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Steps Toward a Danish Power System with 50 % Wind Energy

EcoGrid.dk Phase I
Presentation
September 2009

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Content/Outline

- What is EcoGrid.dk?
- Future challenges of the Danish power system
- Overall conclusions
- Highlights from the work packages
  - WP 2: A Need for New Power System Architecture
  - WP 3:The Green and blue scenarios
  - WP 4: New Measures
  - WP 5: Next step EcoGrid activities (project proposal phase II)
- Common Recommendations

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What is EcoGrid?

- a PSO ForskEL RD&D Program

funded by Energinet.dk

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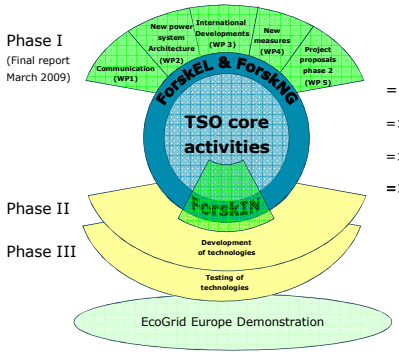
The EcoGrid RD&D program



=> More focus

=> Increased resources

=> Best competences

=> Good solutions in time!

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EcoGrid phase I

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Project participants

VATTENFALL, DONG energy, EC POWER, PowerLynx, DK, kk.group, Danfoss, Vestas, DANISH TECHNOLOGICAL INSTITUTE, DTU Centre for Electric technology, Informatik, Risø System Analysis, Risø Wind Energy, AALBORG UNIVERSITET, Ea Energianalyse, econ, energynautics

Paul-Frederik Back

- 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

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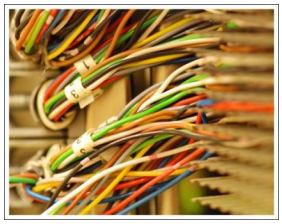

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The 'Danish' Wind Power Challenge

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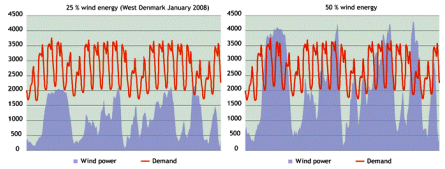

Today (2008)

- 20 % of electricity demand is covered by wind power
- 3180 MW wind power installed
- Wind power already covers the entire Danish demand for electricity in several hours
- Cost of regulation and ancillary services: 1.045 Billion DKK ~ 140 m€

Tomorrow (2025)

- 50 % of electricity demand is covered by wind power
- Doubling wind power capacity (=6,000 MW)
- In the future wind power will exceed demand frequently
- The need and cost for balancing resources and system services will increase significantly

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Higher competition for balancing resources

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- Doubling of wind power increase the requirements of balancing power significantly
- At present 70 % of the Danish wind power variability is balanced through import/export – thanks to the Nordic hydro power system
- Doubt full that Denmark to the same extent can rely on external system 'support' in the future
- Increasing competition and costs for the balancing resources due to significant increase of wind energy penetration in Europe
- Increased competition and higher prices for balancing resources may call for:
  - Increased market integration and development of common market solutions
  - New regional/local sources of system services
  - Development of end-user markets

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Overall conclusions

New challenges = new concerns

New concerns = new requirements

new requirements = new solutions

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Proportion of the challenges

2008

29 GW wind power installed in Denmark and Germany

HVDC transfer capability between the regions is limited to 4.2 GW

2025

Between 38 GW to 65 GW depending of scenario

The required domestic balancing resources can be dramatic

- All EcoGrid.dk scenarios show need for additional "domestic" balancing resources,…
- …but we do not know how much…
- There are no simple solutions - and no other country has shown a sustainable way

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Need for Redesign of the Power System

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

- Significant need for new "domestic" balancing/activating local 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

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More interactive power grids

- Traditionally the grid is build to bring the electricity from central generation units to consumers
- Interactive power grid can increase system flexibility and allow for wider participation of diverse and distributed energy resources
- 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 and domestic resources

- The access to foreign balancing resources depends on several "external" conditions:
  - The availability and cost of balancing resources from neighboring areas
  - International security rules, including shared reserves and system services
  - International market design rules, including market coupling
  - International market prices paid for excess Danish wind power generation
  - Demand for transit through Denmark
  - Bottlenecks in the transmission system
- 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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Promising measures with high potential

Integration with district heating	Integration with other energy technologies	Integration with transport	New market services	Wind power control
Use of existing heat storage capacity in district heating systems Surplus of electricity can be absorbed for at least 12 hours Storage potential in existing district heating systems: 20-30 GWh useful heat Electric heating/ large heat pumps/ Electric boilers in district heating system	Heat pumps with buffer heat storage outside district heating systems Fast reacting regulations means: - New gas turbines - Cooling towers - Micro generation	Penetration of Plug-in Hybrid & Battery Electric Vehicles add new flexible power consumption Great opportunities to develop win-win solutions for the power system & car owners Modest estimate: 100 MW flexible demand in 2025	The potential for demand response solutions is up to 1.3 GW The challenges is to activate many small end-users and local generation (i.e. wind power & micro generation) In a well designed "real- time" market any generation or consumer could participate	Modern wind turbines can increase flexibility in power system Many competing options exist for individual wind turbines and wind power farms Ex. Auxiliary equipment and flexible AC/DC-interconnections

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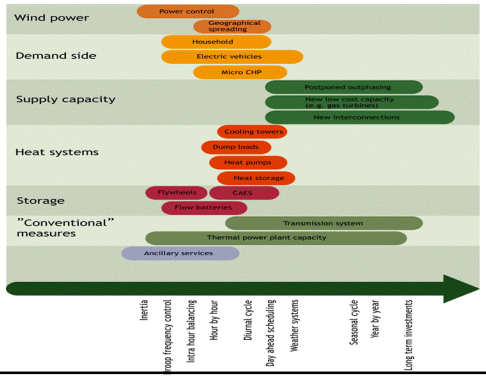
No winning solution



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Highlights from

EcoGrid Phase I

Work Packages 2,3,4 and 5

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WP 2: Power System Architecture

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The system is managed well so far…

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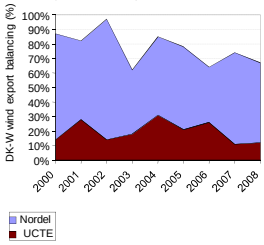
The power system (W-DK)has worked with 25 % wind power - why should the Danish system not manage 25 % more?

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…

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A paradox highlighted in WP 2 report:

"One challenges 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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Key elements of a new power system architecture

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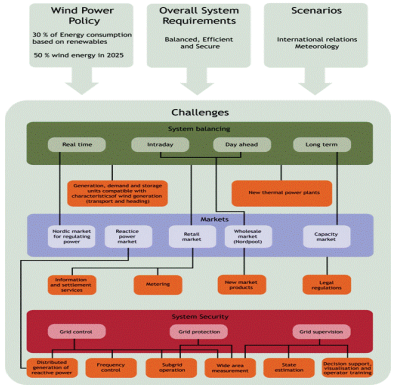

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Challenging the traditional mindset

- 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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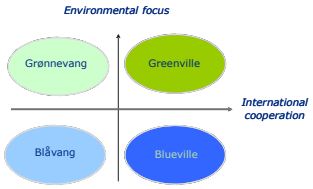
WP 3: International scenarios



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The green and blue scenarios

Very challenging

- Strong focus on renewable energy and energy savings - Up to 24 % wind energy in neighboring areas (31% in Germany!)
- Strong need for domestic balancing resources
- High competition for external balancing resources
- High focus on international coordination can increase market for balancing power

Moderate challenges

- Less focus on environment (12 % wind energy) and more focus on security of supply.
- Less challenging for Denmark is the Blueville scenario where international coordination are encouraged (harmonization, stronger and reinforced grids etc.)

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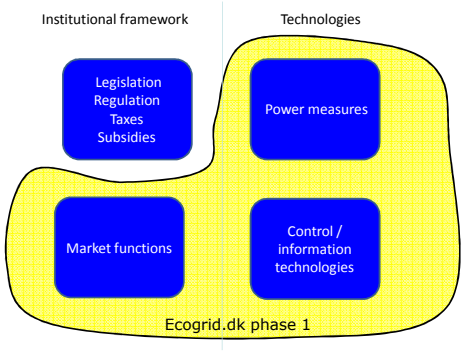
WP 4 - New Measures



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Power measures

Integration with heat – a Danish speciality

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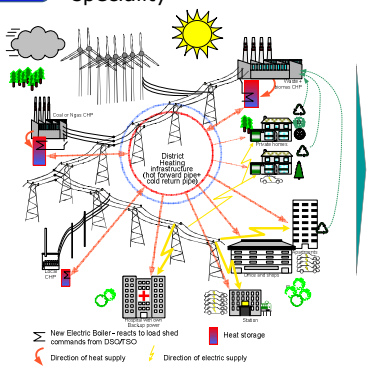

- In the short term - integration with the current heat system provides the most promising measure
- Already available and economically reasonable
- Additional investment needed to enlarge heat storage capacity
- taxation/legislation are the key barrier for wider use

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Power Measure

Flexible demand

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- 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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Market functions

Towards a real-time market…

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- The current power market design favours conventional production and large generation units
- The Nordic regulating power market is traded with a 15 minutes notice
- Limited to suppliers that can send plans and guarantee supply of balancing resources

- In a real-time market all market players can participate (i.e. all end-users, wind power, local CHP and micro generation)
- A real-time market could be based by broadcasted price signals:
  - By offering an adder to the spot price
  - The TSO/DSO could change the adder, for example each five minutes
  - If the system need more generation – the adder must be positive. And vice versa
- Crucial for the success:
  - Two-way communication
  - Interval meters
  - Participation must be voluntary
  - No plans must be send in advance…
  - Critical mass must be defined (large number of active actors)
  - Automation

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Control & IT Measures

Power control and support

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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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Control & IT Measures

Key challenge: Lack of standards!

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- Common challenge for the new support and control measures is lack of communication protocol standards
- Without the standards TSO's/DSO's cannot remotely control the various wind farms of different suppliers/micro generation
- Development/implementation of standards are very critical for the reliability of future power system
- The requirements related to implement ICT systems in the power system cannot be compared with the internet:
  - In the early internet days nobody notice if the system broke down a day or two. This would not be acceptable in the power system
- There is always a risk of installing new IT-based control systems
  - A simple advice: It is possible to prevent serious incidents if you install new equipment without removing the old system…

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WP 4 summary

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Regulation capability of different measures

Measure	Positive	Negative
Integration with heat system		
Cooling tower	√	
Mode shift (back pressure to condensing)	√	
Heat consumption flexibility	√	√
Heat storage	√	√
Interconnected heat system with multiple CHPs	√	√
Turbine bypass		√
Dump loads / electric heating		√
Large heat pumps		√
Boilers		√
Local CHPs		√
Integration with transport system	(√)	√
Other demand side options	√	√
Storage	√	√
Wind power control	(√)	√
New generation units	√	√
New interconnections	√	√

- The measures described in WP 4 work on time scale from second to maximum a couple of days
- Several days without wind is an unsolved problem
- In the long term old and least inefficient thermal generation capacity is expected to close down

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WP5: Next step - EcoGrid Phase II project proposals

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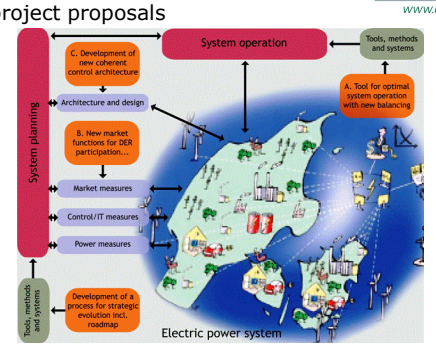

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Common Recommendations

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Development of a Danish EcoGrid/SmartGrids Strategy 2025:

- Establish a Task Force Group led by Energinet.dk representing government authorities, industry, energy sector, energy experts, universities etc.

- Management of an energy system in transition
  - Through EcoGrid.dk phase II workshops plan a process to lay out the strategy towards successful integration of 50% wind energy
  - Using methods from the "Change Management" concept
- 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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Thank you for
your attention!

Read more on:
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