:** **6 m**
- **Water depths:** **120-700 metres**

Characteristics

- **Steel tower and substructur**
- **Dynamic pitch regulation**
- **Completed at inshore site**
- **Towed upright to field**
- **Designed for extreme North Sea conditions**

Lift of upper tower and nacelle on 13 May 2009

Final hook-up

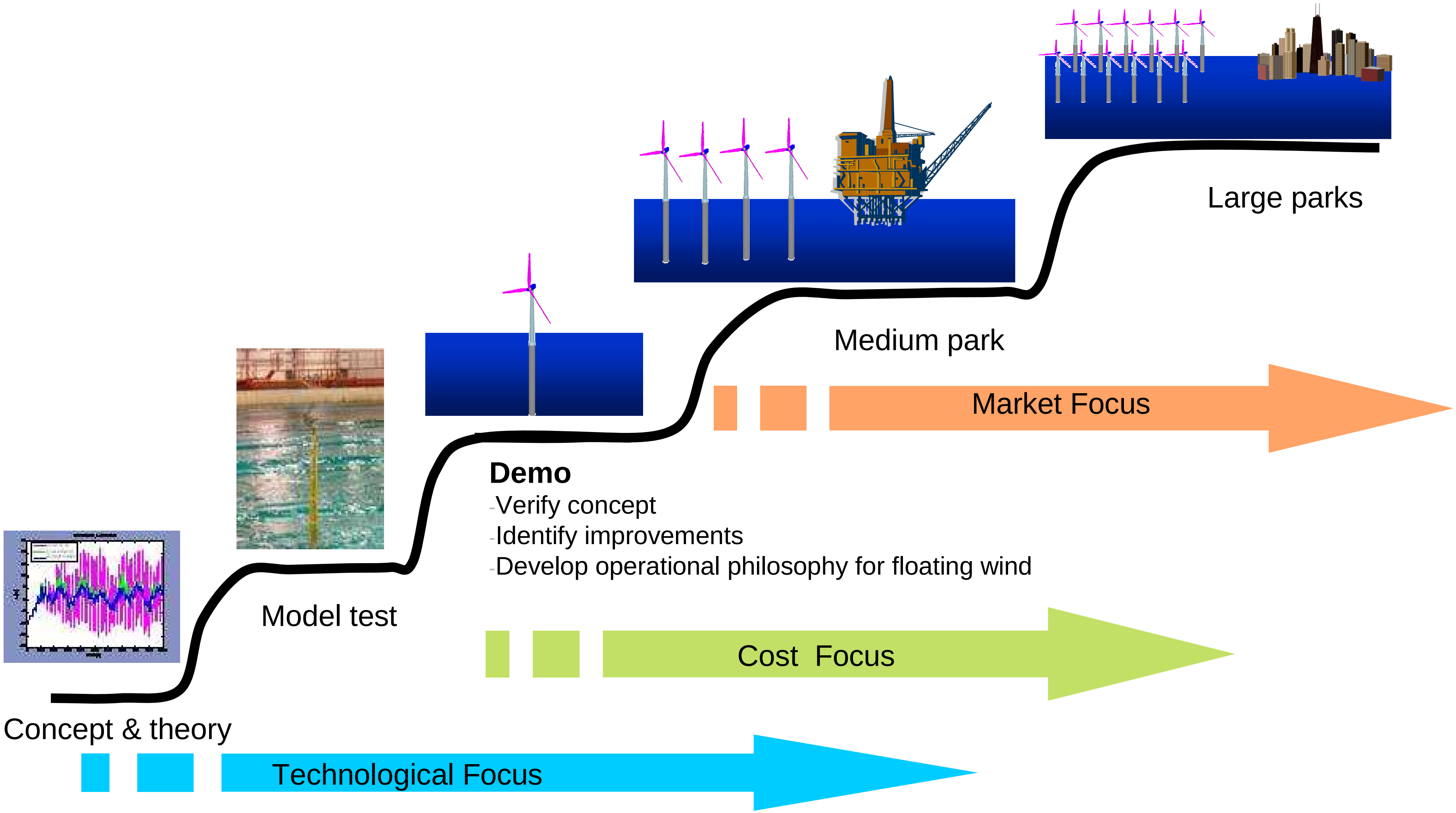
Lessons learnt

- Challenges to be the world first
- The project
  - Planning payes
    - Very satisfied with both Siemens WP and Technip deliveries and work
    - All work performed in a safe and timely manner
      - 3 D visualizing and simulations tool successful used for planning and familiarization
      - Hazops has been a useful tool
    - Inshore MC and commissioning proved to be very efficient completion method
    - Floating to floating lift possible
- Interface management has been a challenge
  - Oil and gas and wind power culture are different
  - Improved mutual understanding

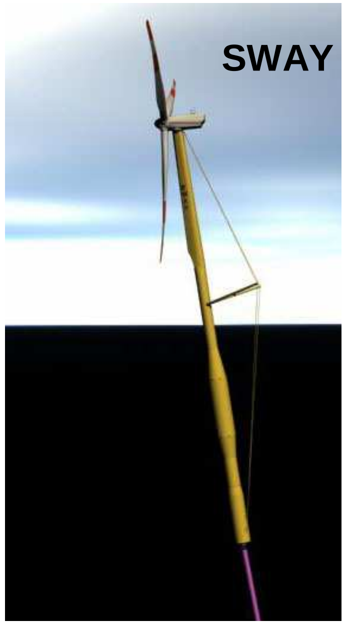
Floating offshore wind turbines – Important differences compared to offshore oil and gas.

- Number of units – one of a kind versus mass production.
- Return are more sensitive to O&M costs
- Safety issues - No hydro carbon and people on board
- Margin business

From idea to commercial concept

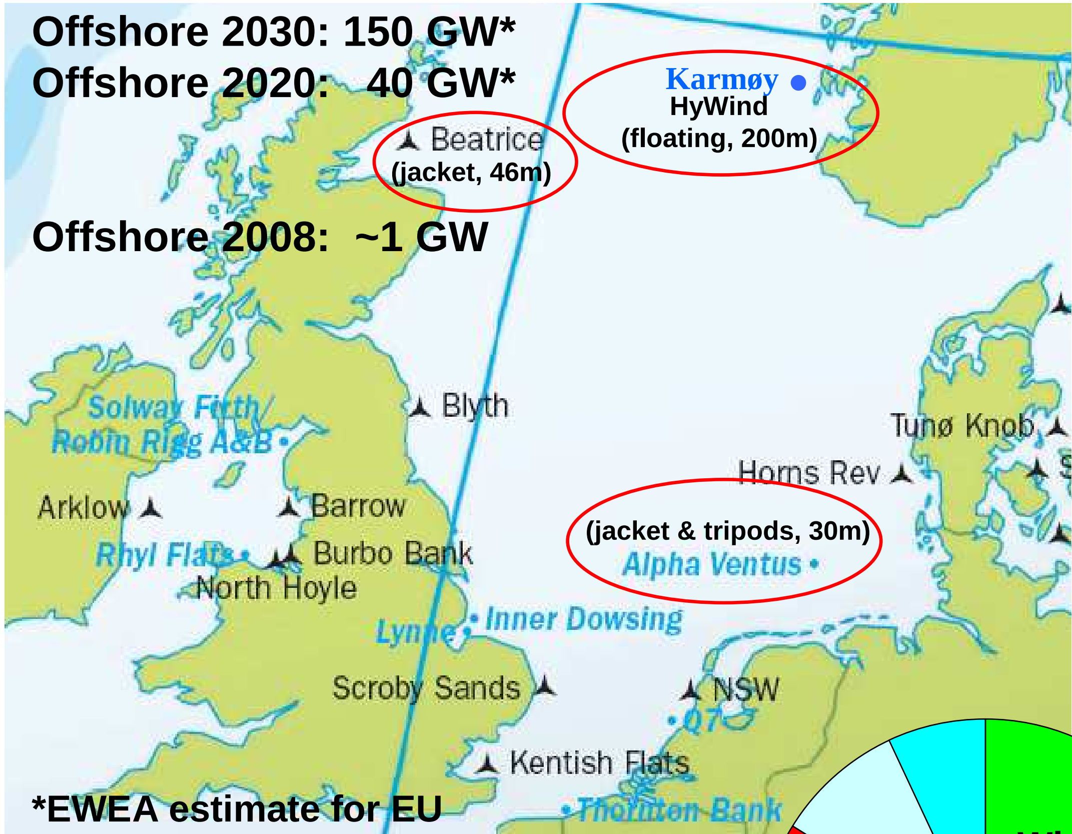


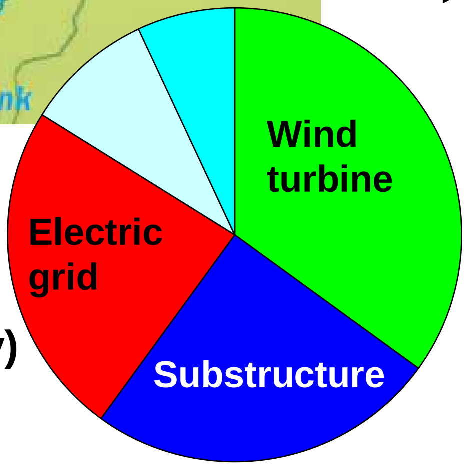
Floating wind turbines - a solution for the future!



- **HyWind 2.3 MW test in operation Sept. 2009**
- **Still a long way to go before large scale commercial deployment of floating wind turbines**

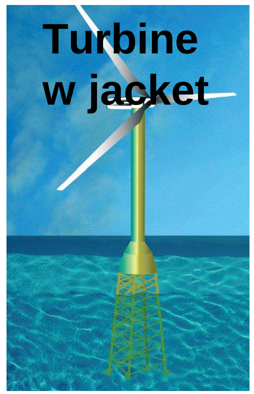
Strong motivation for offshore wind R&D





CAPEX distribution
offshore wind farm (DTI study)

- Huge potential: 150 GW expected by 2030 in EU
- Offshore wind is vital for battling climate change, development of industry and contributing to security of supply
- Development at an early stage – only 3 full scale tests on +30 m water depth realized by 2009
- Technology needs to be developed to reduce costs per kWh

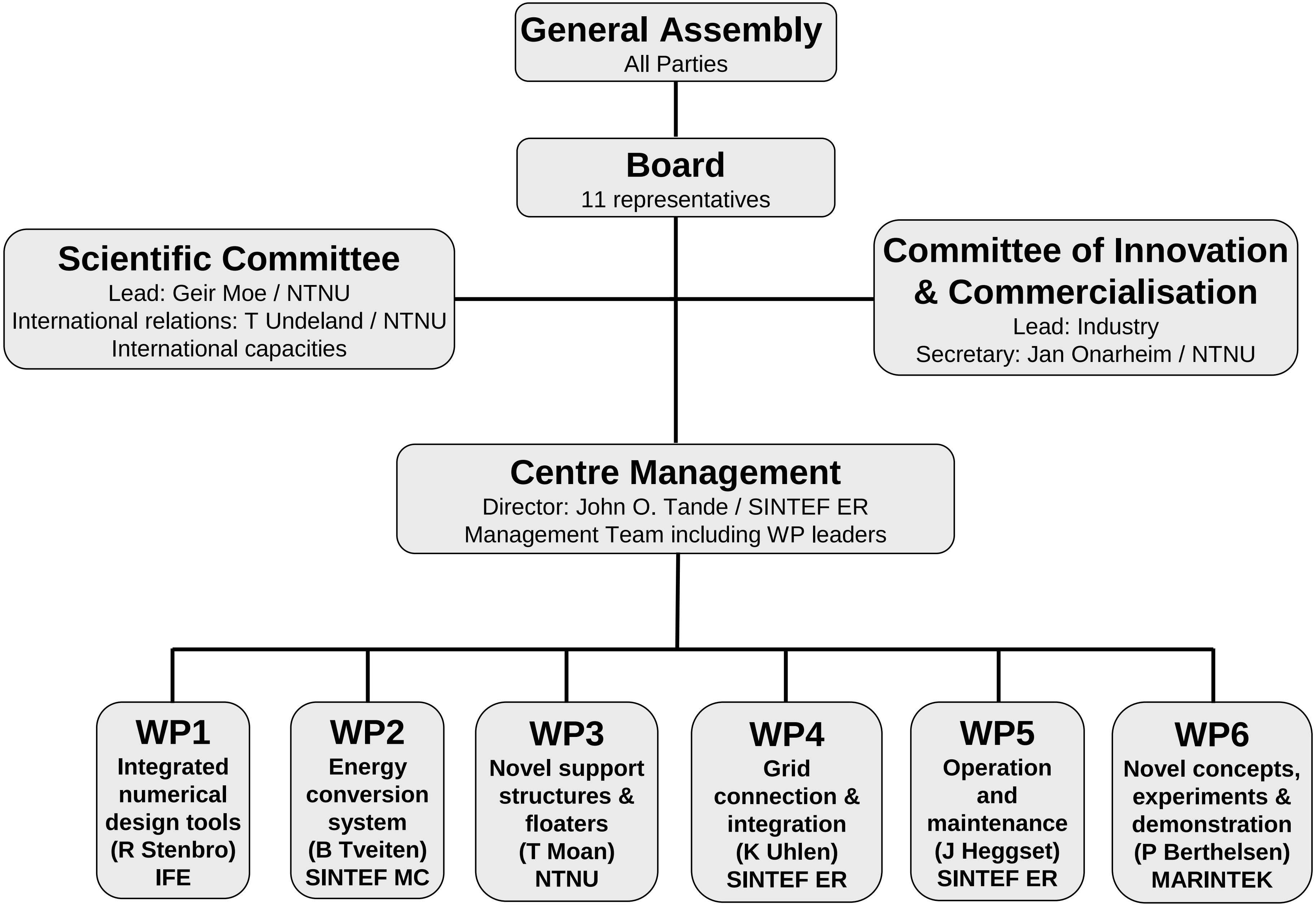


Norwegian Research Centre for Offshore Wind Technology

Director: John Olav Giæver Tande, john.tande@sintef.no

- **Objective:**
  Pre-competitive research laying a foundation for industrial value creation and cost-effective offshore wind farms. Emphasis on deep sea (+30 m).
- **R&D partners: SINTEF, IFE, NTNU + associates: Risø DTU (DK), NREL & MIT, Fraunhofer IWES (DE), University of Strathclyde (UK)**
- **Industry partners: Statkraft, StatoilHydro, Vestavind Kraft, Dong Energy, Lyse, Statnett, Aker Solutions, SmartMotor, NTE, ScanWind, DNV, Vestas, Fugro Oceanor, Devold AMT, TrønderEnergi**
- **+ associates: Innovation Norway, Enova, NORWEA, NVE (invited)**
- **Work packages:**
  1. **Numerical design tools (including wind and hydrodynamics)**
  2. **Energy conversion system (new materials for lightweight blades & generators)**
  3. **Novel substructures (bottom-fixed and floaters)**
  4. **Grid connection and system integration**
  5. **Operation and maintenance**
  6. **Concept validation, experiments and demonstration**

- **Total budget (2009-2017): + $ 54 million including 25 PhD/post docs grants**
- **http://www.nowitech.no**


General Assembly
All Parties
Board
11 representatives
Scientific Committee
Lead: Geir Moe / NTNU
International relations: T Undeland / NTNU
International capacities
Committee of Innovation & Commercialisation
Lead: Industry
Secretary: Jan Onarheim / NTNU
Centre Management
Director: John O. Tande / SINTEF ER
Management Team including WP leaders
WP1
Integrated numerical design tools
(R Stenbro)
IFE
WP2
Energy conversion system
(B Tveiten)
SINTEF MC
WP3
Novel support structures & floaters
(T Moan)
NTNU
WP4
Grid connection & integration
(K Uhlen)
SINTEF ER
WP5
Operation and maintenance
(J Heggset)
SINTEF ER
WP6
Novel concepts, experiments & demonstration
(P Berthelsen)
MARINTEK

IVT 27/09 (PhD)
Quantitative analysis of the aerodynamic performance of the wind turbine rotor by use of Navier-Stokes CFD.
Qualifications: Suitable background would be within computational mathematics, scientific programming, fluid mechanics.
For further information please contact Professor Trond Kvamsdal (trond.kvamsdal@math.ntnu.no)

IVT 28/09 (PhD)
Evaluation of the design criteria and dynamic forces on large floating wind turbines.
Qualifications: Suitable background would be within mechanical engineering, fluid mechanics, physics
For further information please contact Professor Ole G. Dahlhaug (ole.g.dahlhaug@ntnu.no)

IVT 29/09 (PhD or postdoc)
Lift control of wind turbine rotor blades by use of smart material devices manipulating the aerodynamic rotor properties.
Qualifications: Suitable background would be within composite mechanics, laboratory work, structural modeling.
For further information please contact Professor Andreas Echtermeyer (andreas.echtermeyer@ntnu.no)

IVT 30/09 (PhD or postdoc)
Influence of material and process parameters on fatigue of wind turbine blades in a marine environment.
Qualifications: Suitable background would be within composite materials, processing techniques, modeling.
For further information please contact Professor Andreas Echtermeyer (andreas.echtermeyer@ntnu.no)

IVT 31/09 (PhD)
Novel generator concepts for low weight nacelles. Integrated design of generator and mechanical structure for a maintenance free system.
Qualifications: Suitable background would be within electrical machine design, electrical and mechanical analysis.
For further information please contact Professor Robert Nilssen (robert.nilssen@elkraft.ntnu.no)

IVT 32/09 (PhD)
Bottom-fixed support structure for wind turbine in 30 – 70 m water depth
Qualifications: Suitable background would be within structural analysis, vibrations, computational mechanics.
For further information please contact Professor Geir Moe (geir.moe@ntnu.no)

IVT 33/09 (PhD)
Life cycle criteria and optimization of floating structures and mooring systems.
Qualifications: Suitable background would be within marine technology, ocean engineering, structural mechanics.
For further information please contact Professor Torgeir Moan (torgeir.moan@ntnu.no)

IVT 34/09 (PhD)
Analysis of switching transients in wind parks with focus on prevention of destructive effects.
Qualifications: Suitable background would be within electric power engineering, high voltage.
For further information please contact Professor Hans K. Høidalen (hans.hoidalen@elkraft.ntnu.no)

IVT 35/09 (PhD or postdoc)
Balance management with large scale offshore wind integration.
Qualifications: Suitable background would be within electric power engineering, operations research, economics.
For further information please contact Professor Gerard Doorman (gerard.doorman@elkraft.ntnu.no)

IVT 36/09 (PhD)
Development of market models incorporating offshore wind farms and offshore grids.
Qualifications: Suitable background would be within power systems with focus on transmission, electricity markets, technical/economical background
For further information please contact Professor Olav Fosso (olav.fosso@elkraft.ntnu.no)

IVT 37/09 (PhD)
Maintenance optimization of wind farms from design to operation (models, methods, framework).
Qualifications: Suitable background would be within reliability, maintenance, logistics.
For further information please contact Professor Jørn Vatn (jorn.vatn@ntnu.no)

IVT 38/09 (PhD)
Novel coating and surface treatment for improved wear resistance.
Qualifications: Suitable background would be within materials technology, chemistry, physics.
For further information please contact Professor Roy Johnsen (roy.johnsen@ntnu.no)

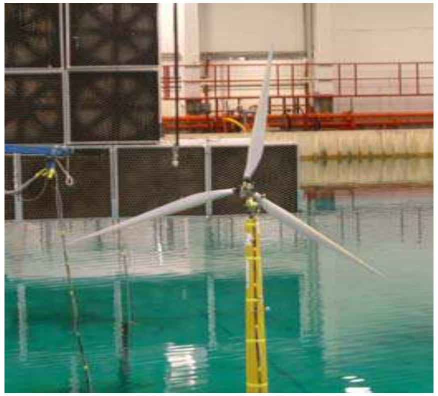
IVT 39/09 (PhD or postdoc)
Comparative study of floating concepts.
Qualifications: Suitable background would be within marine technology, ocean engineering, system design.
For further information please contact Professor Torgeir Moan (torgeir.moan@ntnu.no)

IVT 40/09 (PhD)
Assessment of benefits of downwind rotors due to weight savings using new and thinner airfoils and improved directional stability of turbine.
Qualifications: Suitable background would be within fluid mechanics, aerodynamics.
For further information please contact Professor Per-Åge Krogstad (per.a.krogstad@ntnu.no)

IVT 41/09 (PhD)
Design of control systems for load mitigation and stabilization of floating wind turbines.
Qualifications: Suitable background would be within control systems, engineering cybernetics.
For further information please contact Professor Thor I. Fossen (fossen@ieee.org)

Relevant labs on campus and field facilities

Ocean basin 80x50x10 m

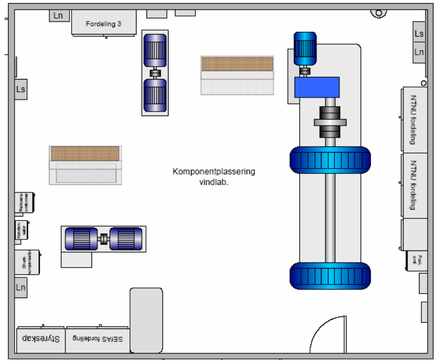


Wind tunnel 11x3x2 m

2x45 m + 2x100 m masts

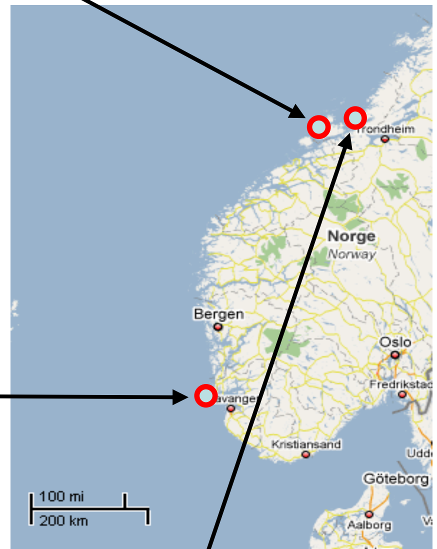
Met-ocean buoys, lidars, etc (to be procured & operated jointly with NORCOWE)

Renewable Energy Sys Lab



Material testing

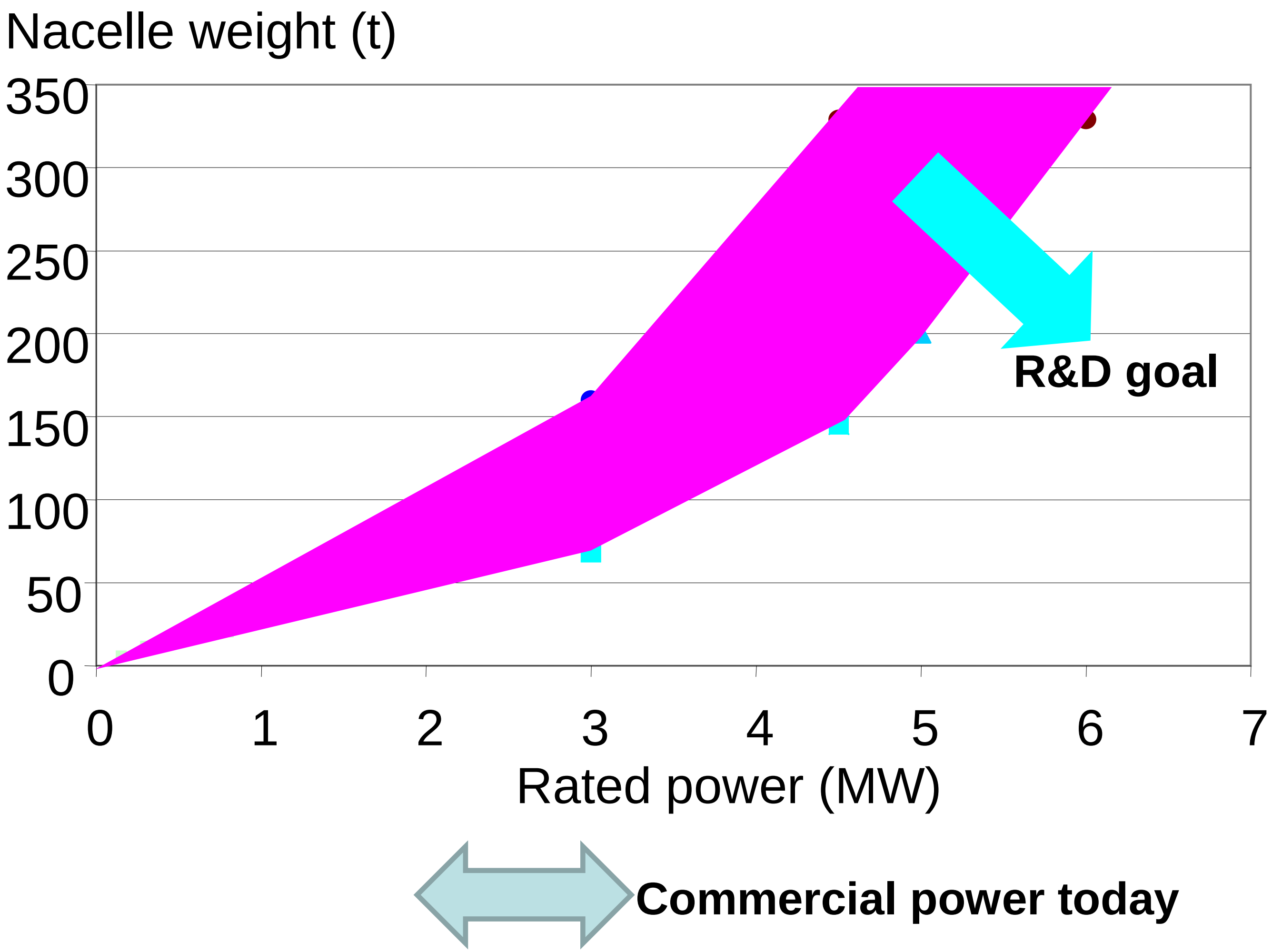
HyWind 2,3 MW floating wind turbine (owned & operated by StatoilHydro)



Test station for wind turbines – VIVA AS
Average wind speed 8.4 m/s @ 50 m agl

Photo / Visualisation: InterPares AS

R&D example:
Tower top weight is critical for keeping the cost down



Use new materials and new designs of generators and transformers to reduce top weight for large wind turbines

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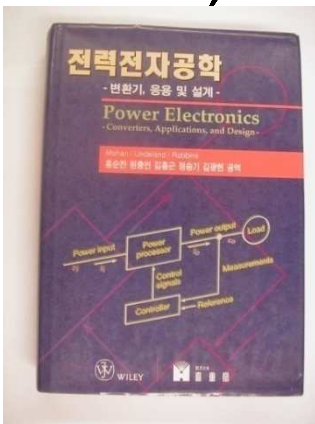
- PhD 1977, Professor at NTNU since 1984
- Sabbaticals at ABB, UMN, Siemens, UMN, UMN
- Adjunct professor at ChalmersTU, Sweden
- Coauthor Wiley book
- Fellow IEEE
- President EPE & Wind Cha
- Board IEEE PELS
- Research: Industrial Power Electronics
- Now concentrating on wind energy



NordicU, RWTH, ETHZ, TorinoPT, UoDelft,
UMN, VirginiaTech, TokyoU, TokyoIT