Smart energy systems and energy storage

in the transition to renewable energy systems in Denmark

September 2012
Work-shop: Integration of Renewable Energies by distributed Energy Storage Systems
IEA, The International Energy Agency, Paris

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Department of Development and Planning, Aalborg University
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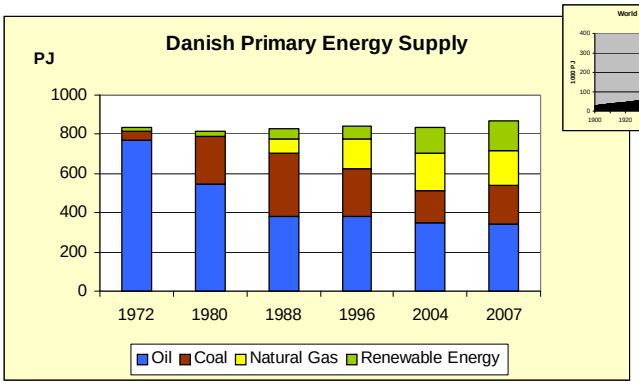
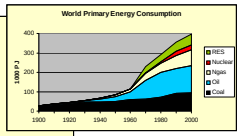
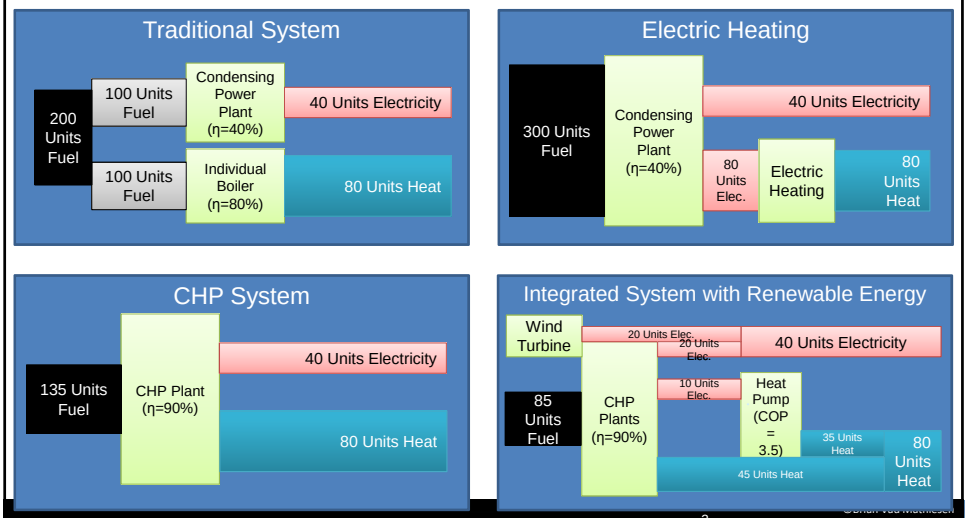
Four decades of years of stable energy consumption with an active energy policy





Types of energy systems and



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Energy research in a real life experiment

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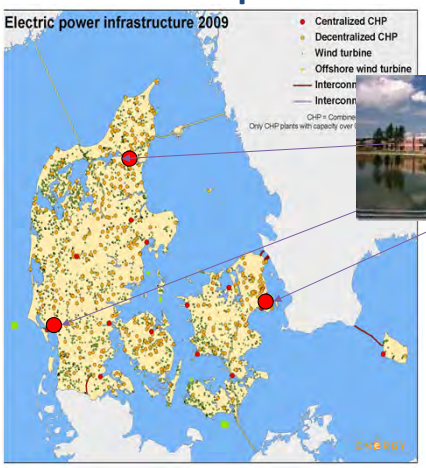
Energy research in a real life experiment



Key facts for energy in Denmark

- 28% (app. 35% in Jylland) wind power
- 120,000 owners of wind turbines
- High share of the world's offshore power
- More than 30% distributed generation
- 50% of electricity from CHP
- Comprehensive energy conservation policy

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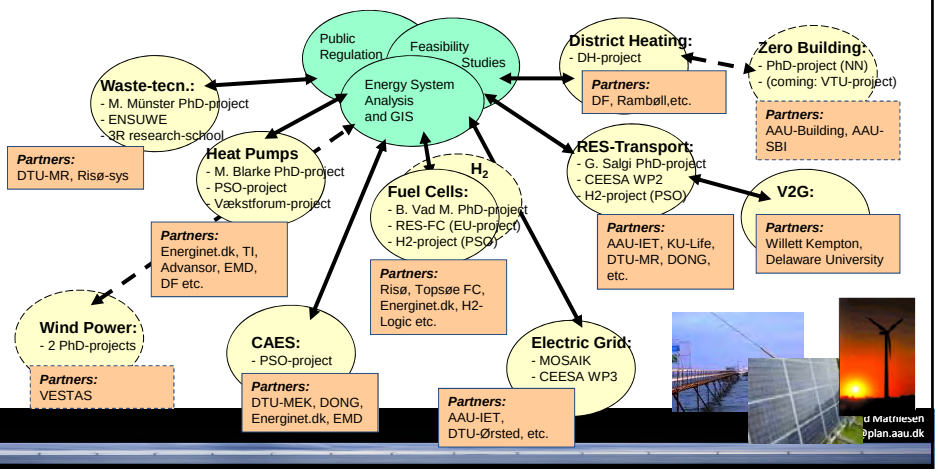
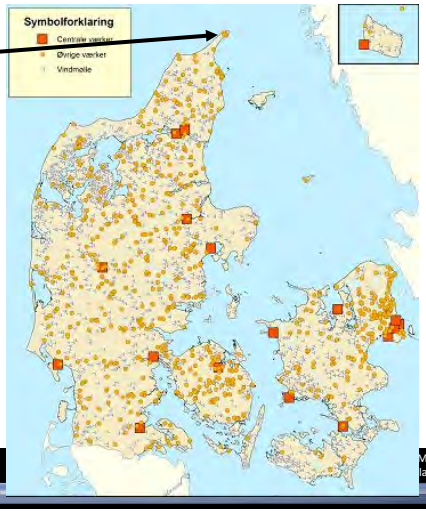
Lokale energimarkeder og MOSAIK	2002 - 2004
DESIRE (EU-project): ESA in diff. European countries	2005 - 2007
IDA Energiplan 2030: 100 per cent RES scenarios	2006 & 2008
CEESA (VTU-project): ESA and LCA etc.	2007 - 2010
EnergiBy Frederikshavn	2006 -
4DH Research Centre: 4G District Heating Technologies	2011 - 2017



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

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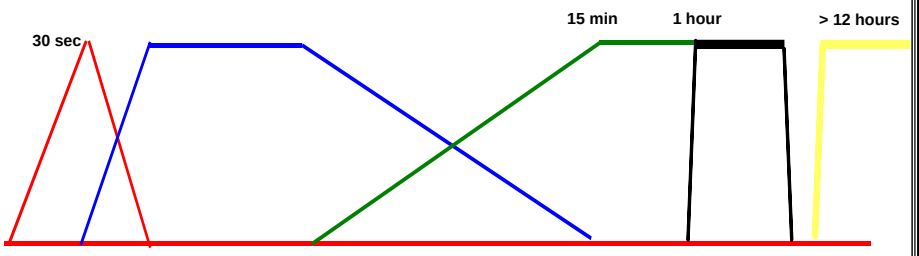
The main electricity markets

- 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



The M.Sc. Programmes in Environm. Managem. & Sustainable Energy Planning and Management, 8. Semester, http://people.plan.aau.dk/~ana

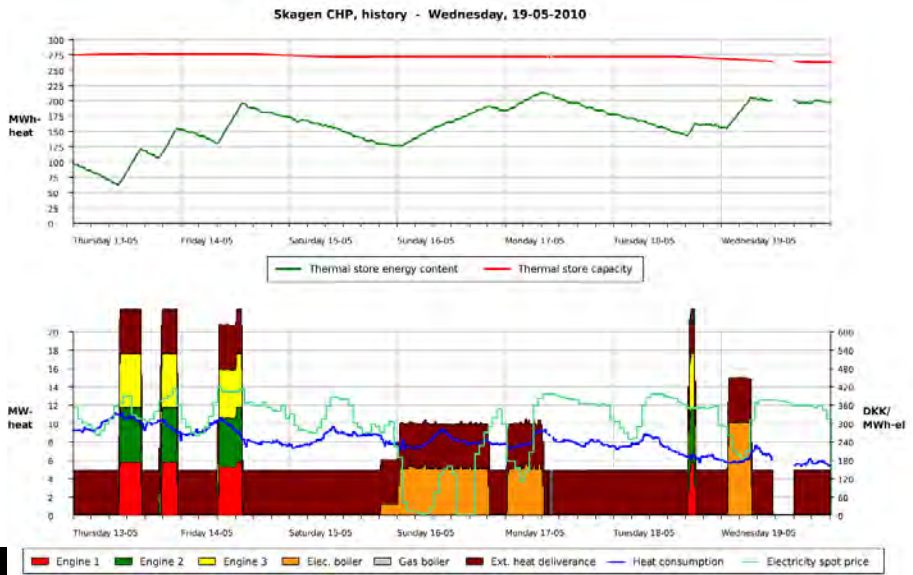
Skagen

- 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.



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

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

Hans Henrik Lindboe
Ea Energy Analyses, Copenhagen, Denmark

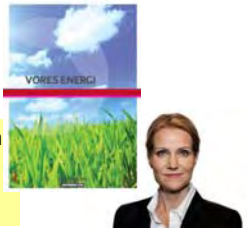

Danish Wind Power
Export and Cost

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:

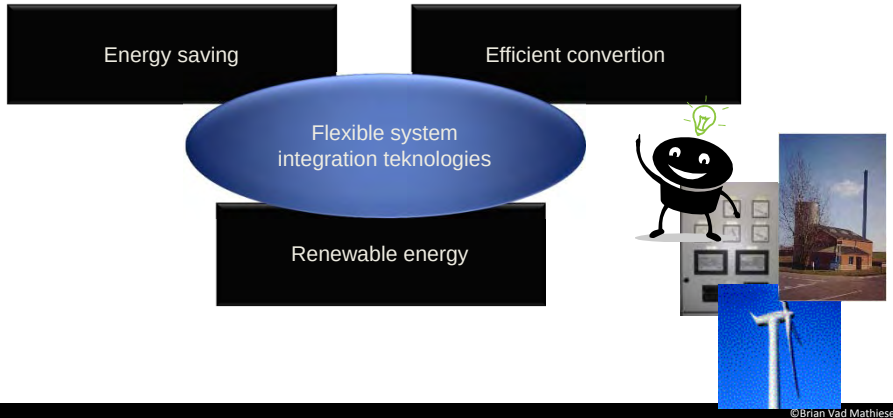
To convert to 100% Renewable Energy

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



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

Systemintegration



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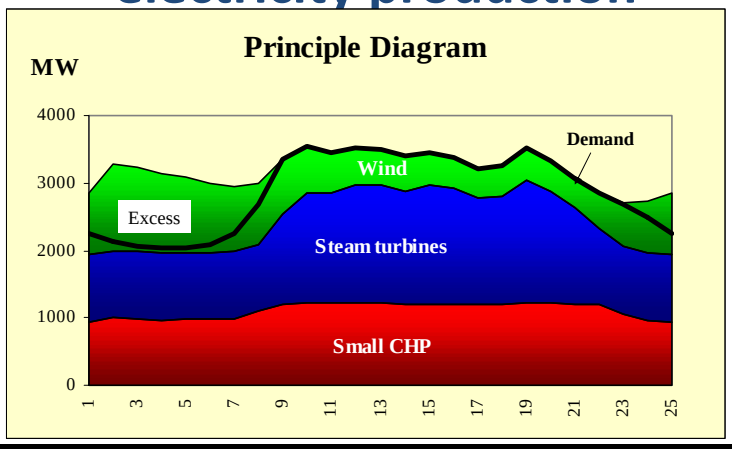
Critical excess electricity production



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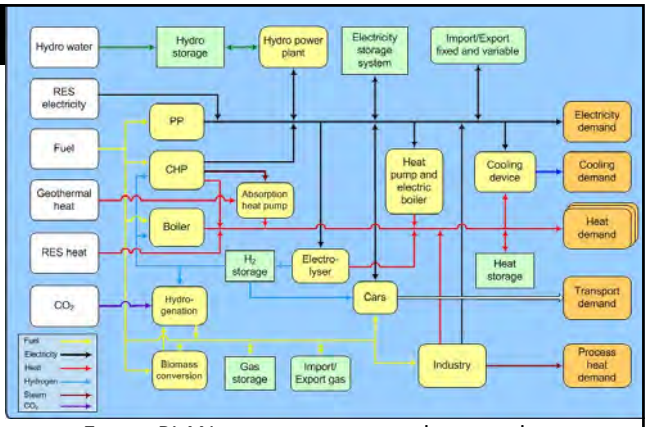
Coherent energy systems analyses

- 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?

www.EnergyPLAN.eu

- 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

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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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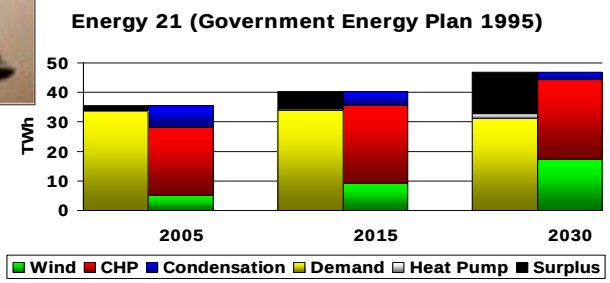
The electricity and heat ballance



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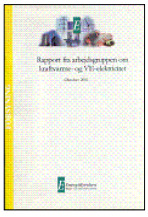
Analyses in 2000-2001

- It is better to use excess electricity from wind and CHP domestically/locally than to build large international transmission lines



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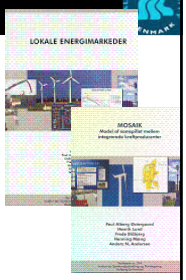
Short-term system integration



- 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 seems small.

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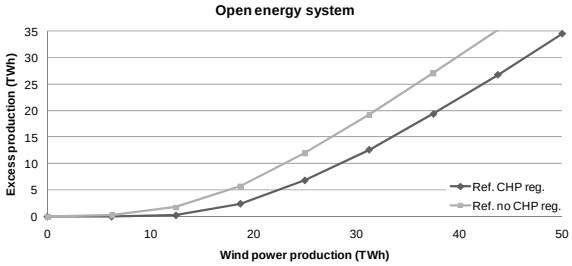
Example of technology study: System integration options



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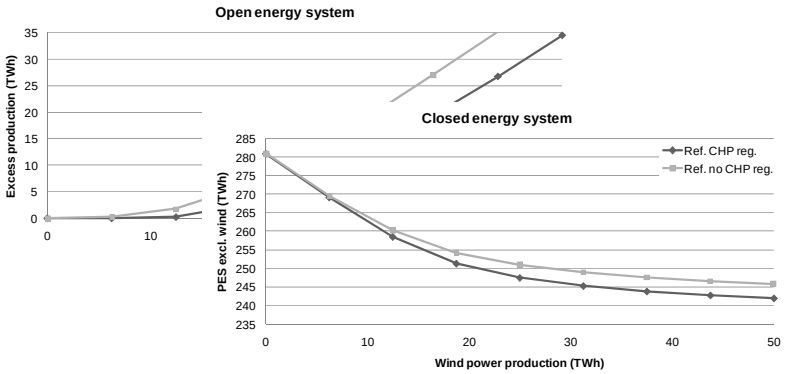
Example of technology study: System integration options



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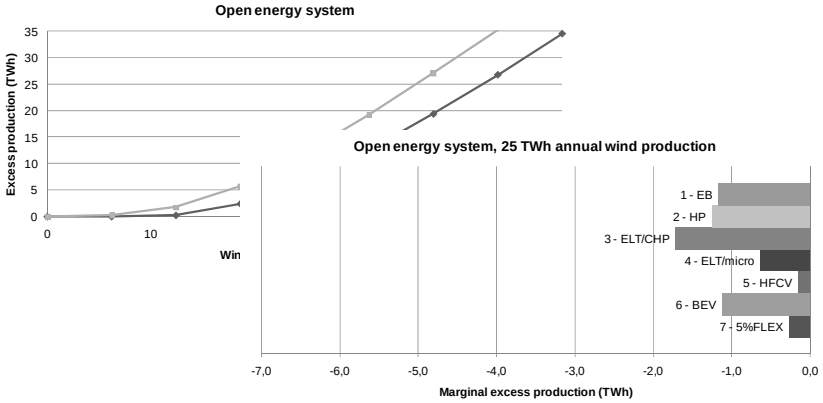
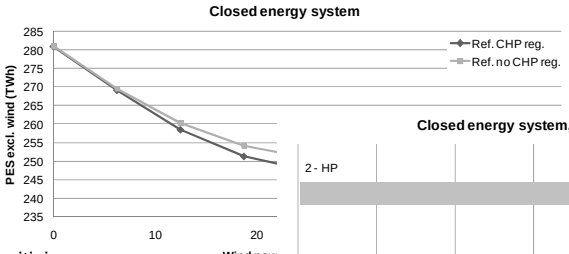
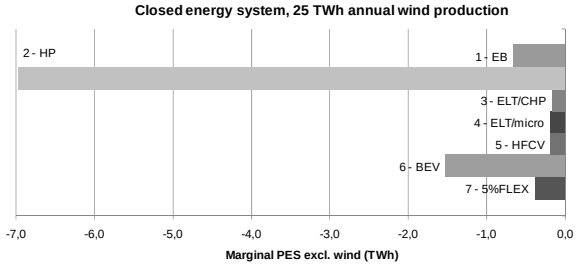


Example of technology study: System integration options





Prioritixing:

1. Heat pumps (large for DH)
2. Battery electric vehicles
3. Flesible demand (incl. small Heat pumps)
4. Electrolysor

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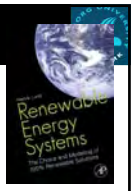
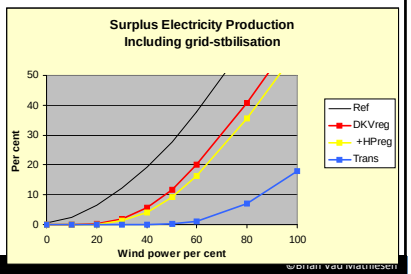
Recommendations I



- Make CHP unit regulation depend on wind power input (10-20% wind without loss of efficiency)
- Add heat pumps (and heat storage capacity) to the CHP units (approx. 40 per cent Wind Power)
- Use electricity for transport as much as possible
- Other kinds of flexible demands are of less importance



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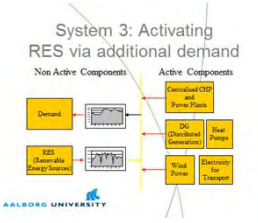
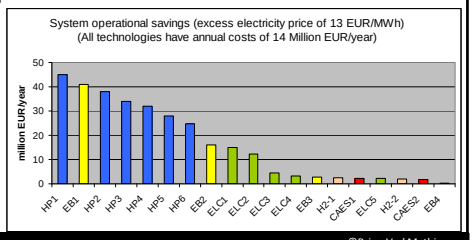
Recommendations II

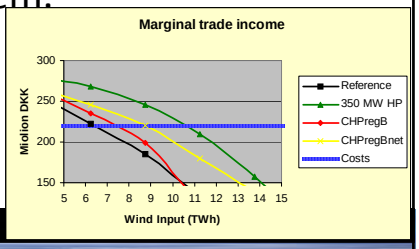
- Not much gained - (integration of wind nor profit) from investing in electricity storage options
- However the inclusion of CHP, heat pumps and transportation units in securing grid stability is essential.





Recommendations III

- The kind of flexibility one need from a technical point of view in a closed system (CHP, HP and transport) is the same kind of flexibility which is needed to raise profits of exchange in an open system.



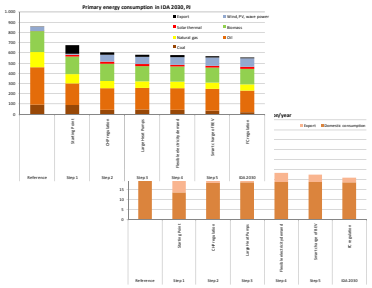
Recommendations IV

- In the medium long term perspective RES electricity has to be transformed into RES gases and liquid fuels (in combination with biomass) to supplement the limited biomass resource. Such conversion opens for the use of gas storage and liquid fuel storage

Technical energy system analyses from 2009 with 50% renewable energy

(Example for IDA 2030 from IDAs Climate Plan 2050)

- Objectives:
  - Reduce excess electricity
  - Decrease fuel demand



	Excess electricity	Boiler share
Step 1: Starting Point	44%	10%
Step 2: CHP regulation	17%	36%
Step 3: Large Heat Pumps	16%	15%
Step 4: Flexible electricity demand	14%	16%
Step 5: Smart charge of battery electric vehicles	10%	20%
Step 6: FC regulation	5%	23%

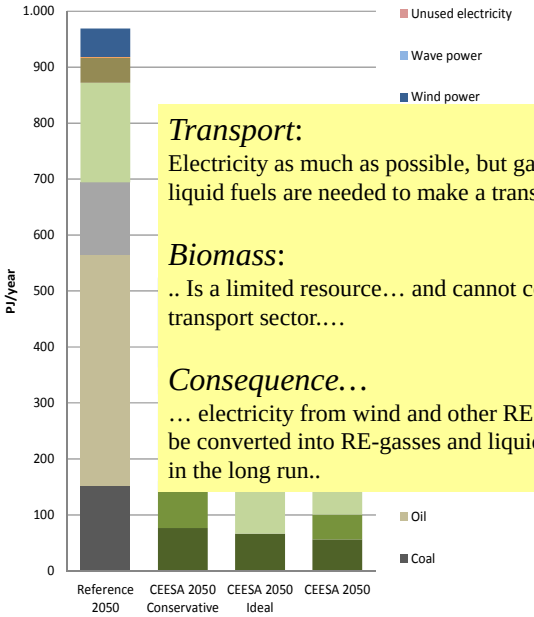
Smart energy systems are crucial in 100% renewable energy systems

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

Primary energy consumption in CEESA scenarios for 2050



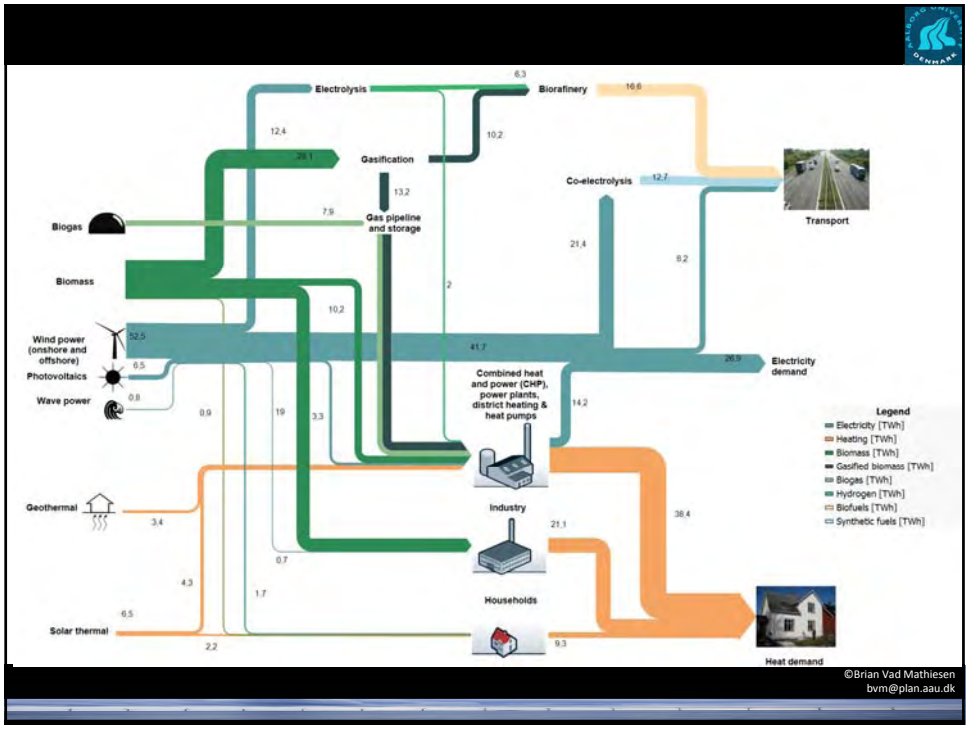
Transport:
Electricity as much as possible, but gas and liquid fuels are needed to make a transition.

Biomass:
.. Is a limited resource… and cannot cover the transport sector.…

Consequence…
… electricity from wind and other RE should be converted into RE-gasses and liquid fuels in the long run..

CEESA-100% Renewable energy

Presented for the Minister of Energy, Climate and Buildings in Nov. 2011.


Electrolysis
Biorafinery
Gasification
Co-electrolysis
Transport
Biogas
Gas pipeline and storage
Biomass
Wind power (onshore and offshore)
Photovoltaics
Wave power
Electricity demand
Combined heat and power (CHP), power plants, district heating & heat pumps
Geothermal
Industry
Households
Solar thermal
Heat demand
Legend
Electricity [TWh]
Heating [TWh]
Biomass [TWh]
Gasified biomass [TWh]
Biogas [TWh]
Hydrogen [TWh]
Biofuels [TWh]
Synthetic fuels [TWh]
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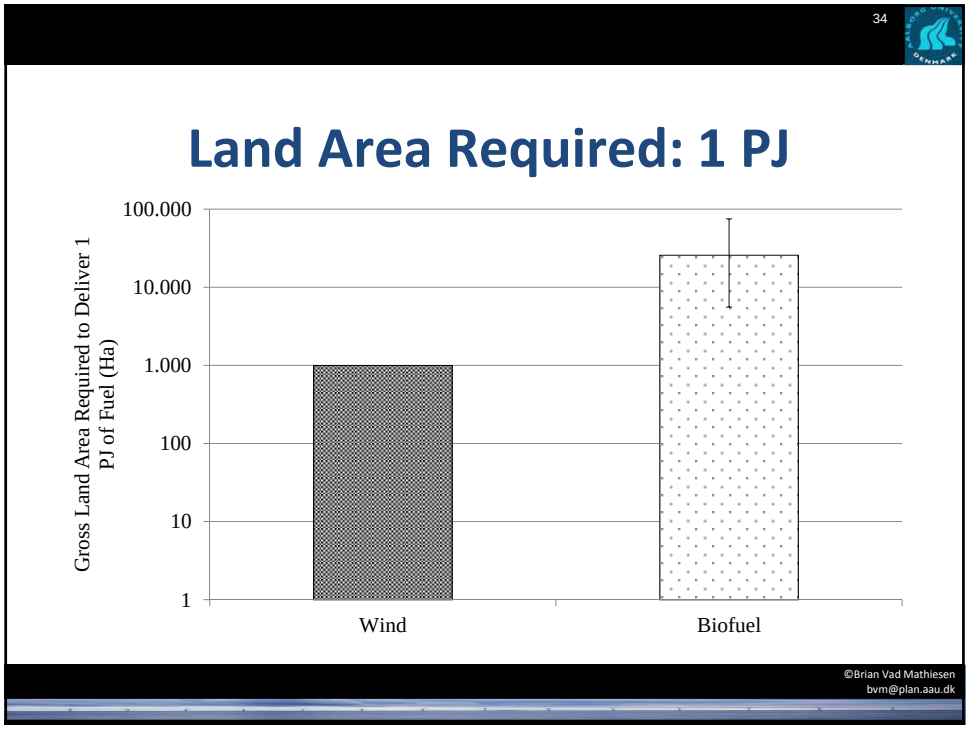
34
Land Area Required: 1 PJ
Gross Land Area Required to Deliver 1 PJ of Fuel (Ha)
100.000
10.000
1.000
100
10
1
Wind
Biofuel
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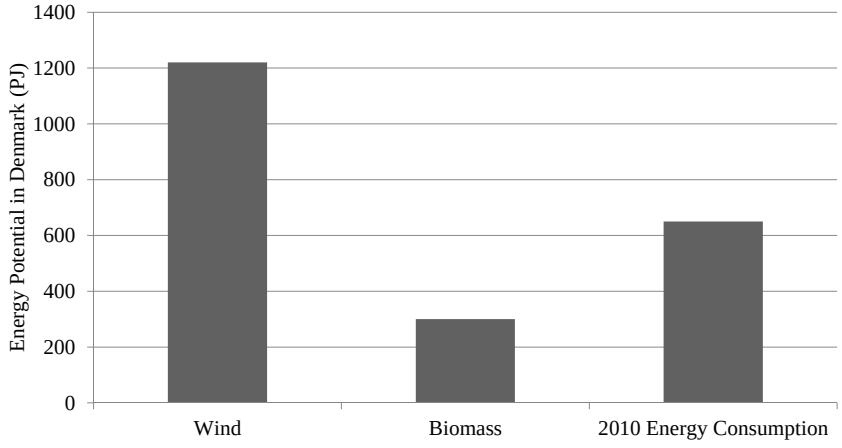
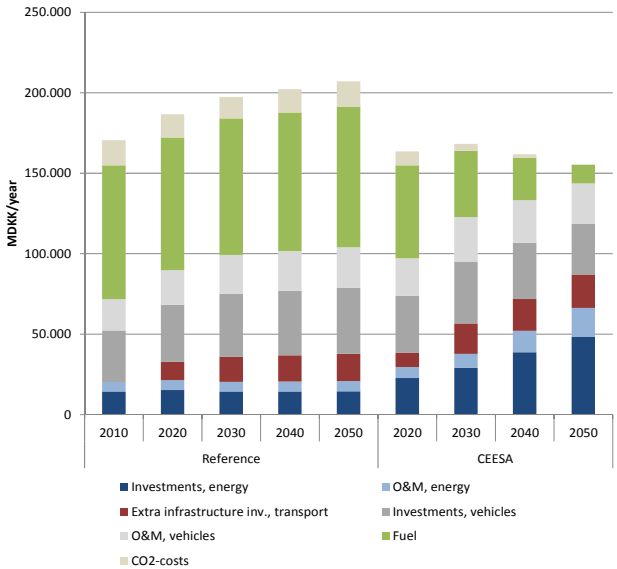
Renewable Resources in Denmark



Socio-economic costs



- Transport pose a very high portion of the costs compared to other energy services
- Direct economic advantages in transition
- In addition:
  - More stable costs
  - More jobs
  - More export
  - Lower health costs

CEESA Publications

- CEESA reports:
  - Main report: Coherent Energy and Environmental System Analysis
  - Part 1: CEESA 100% Renewable Energy Scenarios towards 2050
  - Part 2: CEESA 100% Renewable Energy Transport Scenarios towards 2050
  - Part 3: Electric power systems for a transition to 100% Renewable Energy Systems in Denmark before 2050
  - Part 4: Policies for a Transition to 100% Renewable Energy Systems in Denmark before 2050
  - Part 5: Environmental Assessment of Renewable Energy Scenarios towards 2050
- And a number of other reports including:
  - IDAs Climate Plan 2050, background report
  - Danish Wind Power - Export and Cost
  - Technical potentials of biomass for energy services from current agriculture and forestry in selected countries in Europe
  - Energy Vision for Aalborg Municipality 2050
  - EnergyTown Frederikshavn
  - Heat Plan Denmark (2008 and 2010)
- And 5 PhD projects, 19 book chapters or journal papers, 25 conference proceedings and presentations.

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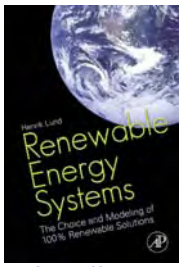

More information

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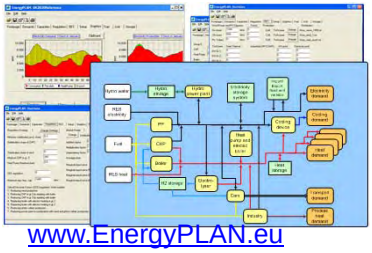
www.energyplanning.aau.dk

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



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