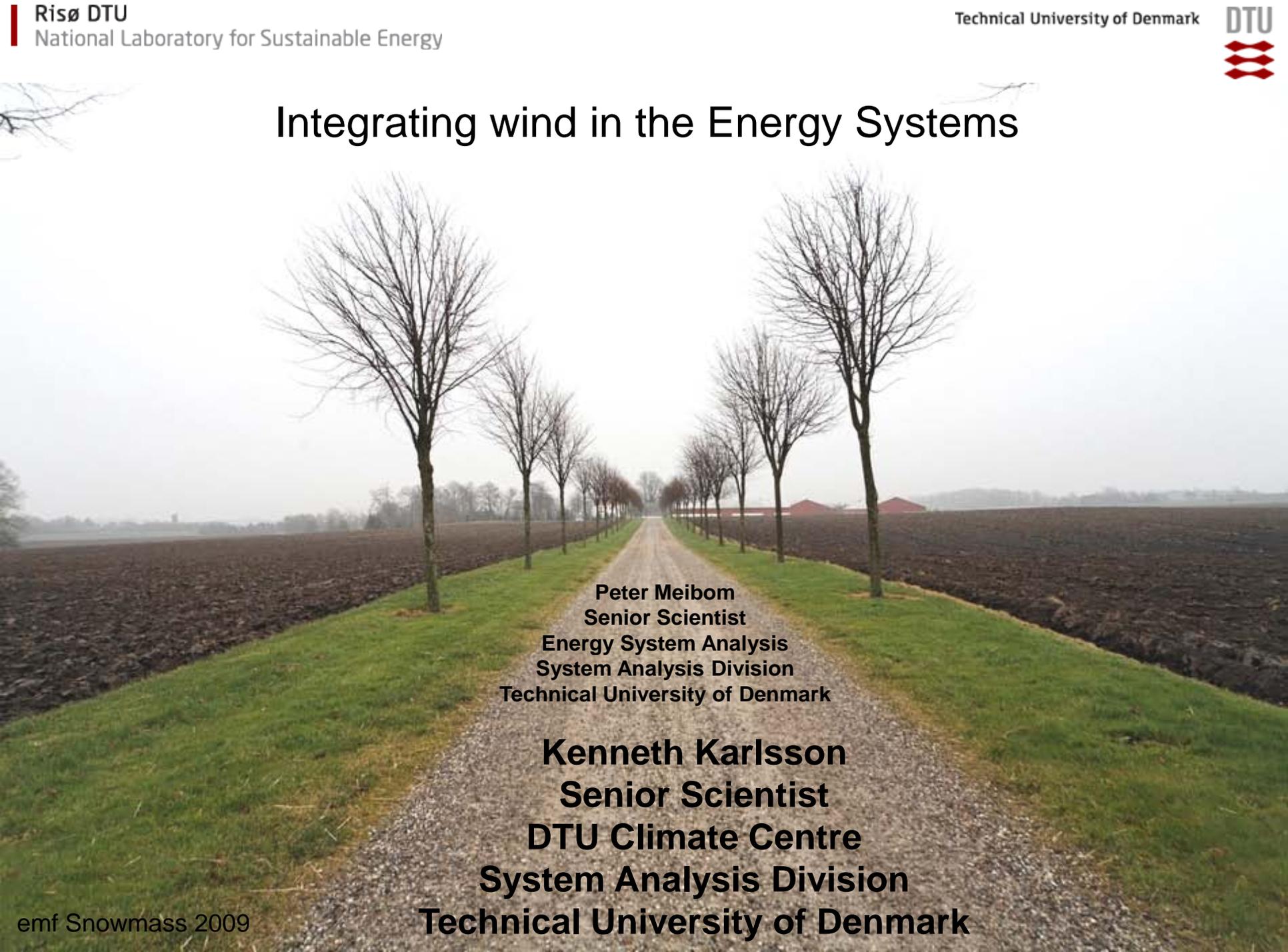


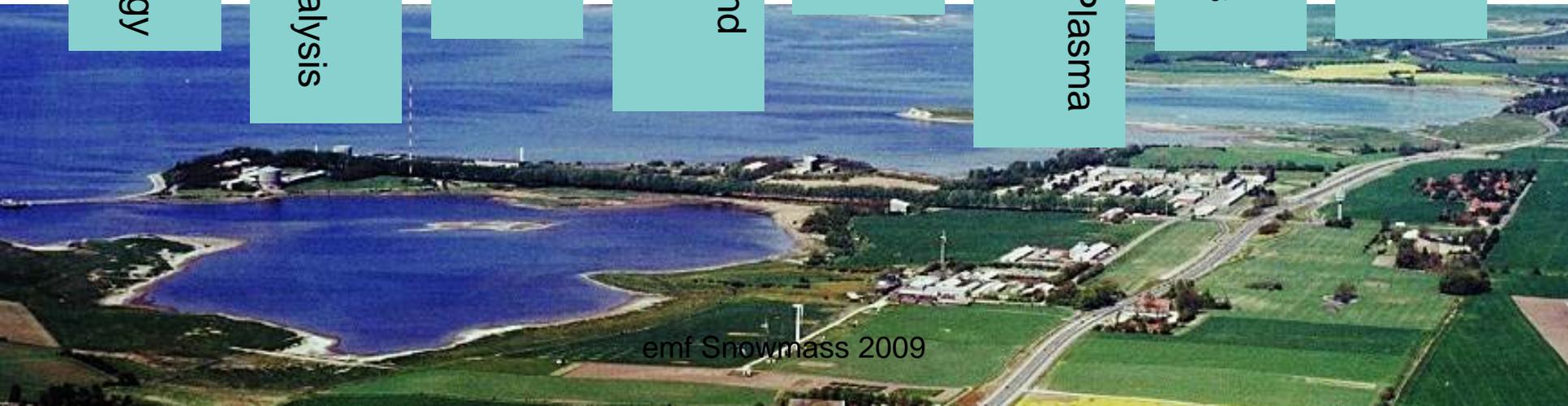
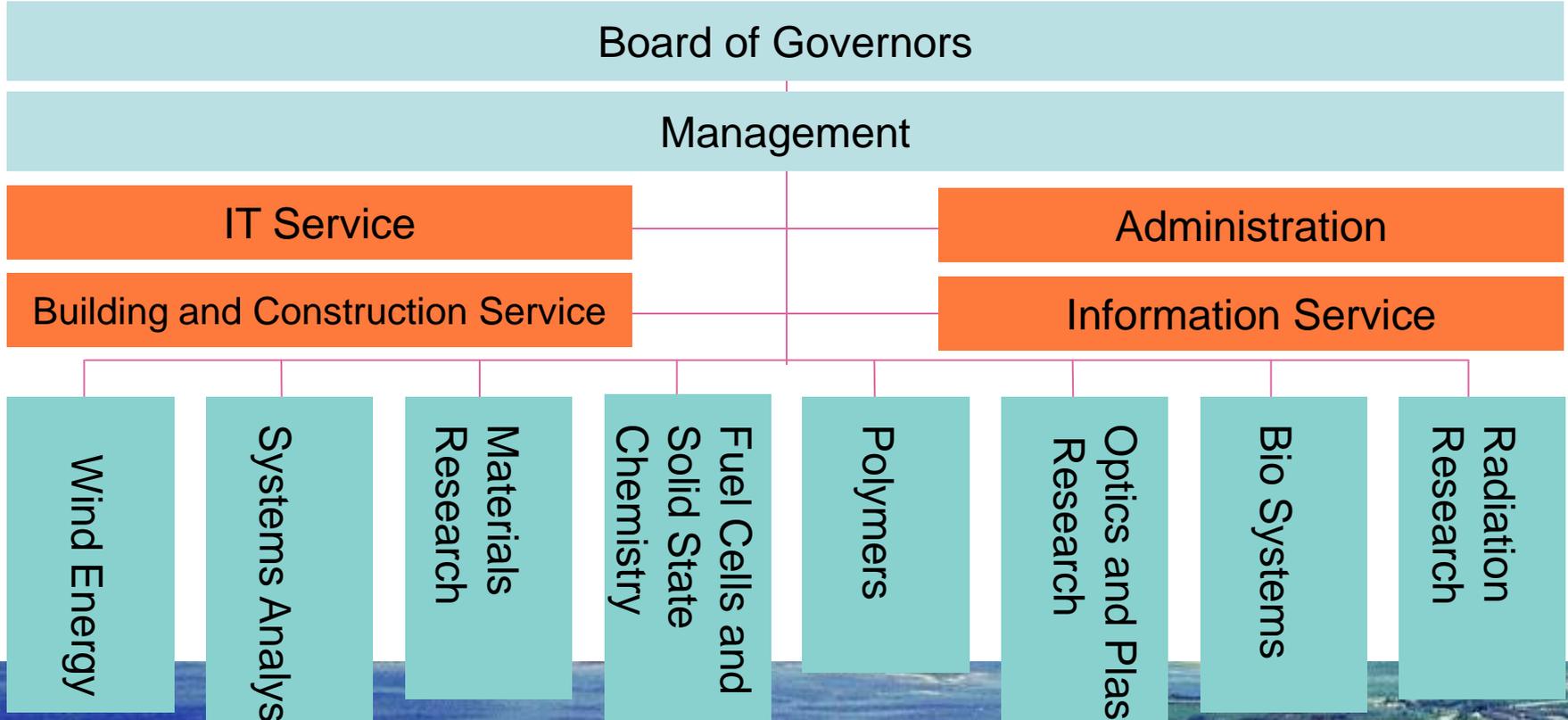
Integrating wind in the Energy Systems

A wide-angle photograph of a gravel path that recedes into the distance, flanked by a row of bare, young trees. The path is bordered by green grass, and beyond that are dark, tilled agricultural fields. In the far distance, a few red-roofed buildings are visible under a grey, overcast sky.

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DTU Climate Centre

Head of programme: Kirsten Halsnæs

DTU Climate Centre aims at integrating technical and economic research on climate change, mitigation and adaptation.

DTU Climate Centre supports cross cutting DTU activities that strengthen the climate perspective of ongoing research programmes

Ongoing projects:

- Advising the Danish Climate Commission
- Supporting the Danish TSO in demand modelling
- Climate labelling of products
- Adaptation – water systems
- TIAM DK

Agenda

- Wind in liberalised power markets
- Models used for modeling integration of wind power
- How much wind can be integrated?
- How can this be used in IAM?

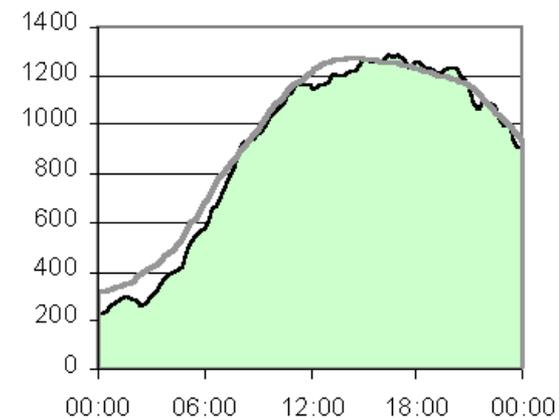
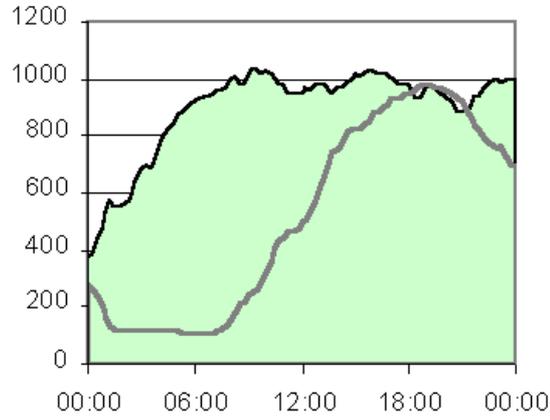
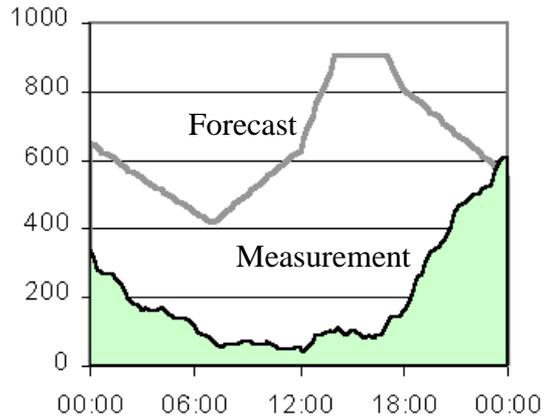
Impacts of wind power in the power system

- Technical impacts:
 - More need for transmission
 - Other production units: more variable production (more start/stop, more part-load operation)
 - More need for reserve power especially on the minutes to days scale (minutes: wind power forecast errors, days: alternative production when wind power production is low)
 - Years: energy balance, maximum variation in wind power production from year to year $\pm 20\%$
 - Modern wind turbines can deliver some types of power system services (e.g. reactive power)

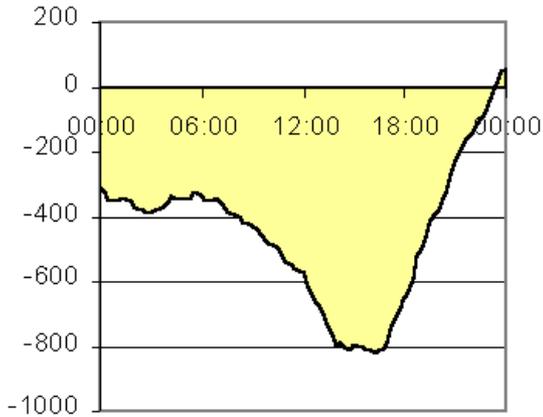
Impacts of wind power in the power system

- Market impacts:
 - Reduce the day-ahead market price
 - Increase the market price for regulating power
 - Consequences for long-term power plant investment behavior?
- Value of the wind power production:
 - Reduced due to integration costs

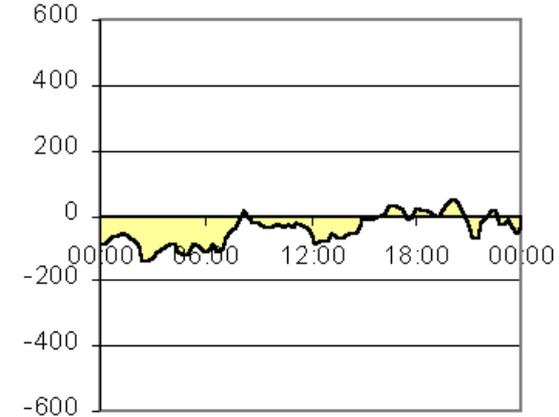
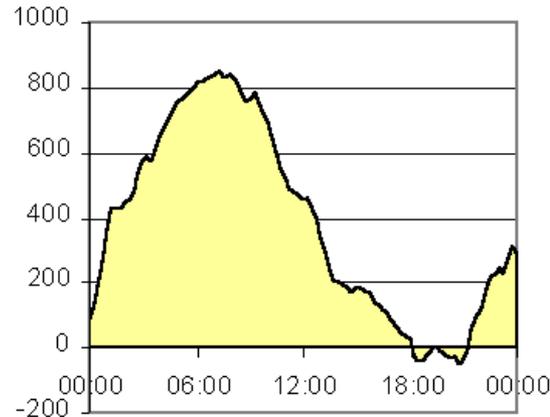
Day-ahead wind power forecasts and realised wind power production in Western Denmark (Hannele Holttinen, VTT)



800 MW in deficit



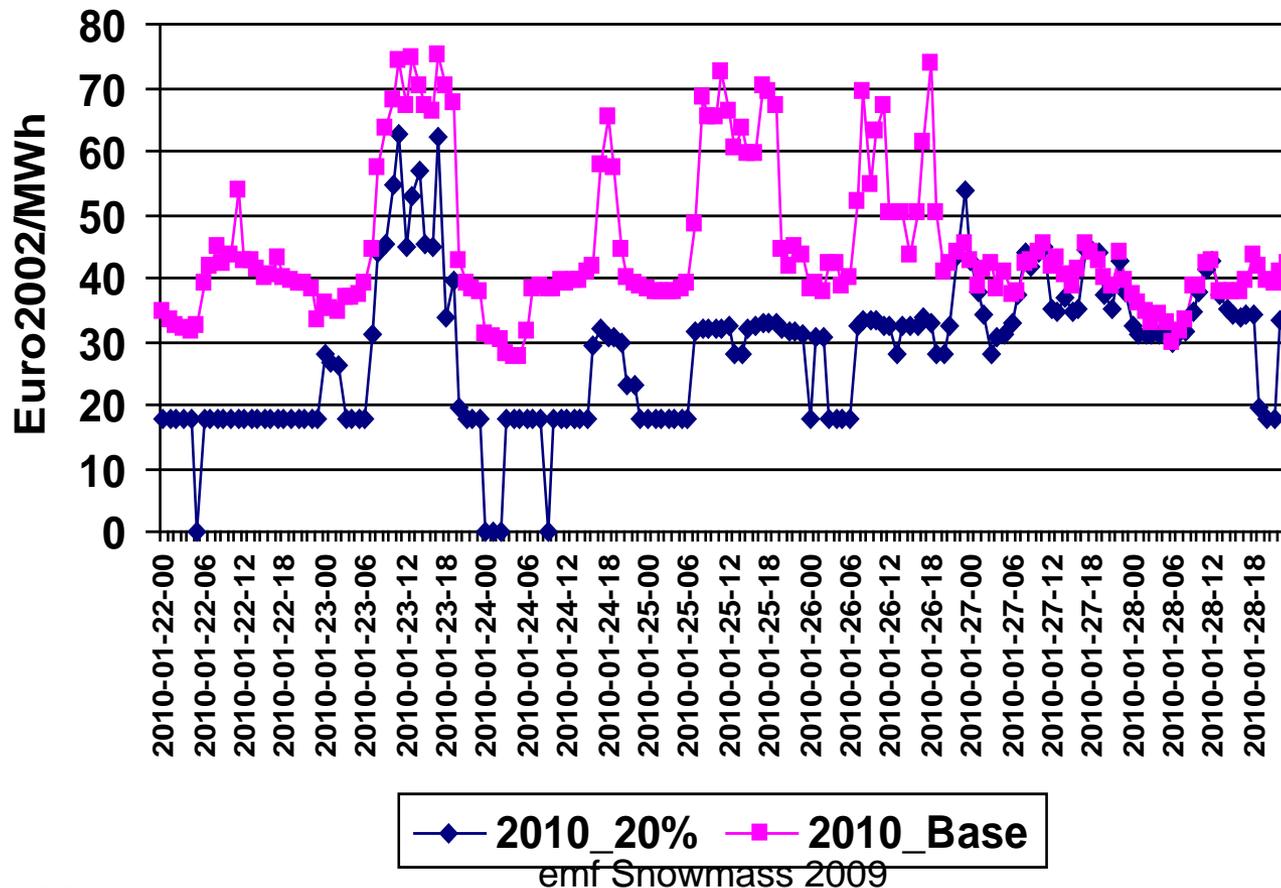
800 MW in excess



emf Snowmass 2009

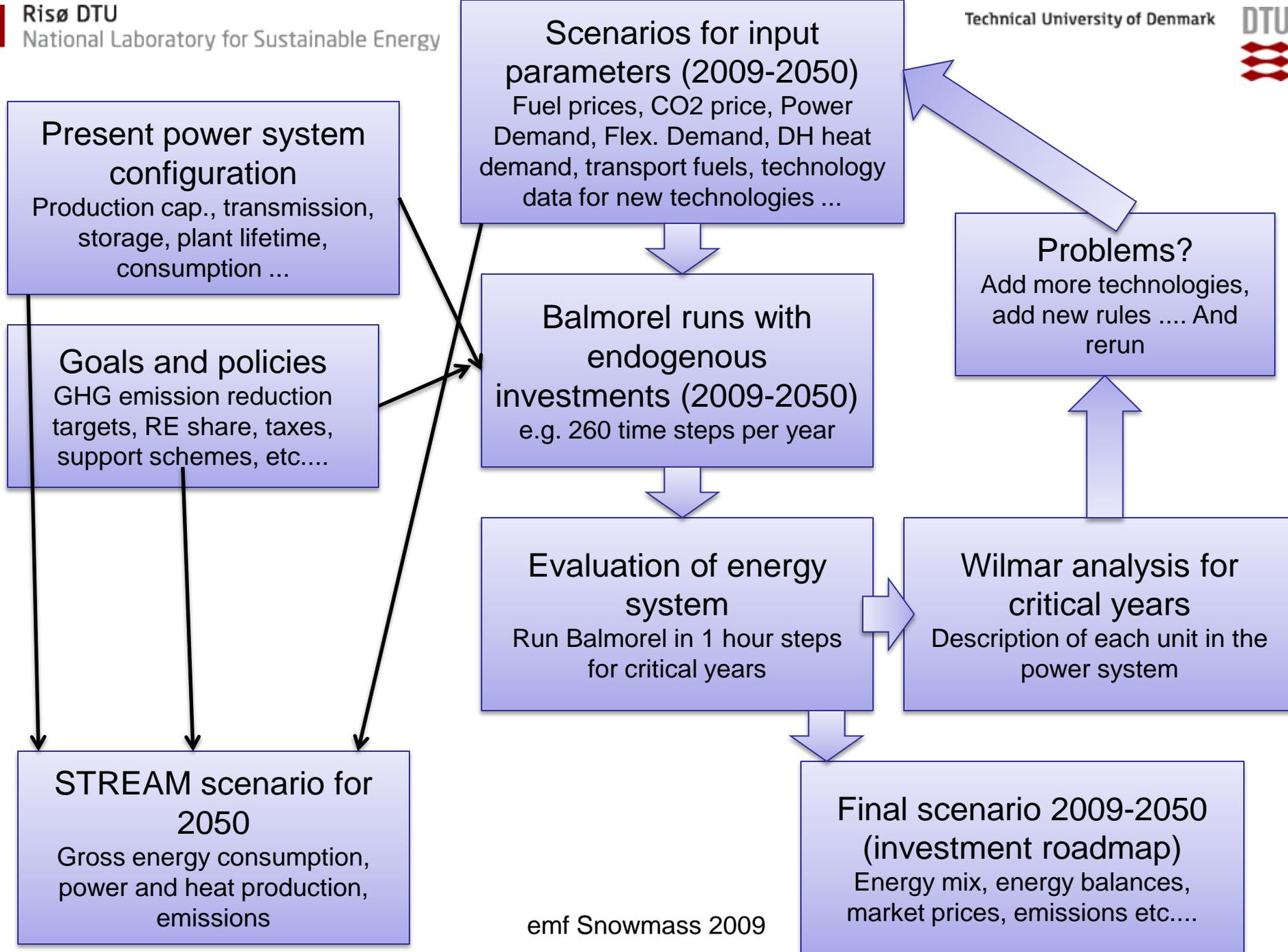
Price impacts of wind power

Intraday prices in northern Germany during the time period 22.01.2010 – 28.01.2010 for the cases 2010_Base and 2010_20%:



Models

- **STREAM** (www.streammodel.org) – spreadsheet based, no dynamics between years, time steps 1 hour
- **Balmorel** (www.balmorel.org) – myopic optimisation model (can run with foresight), endogenous investments, time steps down to 1 hour
- **Wilmar** (contact Peter Meibom peme@risoe.dtu.dk), unit commitment, stochastic wind, time steps 1 hour until now
- **TIAM** (www.etsap.org) – global energy model (full foresight, limited foresight, myopic), endogenous investments, few time steps per year
- Power Grid Models, time steps down to minutes

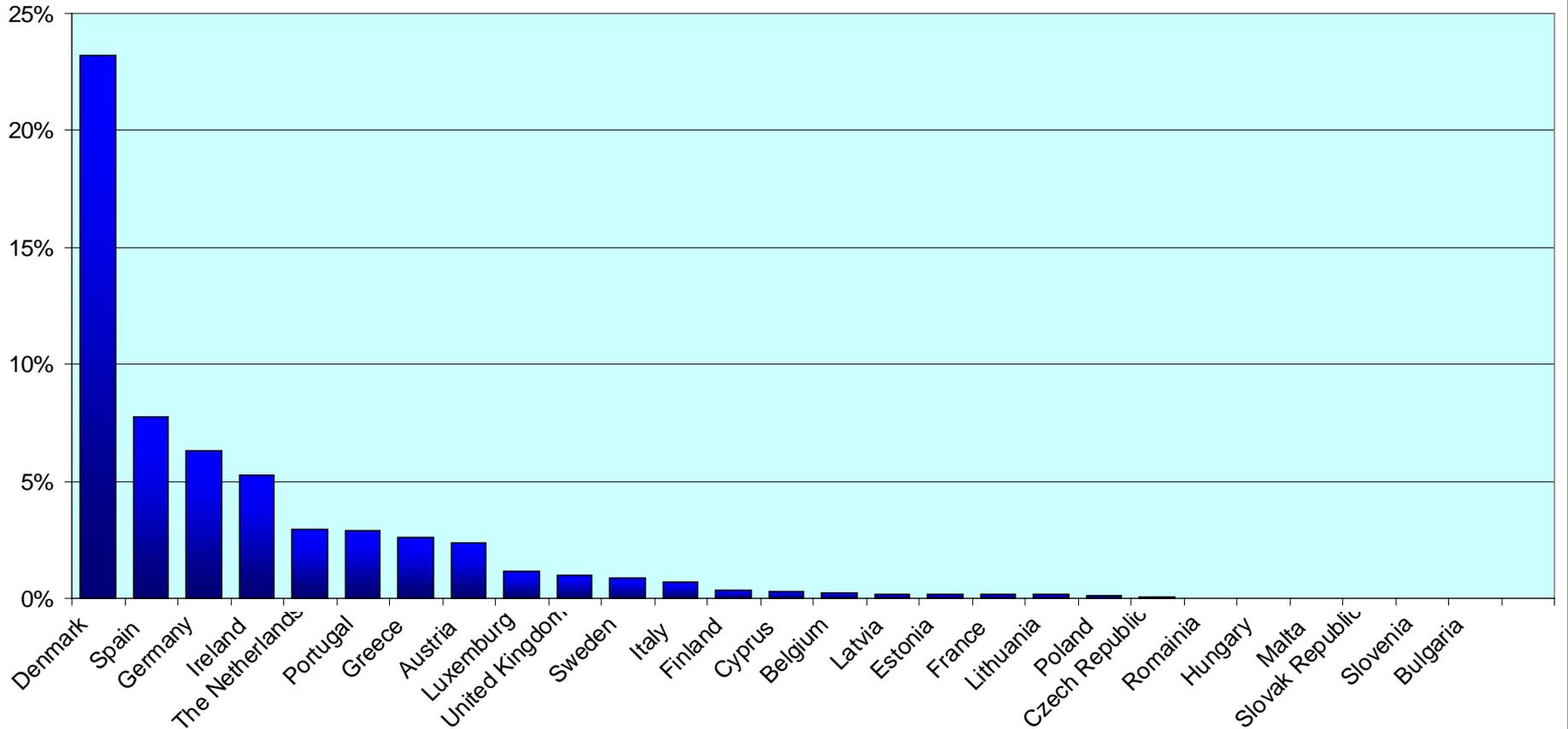


How much wind can be integrated?

	Wind share of electricity production	Model
 danishenergyassociation	DK 50% in 2050	STREAM
 DANISH WIND INDUSTRY ASSOCIATION www.windpower.org	DK 50% in 2025	Balmorel
EA Energy analysis + Risø DTU (STOA)	EU 17% in 2050	STREAM
 The Danish Society of Engineers VIDEN DER STYRKER	DK 48% in 2015 DK 67% in 2030	Energyplan
Energinet.dk (The Danish TSO)	DK 50% in 2025	STREAM/ SIVAEL
All Island Grid study covering Republic of Ireland and Northern Ireland	34% in ??	Wilmar

Wind power share in 2005

Wind power as share of total electricity consumption



Wind power

Future Energy Systems in Europe

Commissioned by STOA and carried out by ETAG

Final Report

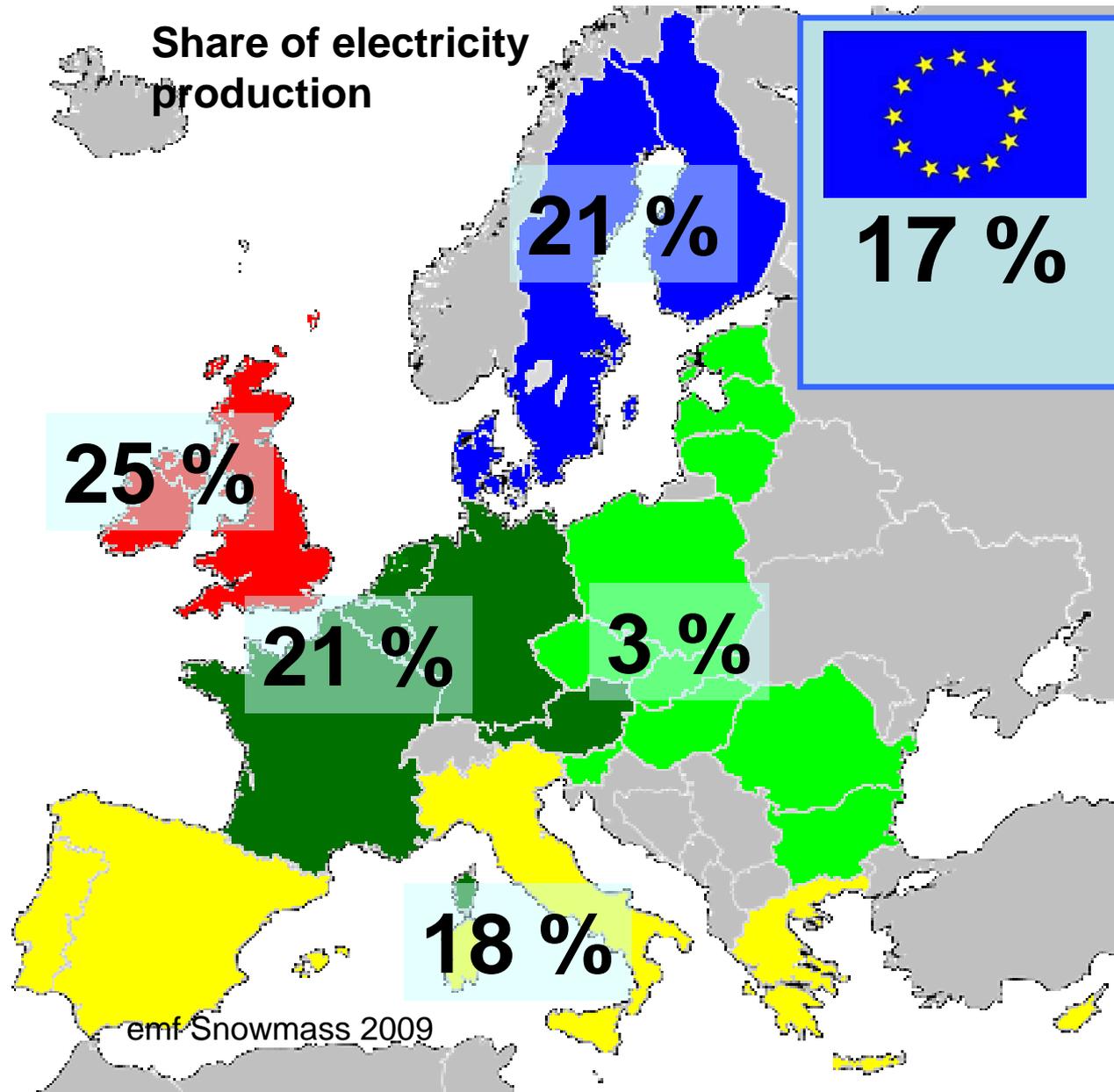
Specific Contract No.: IP/A/STOA/FWC-2005-28/SC33

Ref.: Framework Contract No. IP/A/STOA/FWC/2005-28

February 2009

Report prepared by:

Gy Larsen Project Manager, The Danish Board of Technology and Oliver Bo Schmidt, Project Assistant, The Danish Board of Technology.



All Island Grid study covering Republic of Ireland and Northern Ireland



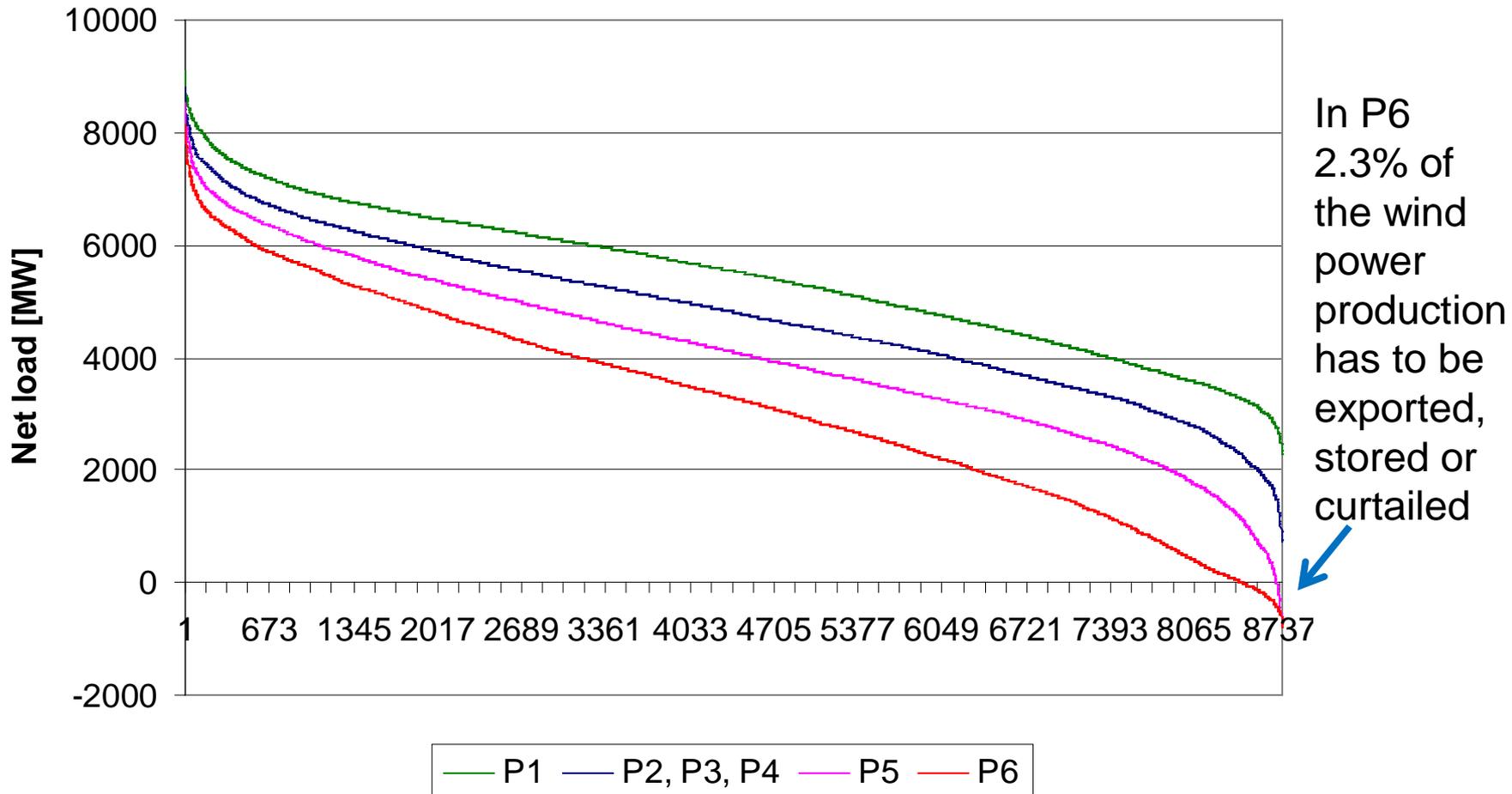
emf Snowmass 2009

Source: Peter Meibom

Operational costs and CO2 emissions

	P1	P2	P3	P4	P5
Wind prod/yearly demand [%]	11	23	23	23	34
Renewable production / yearly demand [%]	16	27	27	27	42
Operational costs incl. payments related to power exchange with GB [MEuro]	2342 (1.00)	2002 (0.85)	2109 (0.90)	1898 (0.81)	1604 (0.68)
Resulting sum of CO2 emissions [Mton]	20.1 (1.00)	17.6 (0.88)	18.4 (0.92)	21.8 (1.08)	15.3 (0.76)

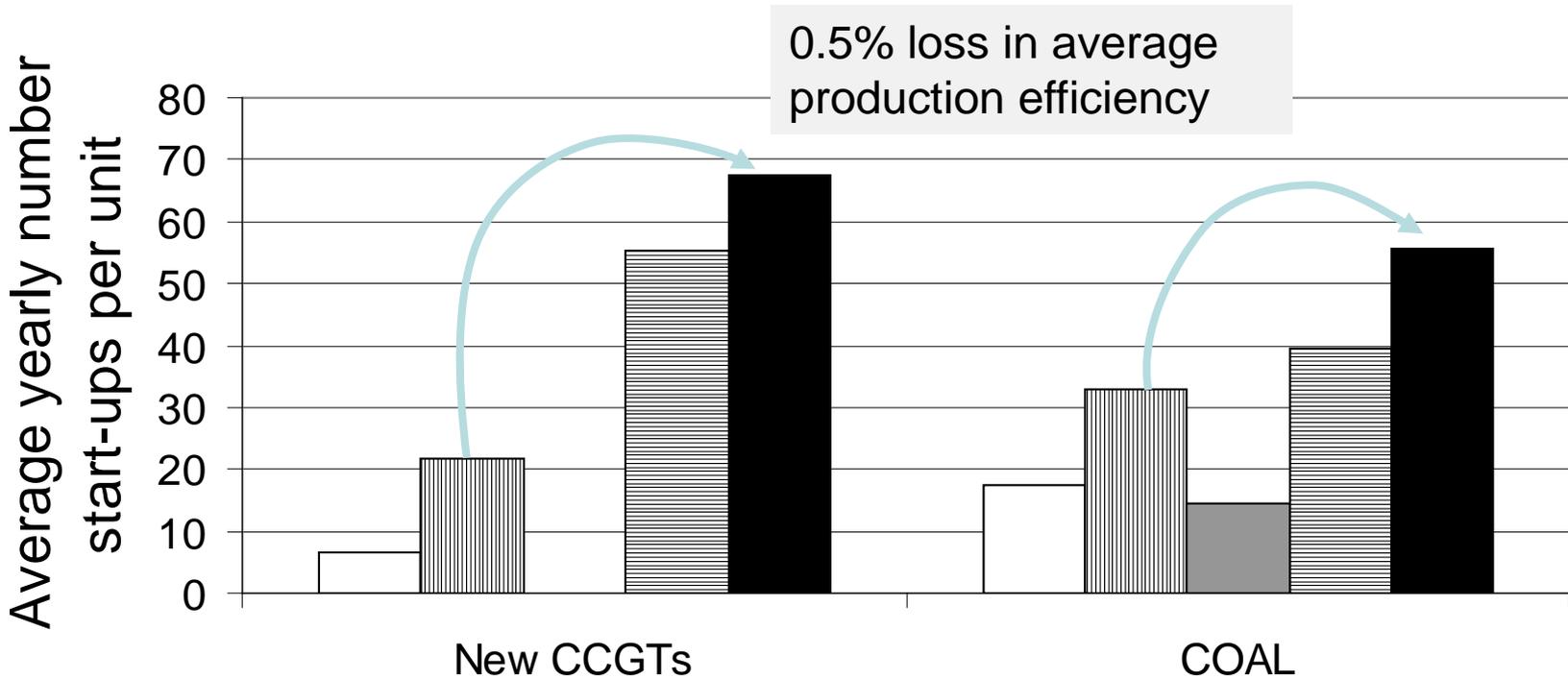
Net load – realised load minus realised wind power production



Negative net load: export to GB, pumped hydro, wind curtailment

emf Snowmass 2009

Average yearly number of start-ups for new CCGTs and coal units in P1-P5. P3 does not have new CCGTs.



8% loss in average production efficiency for peak load gas plants

□ P1 ▨ P2 ■ P3 ▩ P4 ■ P5

Ways of integrating windpower

- Fast reacting flexible power capacity
- Increased transmission capacity
- Integration with district heating and heat storage
– e.g. heat pumps
- Flexible demand (Electric cars, “intelligent” appliances etc.)
- Seasonal electricity storage (batteries, hydrogen, compressed air, pumped hydro etc.)

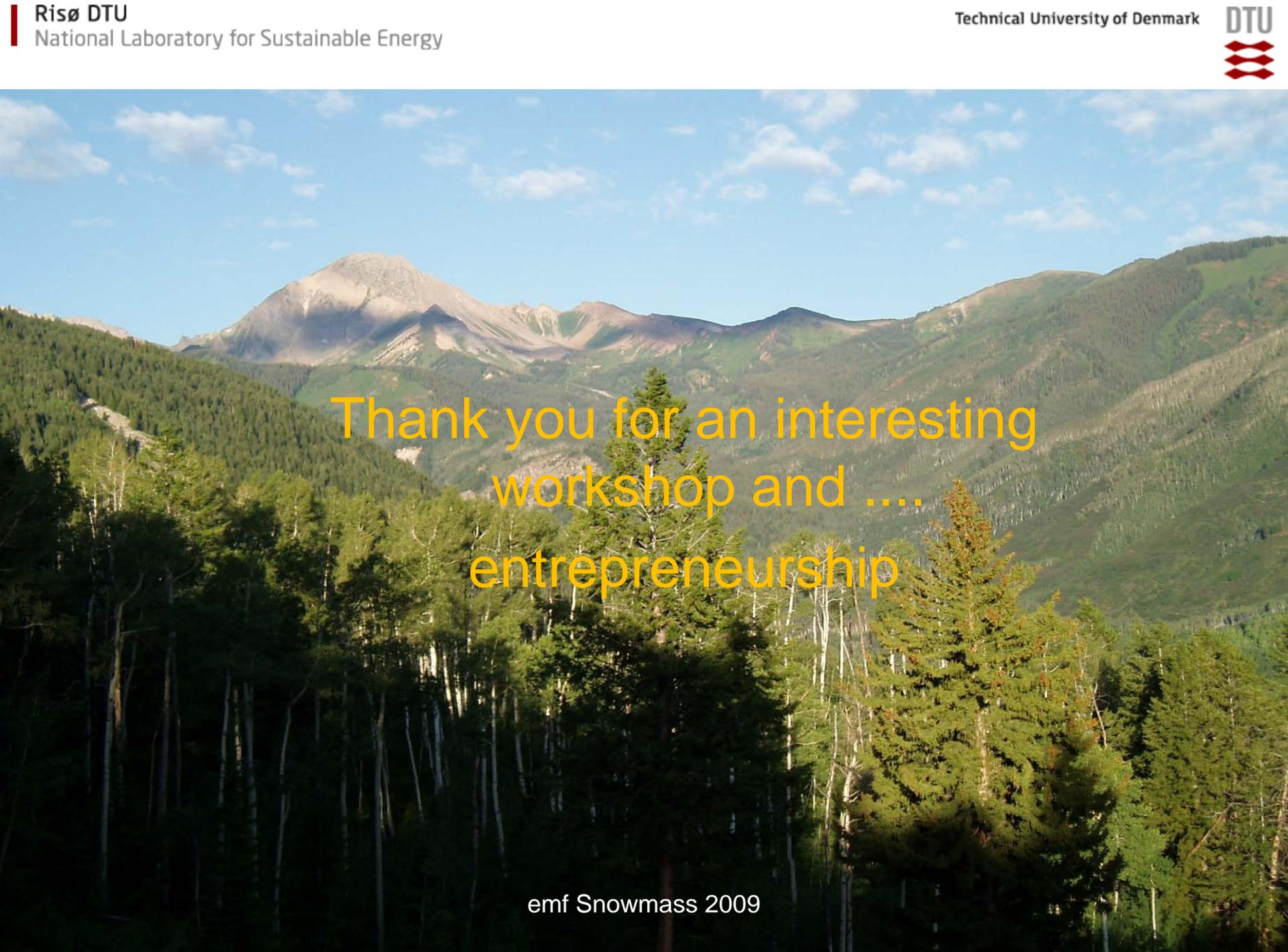
What can be modelled in IAM based on the more detailed models?

When increasing wind share:

- Increased need for backup capacity
- Decreasing efficiency for peak load plants
- Minimum thermal production at any time – stabilising frequency
- Spinning reserve
- Flexible electricity demand – moving demand away from peak

Coming projects

- Renewable resources and mitigation options for China and India in TIAM
- Wind power integration in TIAM
- Climate feed-back in TIAM



Thank you for an interesting
workshop and
entrepreneurship

Wilmar Planning tool widely used

- Wind integration studies:
 - All Island Grid study covering Republic of Ireland and Northern Ireland funded by Irish governments
 - Market model for the EWIS (European wind integration study) performed by European Transmission system operators
 - Study of the Eastern interconnect in the U.S. funded by NREL forthcoming
- EU projects: Wilmar, Supwind, Anemos Plus, Tradewind
- Electricity storage:
 - Compressed air energy storage in Ireland
- Electric vehicles and other Demand side measures
- More information: www.wilmar.risoe.dk, www.supwind.risoe.dk,
peter.meibom@risoe.dtu.dk