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# From 25 to 50% Wind Power in the Danish Power System

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# Content

- Overview Danish Power System
- Extrem Situations
- Results of the Ecogrid Study
- Conclusions


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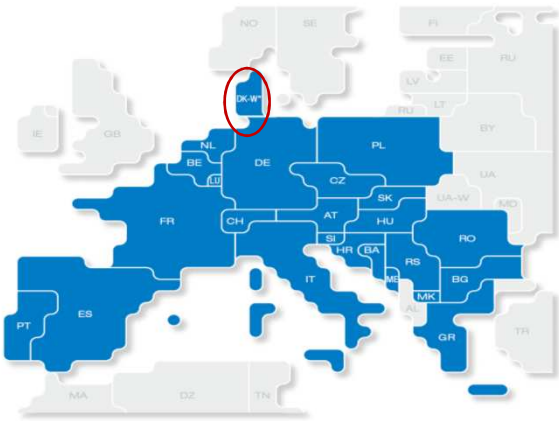
# OVERVIEW DANISH POWER SYSTEM

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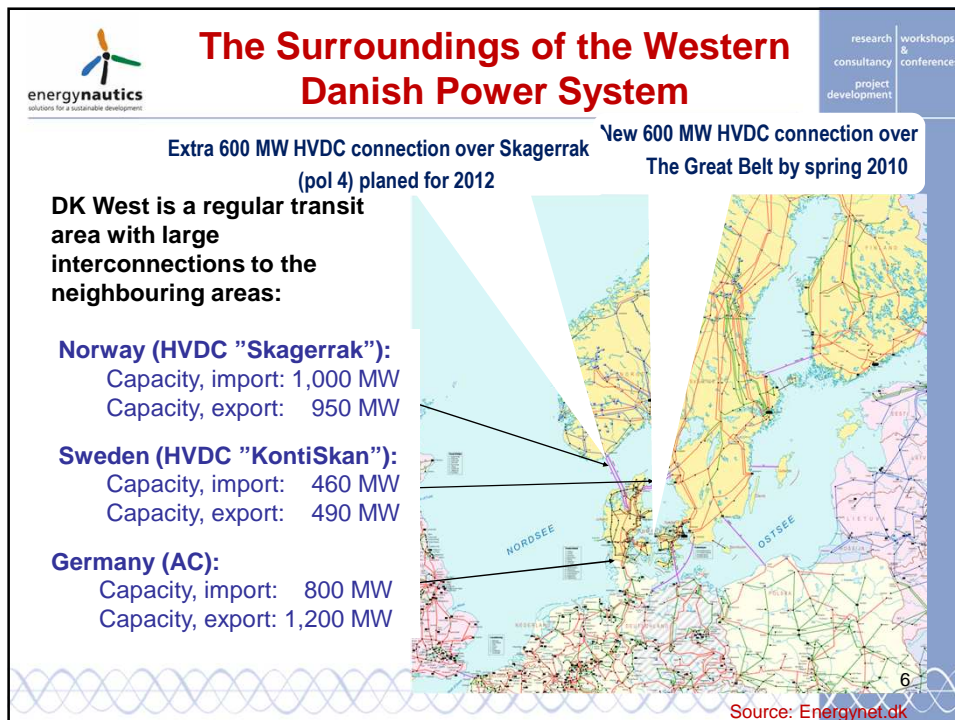
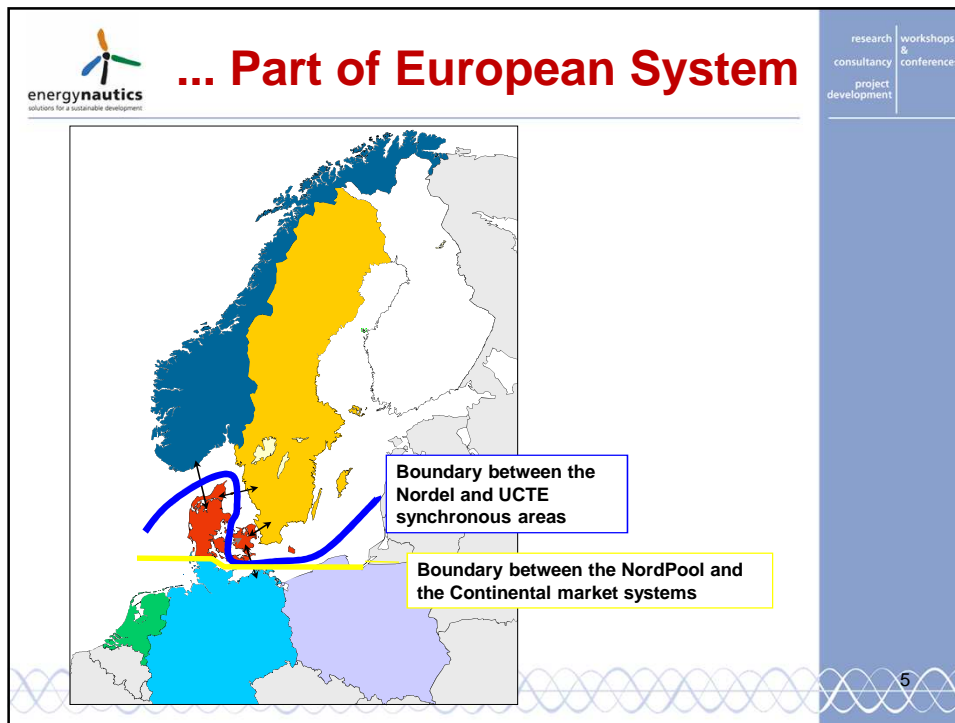
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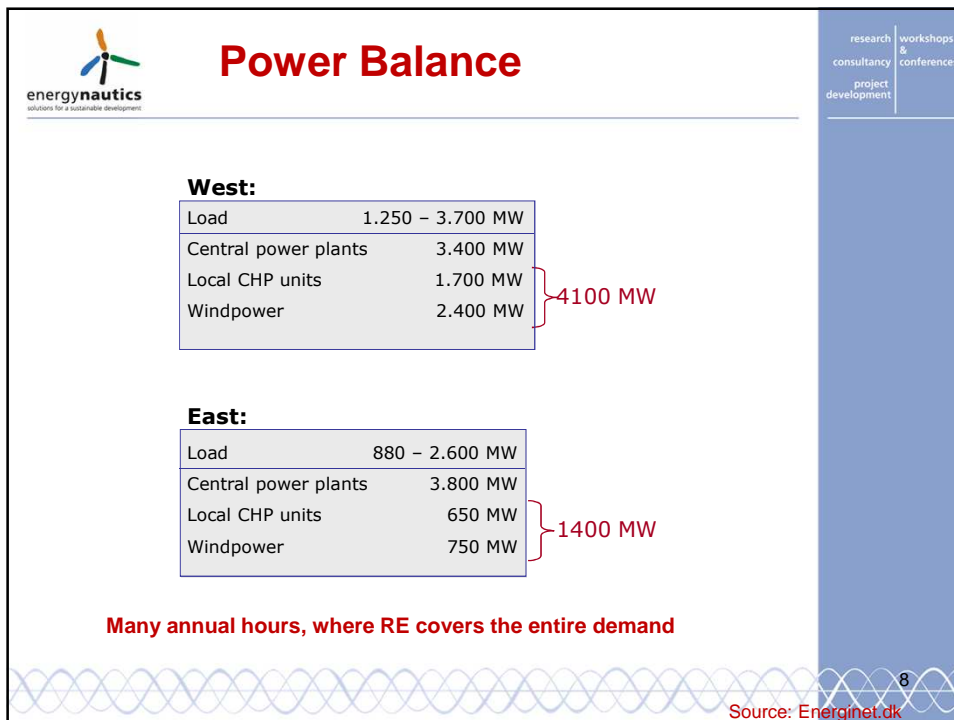
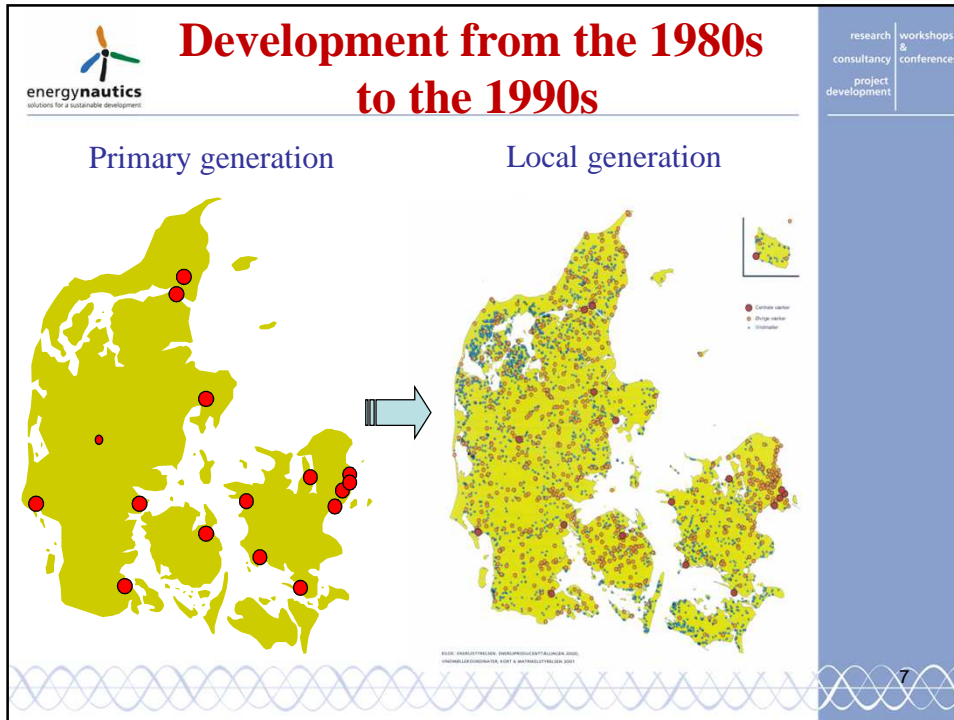
## Eltra - Part of the European Transmission system -

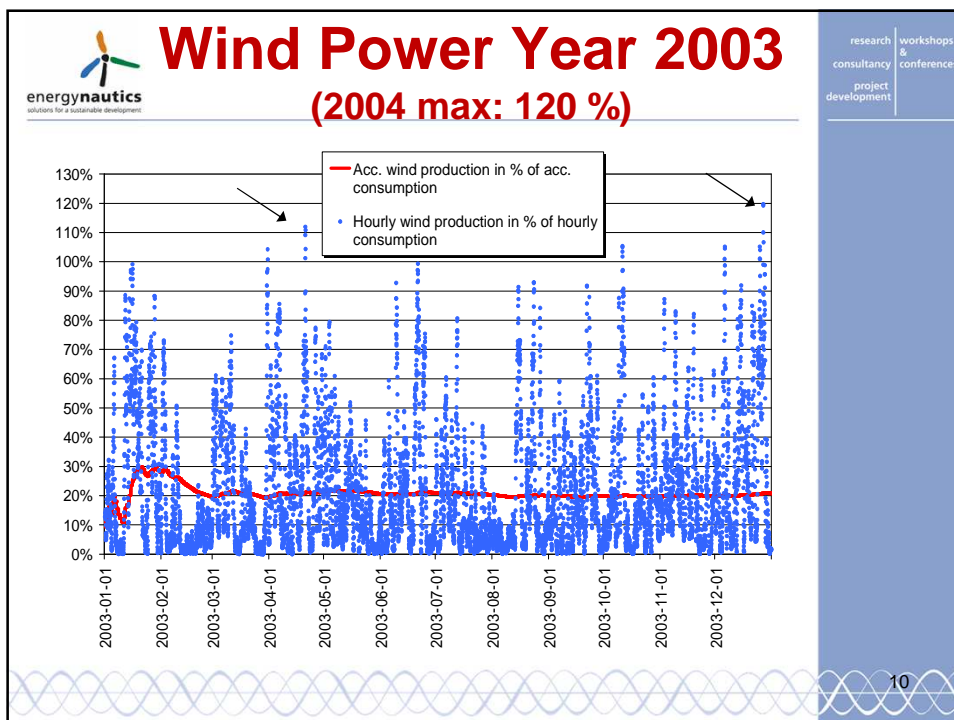
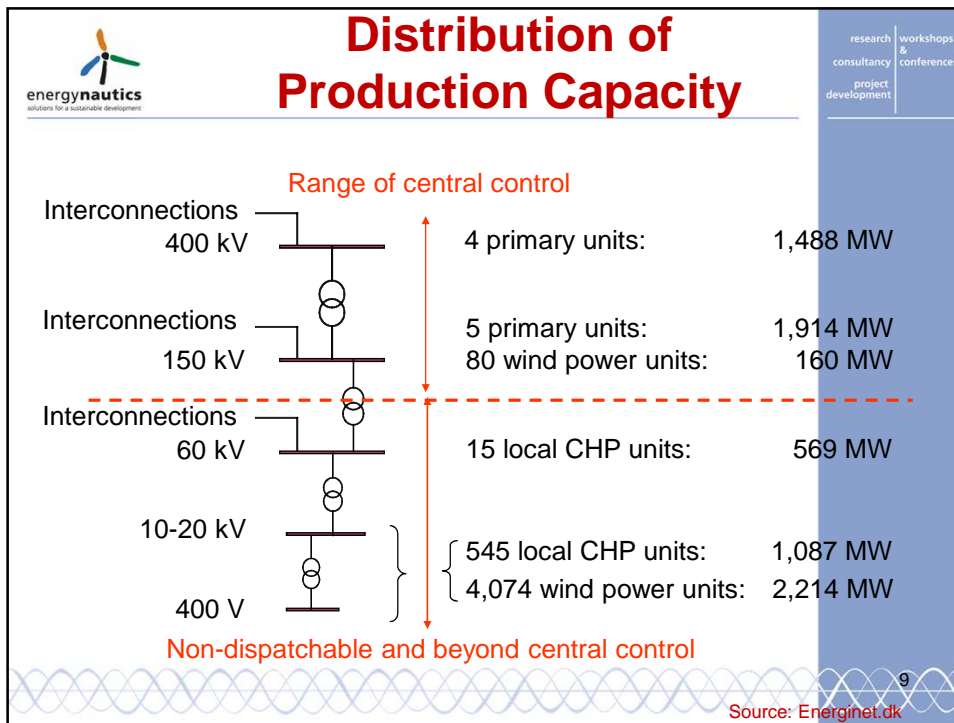
The European area covered by UCTE

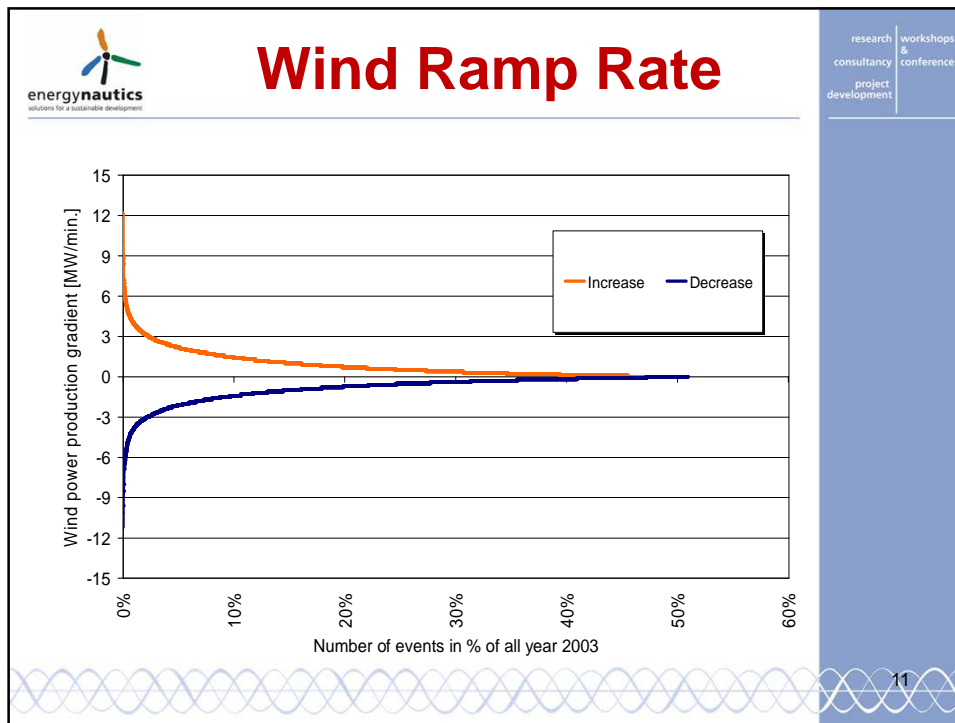


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**EXTREM SITUATIONS**

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 **Extreme Situations are Challenging**

- **Faults:**
  - Solution: Grid Codes (Fault-ride through)
- **Storms:** 
  - Solution: Sufficient Reserves/ Interconnections
- **Black start:**
  - Solution: Cell Project

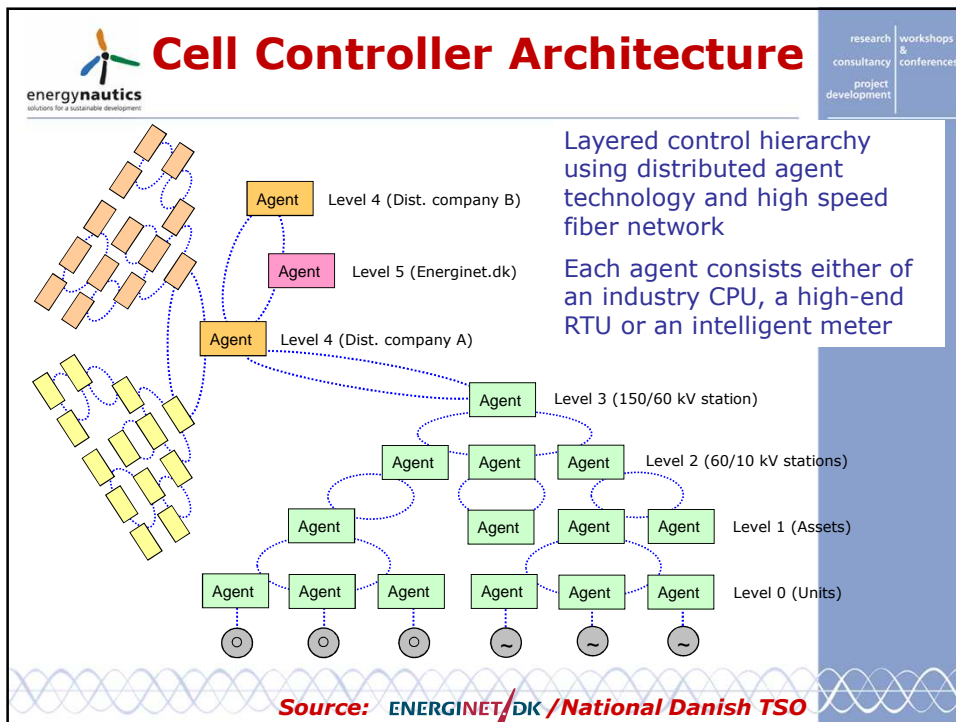
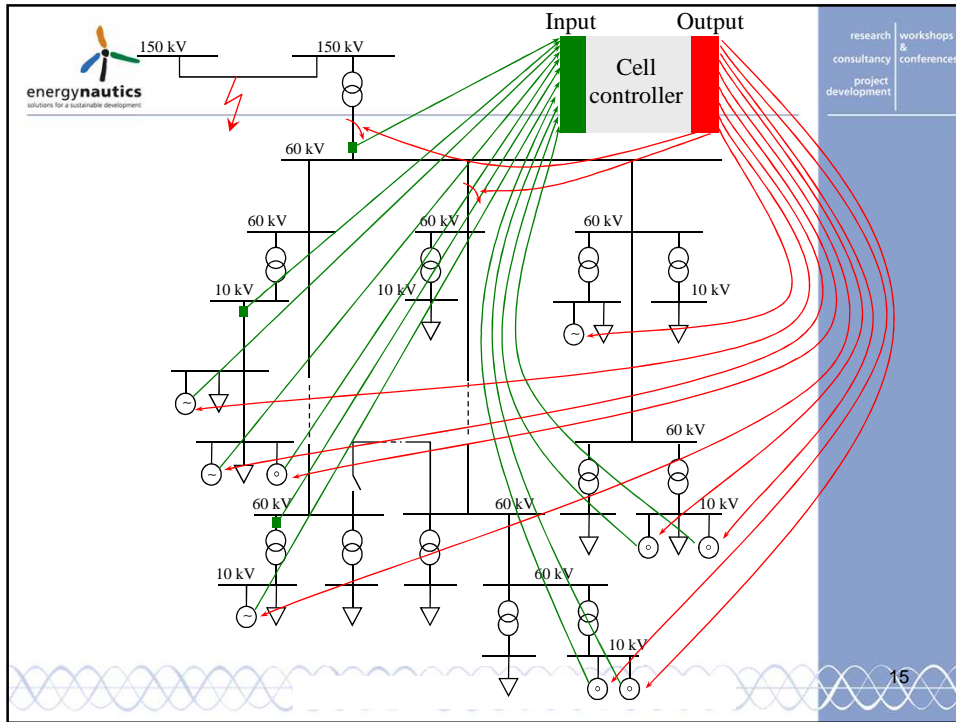
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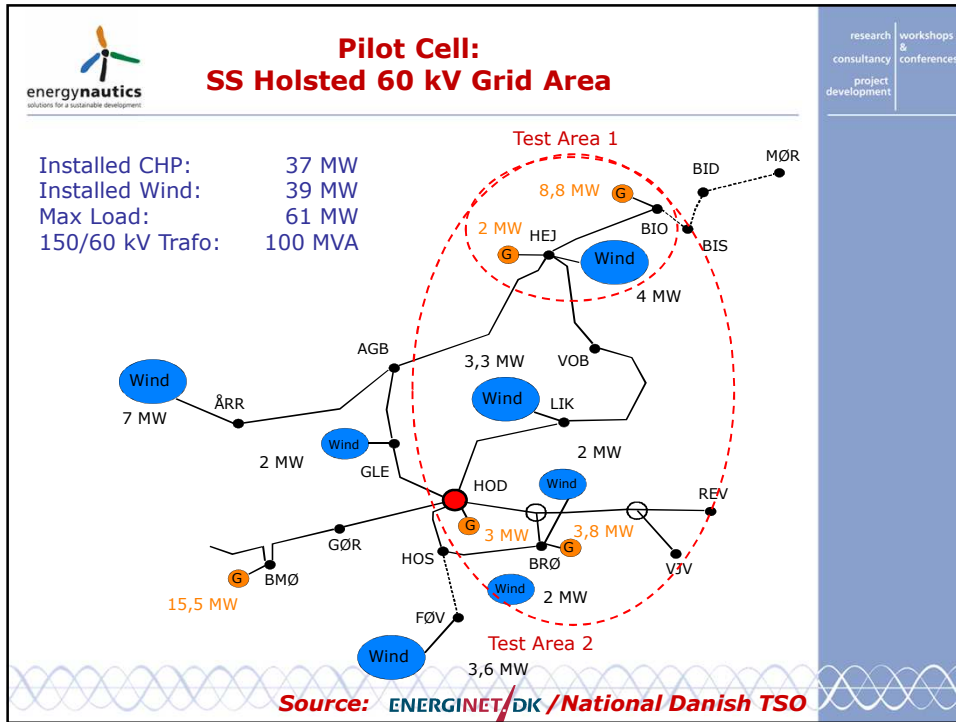
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 **THE CELL PROJECT**

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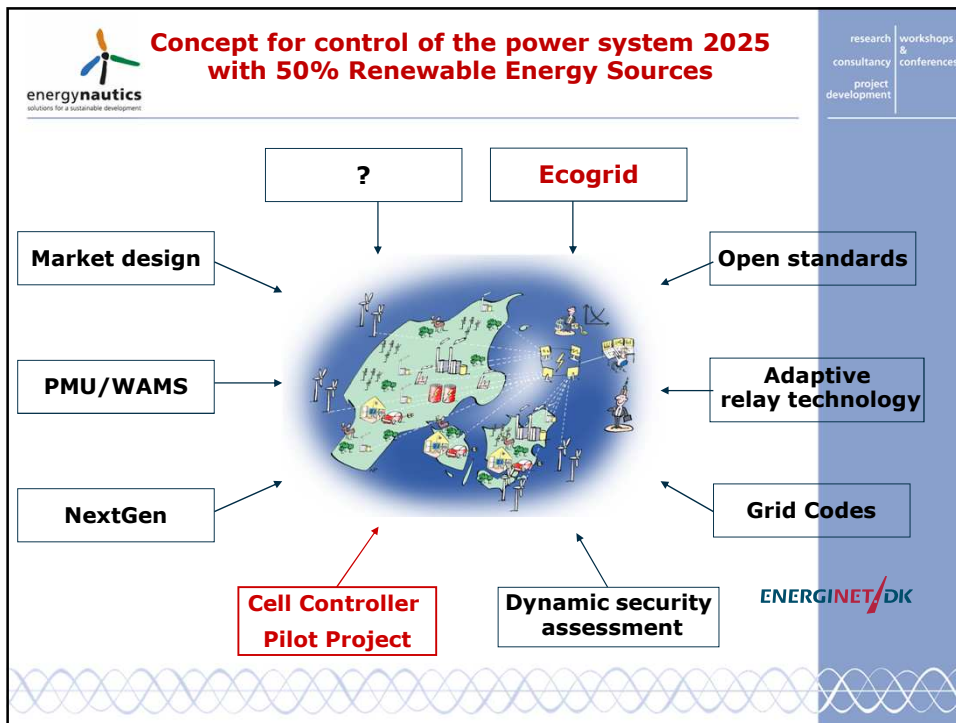


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**THE FUTURE PLANS**

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**Future Challenges of the Danish Power System**  
**Results of Ecogrid.dk – Phase 1:**  
**Steps towards a Danish Power System with 50 % Wind Energy**



EcoGrid.dk Phase I


Thomas Ackermann (Energynautics GmbH, [t.ackermann@energynautics.com](mailto:t.ackermann@energynautics.com)),  
Kjeld Norregaard (Teknologisk Institute), Paul-Frederik Bach, Morten Lind (CET-DTU),  
Poul Sorensen (Riso-DTU), Berit Tennbakk (Econ Pöyry AS),  
Michael Togeby (EA Energy Analyses a/s), Jacob Ostergaard (CET-DTU)  
Maj Dang Trong

**What is EcoGrid?**




PSO ForskEL R&D Program  
Funded by Energinet.dk

## Project Participants



www.ecogrid.dk

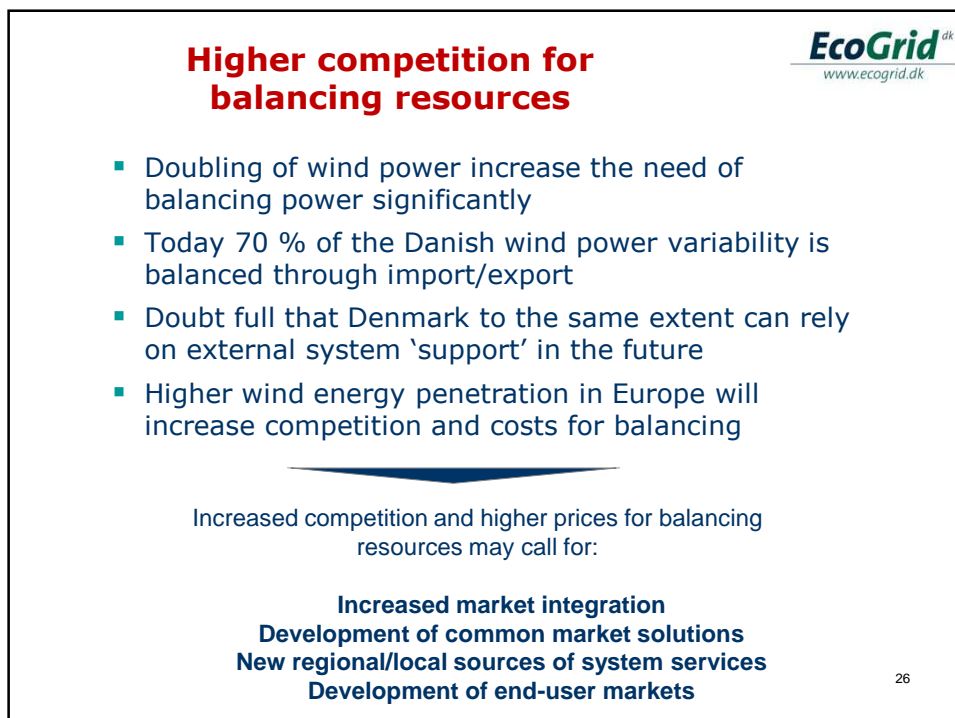
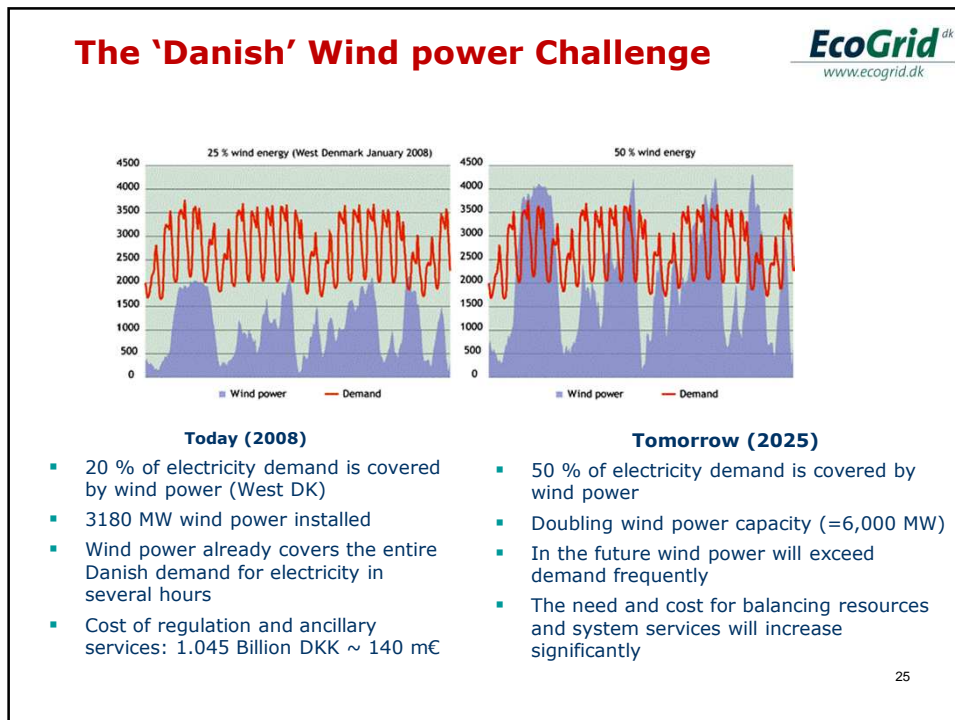


- One common objective
  - Develop new solutions for the power grid & system that...
  - ... can contribute to realizing the Danish goal of 50 % wind energy by 2025
- Specific tasks of EcoGrid Phase I
  - Analyses of the development of the Danish energy system with large scale penetration of wind energy
  - Study of alternative power system architectures
  - Development of international scenarios
  - Survey of new measures
  - Project proposals for EcoGrid Phase II

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## Future challenges of the Danish power system





## Overall Conclusions



New challenges = New concerns  
New concerns = New requirements  
New requirements = New solutions

## Proportion of the challenges



- All EcoGrid.dk scenarios show need for additional "domestic" balancing resources, but...
- ...we do not know how much...
- In 2025 wind energy can increase between 38 GW to 65 GW in Denmark and Germany - depending on scenario (from 29 GW today)
- There are no simple solutions - and no other country has shown a sustainable way

## Need for Redesign of the Power System

**EcoGrid<sup>dk</sup>**  
www.ecogrid.dk

- Significant need for new “domestic” balancing resources due to:
  - Less support from conventional generation units
  - Limited access to international balancing power
- Increasing demand from local generation to participate in the power market (solar, micro generation, wind power, storage facilities etc.)
- Higher environmental awareness make end-users seek greater ability to manage their own energy use and contribute to system flexibility

**100% more wind power will require a Profound redesign of the power system within the next 10-20 years!**

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## More interactive power grids

**EcoGrid<sup>dk</sup>**  
www.ecogrid.dk

- Interactive power grid can increase system flexibility
- A modern grid must enable:
  - National wide use of plug-in and electric vehicles
  - Large scale energy storage
  - Integration of solar energy, micro generation and wind energy
  - Flexible demand
  - Consumer choices and participation
- New requirements and concerns:
  - Wider end-user participation requires a system enabling two-way flow of information and power
  - Implementation of new information and communication technologies, including automation
  - New types of system security and control problems

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## To what extent should Denmark rely on 'foreign' resources?



- The access to foreign balancing resources depends on several "external" conditions, i.e.
  - The availability and cost of balancing resources from neighboring areas
  - International security rules
  - International market design rules
  - Market prices of Danish wind power "surplus"
  - Demand for transit through Denmark/Bottlenecks in transmission
  
- International scenarios identify the relative importance of the challenges and need of new domestic solutions
  - Planning for the "worst" case is costly
  - Planning for the "best" case compromise system security
  - A flexible strategy should be a key concern

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## Highlights from

## EcoGrid Phase I

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## WP 2: Power System Architecture

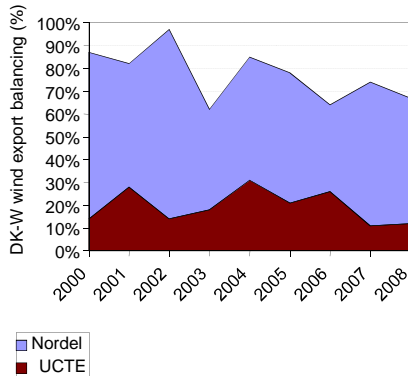
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### The system is managed well so far...

**EcoGrid<sup>dk</sup>**  
www.ecogrid.dk

The power system (W-DK) has worked with 25 % wind power - why should the Danish system not manage 25 % more?

Export participation in balancing of wind power variability in DK-West



- From 2004 – 2008 export balancing fell from 85% to 70 %
- Probably a result of increased participation of local CHP in the power market
- Doubling of wind power requires more activation of end users and local generation
- In parallel the value of wind power will increase and make Denmark less dependent on foreign balancing resources

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## A smarter way...

### A paradox highlighted in WP 2 report:

*"One challenge is that the change from centralized production to the present situation with very high share of distributed generation has occurred without major changes in the power system architecture"*


- The EcoGrid experts neither recommend a "back to basic" nor a "wait and see" approach
  - It is unlikely that the answer is only to extend the power system with more of the same, i.e.
    - More thermal generation, stronger grids and more cables and interconnections
- Bottlenecks will occur in all cases!!!
- A smarter way to face the challenges would be:
  - To use modern IT and communication technology to ensure system balance, reliable and secure power supply
  - Using ITC "intelligently" will enable distributed energy resources to contribute to system balancing and security

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## Challenging the traditional mindset

- The idea of smart grid is not new – but the driver for developing smart grids in Denmark is different from many other countries (in particular the US).
- The WP 2 survey did not find relevant smart grid concepts/test cases which is feasible to the Danish challenges
- The "engineer syndrome": Many people focus with "solutions" without considering the future power system requirements or needs
- Dramatic changes as Denmark faces in the coming years will probably need a tool (requirement capture analysis) to prepare the system for major changes
- Decentralized versus centralized control: A future power systems with high penetration of distributed generation raise new issues as for example delegated control and responsibility of system operation
- The WP 2 synthesis invites an open dialogue and discussion on future requirements – answers and solutions should then be developed by an integrated system analysis


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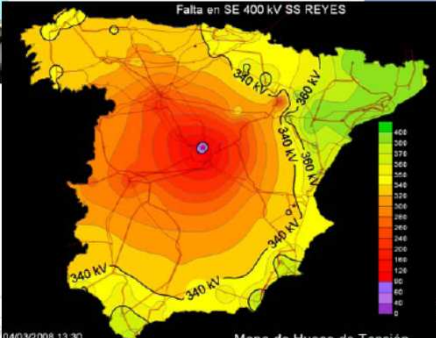
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## Example Spain: Renewable Energies Control Centre

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Wind State Estimation (GEMAS)




Falla en SE 400 kV SS REYES  
Mapa de Hueco de Tensión

www.ree.es

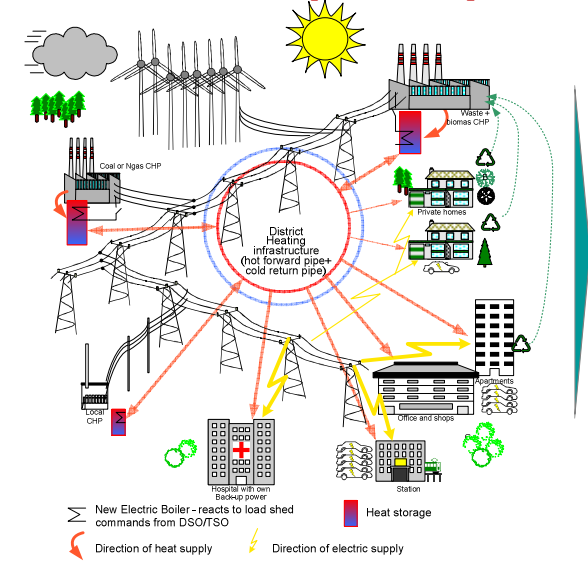
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**Power measures**

## Integration with heat – a Danish speciality




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- In the short term - integration with the current heat system provides the most promising measure
- Already available and economically reasonable
- Additional investment needed to enlarge heat storage capacity
- taxation/legislation are the key barrier for wider use

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Power Measure




## Flexible demand

- In the short and mid term activation of electricity customers or demand can offer a significant source of flexibility, but...
  - ...participation of many small end-users requires investment in infrastructure (meters etc.)
  - The chicken or egg dilemma: Some measures are necessary to make other measures work...
- New demand: Electric and hybrid vehicles are also considered important measure, but...
  - ...the available balancing capacity in the future is uncertain – and depends on the penetration of electric vehicles and infrastructure
- The development in transport sector are decided outside Denmark (car industry, international legislation etc.), but...
  - **...Denmark has one major competitive advantage: The possibility to integration of electric vehicles in a power system with high share of wind power**

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Control & IT Measures



## Power control and support

Tomorrow's wind turbines is available, e.g. at Horns Rev wind farm:

- The turbines have advanced control modes, i.e. delta control
  - Wind farms with delta control can adjust their power production faster than many conventional plants
  - Production can be reduced by 20% in 3-4 seconds – and immediately decrease production if operated in delta control mode

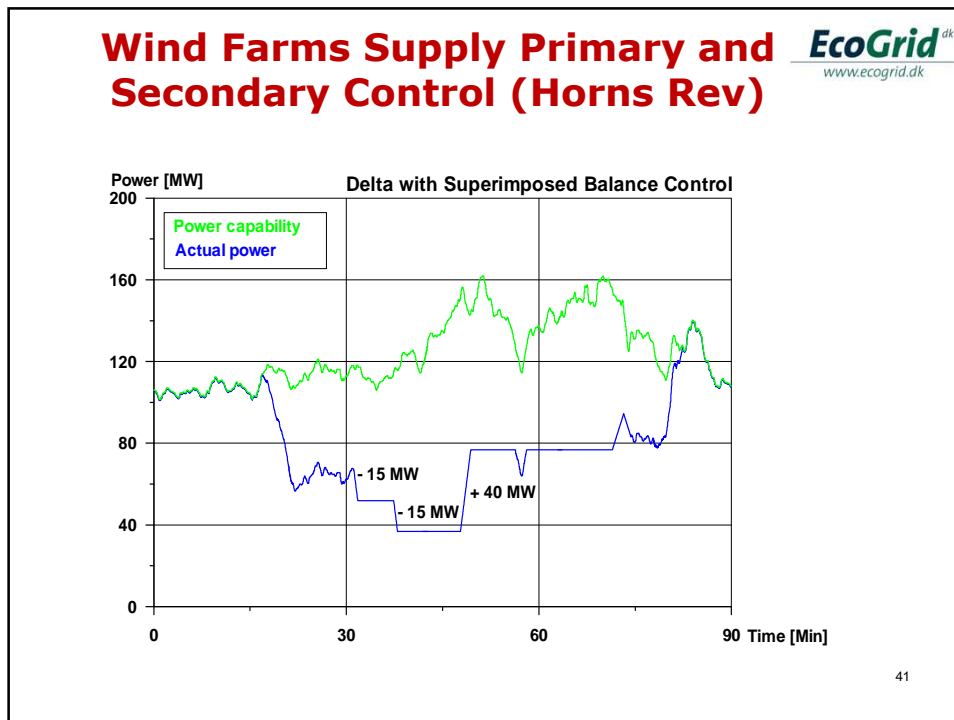
Development of new black-start capabilities

- The capability of wind farms to support grid control in combination with other available generation (e.g. CHP)
- This type of grid control requires:
  - New grid control structures, in particular at distribution level

Micro generation support (generation less than 10 kW), i.e.

- Ancillary grid support (local voltage and frequency control)
- Uninterruptible Power Supply (UPS) for houses in case of blackouts
- Operation as regulating reserve

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## Common Recommendations

**EcoGrid<sup>dk</sup>**  
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- Development of a Danish EcoGrid/SmartGrids Strategy 2025
- Management of an energy system in transition
- Strengthen the international efforts
  - In co-operation with other TSOs continue efforts to:
    - Develop efficient markets
    - Improve integration of the Nordic and surrounding markets
    - Push for international standards
- Focused EcoGrid.dk Phase II project activities
  - Preparing for large scale demonstration
  - Energinet.dk should be an active part of phase II

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 **9th International Workshop**  
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as well as on Transmission Networks for Offshore Wind Power Plants  
**18 - 19 October 2010**  
**Québec City**  
**Québec, Canada**

<http://www.windintegrationworkshop.org>



**10th International Workshop**  
on Large-Scale Integration of Wind Power into Power Systems  
as well as on Transmission Networks for Offshore Wind Power Plants  
**25 - 26 October 2011**  
**Aarhus, Denmark**