Benefits of 100% renewable energy systems for Denmark - the IDA Climate Plan 2050
General introduction

Aalborg University, Denmark

- Master of Sustainable Energy Planning and Management
- PhD courses within the area
- More information at www.energyplanning.aau.dk
Denmark

- 22% wind power
- 120,000 owners of wind turbines (of 5 million)
- High share of the world’s offshore power
- (800 MW going on 1.200 MW)
- More than 30% distributed generation
- 50% of electricity from CHP
- Comprehensive energy conversation policy
Four decades of years of stable energy consumption with an active energy policy

Danish Primary Energy Supply

World Primary Energy Consumption

Oil
Coal
Natural Gas
Renewable Energy
Energy and Economic Growth in Denmark

Danish Energy Intensity

Index 1972 = 100

GDP
PES
Intensity

40 years of active Energy Planning


• Active Energy Policy put on hold by new government in 2001

• NGO strategies and public debate in more than 40 years
The long-term Objective of Danish Energy Policy

Expressed by former Prime Minister Anders Fogh Rasmussen in his opening speech to the Parliament in 2006 and in several political agreements since then:

To convert to 100% Renewable Energy

Former Prime Minister Rasmussen 16 November 2008:
"We will free Denmark totally from fossil fuels like oil, coal and gas"
"... position Denmark in the heart of green growth"

Prime Minister Lars Løkke Rasmussen 6 October 2009:
"... before the next general elections we will present a plan of how and when Denmark will be free of fossil fuels"
One scenario out of many possible pathways

• IDA’s Climate Plan 2050 (IDA: The Danish Society of Engineers)
  – Consists of:
  • Main report (also available in English)
  • Technical background report (also available in English)
  • 9 other technical reports
The IDA Climate Plan 2050

- 4 targets
  - To reduce the emission of greenhouse gasses by 90% in 2050 (including farming)
  - To maintain security of energy supply
  - To expand Denmark's position within energy and climate technologies
  - To improve the Danish economy and prosperity

Danish Energy Production, PJ

Energy and the Balance of payment

Future Climate
Engineering Solutions

Danish Energy Authority, 2008
The IDA Climate Plan 2050

  • Inputs based on 40 meetings and seminars conducted by the IDA groups and societies
  • More than 1600 participants
• More than 15 seminars and workshops following up on with updates of inputs
• Draft report presented on the May 11, 2009
• Subject to a public hearing until May 21, 2009
• Coordination by the IDA Committee for energy and climate and 12 groups of professionals
• Overall technical and socio-economic analyses at Aalborg University
The IDA Climate Plan 2050

- Input from 6 themes by IDAs groups
  - Energy systems and energy production
  - Agriculture
  - Industry, process and service
  - Buildings
  - Transportation and mobility
  - Climate adaptation

- Type of inputs:
  - Technology characteristics, costs and future potentials

For each theme
- Knowledge-seminar
- Future-seminar
- Roadmap-seminar
- Reality check
Coherent energy systems analyses

- Technical energy system analyses.
  - Potentials and problems?
  - Barriers and synergies?
  - System solutions?

- Socio-economic analyses.
  - Good and bad proposals?
  - What proposals make up a coherent total energy plan?
  - What is the total costs?
  - What are the abilities to profit from international trade?

EnergyPLAN energy system analyses model

- Planning model
- Deterministic input/output model
- Enables modelling of radical changes
- Integration of electricity, heat and transport sectors
- Modelling of large-scale integration of renewable energy
- Separation of technical and economic modelling not bound by current institutional schemes

www.EnergyPLAN.eu
Technical energy system analyses of IDA 2030

- Objectives:
  - Reduce excess electricity
  - Decrease fuel demand

<table>
<thead>
<tr>
<th>Step</th>
<th>Excess electricity</th>
<th>Boiler share</th>
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</thead>
<tbody>
<tr>
<td>Step 1: Starting Point</td>
<td>44%</td>
<td>10%</td>
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<tr>
<td>Step 2: CHP regulation</td>
<td>17%</td>
<td>36%</td>
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<tr>
<td>Step 3: Large Heat Pumps</td>
<td>16%</td>
<td>15%</td>
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<tr>
<td>Step 4: Flexible electricity demand</td>
<td>14%</td>
<td>16%</td>
</tr>
<tr>
<td>Step 5: Smart charge of battery electric vehicles</td>
<td>10%</td>
<td>20%</td>
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<tr>
<td>Step 6: FC regulation</td>
<td>5%</td>
<td>23%</td>
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</table>
### Primary energy consumption in IDA 2030, PJ

<table>
<thead>
<tr>
<th>Reference</th>
<th>Step 1</th>
<th>Step 2</th>
<th>Step 3</th>
<th>Step 4</th>
<th>Step 5</th>
<th>IDA 2030</th>
</tr>
</thead>
<tbody>
<tr>
<td>Wind, PV, wave power</td>
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<tr>
<td>Solar thermal</td>
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<tr>
<td>Biomass</td>
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<tr>
<td>Natural gas</td>
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<tr>
<td>Oil</td>
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<tr>
<td>Coal</td>
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</tbody>
</table>

### CO2-emissions in IDA 2030, mio. ton/year

<table>
<thead>
<tr>
<th>Reference</th>
<th>Step 1</th>
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<th>Step 3</th>
<th>Step 4</th>
<th>Step 5</th>
<th>IDA 2030</th>
</tr>
</thead>
<tbody>
<tr>
<td>Export</td>
<td></td>
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<td></td>
</tr>
<tr>
<td>Domestic consumption</td>
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</tbody>
</table>

### IDA 2030

- CHP regulation
- Large Heat Pumps
- Flexible electricity demand
- Smart charge of BEV
- FC regulation
Technical comparison

Primary energy consumption in IDA 2015, 2030 and 2050, PJ

Reference IDA

Primary energy consumption in IDA 2015, 2030 and 2050, PJ

Export
Wind, PV, wave power
Solar thermal
Biomass
Natural gas
Oil
Coal
Technical comparison

Primary energy consumption in IDA 2015, 2030 and 2050, PJ

Export
- Wind, PV, wave power
- Solar thermal
- Biomass
- Natural gas
- Oil
- Coal

Climate gas emissions in CO2-eq.

- Reference
- IDAs Climate Plan 2050
Socio-economic costs

Socio-economic costs in the 2015 reference

Socio-economic costs in the 2030 reference

Socio-economic costs in IDA 2015

Socio-economic costs in IDA 2030

Mio. €/year

CO2-costs

Fuel

O&M

Investment

60$/b-30€

122$/b -30€

132$/b -30€

60$/b-60€

122$/b -60€

132$/b -60€
Socio-economic costs

Socio-economic costs in the 2015 reference

Socio-economic costs in the reference

Socio-economic costs in the 2030 reference

Socio-economic costs in the Climate Plan

Socio-economic costs in the reference

Socio-economic costs in IDA 2015

Socio-economic costs in IDA 2030

Socio-economic costs in the Climate Plan

Socio-economic costs in the reference

Socio-economic costs in IDA 2015

Socio-economic costs in IDA 2030

Socio-economic costs in the Climate Plan
- Status 2008 approx. 64 mia. DKK and approx. 30.000 jobs
- IDAs Energy Plan 2030 from 2006: 160 mia. DKK
- Association of Danish Industry and the energy Industry in: 200 mia. DKK and approx. 60.000 jobs

Please note that such estimates, are associated with significant uncertainties.
Job effects

- The extra jobs created in the Climate Plan compared to the reference are in the range of 30,000-40,000 in the period towards 2050
  - Fewer jobs for fossil fuel handling
  - Jobs created from investments in renewable energy technology, in building improvements and in the handling of biomass
  - The amount of jobs in the short term depends on when the initiatives are started
  - In the long term, when the Climate Plan is fully implemented the extra employment will fall to approx. 15,000

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<thead>
<tr>
<th></th>
<th>2010</th>
<th>2030</th>
<th>2050</th>
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<tbody>
<tr>
<td>Fuels</td>
<td>-2,929</td>
<td>-16,431</td>
<td>-4,177</td>
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<tr>
<td>Operations and Maintenance</td>
<td>-451</td>
<td>5,838</td>
<td>18,312</td>
</tr>
<tr>
<td>Inv. (Civil works)</td>
<td>23,450</td>
<td>22,190</td>
<td>20,930</td>
</tr>
<tr>
<td>Inv. (Prod. &amp; Machinery)</td>
<td>9,420</td>
<td>9,300</td>
<td>9,180</td>
</tr>
<tr>
<td>Total</td>
<td>29,490</td>
<td>20,898</td>
<td>44,245</td>
</tr>
</tbody>
</table>
Job effects

• There are two reasons to start the conversion in the beginning of the period towards 2050:
  – Labour is available in the beginning of the period as the work force of the total population is falling towards 2040
  – More and more labour will be available as fossil fuels in the North See becomes less and less.

• Additional potential job effects as a result of the potential for increased export:
  – Approx. 200,000 jobs (with 50 per cent import share)

• Please note that such estimates, are associated with significant uncertainties
Health costs in the Climate Plan

Health costs

- Transport
- Boilers (heat)
- Power and CHP plants

Million DKK/year

<table>
<thead>
<tr>
<th>Year</th>
<th>2015</th>
<th>2030</th>
<th>2050</th>
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CEESA Overall Objective

- Coherent Energy and Environmental System Analyses [www.ceesa.dk](http://www.ceesa.dk)
- A multi-disciplinary co-operation involving:
  - Life cycle assessment
  - Market analyses
  - Energy system analyses
- Goal – pathway to implementing and technically handling 100% renewable energy system and coherent analysis of 100 per cent renewable energy systems
- To integrate existing energy and environmental analysis tools through a combination of life cycle assessment (LCA) and energy system and market analysis methodologies (ESA).
- Budget: DKK 21 million (EUR 2.8 million)
Summary and conclusions

• Showing what may be possible is important to illustrate and document possible changes

• IDA’s Climate Plan 2050 has already had that effect in Denmark

• The results in the Climate Plan are:
  • 100% renewable energy systems will be technically possible
  • In the short term the Danish society can benefit from lower costs
  • In the long term the cost of 100% renewable energy systems are potentially lower than traditional systems (the total system)
  • The total emissions of green house gasses incl. Agriculture can be reduced by 90%.
  • There are additional potential benefits for job creation, export and lower health related costs.
  • 80% of technologies invested in are known today
Thank you