The Role of District Heating in Danish Sustainable Energy Supply

11 June 2013

Sustainable Cities event, Danish-French sharing on high quality & efficient city solutions

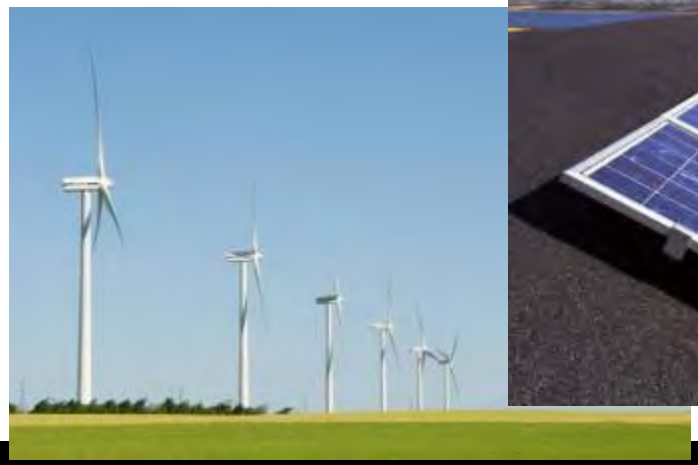
Organized by The Danish Embassy in Paris and DI
La Maison du Danemark, Paris
Associate Professor Brian Vad Mathiesen,
Department of Development and Planning, Aalborg University
people.plan.aau.dk/~bvm/

100% Renewable energy and transport systems

- The importance of CHP and Wind Power in Denmark
- Electricity Balancing CHP is part of the solution
- Smart Grid and CHP: The case of Skagen





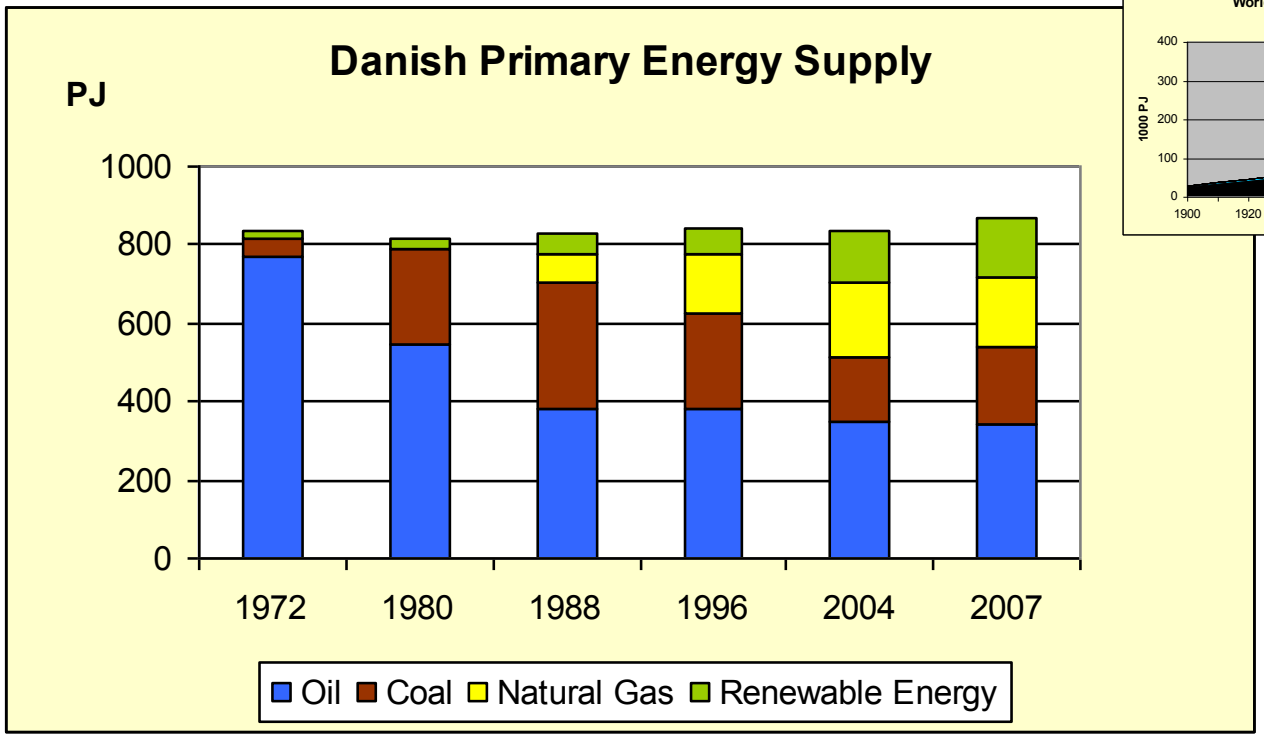
©Brian Vad Mathiesen
bvm@plan.aau.dk

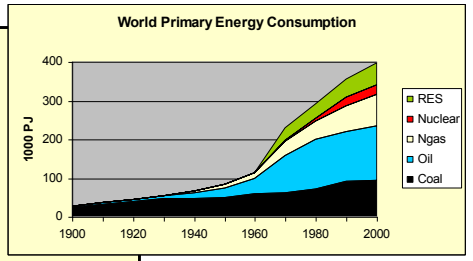
40 years of active Energy Planning

- 40 years of active Government and Parliament Energy Policies.
- Active Energy Policy put on hold by new government in 2001
- NGO strategies and public debate in more than 40 years

bvm@plan.aau.dk

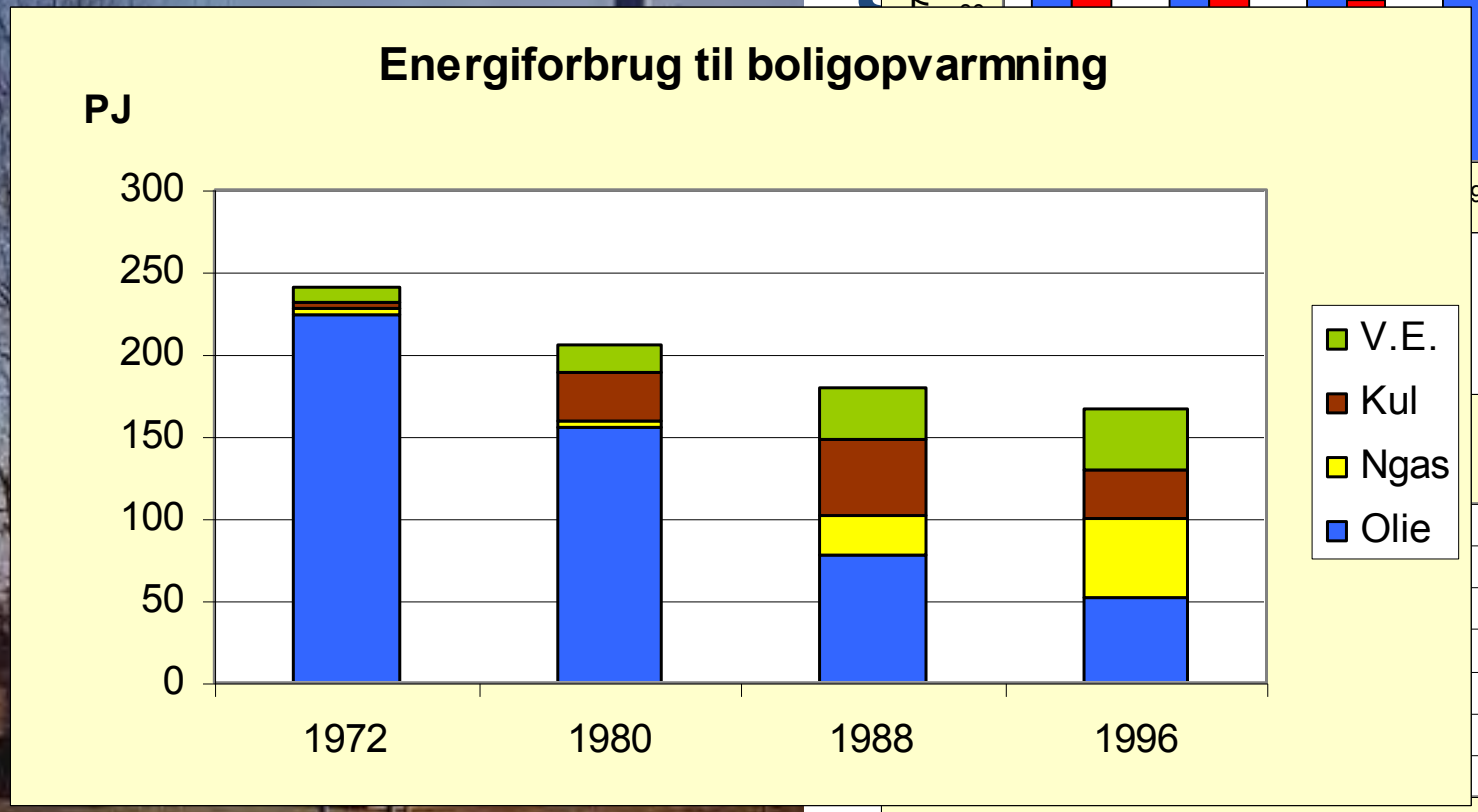
Four decades of years of stable energy consumption with an active energy policy

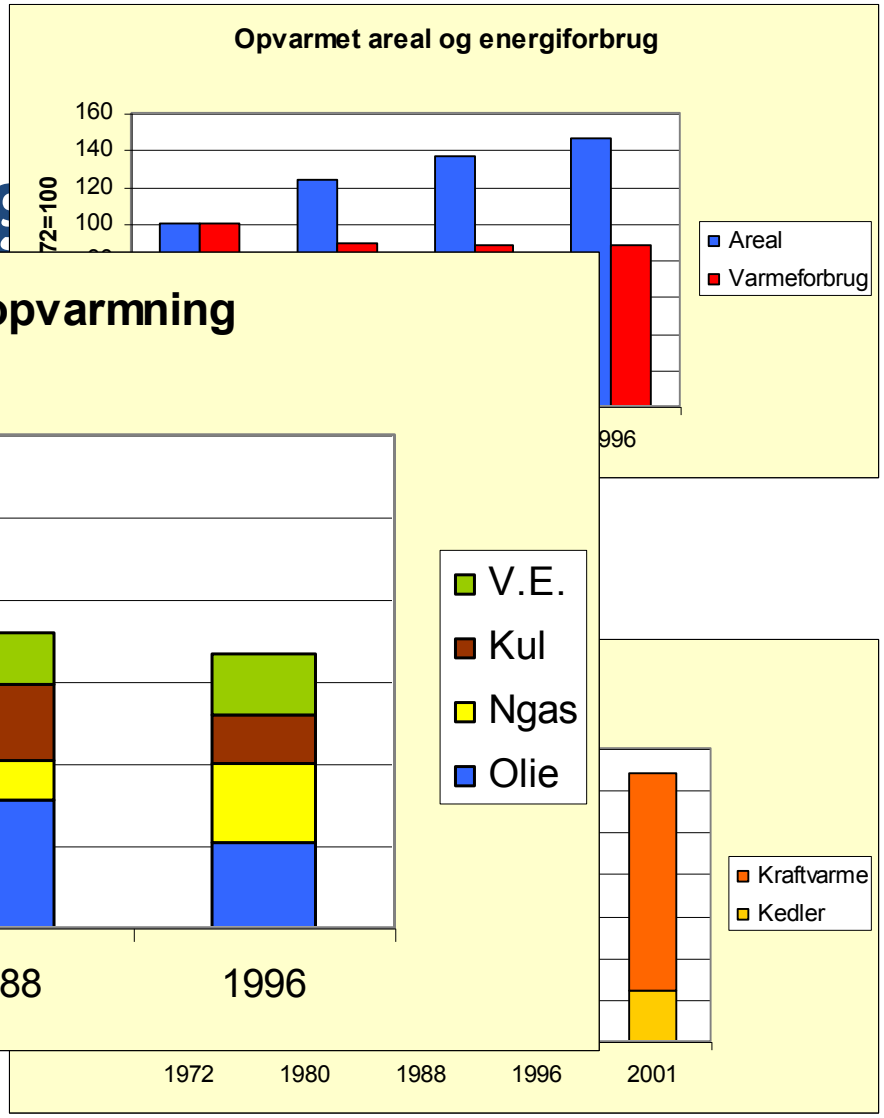




bvm@plan.aau.dk

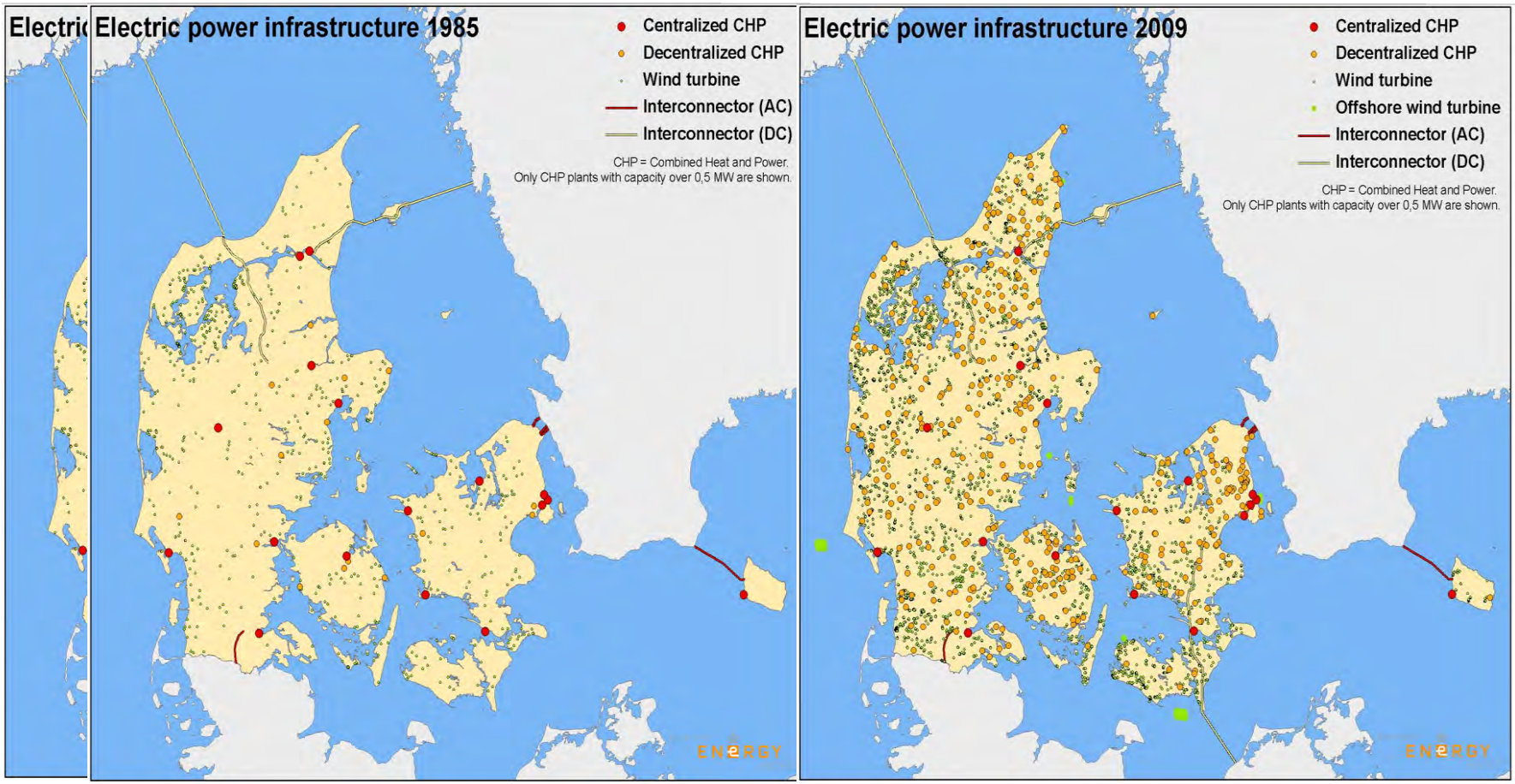
Domestic heating





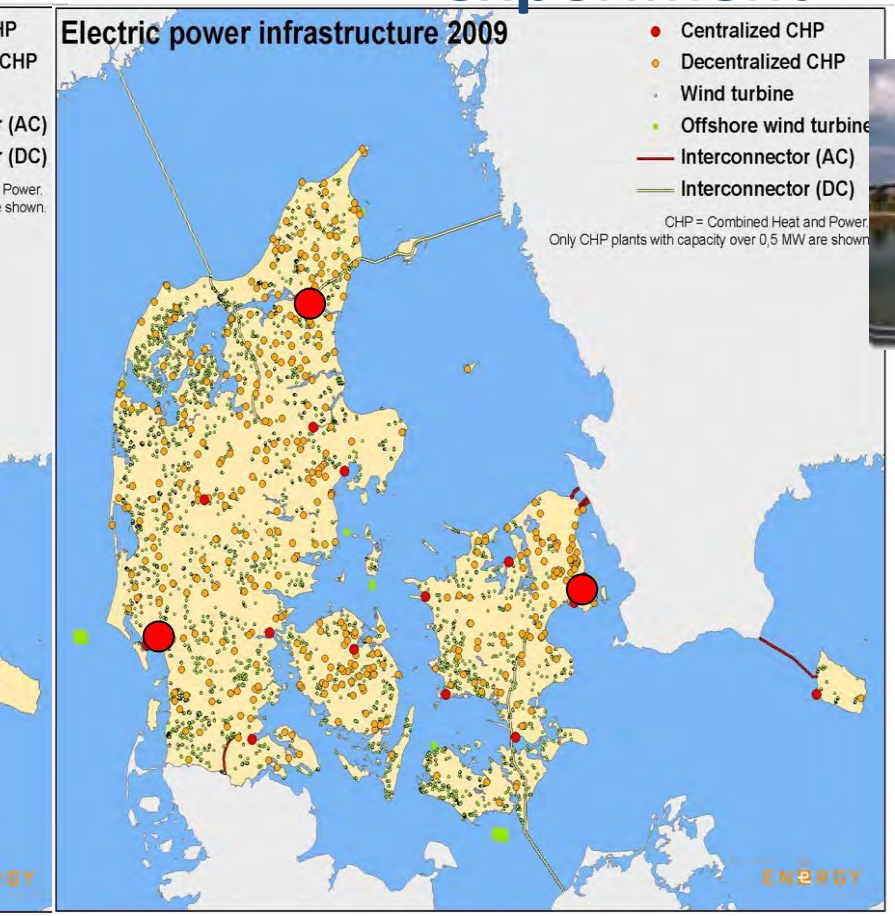
©Brian Vad Mathiesen
bvm@plan.aau.dk

Transition from a hierarchal centralised to a semi-decentralised energy system – Status



©Brian Vad Mathiesen
bvm@plan.aau.dk

Energy research in a real life experiment



Key facts for energy in Denmark

- 5,6 Million inhabitants

2012:

- 30% (app. >35% in Jylland) wind power
- Approx. 120,000 owners of wind turbines
- High share of the world's offshore power
- More than 30% distributed generation
- 50% of electricity from CHP
- >60% of houses have district heating
- Comprehensive energy conservation policy

©Brian Vad Mathiesen
bvm@plan.aau.dk

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

By
Henrik Lund, Frede Hvelplund, Poul A. Østergaard,
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
and Marie Münster
Risø DTU, National Laboratory for Sustainable Energy, Roskilde, Denmark

Jesper Munksgaard
Pöyry, Copenhagen, Denmark

Peter Karnøe
Department of Organization, Copenhagen Business School, Copenhagen,Denmark

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

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:

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

To convert to 100% Renewable Energy

New broad agreement in March 2012 with 2020 targets on energy savings and 50% wind power + 2050 100% RE target

bvm@plan.aau.dk

Systemintegration

Energy saving

Efficient convertion

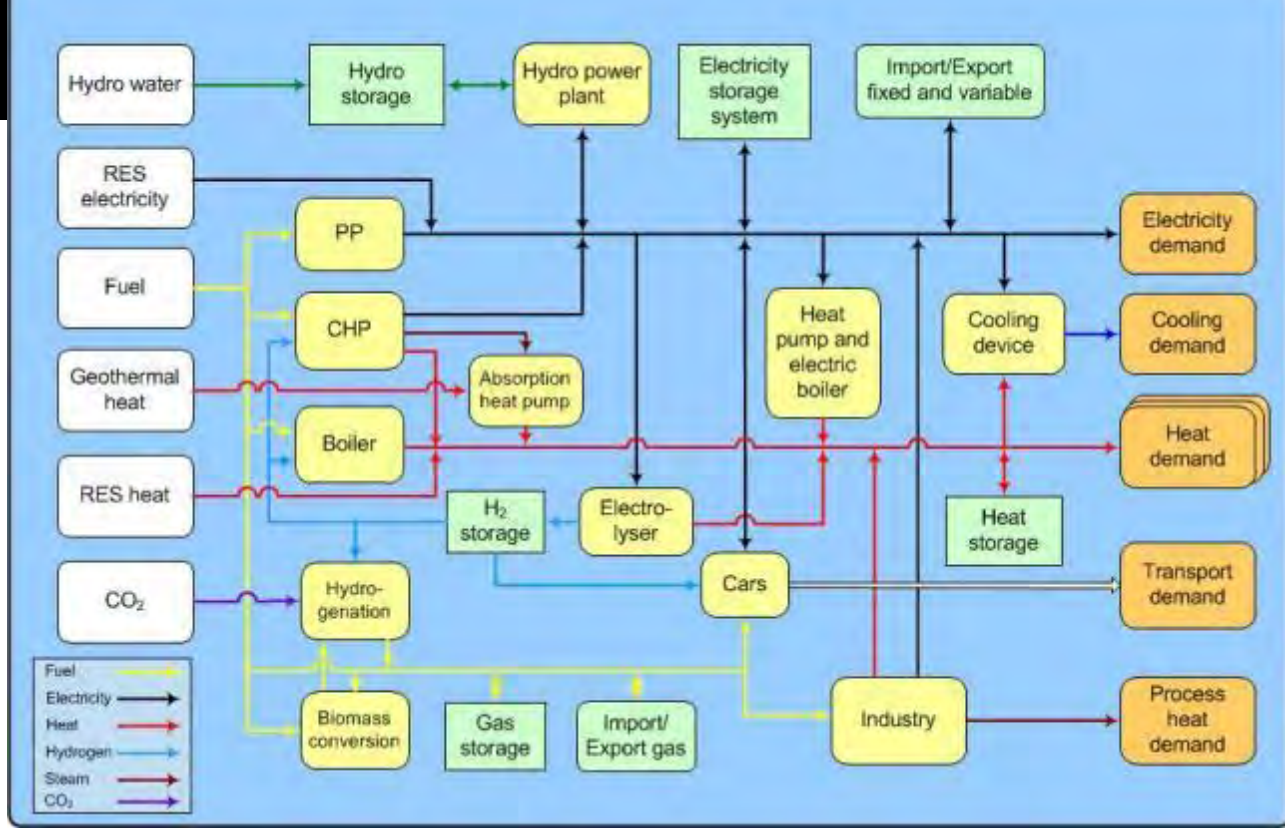
Flexible system integration teknologies

Renewable energy

bvm@plan.aau.dk

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?

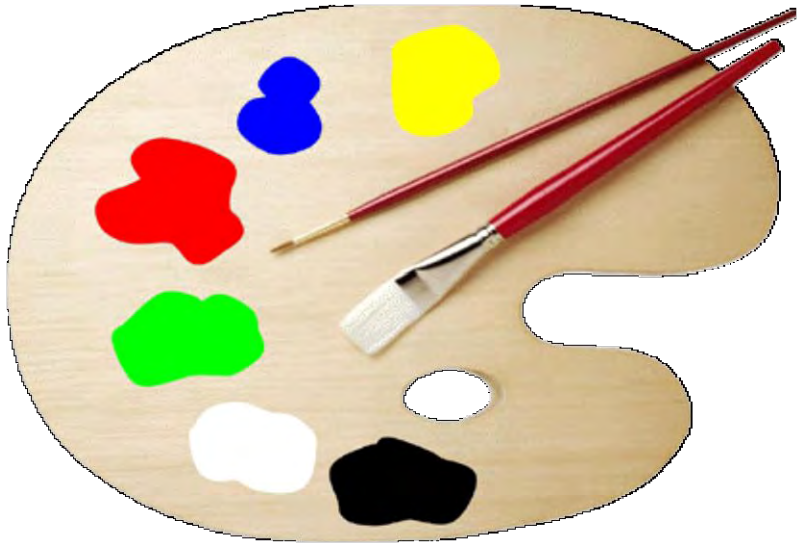
- EnergyPLAN energy system analyses tool
  - ***Free software***
  - Planning model
  - Deterministic input/output model
  - Enables modelling of radical changes
  - Integration of electricity, heat and transport sectors
  - Modelling of large-scale integration of renewable energy
  - Separation of technical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

www.EnergyPLAN.eu

©Brian Vad Mathiesen
bvm@plan.aau.dk

A palette of solutions

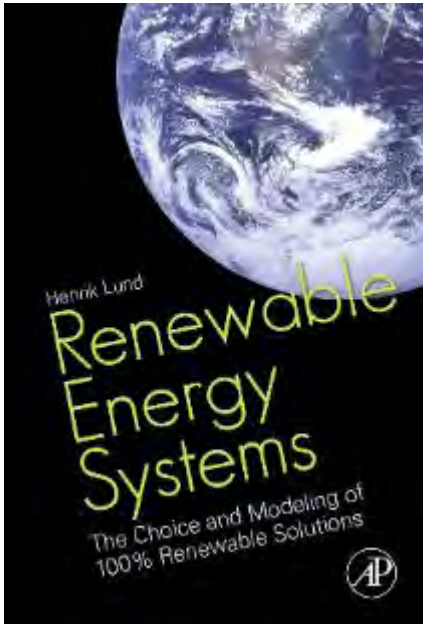
- Flexible consumption
- Electricity storage
- CAES systems
- Regulation of CHP plants
- Electric heating
- Heat pumps
- Electric cars
- Stopping of wind turbines
- Production of hydrogen
- Transmission abroad
- V2G



bvm@plan.aau.dk

Conclusions of our research:

- 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



bvm@plan.aau.dk

Smart energy systems are crucial in 100% renewable energy systems

Electricity smart grids are only one part of this system. The scenarios rely on a holistic *smart energy system* including the use of:

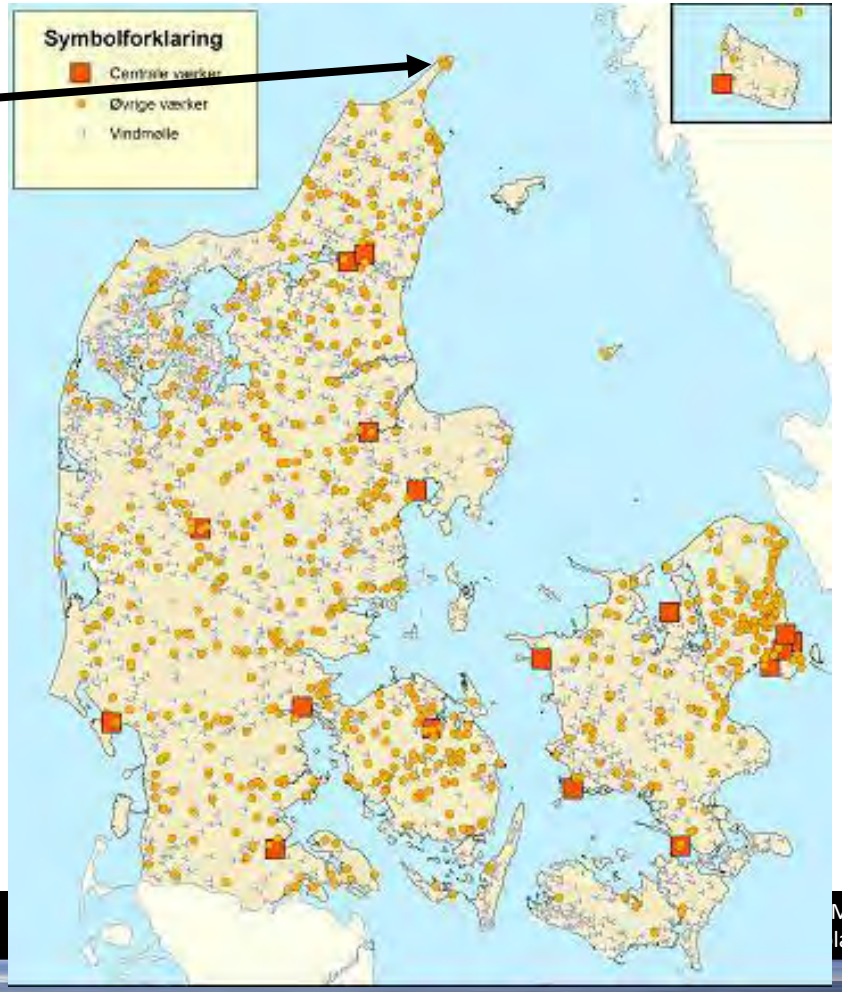
- ***Heat storages*** *and district heating with CHP plants and large heat pumps.*
- ***New electricity*** *demands from large heat pumps and electric vehicles as storage options.*
- ***Electrolysers and synthetic liquid fuel*** for the transport sector, enabling energy storage in a dense liquid form;
- ***The use of gas storage and gas grids*** for biogas and syngas/methane

Flexible integration of electricity, heat, gas and transport

www.CEESA.plan.aau.dk

bvm@plan.aau.dk

Case: Skagen CHP plant



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 considerati

Operated together with a
Waste Incineration plant (heat only).

bvm@plan.aau.dk

The main electricity markets

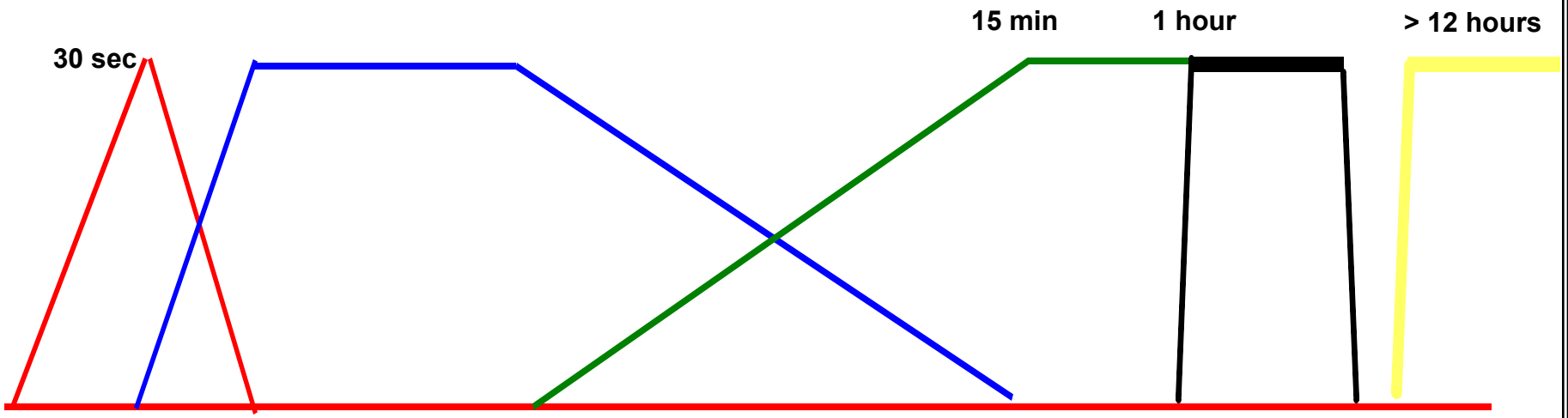
Primary reserves (frequency controlled production)

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

bvm@plan.aau.dk

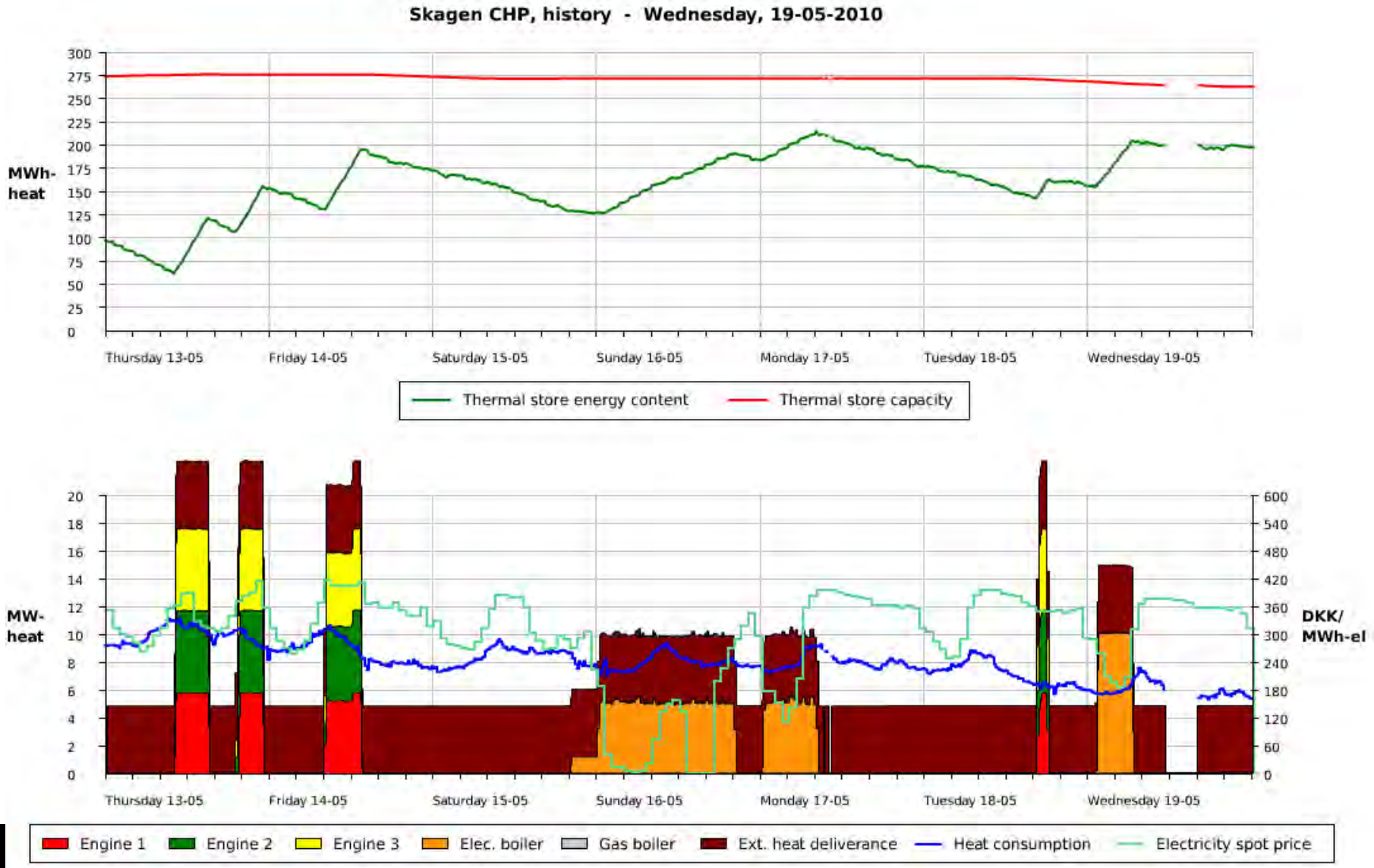
Cost of entering primary automatic reserves market

- 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.

bvm@plan.aau.dk


Skagen CHP, history - Wednesday, 19-05-2010
MWh-heat
300
275
250
225
200
175
150
125
100
75
50
25
0
Thursday 13-05
Friday 14-05
Saturday 15-05
Sunday 16-05
Monday 17-05
Tuesday 18-05
Wednesday 19-05
Thermal store energy content
Thermal store capacity
MW-heat
20
18
16
14
12
10
8
6
4
2
0
600
540
480
420
360
300
240
180
120
60
0
DKK/MWh-el
Engine 1
Engine 2
Engine 3
Elec. boiler
Gas boiler
Ext. heat deliverance
Heat consumption
Electricity spot price

Short term challenges!

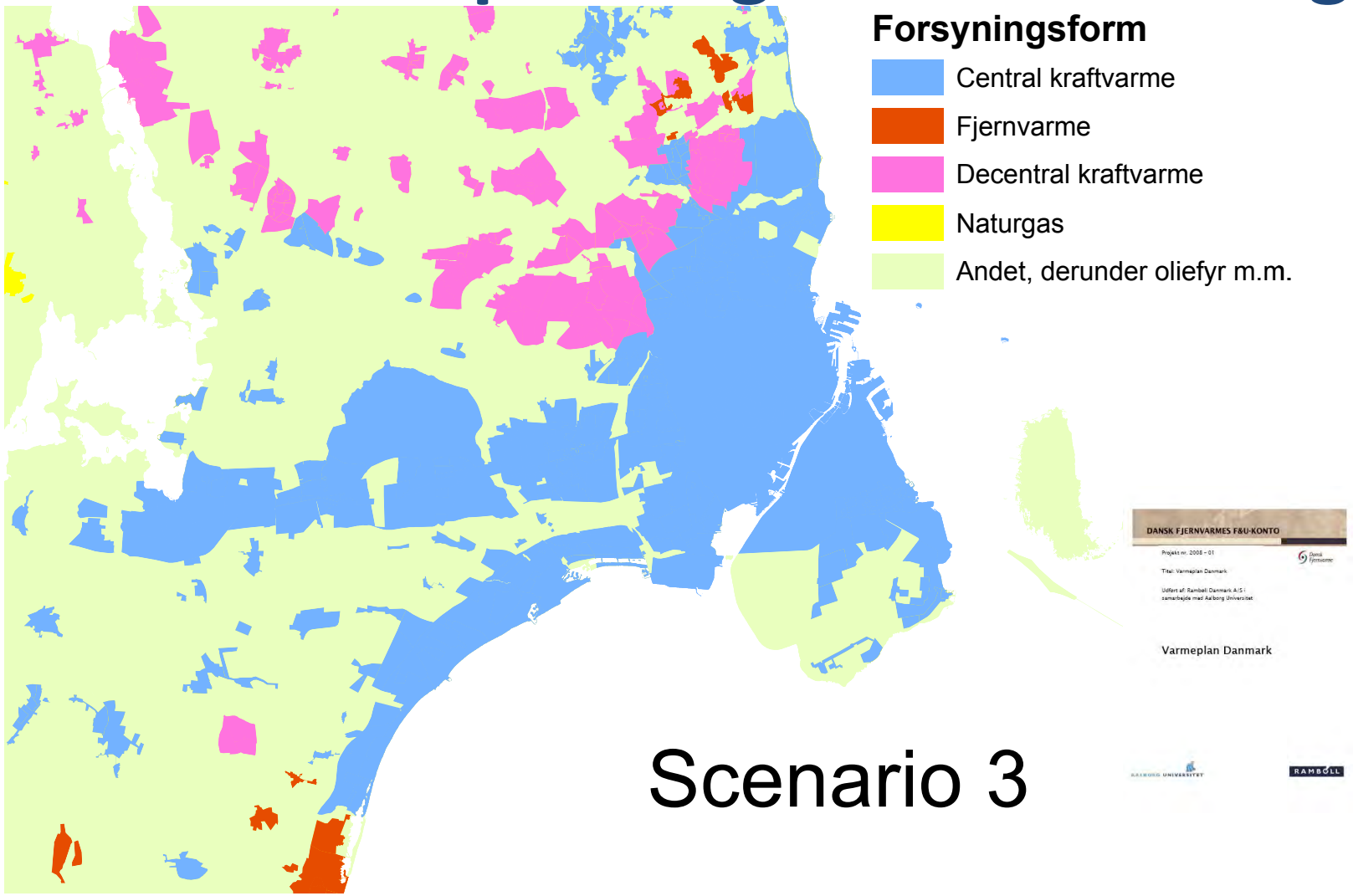
- Implement those energy saving!
- We need more wind turbines
- Implement the next step in the smart energy system – i.e. install large heat pumps (and CHP)
- Avoid suboptimal storage in individual houses and single house heating systems
- Plan flexible CHP plants
  – Risk of lock in to base load thermal biomass plants
- Long term planning for short term transport infrastructure investments
- Fuels based on renewable energy for transport that enables the long term objective of hydrogenation

- Activation of local communities

70-80% of investments in future 100% RE systems are made in known technologies (in IDA 2050)

bvm@plan.aau.dk

Scenarios for expanding district heating



Scenario 3

©Brian Vad Mathiesen
bvm@plan.aau.dk

EUROHEAT & POWER

Pre-study

Heat Road Map Europe

4DH
4th Generation District Heating Technologies and Systems

Aalborg University

David Connolly

Brian Vad Mathiesen

Poul Alberg Østergaard

Bernd Möller

Steffen Nielsen

Henrik Lund

Halmstad University

Urban Persson

Daniel Nilsson

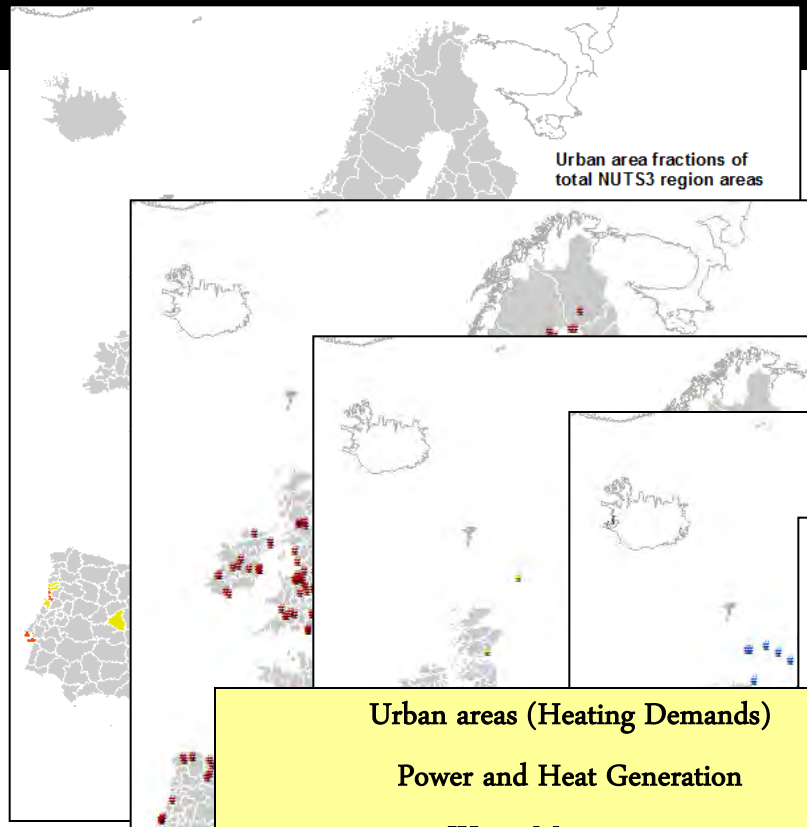
Sven Werner

Planenergi

Daniel Trier

bvm@plan.aau.dk

GIS based information



Urban areas (Heating Demands)

Power and Heat Generation

Waste Management

Industrial waste heat potential

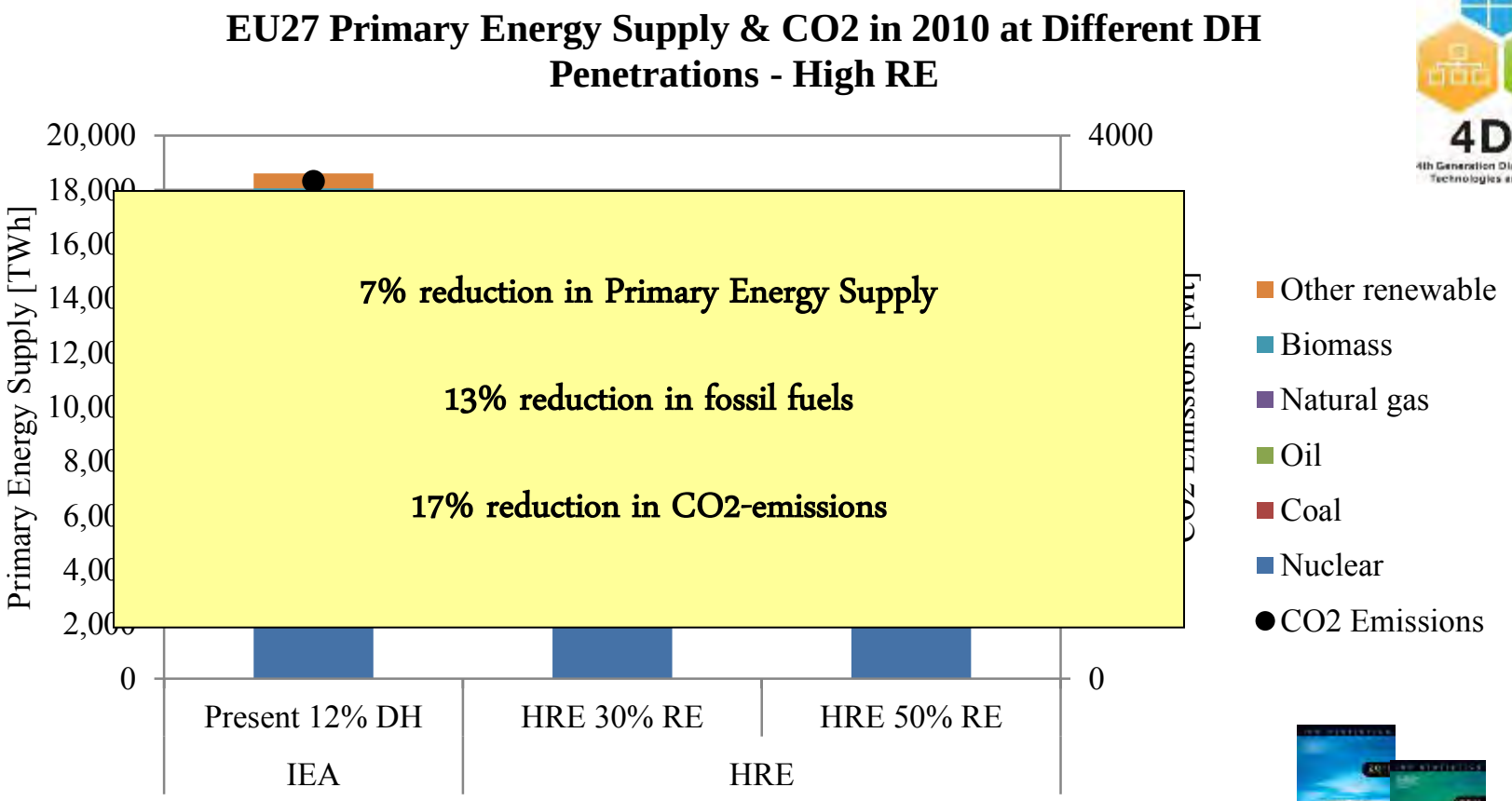
Geothermal heat

Solar Thermal

4DH
4th Generation District Heating
Technologies and Systems

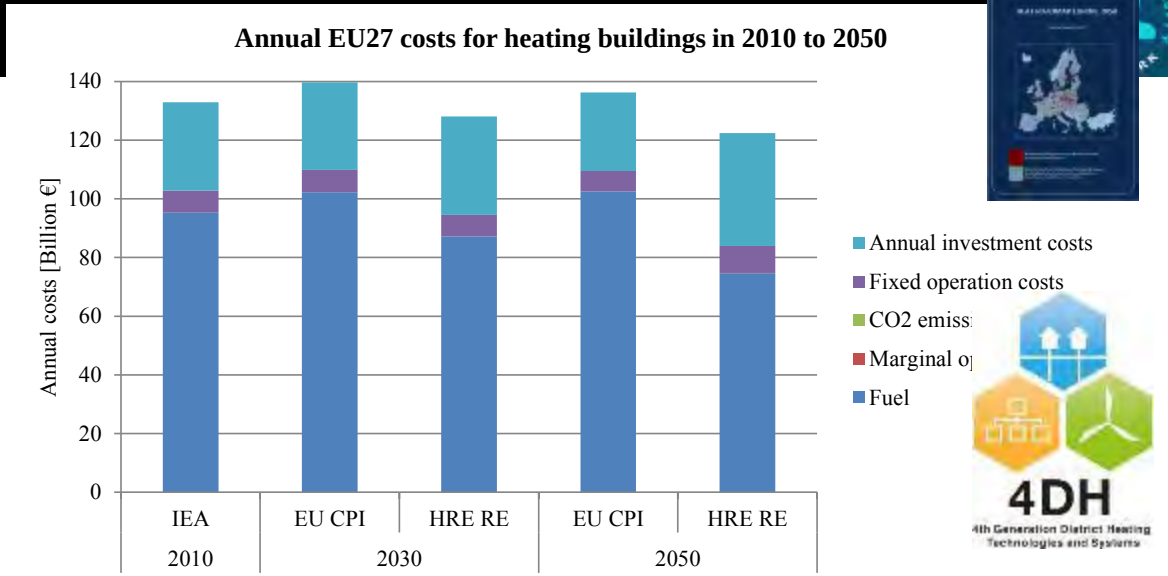
bvm@plan.aau.dk

Total European Energy Supply



IEA Statistics

Cost and Jobs:



4DH
4th Generation District Heating Technologies and Systems

- Saved fuel costs approx.
  EUR in 2050
- In total cost are reduced by 14 Billion EUR in 2050 (approx. 10%)
- Additional investments of a total of 500 billion EUR
- Additional jobs from to 2013 to 2050:
  8-9 million man-year in total
  Approx. 220,000 jobs.

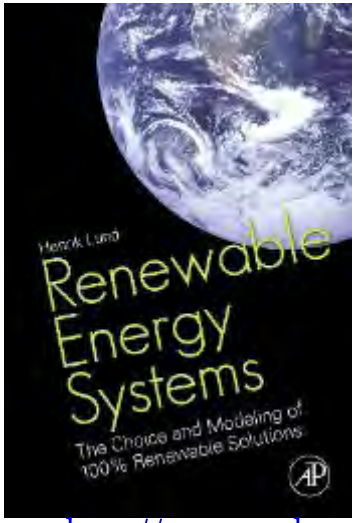
©Brian Vad Mathiesen
bvm@plan.aau.dk

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.
- These elements are important in the EU as well.

bvm@plan.aau.dk

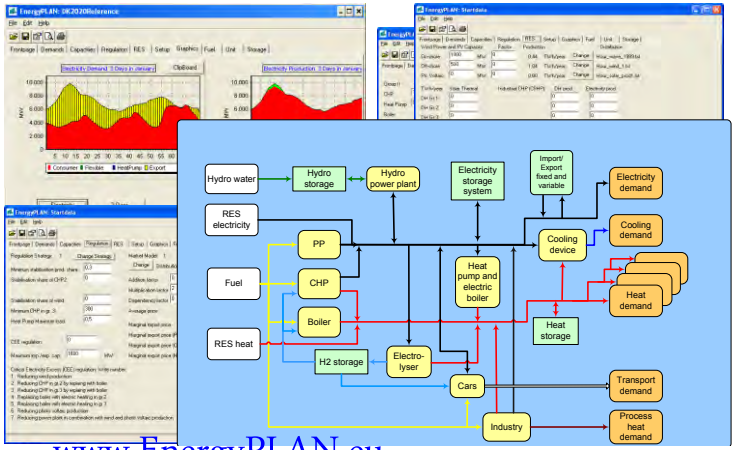
More information



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

www.ceesa.aau.dk

www.energyplanning.aau.dk



www.EnergyPLAN.eu

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

http://www.emd.dk/el

bvm@plan.aau.dk