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Integrating wind power in European power systems

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Pre-conference seminar
Wind Energy The Facts
Marseille, 15 March 2009

roadmap

- Wind power generation characteristics
- Design and operation of power systems with wind power
- Network upgrades for accomodating wind power
- Capacity value of wind power
- Grid connection requirements
- Power market design considerations

Premises

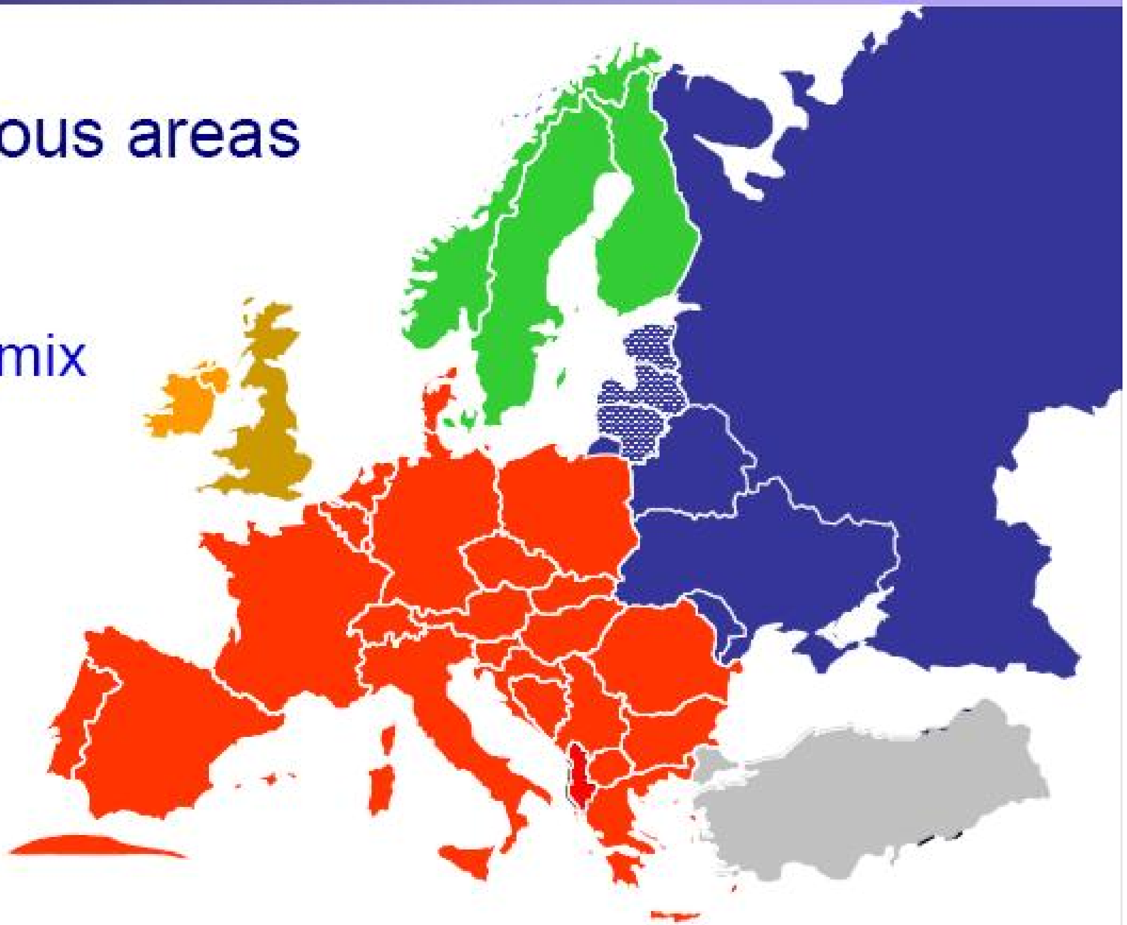
- 300 GW of wind power in Europe including 120 GW offshore in 2030: 25% of electricity demand
- Increasing transmission capacity is option number one for large scale integration of variable output renewables
- Adequate power market design (and regulation) is needed for economic integration of wind power

Transmission networks

etso
EUROPEAN TRANSMISSION SYSTEM OPERATORS

European Electricity Today

- Several synchronous areas
  - ➢ Installed generation
    Highly diversified mix
    > 650 GW
  - ➢ Consumption
    3,000 TWh/year
  - ➢ Physical exchanges
    300 TWh/year



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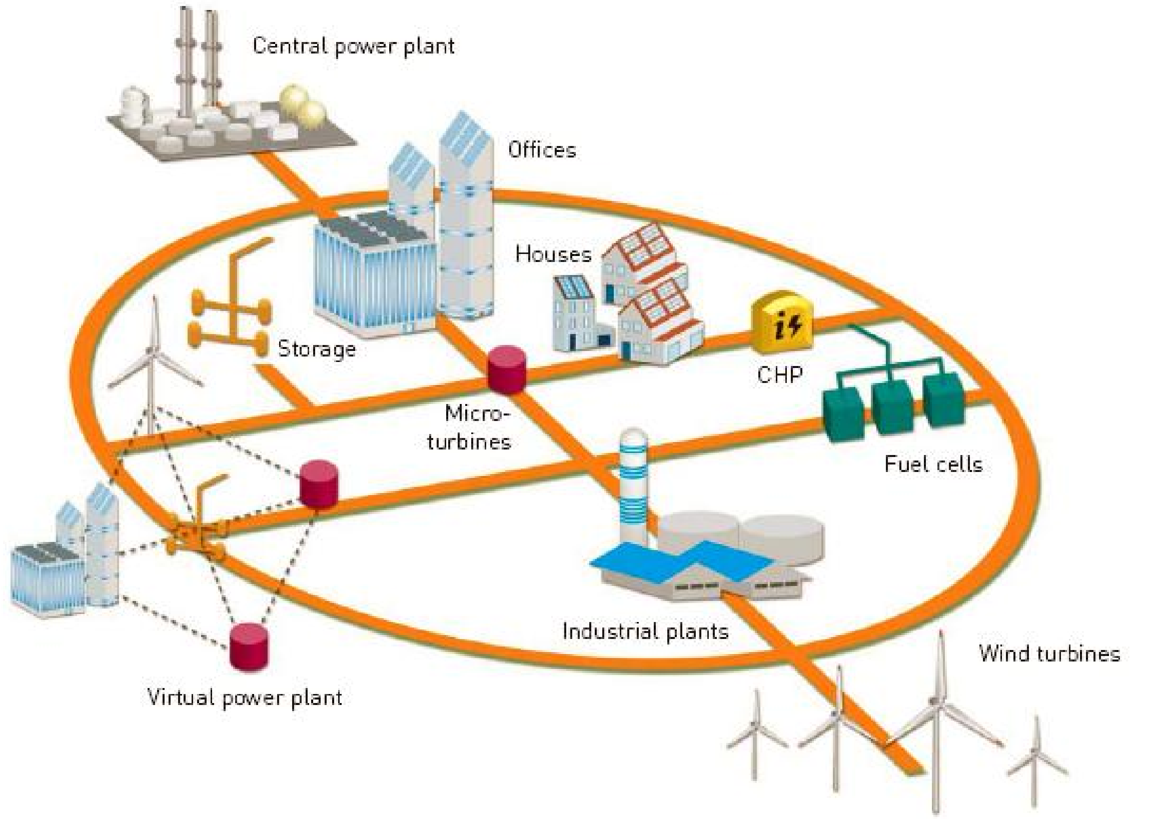
Power Systems



Future: Operation of system will be shared between ***central and distributed generators****. Control of distributed generators could be aggregated to form microgrids or 'virtual' power plants to facilitate their integration both in the physical system and in the market.*

Components

- Generating plants
- Transmission and distribution grid
- Loads
- Storage
- Controls

Stakeholders

- Generating companies
- Network operators (TSO, DSO)
- Regulators
- Energy traders
- Market operators
- Service providers
- Energy consumers

System must always be in balance
Security of supply and reliability

Wind power: type of generator

- Various electrical conversion systems are used for wind power plants, they do not behave identically to traditional power plants
  - *Advances in technology give **power plant characteristics** to modern wind farms (e.g. active power control, fault-ride-through)*
- Due to prime mover (wind), wind power plants are VARIABLE OUTPUT generation
  - *Geographical aggregation reduces the fluctuations in output*
  - *Operating wind plants with forecast tools enhances the predictability of the output.*

Wind plants are different from traditional power plants

- TYPE OF GENERATOR: wind plants are different from traditional power plants as ‘type of generator’
- LOCATION: distributed, and often far from consumer centra (especially offshore)
- ECONOMICS: majority of costs is upfront investment, low O&M costs, low marginal costs of generation

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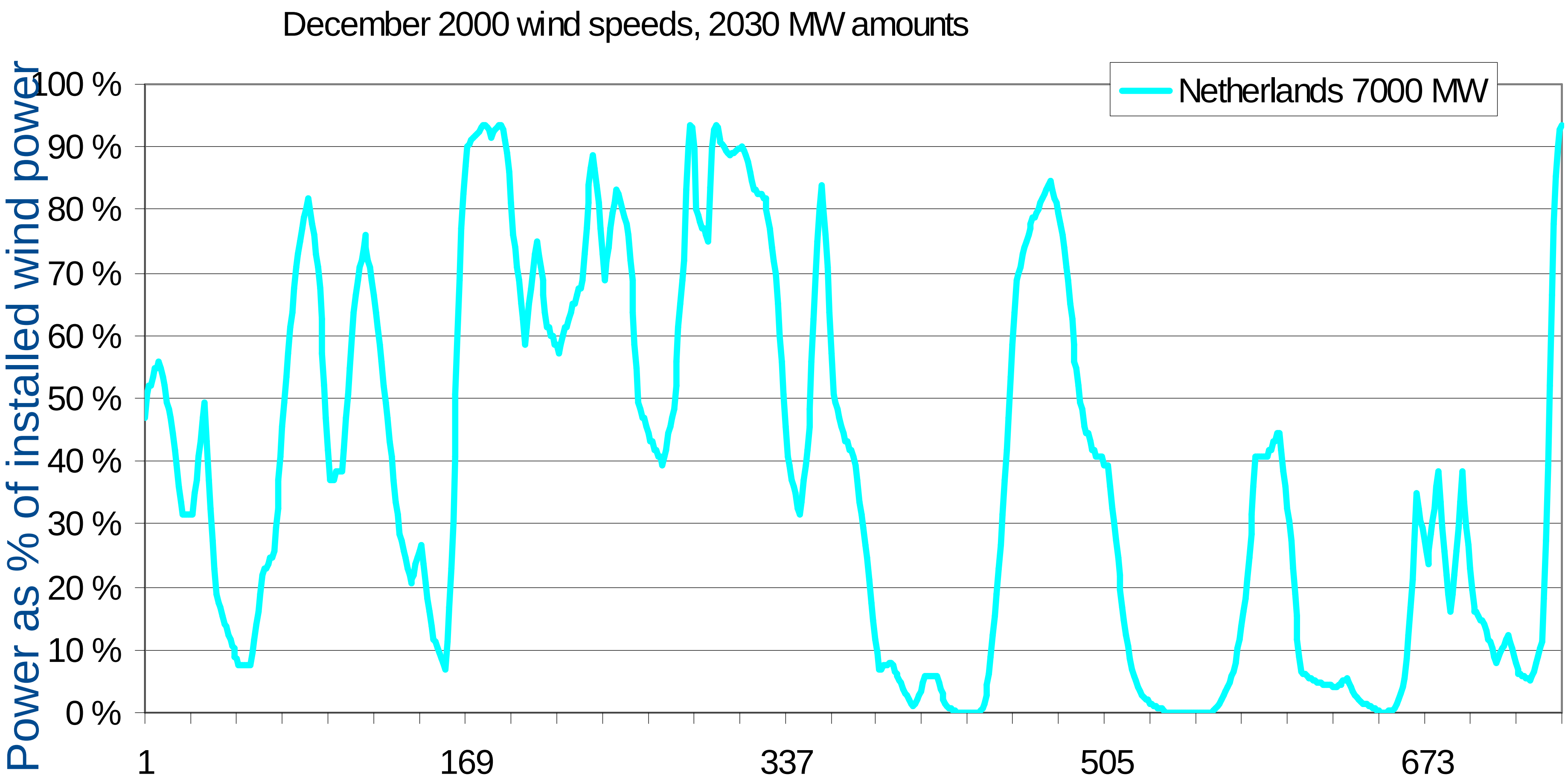
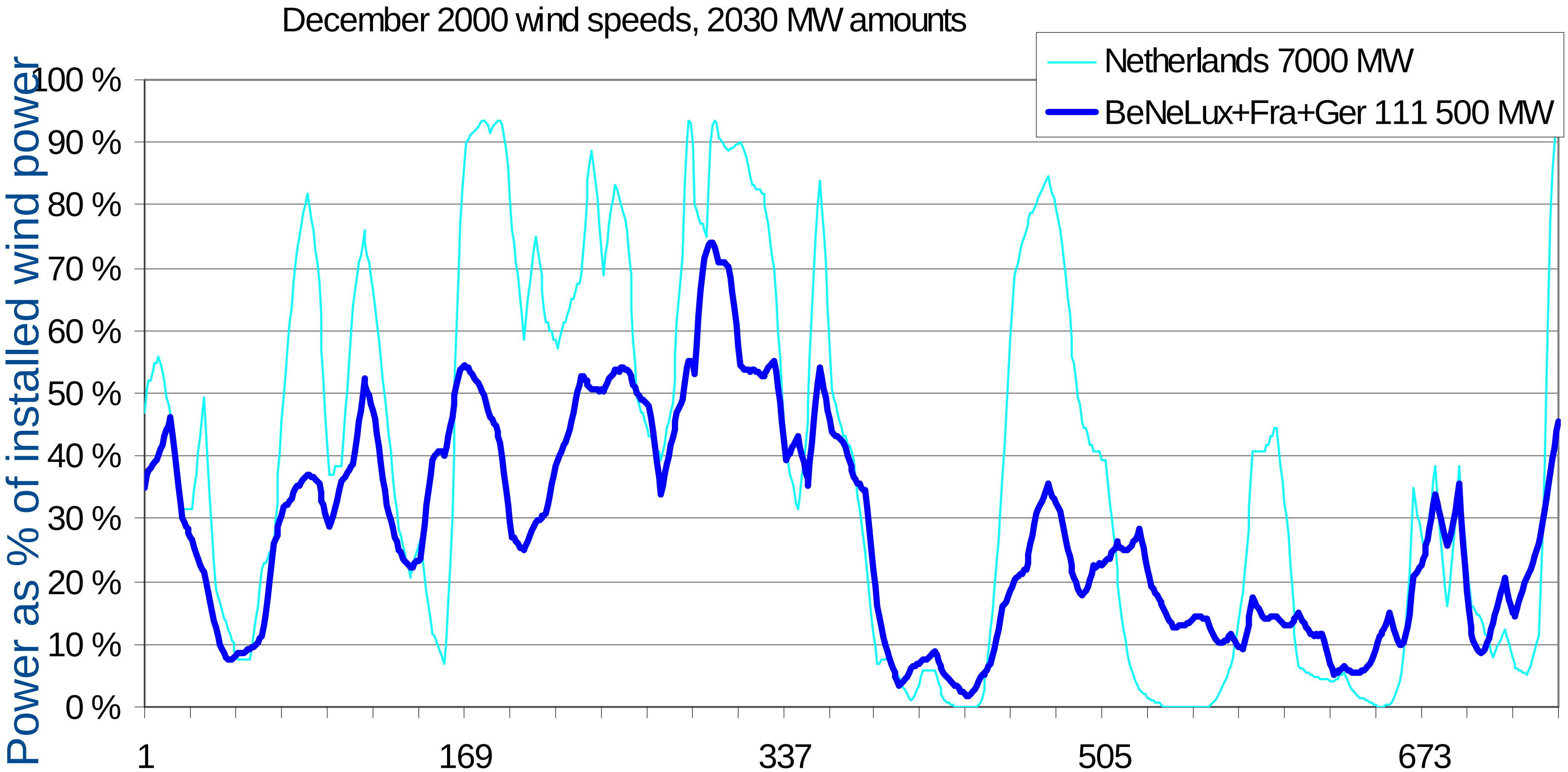
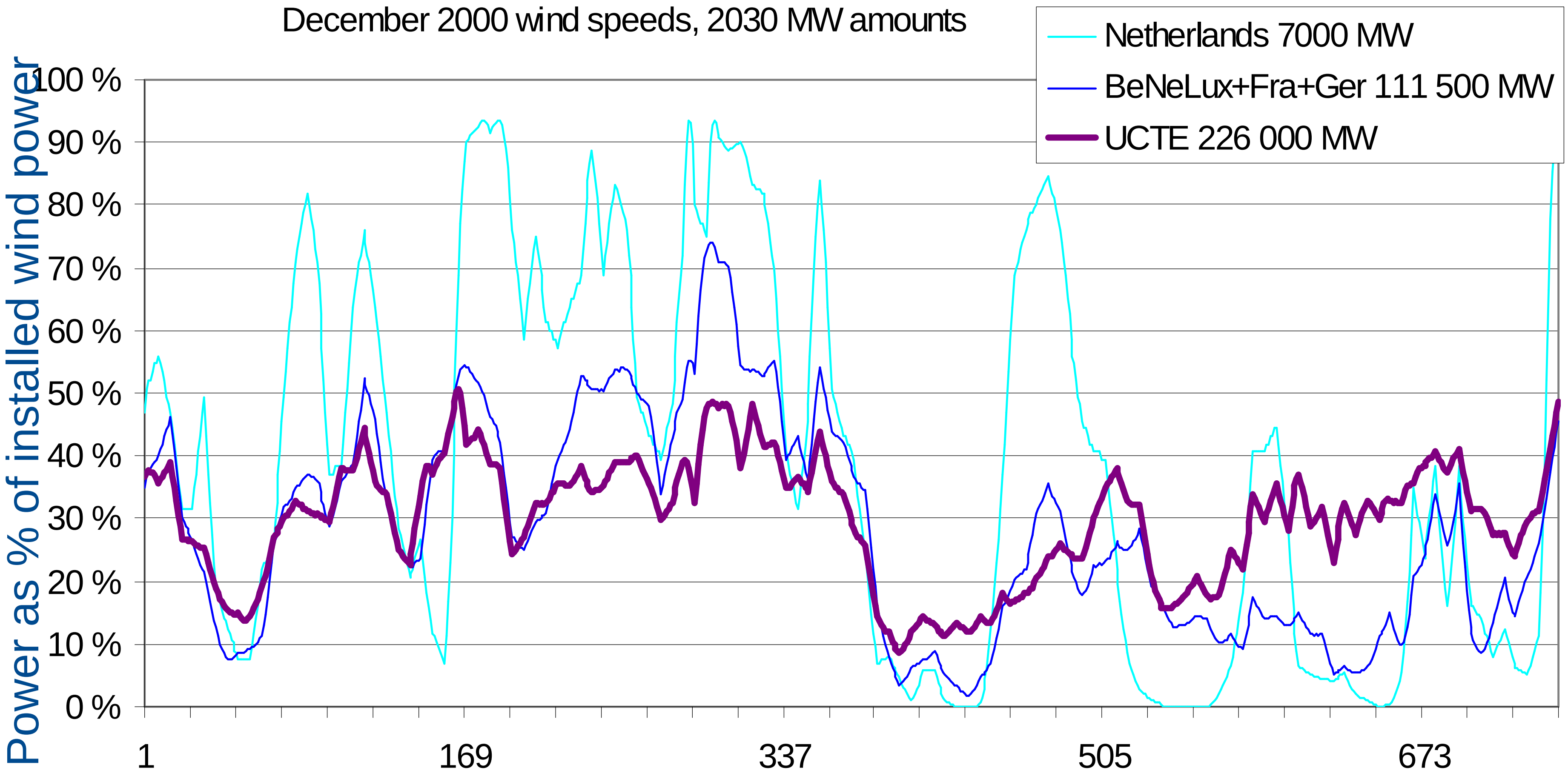
Smoothing effect



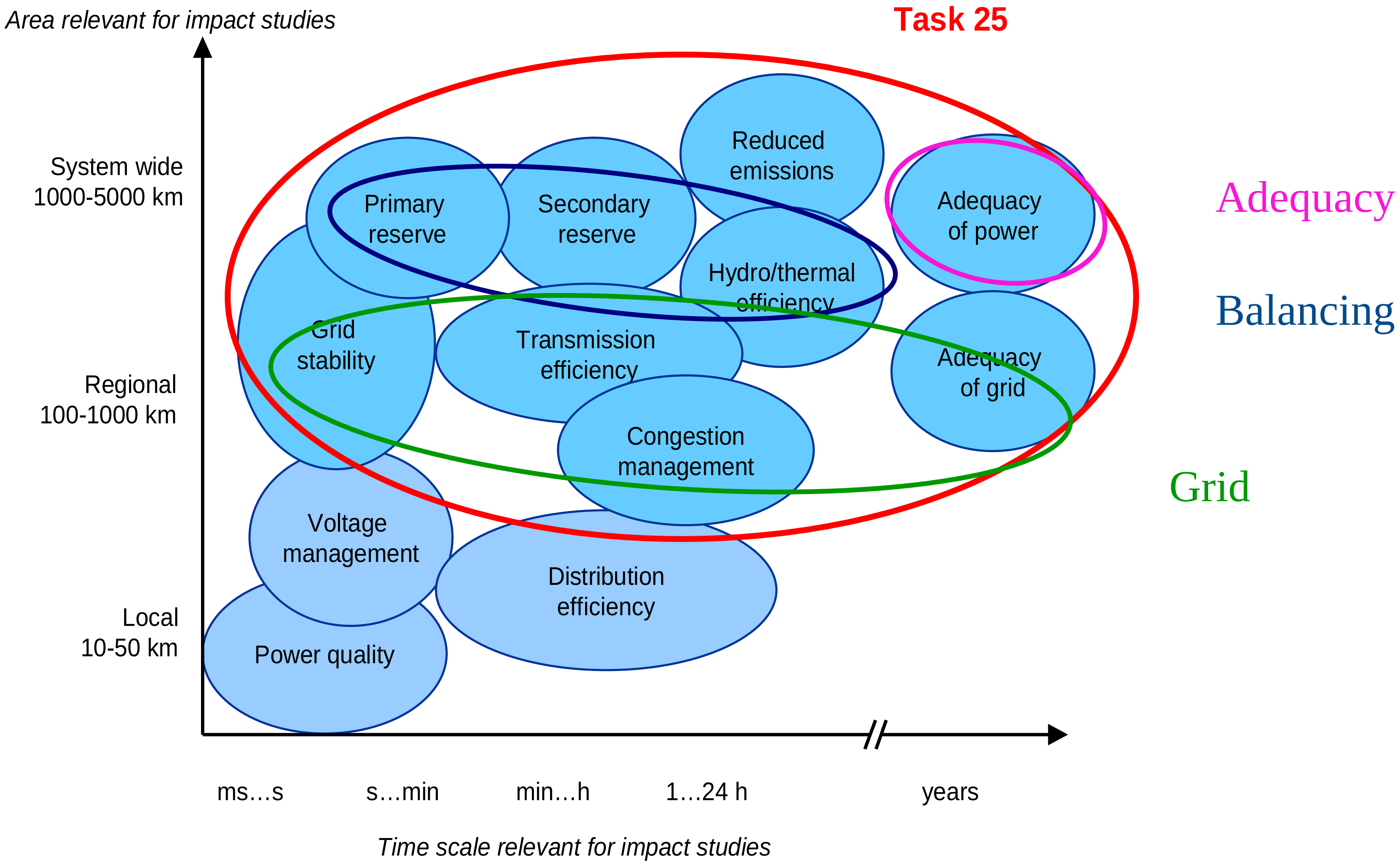
Smoothing effect

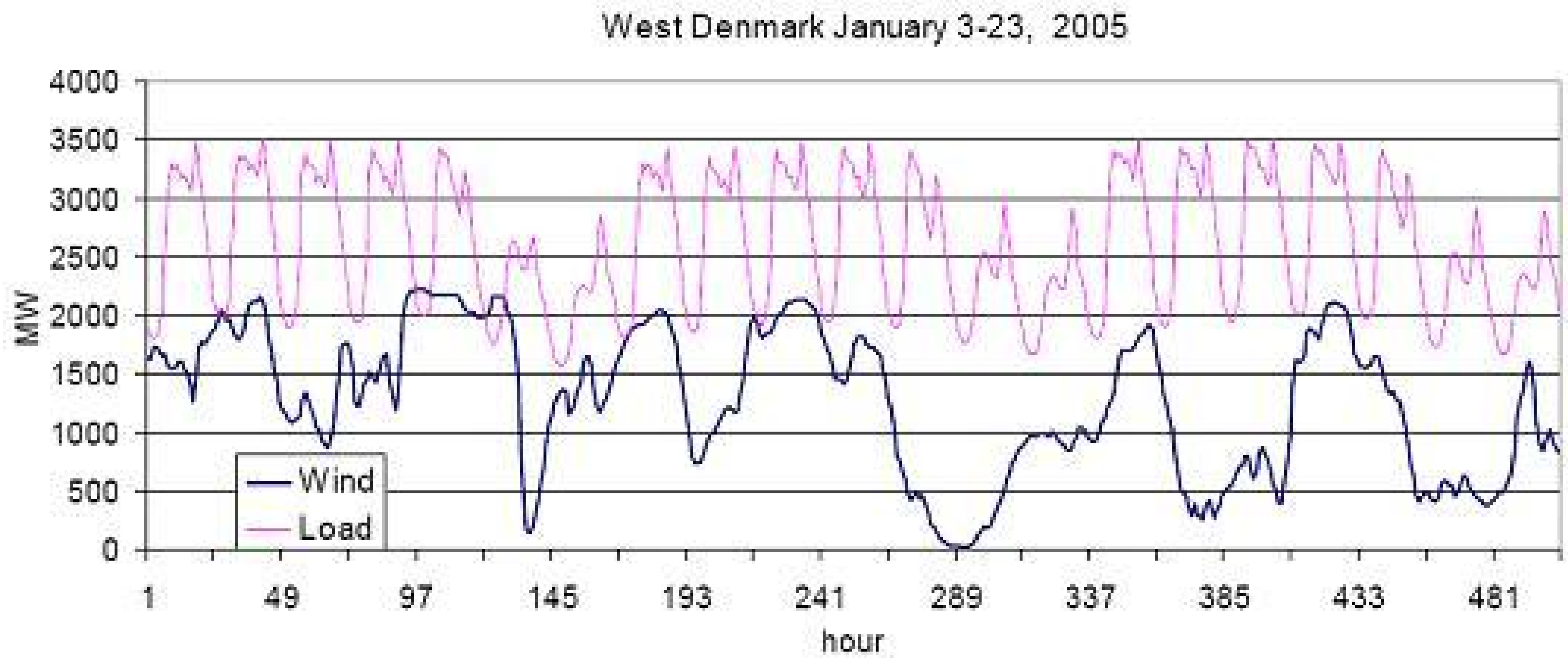


Smoothing effect



Power system impacts in time and scale





West Denmark January 3-23, 2005
4000
3500
3000
2500
2000
1500
1000
500
0
MW
Wind
Load
1
49
97
145
193
241
289
337
385
433
481
hour

wind power penetration

ENERGY PENETRATION

$$\frac{\text{Annual wind power production (GWh)}}{\text{Gross electricity consumption (GWh)}}$$

CAPACITY PENETRATION

$$\frac{\text{Wind power capacity (GW)}}{\text{Peak load in the system area (GW)}}$$

With a given capacity in the system the energy penetration is ca 3x lower than capacity penetration

Better definition of penetration for integration studies

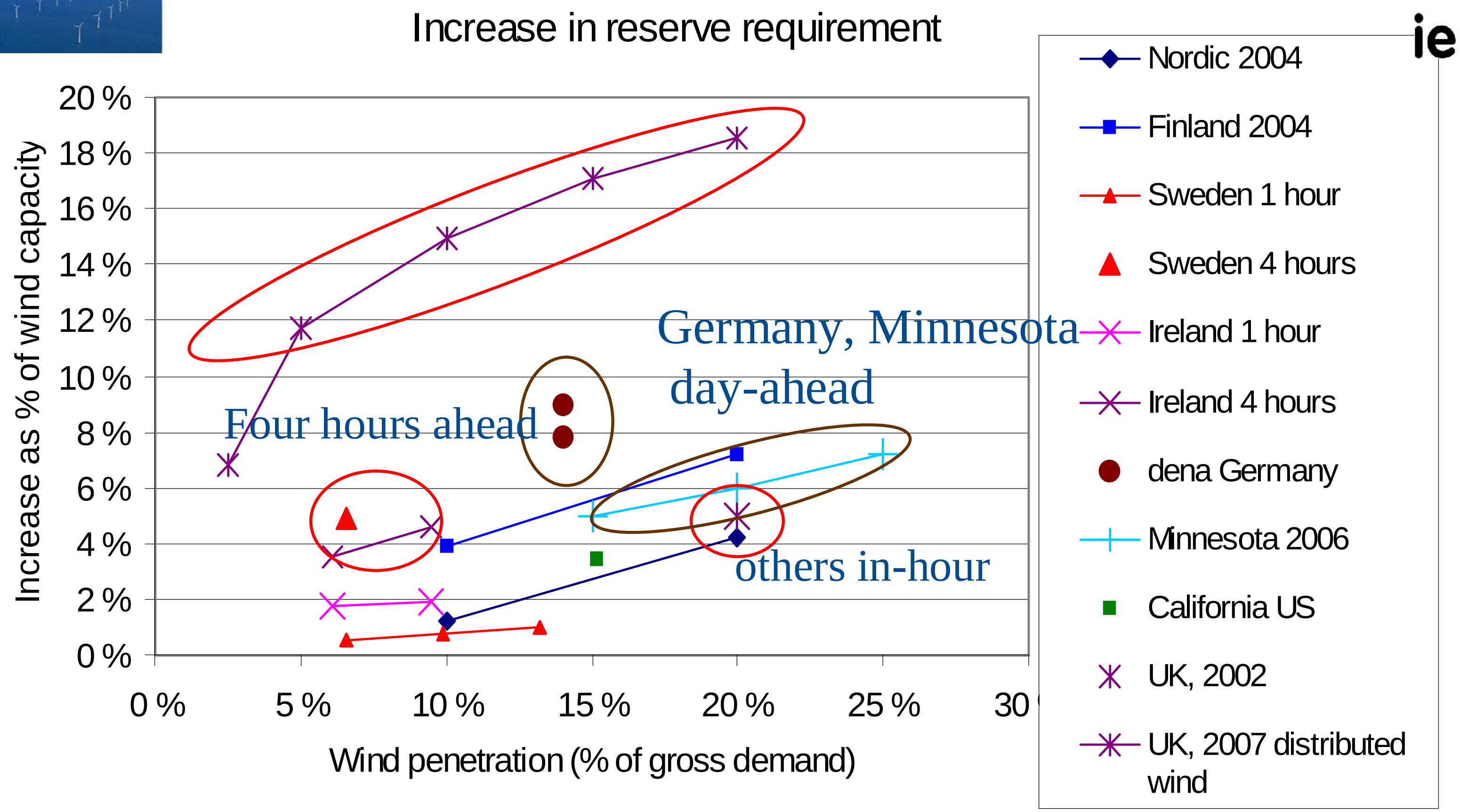
$$Maximal\ share\ of\ wind\ power = \frac{Maximal\ wind\ power}{Lowest\ consumption + possible\ exchange}$$

Region	**Wind power**	**Share of local load energy**	**Maximal share of wind power**
Gotland	90 MW	19 %	40%
West Denmark	2380 MW	24 %	57 %
Schleswig-Holstein	2275 MW	33 %	44 %
New Mexico	204 MW	3.6 %	9 %
Ireland	596	4 %	25 %

Power system: integration efforts needed

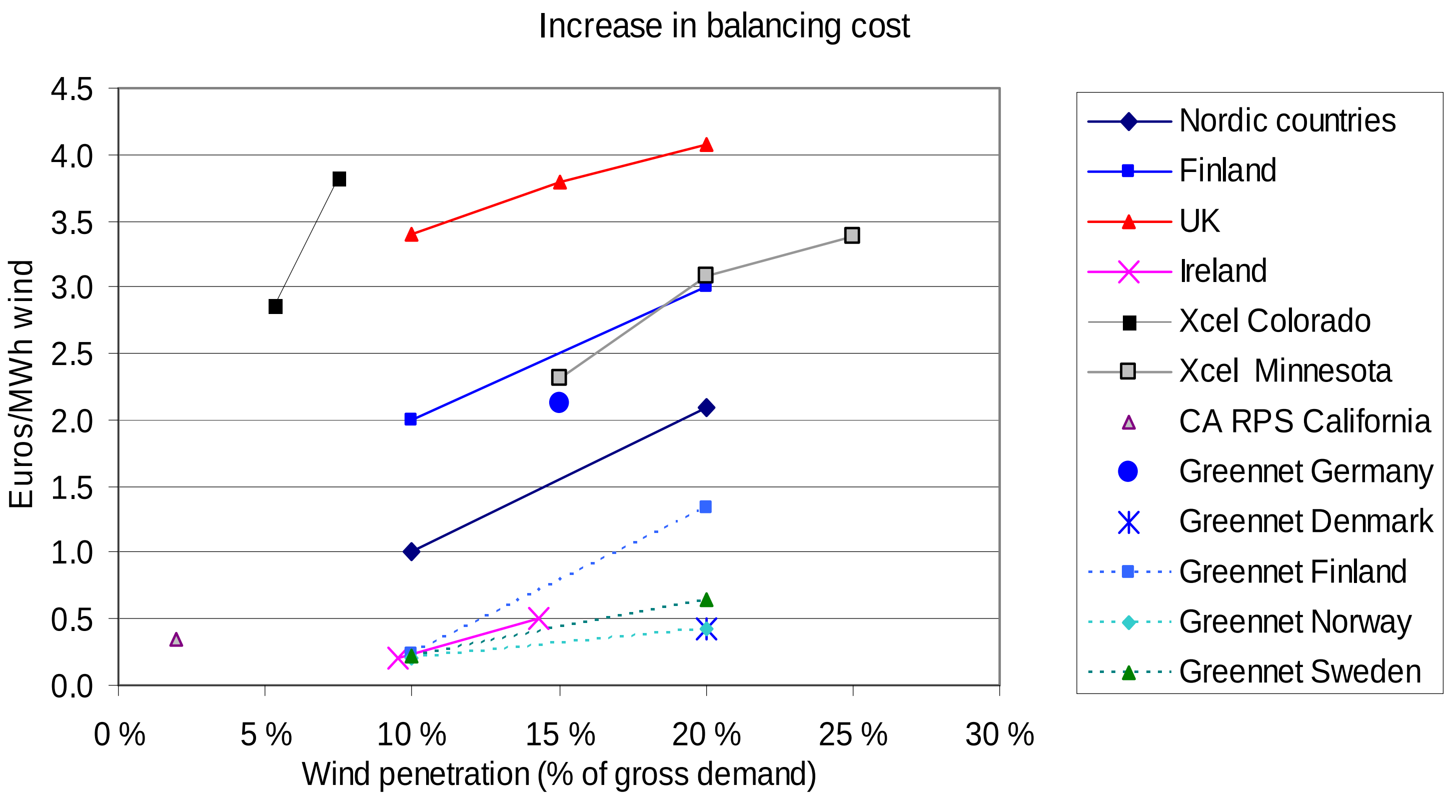
- Wind power fits well in power systems, requires additional 'integration efforts', depending on:
  - Wind power penetration
  - Flexibility of the power system in question
    - Generation (up and down regulation capability)
    - Demand management and storage
    - Interconnection (available capacity)
    - Power market characteristics (e.g. for balancing services): time, geographical area.
- Flexibility varies widely in EU.
- Integration efforts (e.g. moving to more flexibility) can be implemented by suitable market design (rules, incentives).

Summary reserve requirements



- different time scales for estimating the reserve requirement – in-hour, 4 hours ahead, day-ahead
- UK, 2007 assumes 4 hours ahead wind variations (persistence forecast) combined with load forecast errors

Additional balancing costs

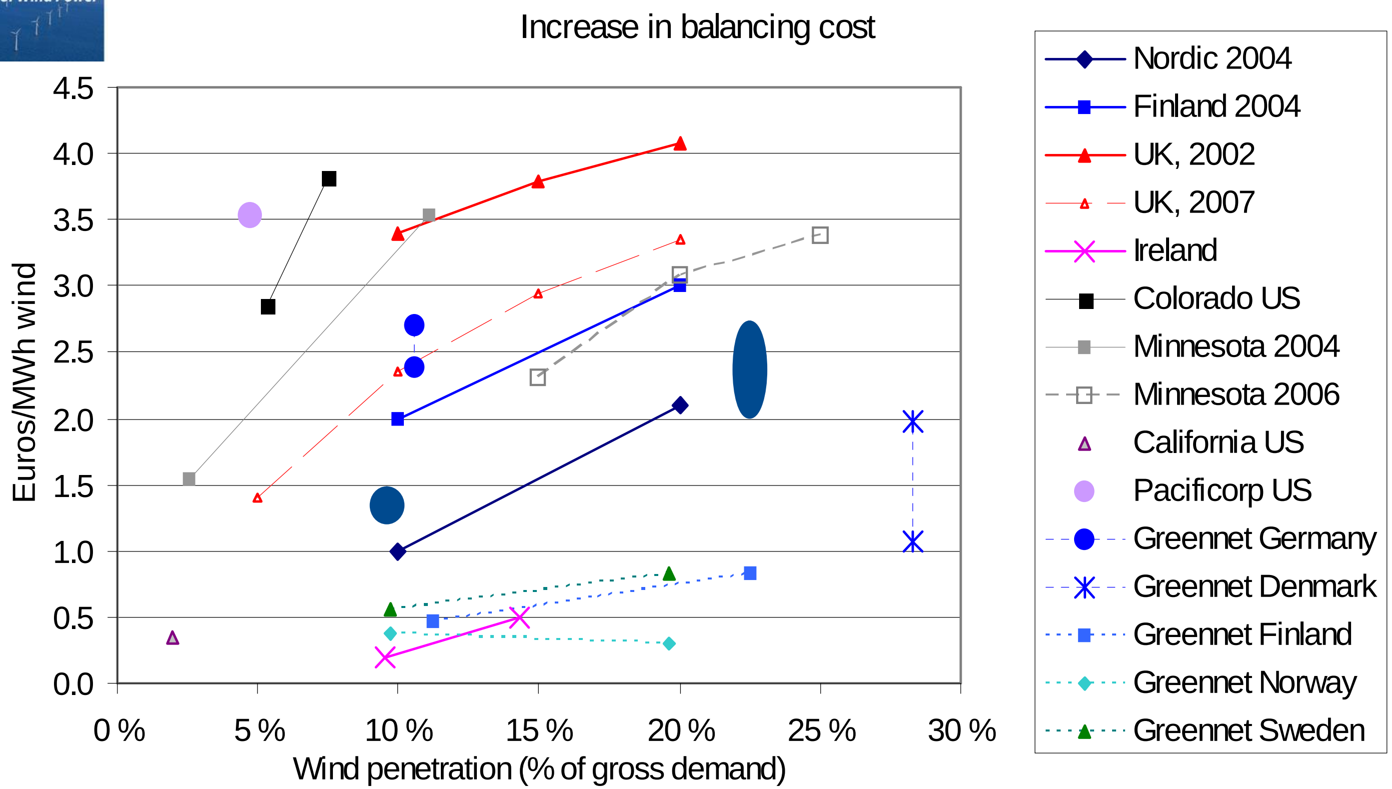


Not directly comparable due to: different time scales; allocating investment for new reserve or only use of reserves; possibilities for power exchange to neighbouring countries; method for calculating costs based on assumptions on thermal power

Increase in cost of balancing due to wind power

- In most cases, even if high estimates of reserve requirements, the current conventional capacity can handle these and no new reserve capacity is needed in the system
- In all cases, a clear increase in the use of short term operating reserves is seen
  - this is also the experience of integrating wind power from Denmark and Spain

Summary balancing costs



- Integration costs 0.5 - 4 €/MWh
  - Small compared to production cost /market value of wind power (~ 40-60 €/MWh)
  - Not directly comparable due to: only use of reserves or allocating investment for new reserve; interconnection taken into account or not; assumptions on thermal power costs

Grid infrastructure: the challenge

THE MAIN CHALLENGES

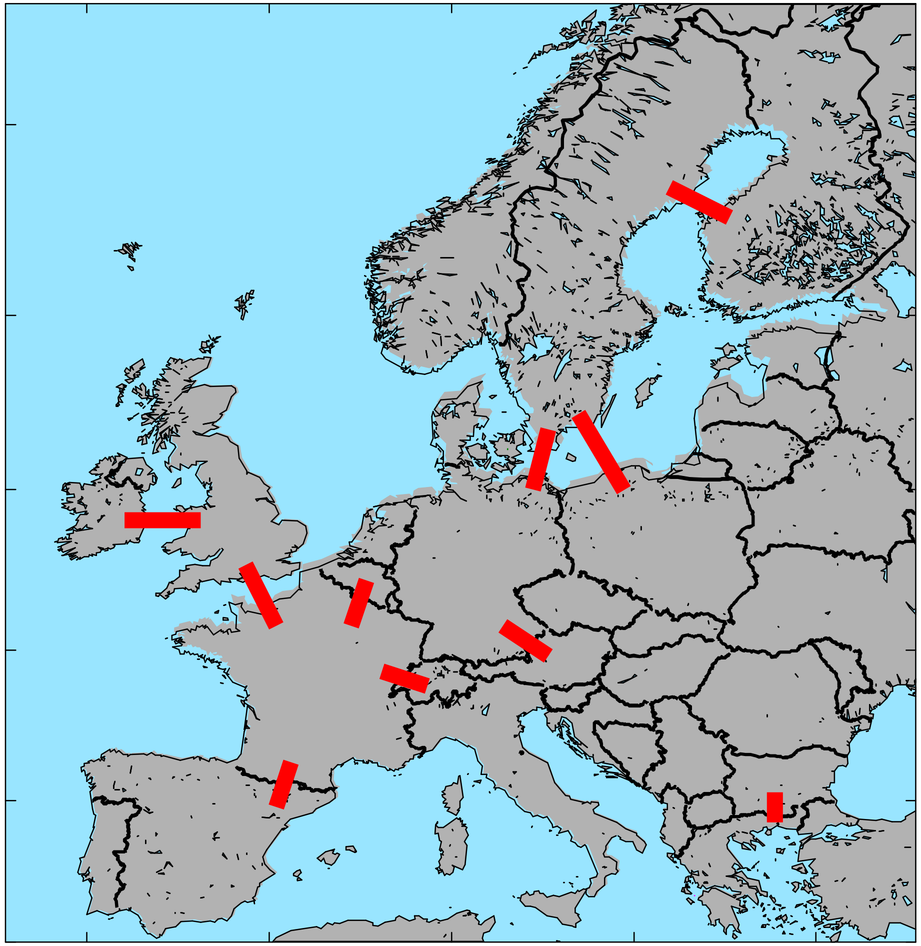
- Increased power flows as wind power capacity increases
- Distance of wind power from load centres

ISSUES

- European grid is weak on interconnections
- Often weak distribution grids
- Interconnection projects face long lead times (10 years) due to planning obstacles.
- Cost allocation : example approach: Infrastructure planning law in Germany (offshore grids for wind power to be built by TSO’s.

Wind power and congestions in cross-borders (TradeWind)

- Large amounts of wind power (2020, 2030 scenarios) will increase congestions in interconnectors
- Prediction errors results affect actual cross-border flow during a substantial part of the time à can aggravate the congestions.



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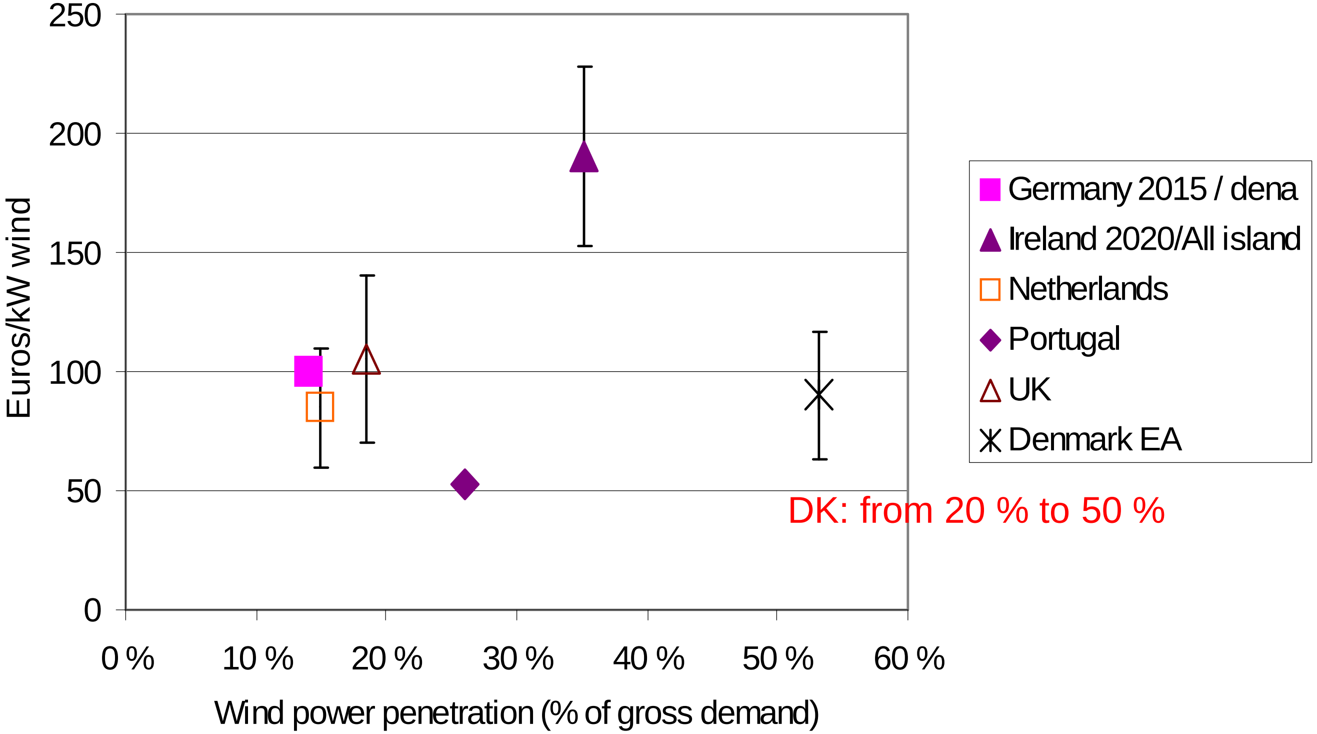
Wind power impact on network needs

- Stability:
  - With limited penetration levels **wind power can improve system performance** by damping power swings and supporting post-fault voltage recovery
  - At higher penetration levels **requiring FRT capability** for large wind power plants is **economically efficient** compared with modifying power system operation to ensure system security
- Grid reinforcements
  - May be needed for stability, often needed if wind resource far from load centres and weak grid

Grid reinforcement costs from studies



- Not comparable:
  - Depends on wind resource location versus load centres
  - Depends on how grid costs are allocated to wind power
  - Grid reinforcement costs are not continuous, there can be single very high cost reinforcements

Costs from grid reinforcement studies

- UK : £50-100 / kW (70-140 €/kW) for 26 GW wind
- Netherlands : 60-110 €/kW for 6 GW offshore wind
- Portugal : 53 €/kW for 5.1 GW wind
- German dena study:100 €/kW for 36 GW wind

- Cost results are often not directly comparable:
  - Distances and grid densities (km/km2) are different
  - Grid reinforcement costs are not continuous, there can be single very high values
  - Different ways of allocating costs to wind power:
    - Shallow / deep costs
    - Wind farm and power system interface

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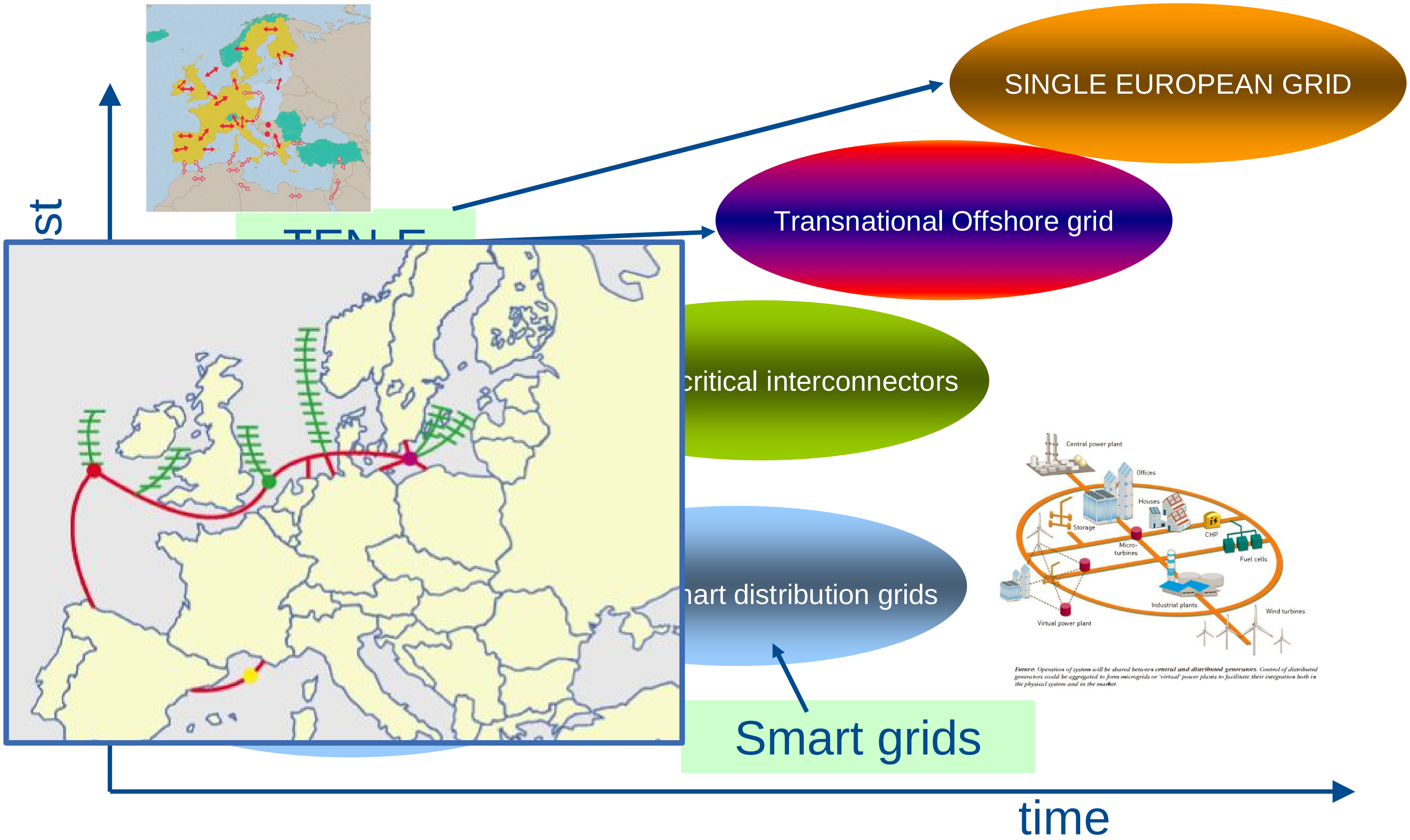
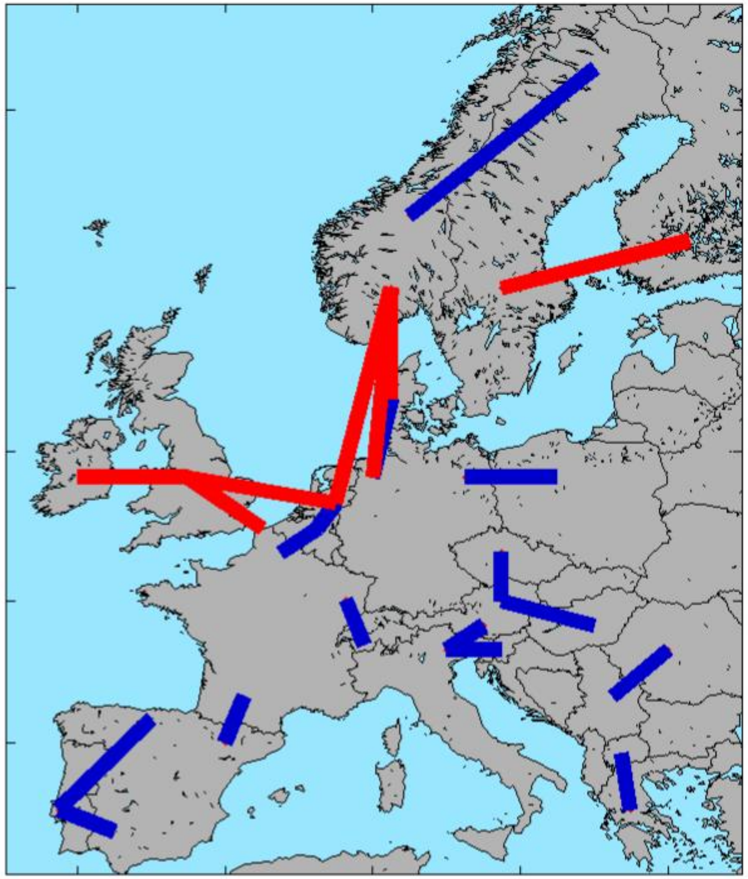
Grid upgrade strategy for future large scale integration

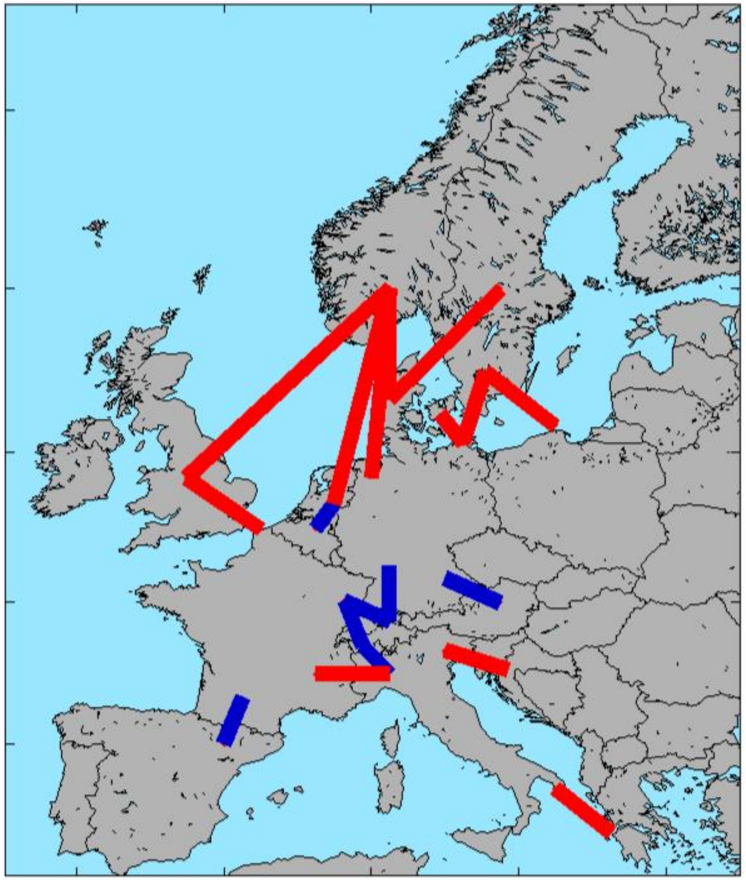


2030 scenario – new connections analysed

Stage 1 grid upgrades

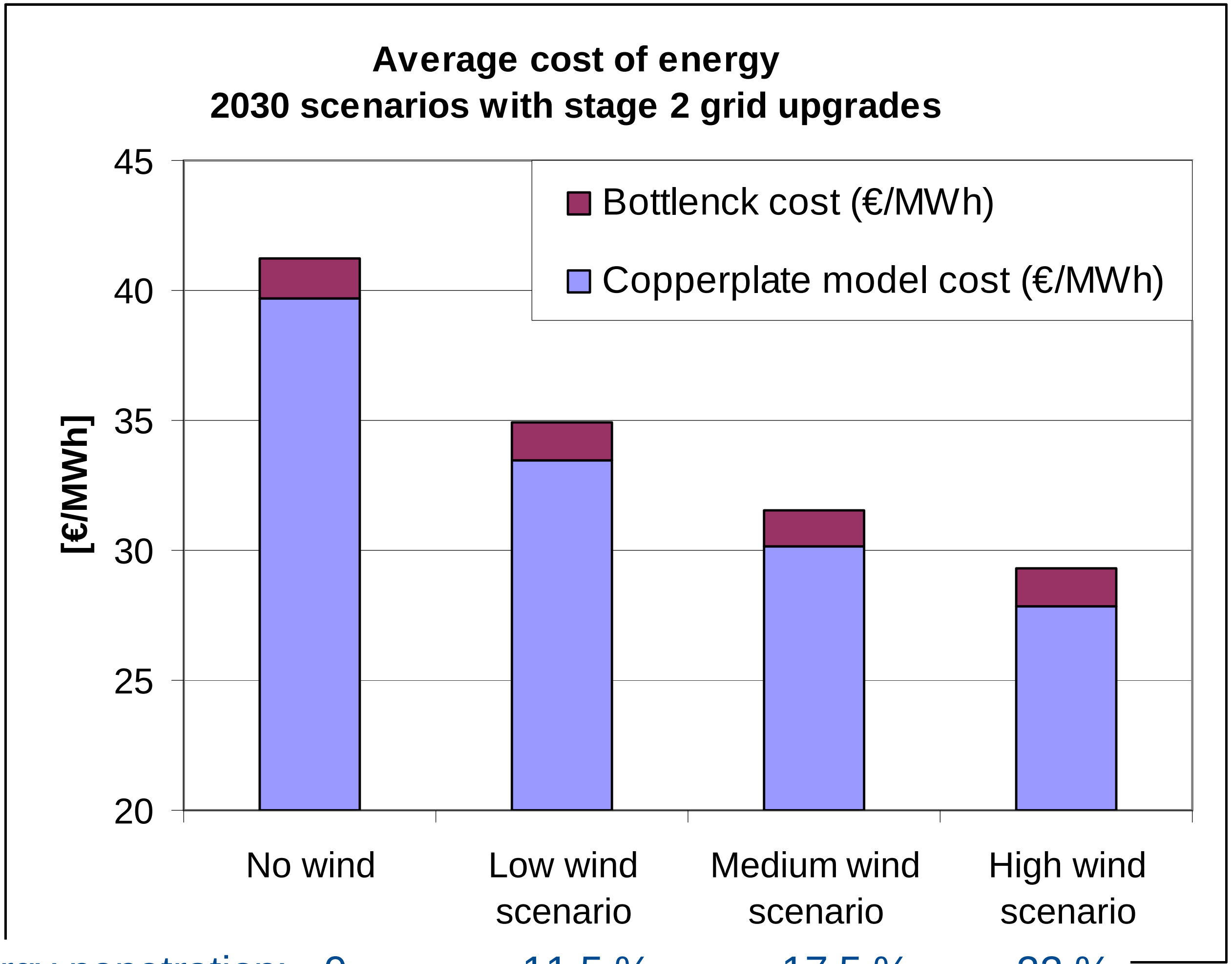


Stage 2+3 grid upgrades



Intelligent Energy Europe

Value of upgraded transmission network

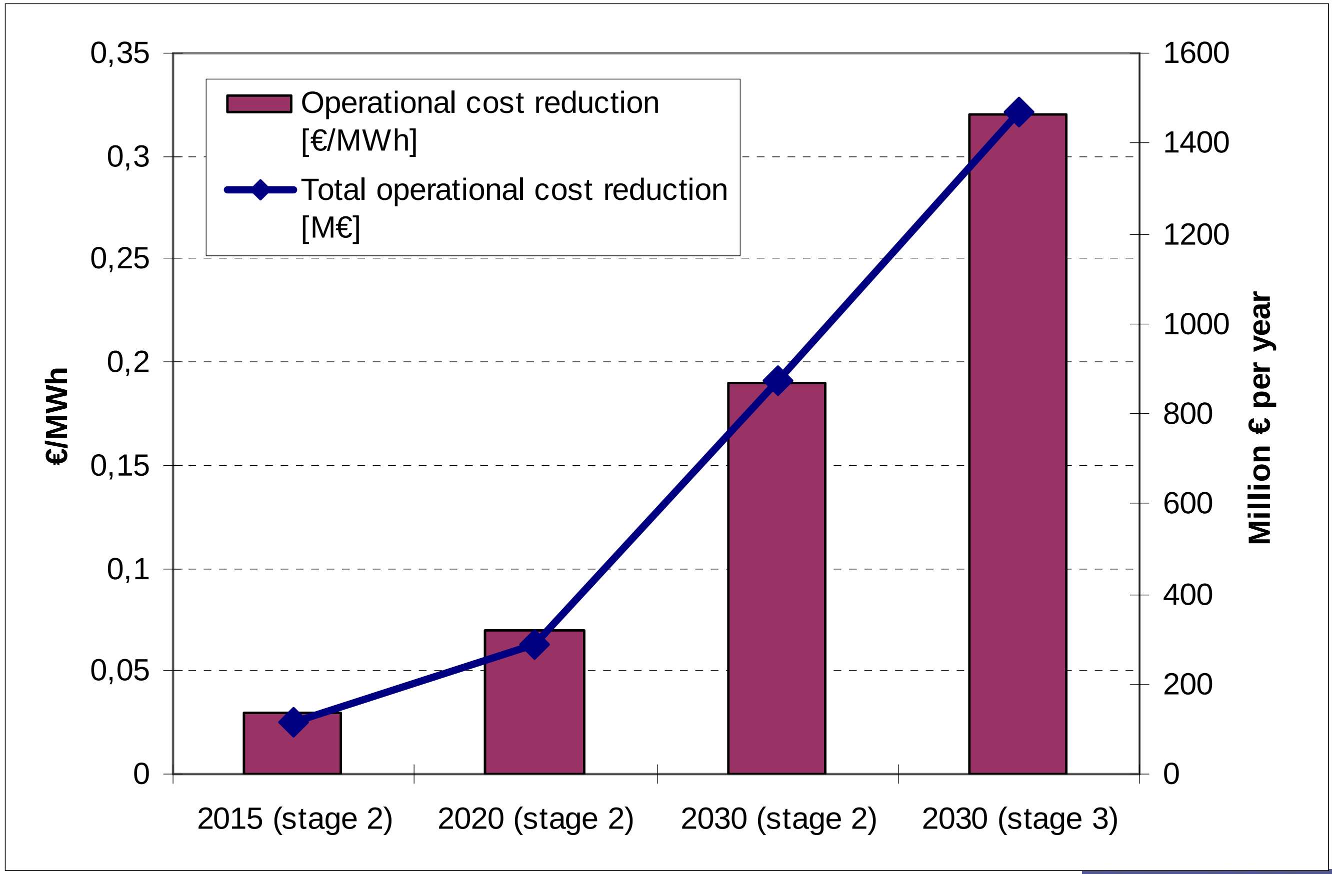


Wind energy penetration: 0 11.5 % 17.5 % 22 %

Operational cost reduction from the proposed grid upgrades

TradeWind

For the 2030 scenario the cost reduction allows for an average investment cost of minimum 475 Million € for each of the 42 projects that were identified



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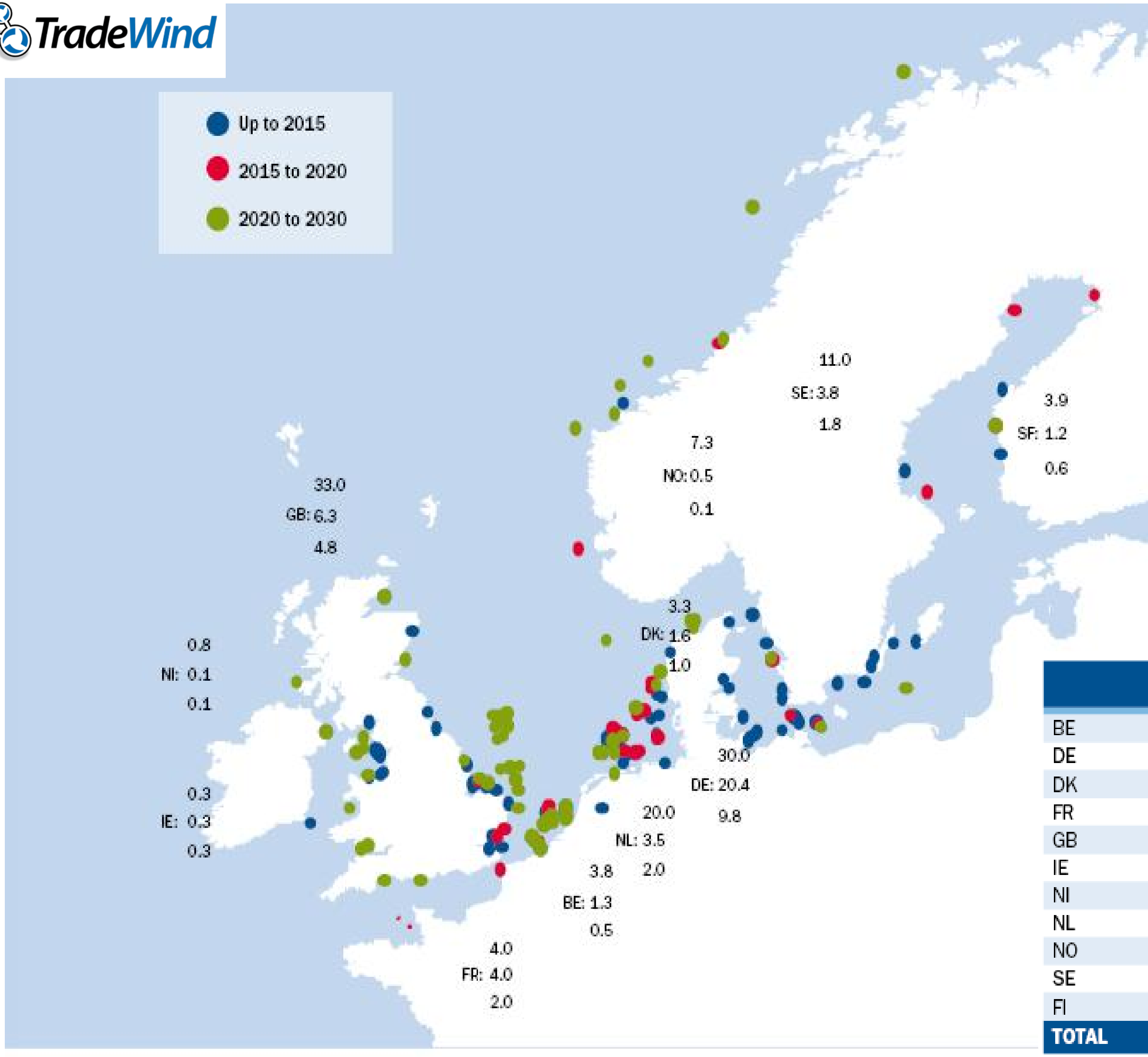
120 GW Offshore wind power : 12% of EU electricity demand

TradeWind



	2015 M	2020 M	2030 H
BE	0,5	1,3	3,8
DE	9,8	20,4	30,0
DK	1,0	1,6	3,3
FR	2,0	4,0	4,0
GB	4,8	6,3	33,0
IE	0,3	0,3	0,3
NI	0,1	0,1	0,8
NL	2,0	3,5	20,0
NO	0,1	0,5	7,3
SE	1,8	3,8	11,0
FI	0,6	1,2	3,9
TOTAL	**23,0**	**42,8**	**117,4**

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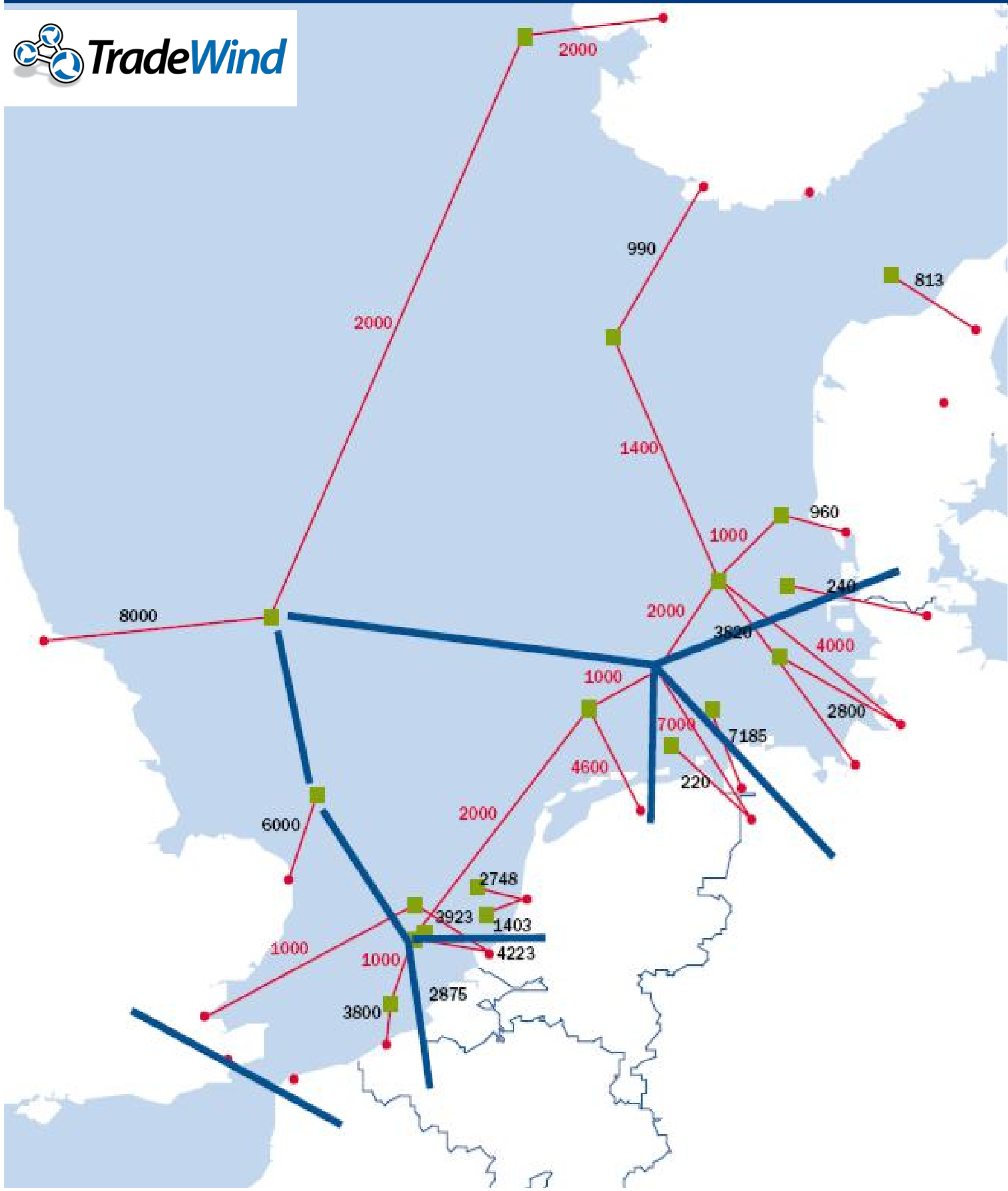
Transnational offshore grid - a form of Supergrid

TradeWind



Definition: An electricity transmission system, mainly based on direct current, designed to facilitate large scale sustainable power generation in remote areas for transmission to centres of consumption, one of whose fundamental attributes will be the enhancement of the market in electricity (Eddie O'Connor).

Functions and advantages:

- Access to the wind resource
- Smoothening of variability
- Better utilisation of cables
- better access to flexible hydro of Norway,
- greater flexibility to transport offshore wind to high price areas,
- improved power trade between Sweden, East Denmark, Germany and UK.

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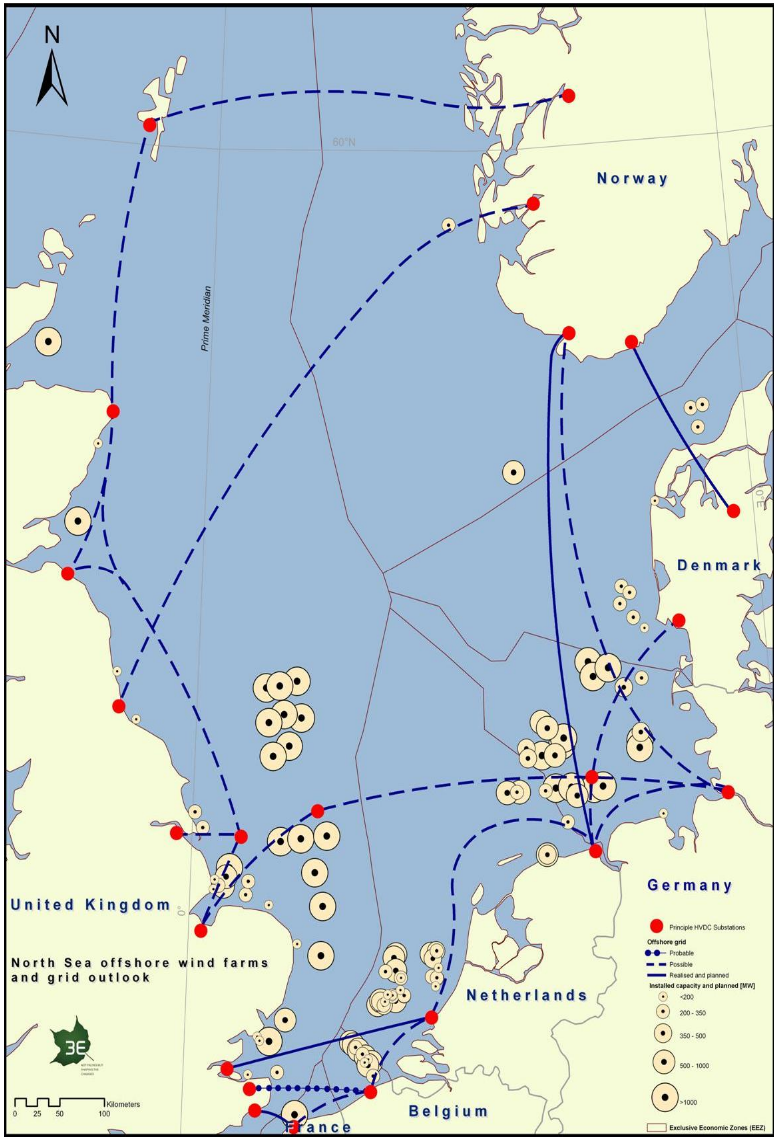
Coordinated planning needed



DEVELOPMENT BLOCKS OF A EUROPEAN SUPERGRID

- Offshore in-feed: where, how much, when
- Onshore reinforcements: AC or HVDC
- Offshore supergrid (and possibly other supergrids)
- Onshore supergrid

Master plan and coordinated planning of these blocks needed

Framework for planning and development is offered by European Commission

Operation and regulation requires specific solution: case for an Offshore TSO

Technology: HVDC VSC most attractive option

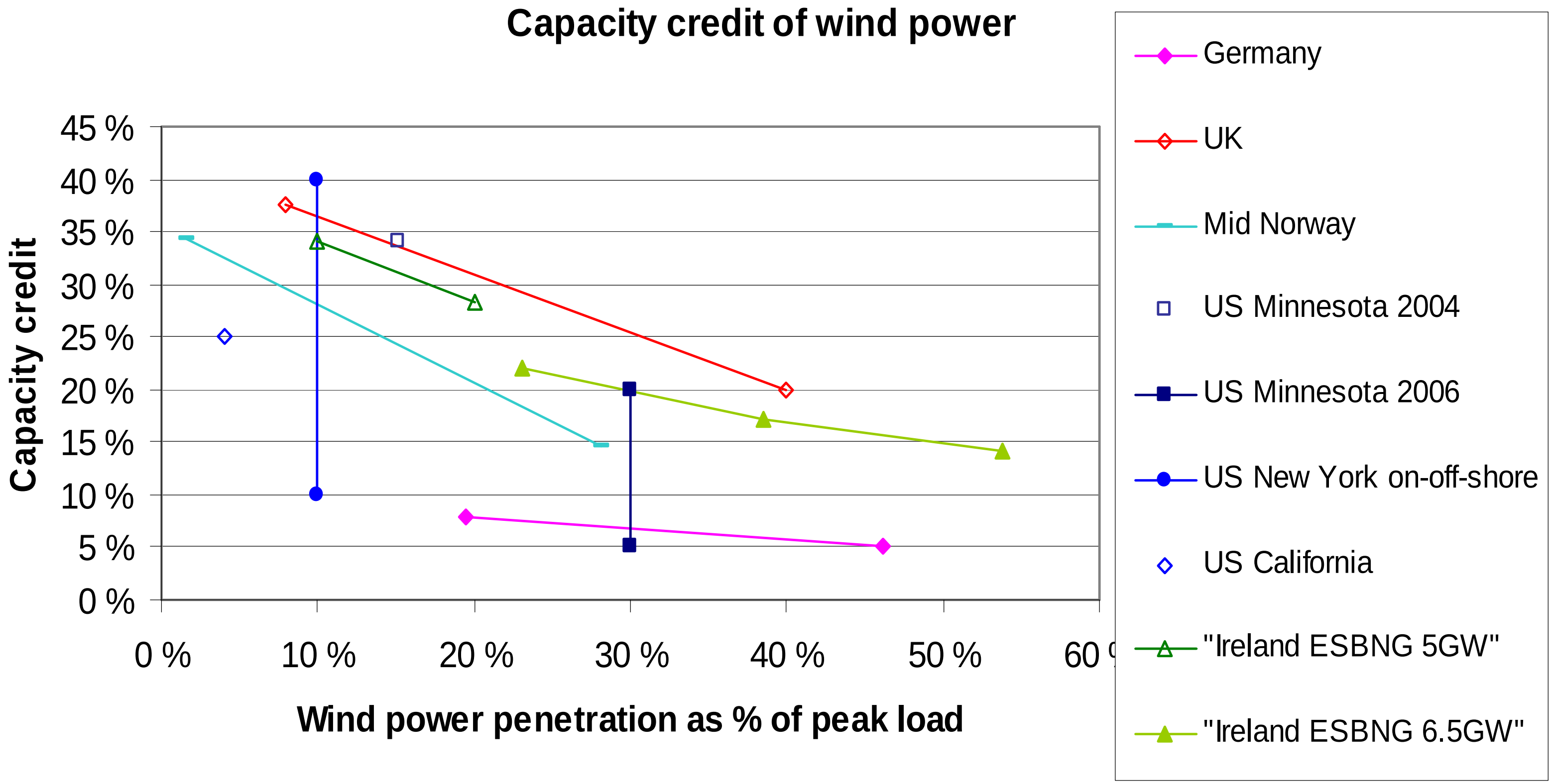
ATTRACTIVE BECAUSE

- Long distances
- Synchronous zones
- Modular
- Possibility for terminating deeper inside AC grids
- ....

CHALLENGES

- Conceptual decisions: standard voltage and large plug and play boundary
- Technical key-elements missing requiring VERY FAST development: circuit breakers, load flow control, DC/DC trafos etc.

Capacity value of wind power



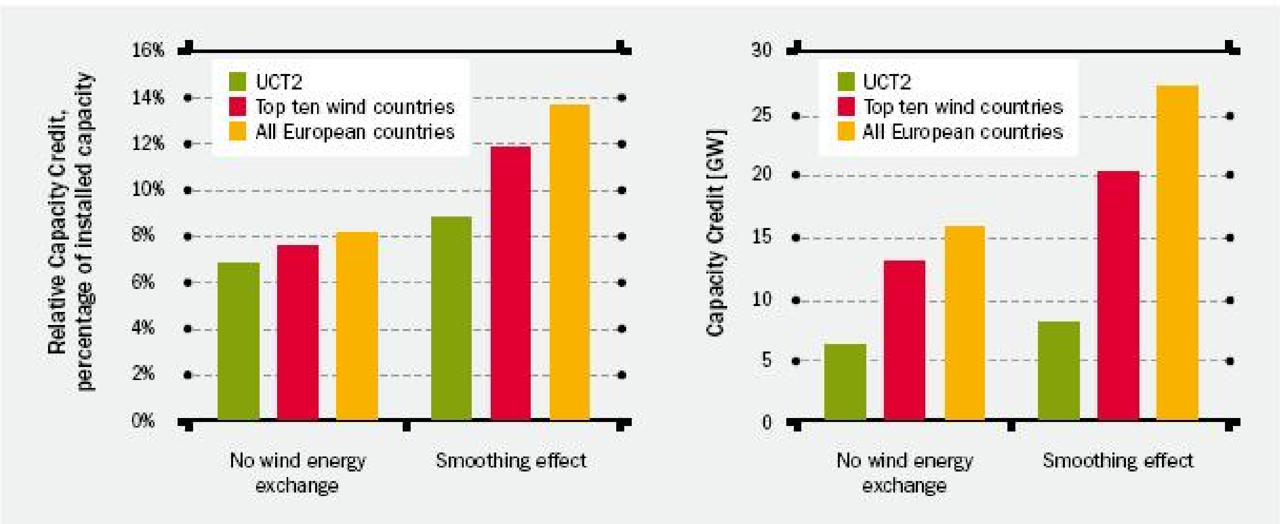
- Even if mainly energy resource, wind has a capacity value to power systems. However, at larger penetrations the value decreases. Value decreases faster for smaller areas.

Results capacity value

TradeWind

- Aggregating wind energy production strongly increases wind power's contribution to firm power capacity in the system
- Year 2020, 200 GW of wind power, capacity credit almost doubles compared with calculating the capacity credit to a single country, rising to a level of 14% (27 GW)
- Harmonised method for calculating capacity credit of wind power for system adequacy forecasts should be established

FIGURE [28]: **Increase in the capacity credit in Europe due to wind energy exchange between the countries in the 2020 M Scenario (200 MW, 12% penetration)**



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Grid connection requirements: the challenge

- Manufacturers and developers will almost always prefer relaxed grid codes.
- On the other hand grid codes needs to be so strict in due time that a given future penetration level is not blocked due to technical reasons.
- TSO and wind sector about to start to co-operate at EU level for further development of grid code requirements
- EWEA Working Group is developing industry strategy on European harmonisation (structural / technical) of Grid code requirements for wind power

market design: challenges and the way forward

- Integration costs can be further reduced by appropriate market design
  - Intraday trading (reducing gate-closure time)
  - develop fast energy markets
  - market aggregation (balance area consolidation) by facilitating cross border trading
  - new demand markets to use wind power overflow at large penetrations
- Improved (use of) forecasting helps to further reduce costs

SUPPORTING POLICY AND REGULATORY FRAMEWORK:

Development of the Internal Electricity Market in Europe. Third liberalisation package,

- Unbundling and European Cooperation of TSO's
- Strengthening of powers and European Coordination of regulators

Relevant ongoing efforts at international level

- European integration studies
  - Wind industry: TradeWind
  - TSO's: ewis – european wind integration study
- IEA Task 25: Design of power systems with large amounts of wind power