DISPOSITION

1. Global outlook for windpower in the energy system (IEA, COP21)
2. European scenarios for windpower (ENTSO-E/G)
3. Offshore perspectives - North sea wind power hub (nswph)
4. Future windpower integration in the energy system (danish case)
5. Summing up
6. Questions and debate
Gode råd:

Modtageren vil høre din præsentation, ikke læse slides.

Brug notefeltet som hjælp til at huske, hvad du vil sige.

Har du behov for, at modtageren skal huske vigtig information, så lav faktaark og del ud.
GLOBAL CONTEXST – IEA WEO AND COP 21

Figure 2.1 World primary energy demand and CO₂ emissions by scenario

- Primary energy demand:
  - Current Policies Scenario
  - New Policies Scenario
  - 450 Scenario

- Energy-related CO₂ emissions (right axis):
  - Current Policies Scenario
  - New Policies Scenario
  - 450 Scenario

- Global: 2,1 ton CO₂/capita

Mission Innovation
More global R&D

Target: "Well below 2 degr."

INDC’s

http://ClimateParis.org

A tough challenge to realise Paris COP21 targets – significant CO₂-reduction needed
GLOBAL PLANS (INDC’S) – SIGNIFICANT GROW IN WIND/SOLAR

- INDC’s does not lead to needed reduction in CO2 if ”Well below 2 degr” should be realised
- Investment in more than 600 GW wind towards 2030 (INDC)
- But a need for even more wind, solar, RE-fuels and energy efficiency!
EUROPEAN SCENARIOS
Europe – A high population density region with a mix of wind and solar resources
- Europe a representative case for wind/solar system-integration
- North-sea area a high-wind area (offshore and onshore)
Wind and solar production profile based on Danish conditions

Socio-economic costs, on 4% discount and technical lifetime

Onshore wind very cost-effective if efficiently integrated

Offshore wind getting closer to onshore wind cost toward 2030
ENTSO E/G Tyndp 2018 – Three scenarios defined!

GLOBAL CLIMATE ACTION (on track with EU targets)
- Strong international green framework
- EU on track with 2050 vision for CO2-reduction
- Moderate oil prices and very high CO2-prices (IEA 450 PPM)
- 50% electricity from wind/solar in 2040

DISTRIBUTED GENERATION
- High impact from “local” prosumer solutions (PV/batteries)
- EU on track with 2050 vision for CO2-reduction
- High oil prices (IEA New policies) and high CO2 prices
- 50% electricity from wind/solar in 2040

SUSTAINABLE TRANSITION (almost on track with EU targets)
- EU not fully on track with 2050 vision for CO2-reduction
- Low oil/natural gas prices and moderate CO2-prices (IEA Low oil price scenario)

- Target in set plan:
  2030: 40% – 2040: 60% – 2050: 80%
- Significant reduction of CO2 in power-sector
- Electrification of other sectors needed
Goderåd:
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EUROPEAN TRANSISTION AND ENTSO-E/G SCENARIOS

25-34% electricity covered by wind in Europe 2040
Gør råd:
Find inspiration til præsentationer på InSite under Værktøjer – Kommunikation.
Du kan finde billeder og grafiske elementer i Energinet.dk’s billedatabase (Cumulus) på InSite under Værktøjer – Kommunikation.

NORTH SEA AREA – HIGH WIND AREA

Wind/solar capacity in Europe

Wind/solar capacity in NorthSea region

Wind/solar power production minus consumption (DE,NL,GB,DK) in GCA 2040 scenario

A need to run the powersystem with a minimum of thermal base-load
A need for integration of RE-electricity in other sectors (P2G etc.)

Wind-energy in the future energy system

2017-09-13 11
DANISH PERSPECTIVES ON SYSTEM SUPPORT FROM DIFFERENT TECHNOLOGIES

<table>
<thead>
<tr>
<th>Generator &gt;100 kV</th>
<th>Generator &lt;100 kV</th>
<th>WT &gt;100 kV</th>
<th>WT &lt;100 kV</th>
<th>Classical HVDC</th>
<th>New HVDC</th>
<th>SVC/STATCOM</th>
<th>Synch. comp</th>
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<tbody>
<tr>
<td>Inertia</td>
<td>++</td>
<td>+</td>
<td>(+)</td>
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<td>Short circuit power</td>
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<tr>
<td>Dynamic voltage support</td>
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<td>Damping of system oscillations (PSS)</td>
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</tbody>
</table>

| ++ | Large contribution |
| +  | Minor contribution |
| (+/++) | Conditionally available |
| ÷  | Unavailable |

System development to use windpower for ancillary services essential
OFFSHORE PERSPECTIVES
- NORTH SEA WIND POWER HUB (NSWPH)
PRICE DEVELOPMENT: ROLE OF THE TSO

Comparison of future CAPEX for wind power – divided into the turbine and grid connection

A challenge is to keep up with the cost reductions on wind turbines, foundations etc.
Paris climate agreement
80-95% CO₂ reduction in 2050

Needed in Europe in 2050
150 GW North Sea Wind

Regional cooperation is essential
Barriers:
• Subsidy schemes
• Focus on national sustainability goals
SOLUTION: NORTH SEA WIND POWER HUB

R&D project

Cooperation
• TSOs: TenneT Netherlands & Germany, Energinet.dk
• Partnerships other infrastructure operators

Studies done
• Dogger bank wind capacity
• Ecological Quick scan
• Ecological follow up studies
• Translate COP 21

Studies ongoing
• Concept business case - Market analysis
• Technical island conceptual design
• More to come!
SOLUTION: LOCATION

Shallow waters
Water depth has a significant impact on the development for offshore wind.
A development in shallow waters contributes significantly to cost reduction.

Wind conditions
Wind conditions get better further at sea, which partially compensates the increase in cost for distance.

Central location
For a European coordinated roll-out, a central location is important.
SOLUTION: LOCATION DOGGER BANKE

Dogger Banke – Large area in NorthSea with <40 m depth
SOLUTION: INFRASTRUCTURE

The ‘wind-connector’: offshore wind infrastructure and interconnector are one

Wind-energy in the future energy system
North Sea Wind Power Hub

The Power Link Island: a modular approach (30 GW per island, 70-100 GW in total)

- Far shore becomes near shore
- Distribution point for different countries
- Space for multiple converters (AC→DC)
PERSPECTIVE: POWER TO GAS

Potential synergies

- After 2030 electrolysis is expected to be a mature technology for making green hydrogen
- Making green gas from the wind power source
- Onsite flexible consumption of wind power reduce transmission losses and optimize grid utilization
- Gas is much cheaper to transport over long distances than power
- Potential synergies with existing North Sea gas infrastructure?
WINDPOWER INTEGRATION IN THE ENERGY SYSTEM - DANISH CASE
RE-GAS AS FEEDSTOCK FOR FUELS ETC.

- **Biogas Anaerob**
- **Thermal gasification**
- **Electrolysis Alkal./SOEC**

**Legend:**
- CH4
- H2
- CO

**Power/heat Industry Transport etc.**
- Methanol
- DME
- Synt. Gasoline/diesel
- Hydrogen
- PE plast etc.
- Fertilizer

**Nutrients etc. (N,P,K and carbon)**

**400-600 °C**

**200-300 °C**

**>200 °C**

**>800 °C**
Goder råd:
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Brug notefeltet som hjælp til at huske, hvad du vil sige.
Har du behov for, at modtageren skal huske vigtig information, så lav faktaark og del ud.

ANNUAL ENERGY FLOW IN ENERGY SYSTEM 2013

Transport almost totally based on fossil oil – wind and solar still quite a small part of total gross energy
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DENMARK – A SCENARIOS TOWARDS 2030-2050 - TOWARDS RE-BASED ENERGY SUPPLY IN 2050

Wind-energy in the future energy system

**Figure 2.1** World primary energy demand and CO₂ emissions by scenario

- **Primary energy demand:**
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  - 450 Scenario

- **Energy-related CO₂ emissions (right axis):**
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  - New Policies Scenario
  - 450 Scenario

14 mio ton CO₂

10 TWh = 36 PJ
Figure 2.1 World primary energy demand and CO\textsubscript{2} emissions by scenario

- **Primary energy demand:**
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  - New Policies Scenario
  - 450 Scenario

- **Energy-related CO\textsubscript{2} emissions (right axis):**
  - Current Policies Scenario
  - New Policies Scenario
  - 450 Scenario

**World primary energy demand and CO\textsubscript{2} emissions by scenario**

- **1990:** 5000 Mtoe
- **2000:** 10000 Mtoe
- **2010:** 15000 Mtoe
- **2020:** 20000 Mtoe
- **2030:** 48 Gt
- **2040:** 32 Gt

**CO\textsubscript{2} emissions (right axis):**

- **1990:** 16 Gt
- **2000:** 32 Gt
- **2010:** 48 Gt
- **2020:** 64 Gt

**Additional Notes:**

- **Bio, waste etc.:**
- **Natural gas:**
- **6 mio ton CO\textsubscript{2}**
- **Liquid fuels fossil/RE (Gasoline, Diesel, Ethanol, Methanol, DME etc.)**
- **10 TWh = 36 PJ**
MAX RESIDUAL LOAD IN PERIODS OF 1 HOUR TO 1 YEAR (2035 SCENARIO) (ANALYSIS BASED ON 10 YEAR DTU WIND TIME SERIES)

Residual load = Consumption – wind/solar
USE OF FLEXIBLE LOAD TO REDUCE PEAK DEMAND

Now the max residual load is in a 12 hours period
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- Essential to use the geographical spread of windpower

WINDPOWER IN NORTH SEA REGION IN A WEEK WITH ”WORST CASE I DK”

From 12/12 kl. 24.00 and 7 days ahead

Wind-energy in the future energy system
BALANCING THE POWER SYSTEM – COMBINATION OF MEANS

Use of transmission system to balance fluctuating power production

Gas storage (11 TWh methan-gas)
Energy input to power-to-gas

Transmission system:
Interconnectors yearly accumulated energy in 2035 (2,3 TWh)

District heat+storage
Indivi. heat pump
El- og plugin hybrid case 2035

Wind-energy in the future energy system
SUMMING UP

- The COP21 (Paris) agreement on CO2 reduction is very ambitious and there is need for very large amounts of wind-power to decarbonise the power system.

- All three European ENTSO-E/G scenarios indicate very large increase in wind- and solar power production for Europe

- The North-Sea region is expected to be highly dominated by wind and a strong grid and efficient integration with heat and gas-system (Power-to-gas) is essential for balancing the power-system

- Development of new cost efficient grid-connection solutions is a focus area in offshore windpower area (e.g. North Sea Wind Power Hub - NSWPH)

- A need for further development of windpower to deliver ancillary services (including virtual inertia) to operate the power system with a minimum of thermal power plants in periods with high wind and solar.

- A need for further development of Power-to-gas solutions to integrate large amounts of windpower in the energy system
Gorde råd:
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Thank you for attention
Link: www.energinet.dk/energianalyser