Design and Operation of Power Systems with Large Amounts of Wind Power - first results of IEA collaboration -

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Background

- Wind power penetration increasing: system integration costs is becoming an issue for many countries.
- Ongoing work in many countries and organisations. Difficult to compare the results.

- Task 25 for IEA WIND Implementing Agreement:
  "Design and operation of power systems with large amounts of wind power"
  was started in 2006, duration 3 years
  Participation as of 1.9.2006: Denmark, EWEA, Finland, Germany, Ireland, Norway, Netherlands, Portugal, Spain (unconfirmed), Sweden, UK, USA
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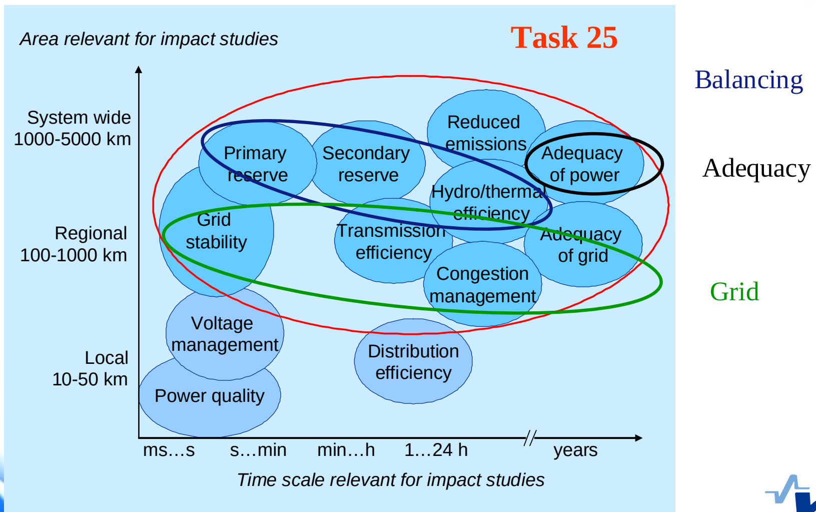
Integration costs

- Extra costs for power system for accommodating wind power, not included in wind power investment costs
- Policymakers
  - make sure that increasing renewable energy will not be offset by negative impacts.
- System operators, regulators
  - market design / rules and tariffs, allocation of costs

Possible impacts of wind power on the power system: impacts on reliability and efficiency



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Experience from regions with large wind power NWPC conference paper results

- Gotland, Sweden: 90 MW wind power, 160 MW peak load (19 % of energy)
  - Maximal wind power share 40 % (max wind /(min load + transmission))
  - Balancing solved outside region: **control enhanced to enable around 0 MW operation of HVDC link to mainland**
- West Denmark: 2380 MW wind power, 3700 MW peak load (24 % of energy)
  - Maximal wind power share 58 % (max wind /(min load + transmission))
  - Balancing solved both inside and outside region. Wind power regulation has been used in rare occasions.
- North Germany: 2275 MW wind power, 2000 MW peak load (33 % of energy)
  - Maximal wind power share 18 % (max wind /(min load + transmission))
  - Balancing solved both inside and outside region. Wind power regulation has been used since 2003 in occasions with high wind and congested transmission. **Fault-ride-through needed to avoid wind power becoming a dimensioning fault** (> 3000 MW tripping off)

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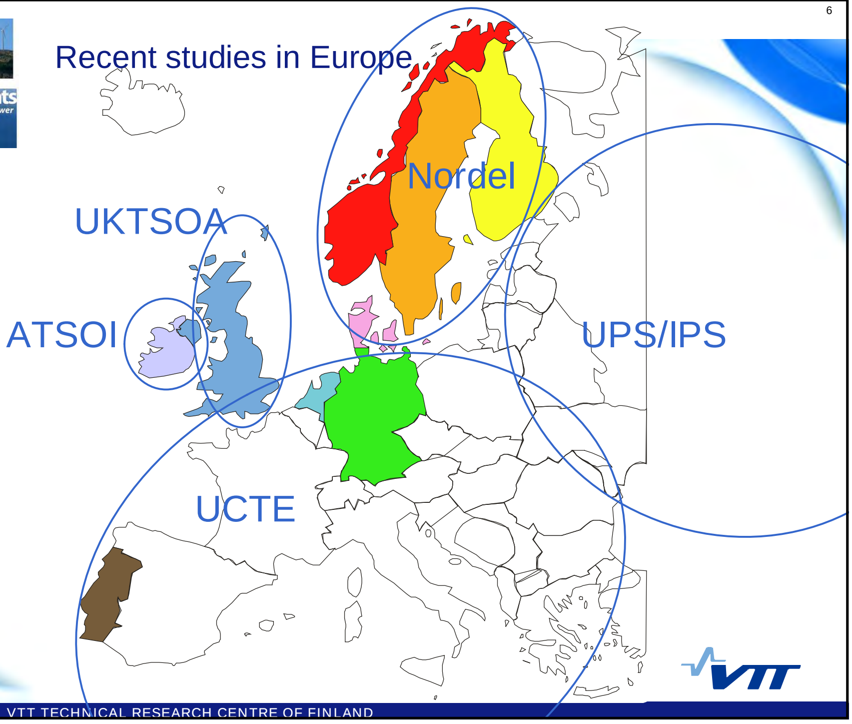
Recent studies in Europe



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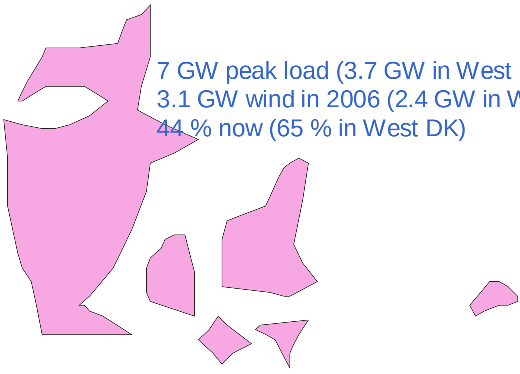
Denmark



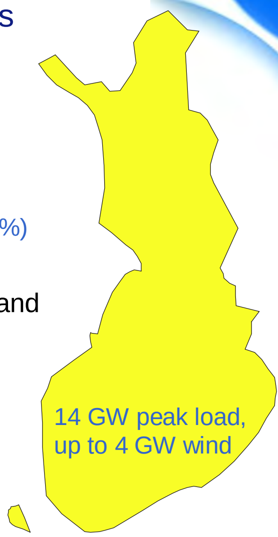
7 GW peak load (3.7 GW in West DK)
3.1 GW wind in 2006 (2.4 GW in West DK)
44 % now (65 % in West DK)

- Greennet Eu27 (WILMAR model): increase in operating costs
- EnergyPLAN and Balmorel models: heat flexibility
- SIVAEL model – 100 % wind study: market for surplus energy

Finland
Studies for the Nordic countries

Nordic countries 69 GW peak load, up to 20 GW wind (29 %)

- EMPS model - impact on Nordic electricity market and hydro power
- Reserve requirement :
  analysis of time series of wind and load



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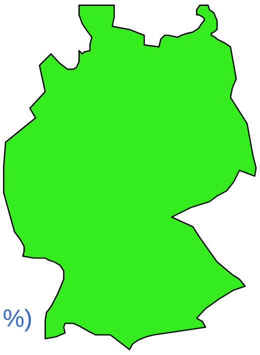
Germany

- Dena study: wind power from 14.6 GW (2003) to 36 GW (2015)
  - Grid reinforcement
  - Capacity credit
  - Balancing
  - System stability



80 GW peak load
up to 36 GW wind (45 %)

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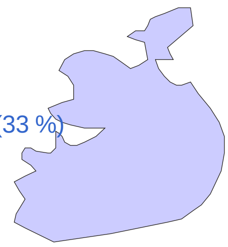
Ireland



6 GW peak load,
up to 2 GW wind (33 %)

- Operating Reserve Requirements as Wind Power Penetration Increases in the Irish Electricity System
- Renewable Energy Resources for Ireland 2010 & 2020
  - limits for maximum amount of wind power in the system
- Renewable Energy in the New Irish Electricity Market
  - costs of ramping & start-ups are reasonable for 1500 MW wind
- All Island Grid Study on the way in 2006

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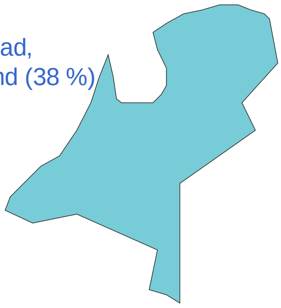
Netherlands

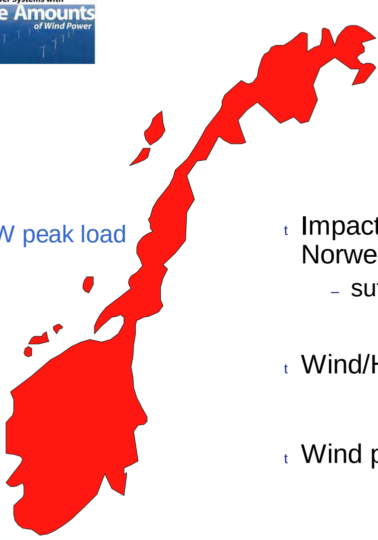
16 GW peak load,
up to 6 GW wind (38 %)



- Effects of 6000 MW offshore wind on the Dutch grid
  - reinforcements
  - connection issues, grid topology, AC, DC

Norway

24 GW peak load



- Impact of integrating wind power in the Norwegian power system
  - sufficient transmission is the key issue
- Wind/Hydro integration and co-ordination
- Wind power capacity credit for a region

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Portugal

- Ambitious wind energy plans up to 15% of gross demand in 2013
- Grid reinforcement need and costs
- Grid stability

7 GW peak load
up to 5 GW wind (71 %)

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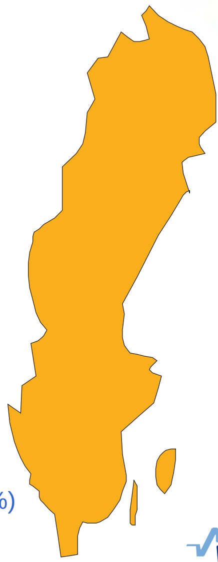
Sweden



- 4000 MW wind study: Balancing
- Wind/Hydro integration and co-ordination

28 GW peak load
up to 4 GW wind (14 %)

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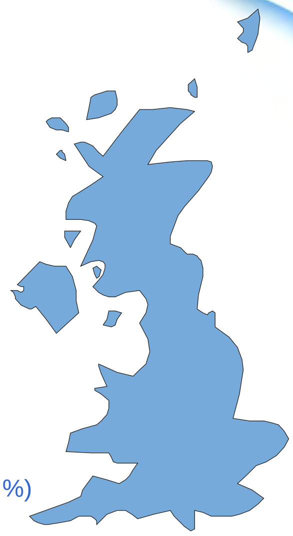
United Kingdom

- Balancing
- Grid reinforcement
- Capacity credit
- Stability



65 GW peak load,
up to 26 GW wind (40 %)

Recent studies in USA

- Minnesota: 1500 MW of wind in 10 GW peak load system (=15 %)
  - Balancing, capacity credit
- New York: 3300 MW of wind in 33 GW peak load system (=10 %)
  - Balancing, stability, grid reinforcement needs, capacity credit
- Colorado 700 and 1050 MW in 7 GW peak load system (=10-15 %)
  - Balancing
- California: existing wind power, 4 % of peak load
  - Balancing, capacity credit

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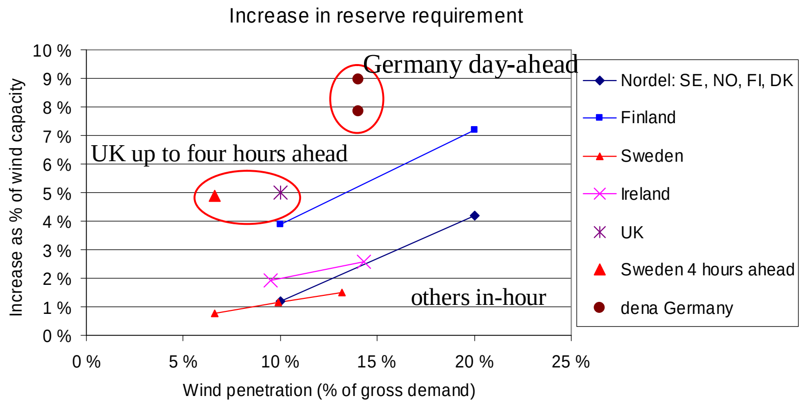
Summary balancing requirements



- different time scales for estimating the reserve requirement
- different methodology used

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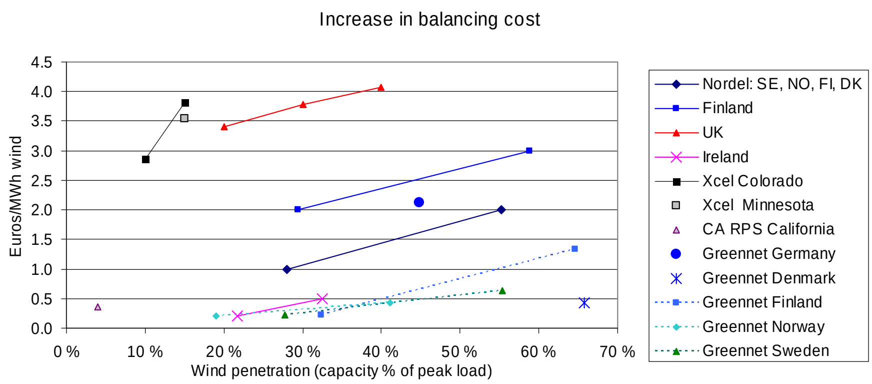
Summary balancing costs



- Not directly comparable due to: different time scales; allocating investment for new reserve or only use of reserves; method for calculating costs based on assumptions on thermal power; possibilities for power exchange to neighbouring countries etc

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Summary grid reinforcements

- UK : £50-100 / kW (70-140 €/kW).
- Netherlands : 60-110 €/kW for 6000 MW offshore
- Portugal : 53 €/kW
- The German dena study:100 €/kW

- Problems in comparisons:
  - grid reinforcement costs are not continuous, there can be single very high cost reinforcements
  - the way that grid costs are allocated to wind can differ

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Conclusions from the studies

- Integration costs 0.5-4 €/MWh for balancing
  - Small compared to production cost of wind power (~ 40-60 €/MWh) or to avoided fuel costs (~ 20-30 €/MWh with 2001 price level)
  - In some countries wind power producers pay imbalance payments that are greater than the actual extra cost incurred to the power system
- Integration costs 50-100 €/kW for grid reinforcements
  - Depending on wind resource location versus load centres

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Recommended practise (so far)

- Capture the smoothed out variability of wind power production time series for the geographic diversity assumed:
  - Actual data from tens of wind farms and/or met towers or synchronized weather simulation
  - Wind forecasting best practice for the uncertainty of wind power production.
- Examine wind variation in combination with load variations
- Capture system response through operational simulations
- Examine actual costs independent of tariff design structure

Further work of the IEA Task 25

OBJECTIVE:

to analyse and further develop the methodology to assess the impact of wind on power systems

GOALS:

- Provide an international forum for exchange of knowledge
- State-of-the-art: review and analyse the studies and results so far
  - methodologies and input data, system operation practices, planning methodologies and modifications that have been necessary with high penetration, concepts and technologies enabling enhanced penetration
- Formulate guidelines:
  - recommended methodologies and input data when estimating impacts and costs of wind power integration
- Quantify the impacts of WP on power systems
  - range of impacts/costs; rules of thumb

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