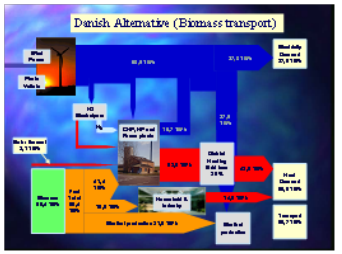
9th Annual ASPO Conference

Albert Hall, Brussels

27-29 April 2011



Integration of Renewable Energy Sources in the European Electricity Grid

Henrik Lund

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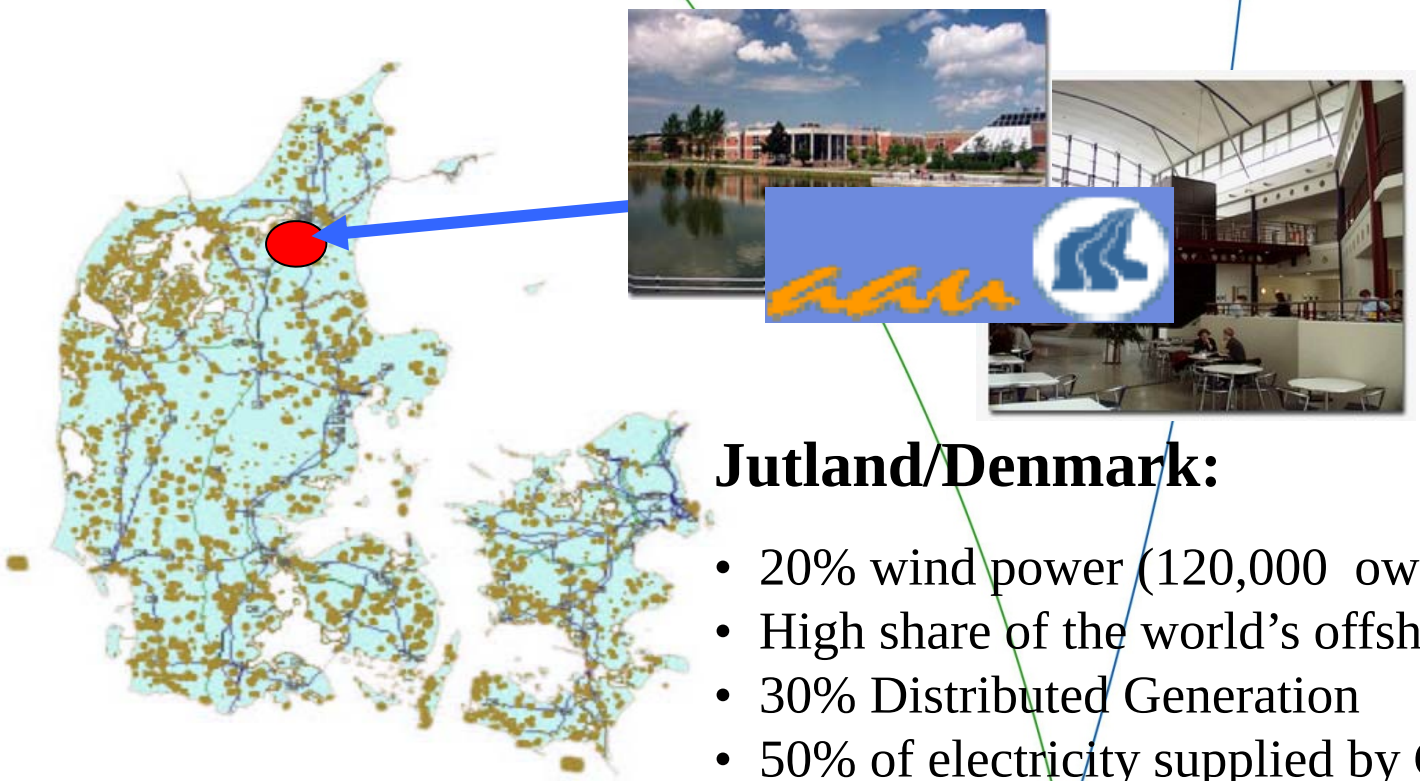
Aalborg University, Denmark



Jutland/Denmark:

- 20% wind power (120,000 owners)
- High share of the world's offshore power
- 30% Distributed Generation
- 50% of electricity supplied by CHP

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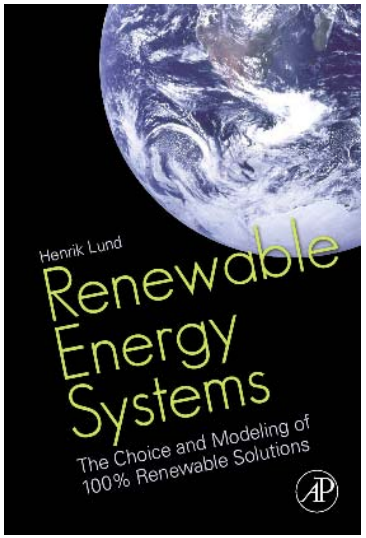
Content



- Renewable electricity production
  and sustainable energy solutions
- Electricity Balancing:
  CHP and transport is part of the solution
- Smart Grid and CHP: The case of Skagen

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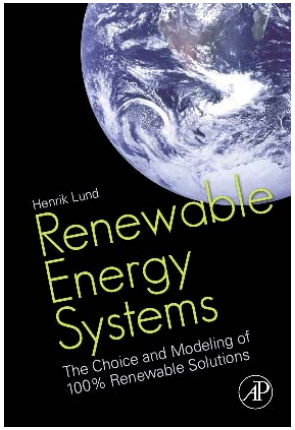
Sustainable energy systems



- A sole focus on renewable **electricity** production leads to storage solutions!

- Looking at renewable electricity as a part **energy systems** including heating, industry and transportation opens for cheaper and better solutions…

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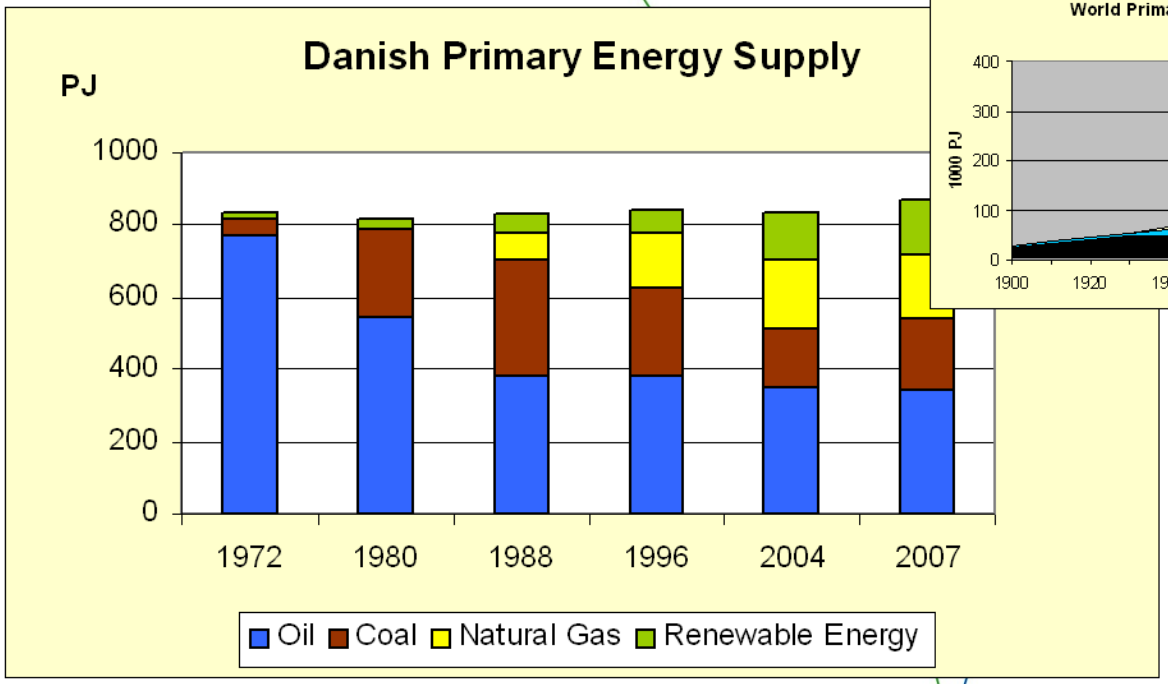
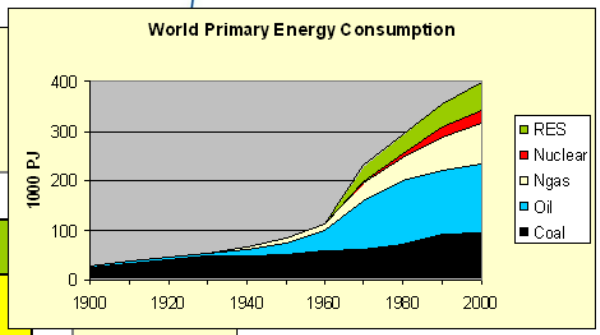
40 years with a stable energy consumption





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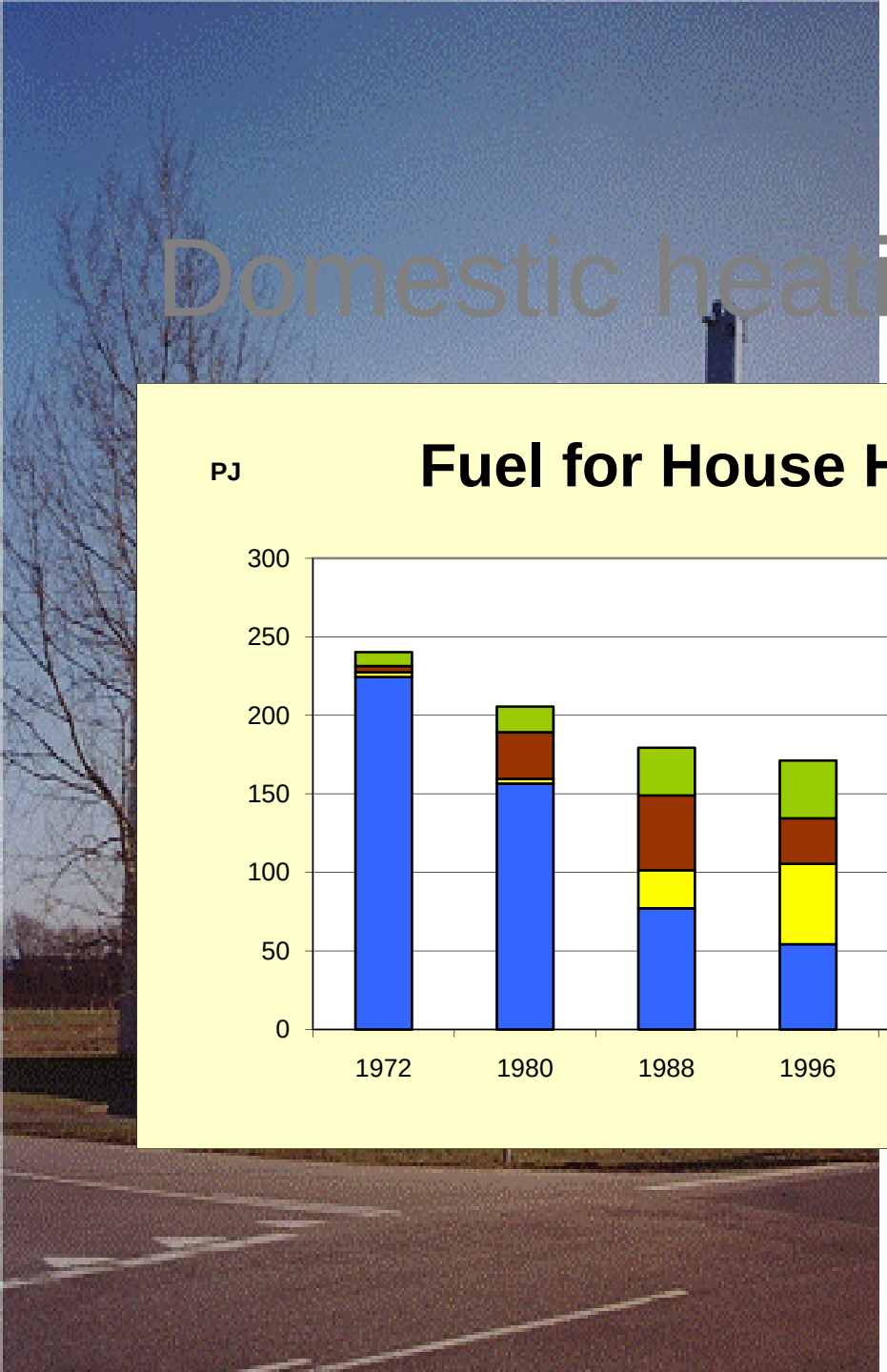
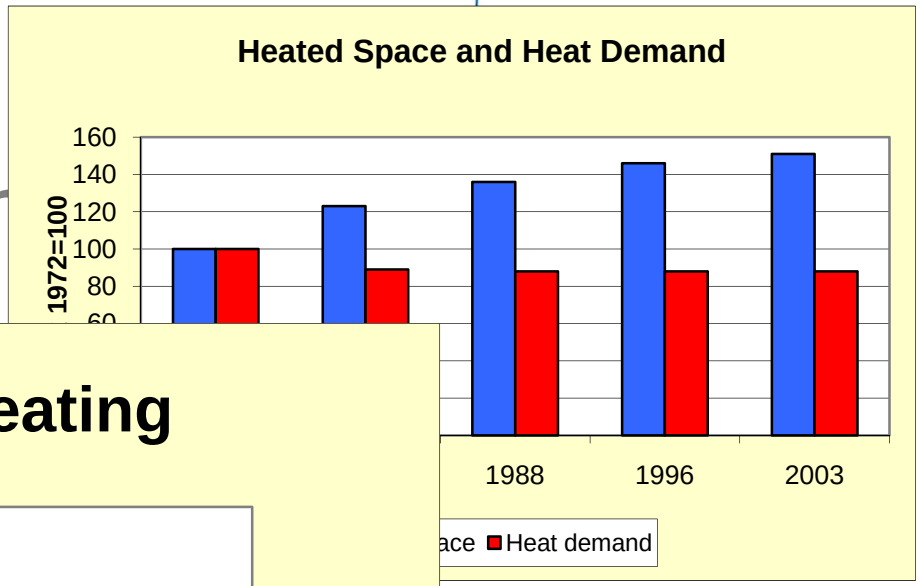
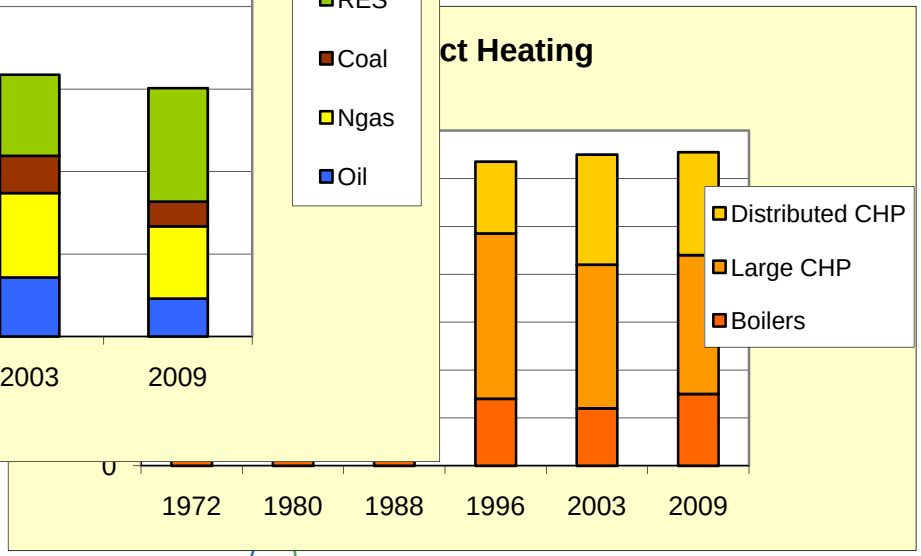


Domestic heatir



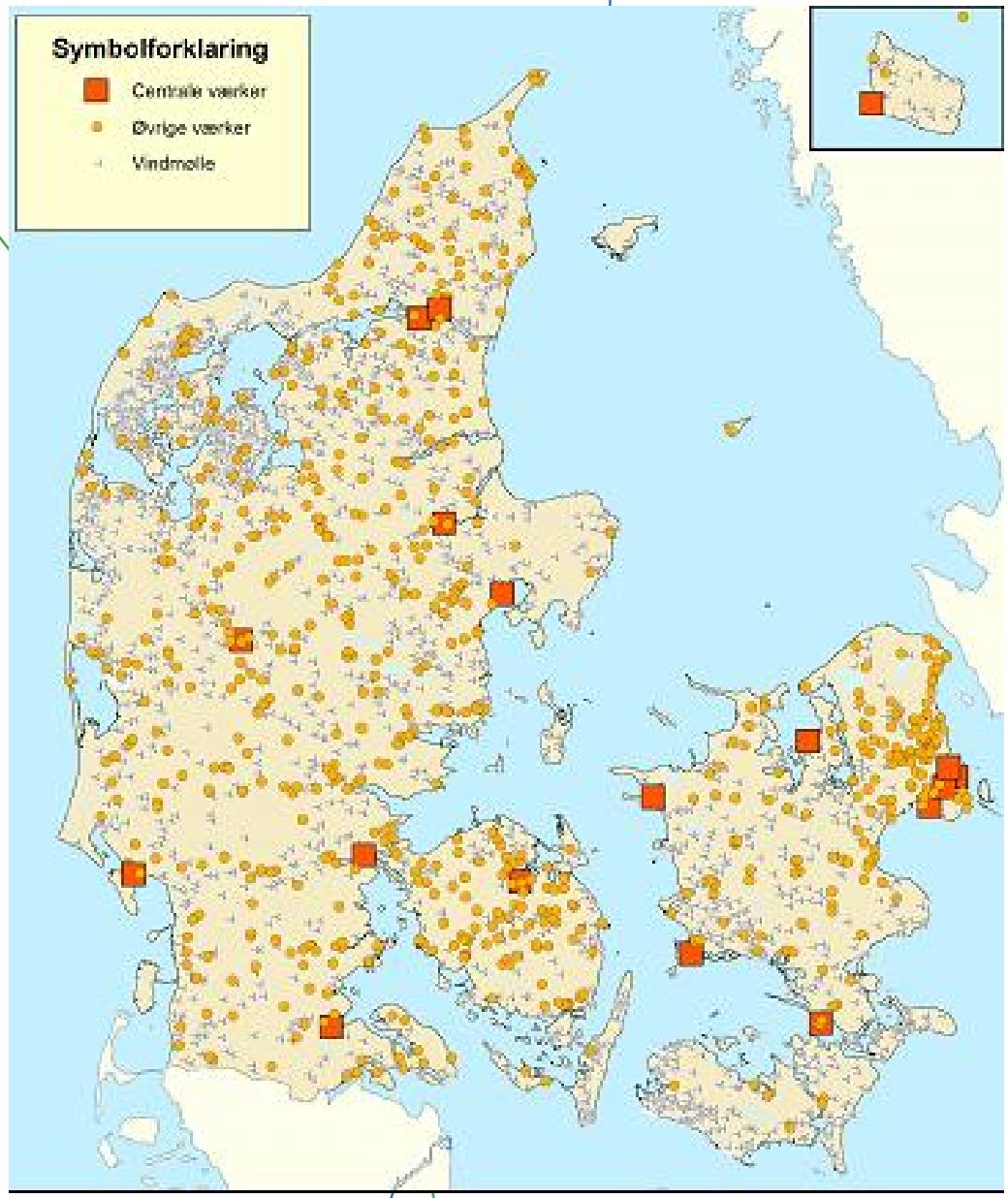


Danish electricity production

Big power stations

Small CHP plants

Wind turbines



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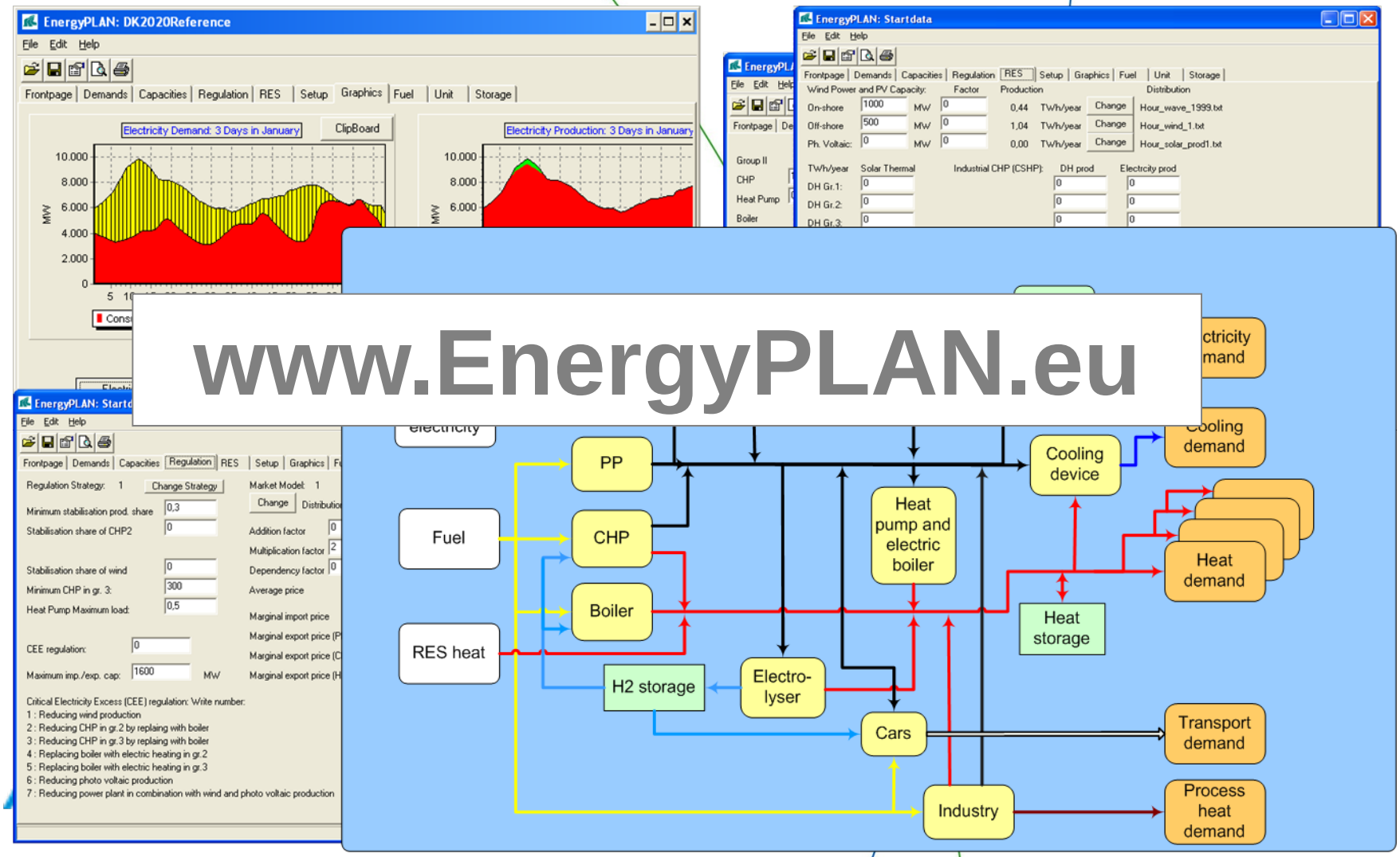
ENERGISTYRELSEN

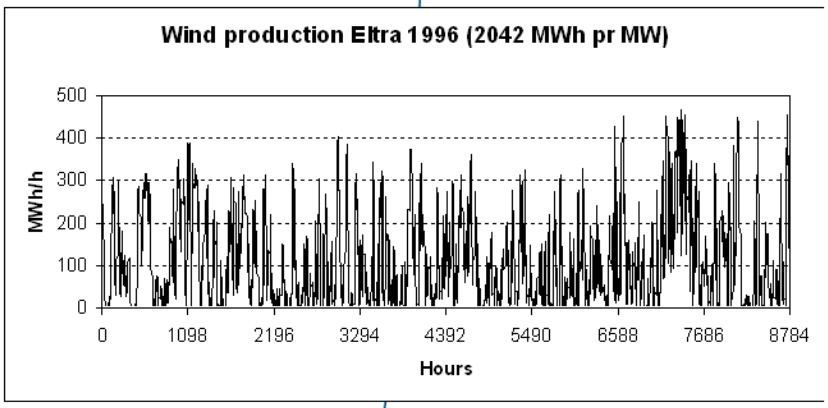
Energy System Analysis Model

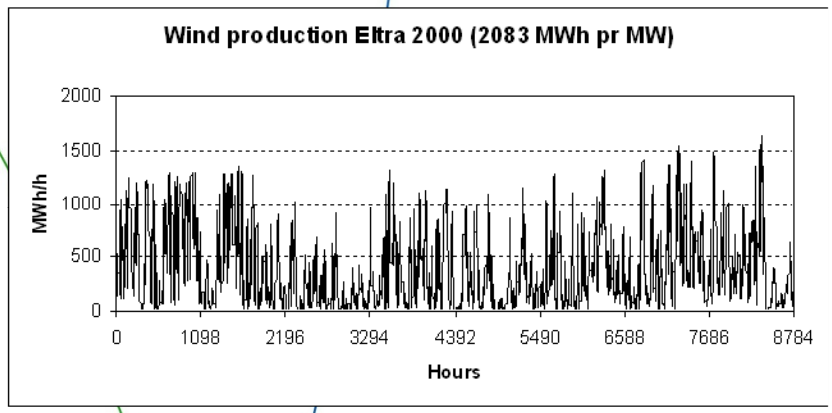


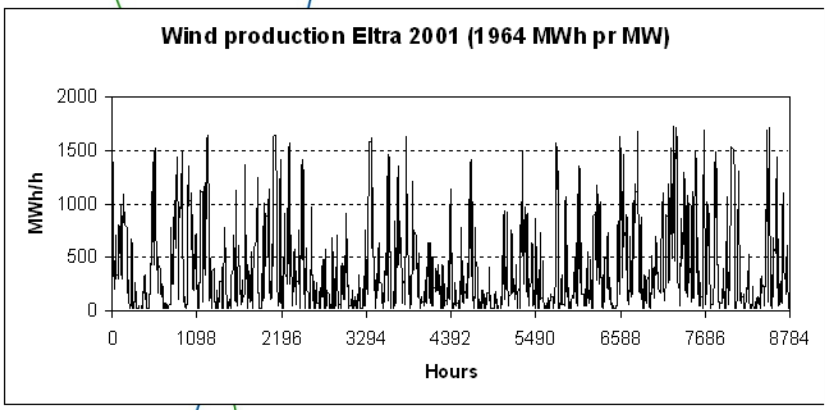
Wind energy

Input:

- Data from total productions of wind turbines in the TSO Eltra area (West Denmark).







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At present 99% of Danish Wind Power is used in Denmark to meet Domestic demands

By
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Bernd Möller, Brian Vad Mathiesen
Department of Development and Planning, Aalborg University, Aalborg

Anders N. Andersen
EMD International, NOVI Research Park, Aalborg, Denmark

Poul Erik Morthorst, Kenneth Karlsson, Peter Meibom
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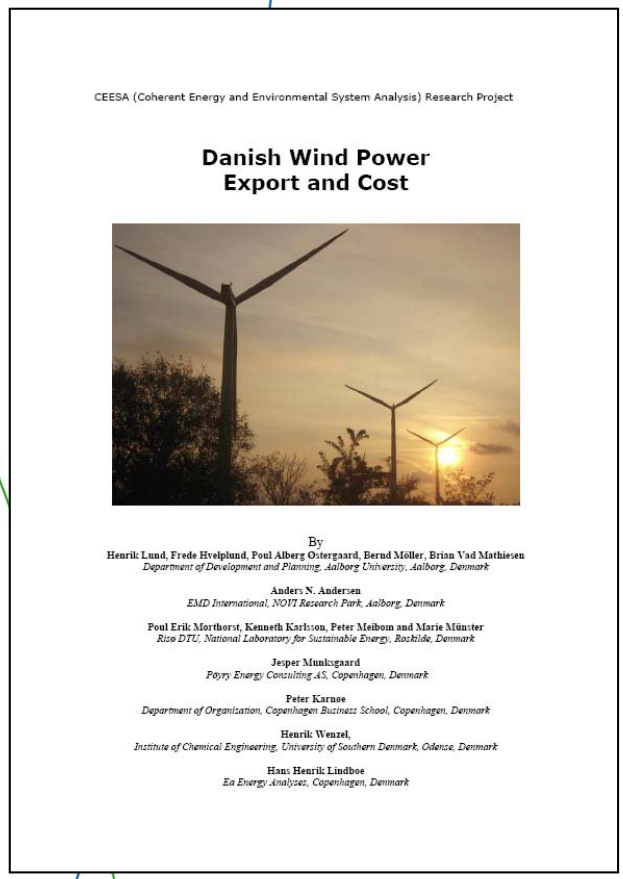
Henrik Wenzel,
Institute of Chemical Engineering, University of Southern Denmark, Odense, Denmark

Hans Henrik Lindboe
Ea Energy Analyses, Copenhagen, Denmark


CEESA (Coherent Energy and Environmental System Analysis) Research Project

Danish Wind Power
Export and Cost

By
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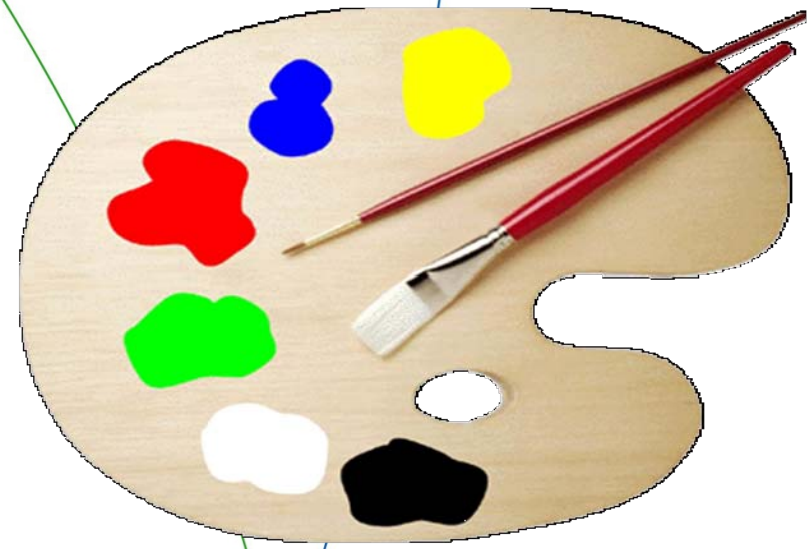
A palette of solutions

- Flexible consumption
- Electricity storage
- CAES systems
- Regulation of CHP plants
- Electric heating
- Heat pumps
- Electric cars
- Stopping of wind turbines
- Production of hydrogen
- Transmission abroad
- V2G



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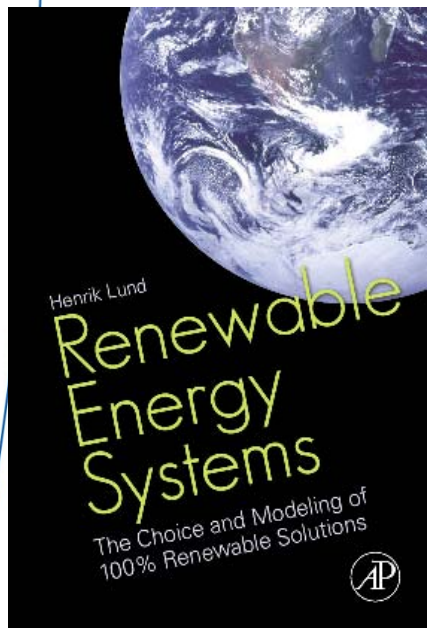
Conclusions:



- Regulation of CHP and heat storage (implemented in DK in 2004): Makes possible to integrate 20% Wind Power (and 50% CHP)
- Adding large heat pumps and heat storage capacity to existing CHP plants: Makes possible to integrate 40% Wind Power (and 50% CHP)
- Electricity for transportation (integrate approx. 60% wind power)
- Important to involve the new flexible technologies in the grid stabilisation task

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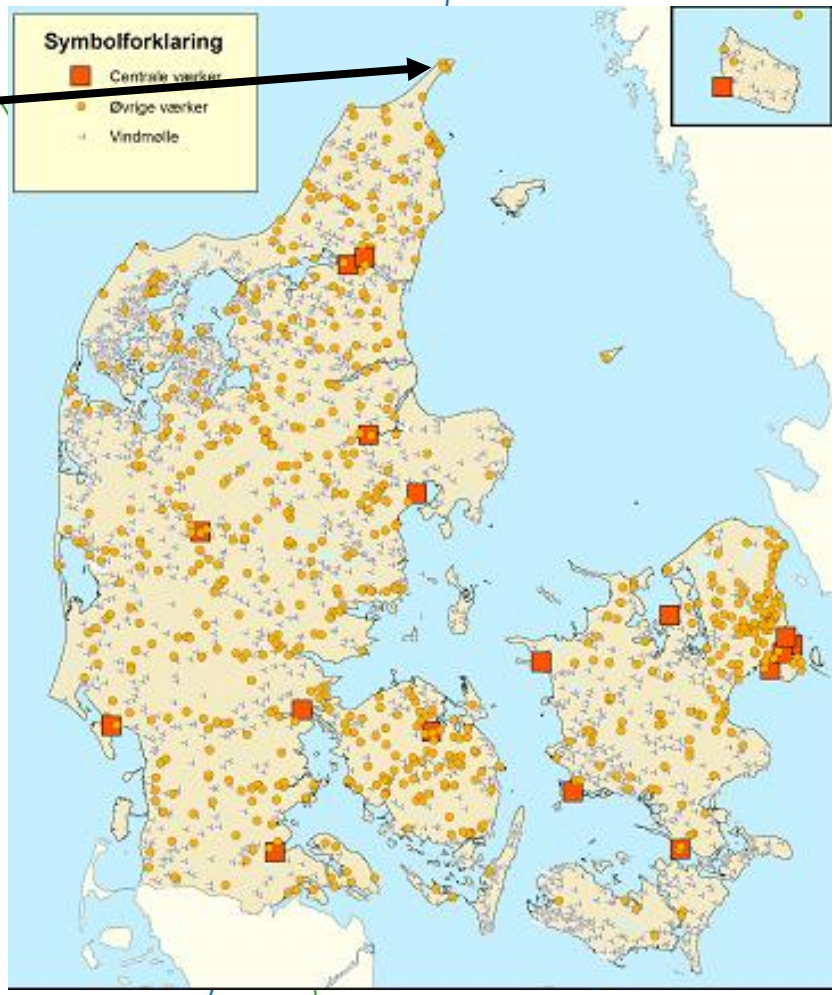
Case: Skagen CHP plant



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Skagen CHP plant

- CHP capacity: 13 MWe and 16 MWth
  (Three 4.3 MWe Wärtsilä Natural Gas engines
- 250 MWh heat storage
- 37 MW peak load boilers
- 10 MW electric boiler
- Heat Pumps Investment under consideration

Operated together with a

Waste Incineration plant (heat only).

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The main electricity markets

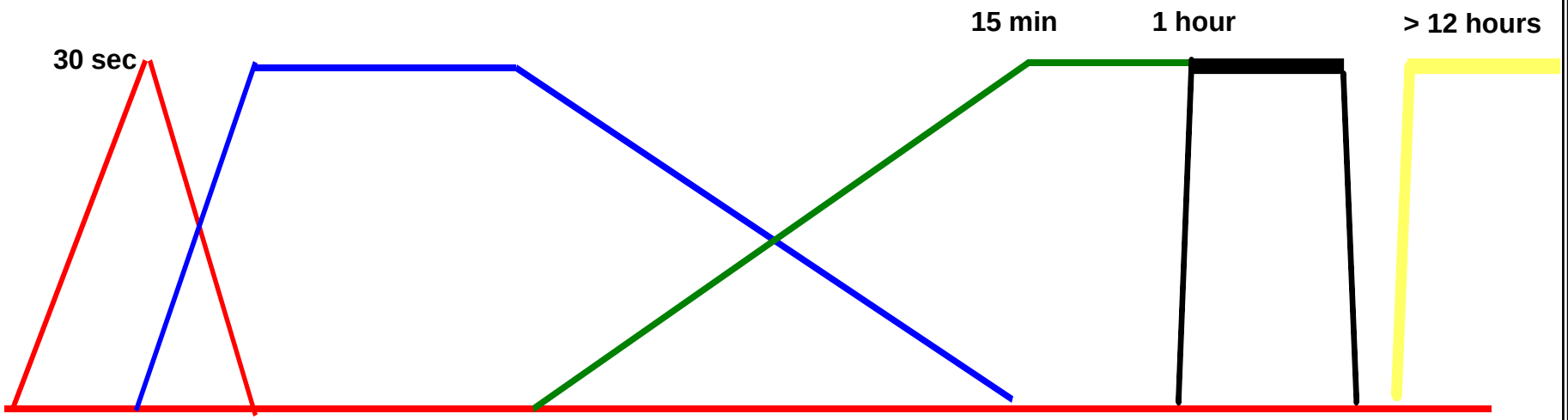
Primary reserves (frequency controlled production)

Secondary reserves (controlled by status of primary reserves)

Manuel regulating power (Tertiary reserves)

Intra day market

Day ahead spot market



Skagen

- Day ahead spot market in Jan. 2005
- Regulating power market in approx. 2006
- Automatic primary reserve market in Nov. 2009

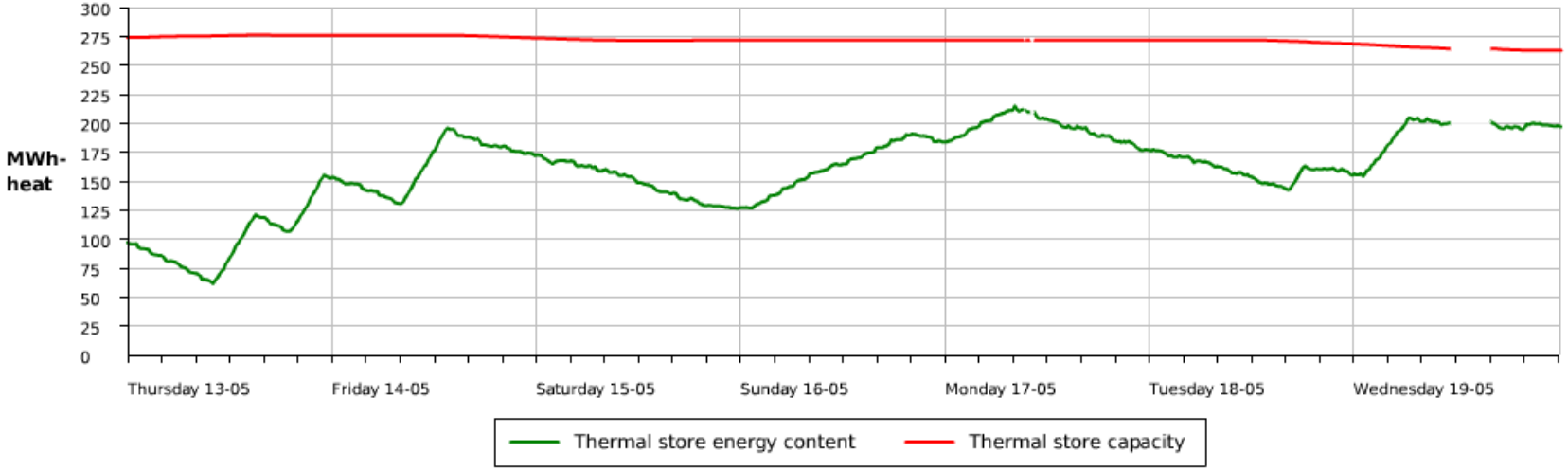
Cost of entering primary automatic reserves market

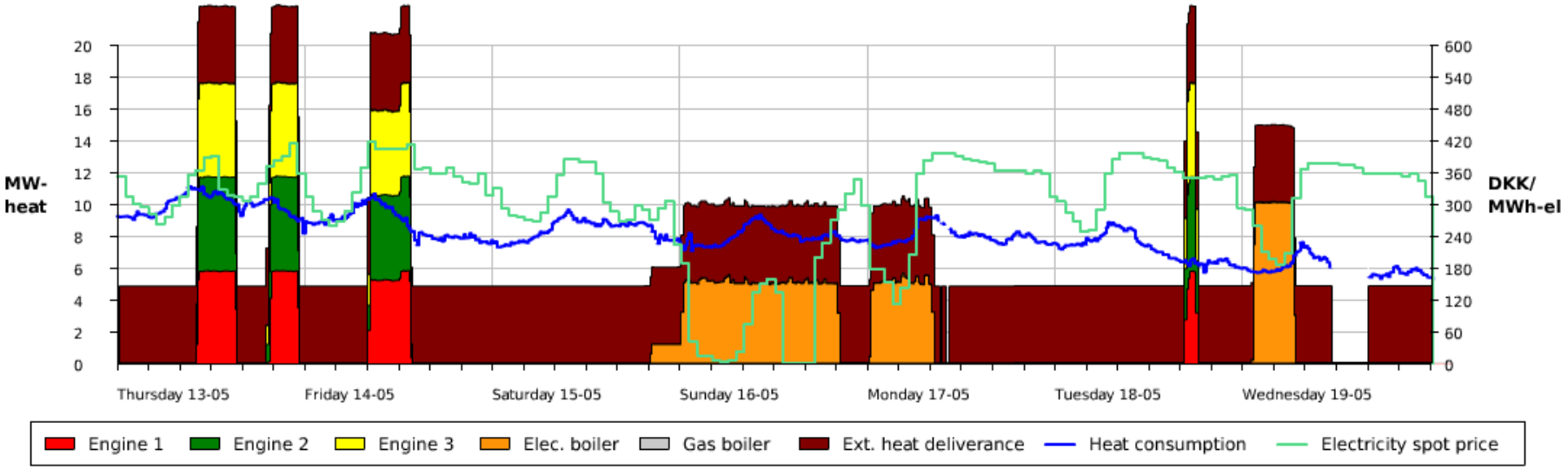
- Cost of making +- 1.4 MW available on the engines: Only approx. 27.000 EUR.

- Investing in 10 MW electric boiler:

  Approx 0.7 MEUR.

Skagen CHP, history - Wednesday, 19-05-2010

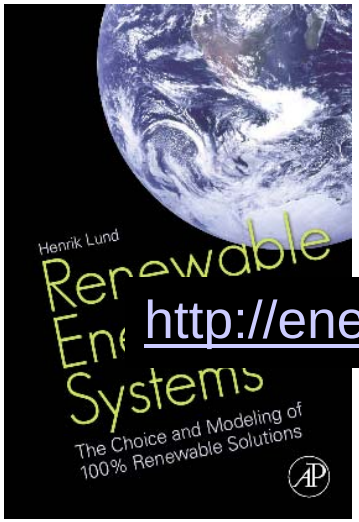




Conclusions

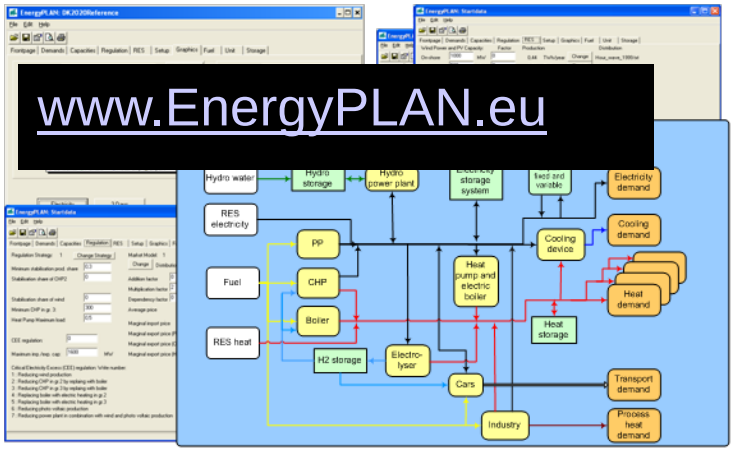
- Denmark can operate a system with 20% Wind and 50% CHP
- By adding heat pumps to the CHP units the integration of wind power can be raised to approx. 40% with-out loosing efficiency (nor wind power)
- Including the CHP plants in the various electricity markets is essential.
- Once the markets are open for CHP plants the cost of entering them seams small.

More information

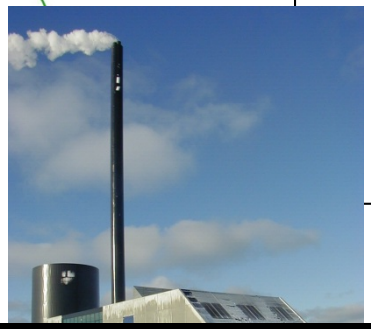


http://energy.plan.aau.dk/book.php

www.energyplanning.aau.dk



www.EnergyPLAN.eu



- http://www.emd.dk/desire/skagen
- http://www.emd.dk/el

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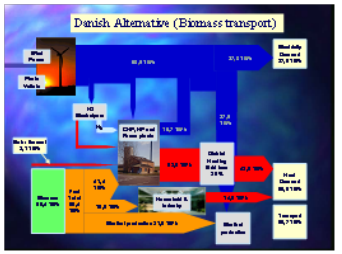

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