Smart Energy Systems

- a holistic and integrated approach to 100 % renewable energy

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KEYNOTE AT THE 8TH CONFERENCE ON SUSTAINABLE DEVELOPMENT OF ENERGY, WATER AND ENVIRONMENT SYSTEMS – SDEWES

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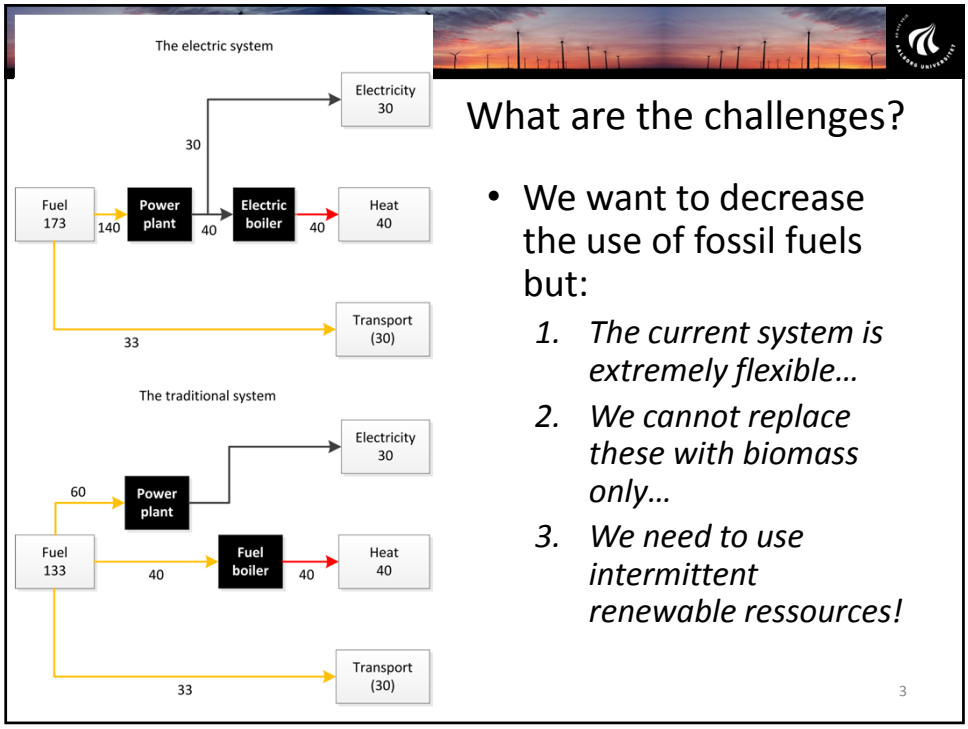
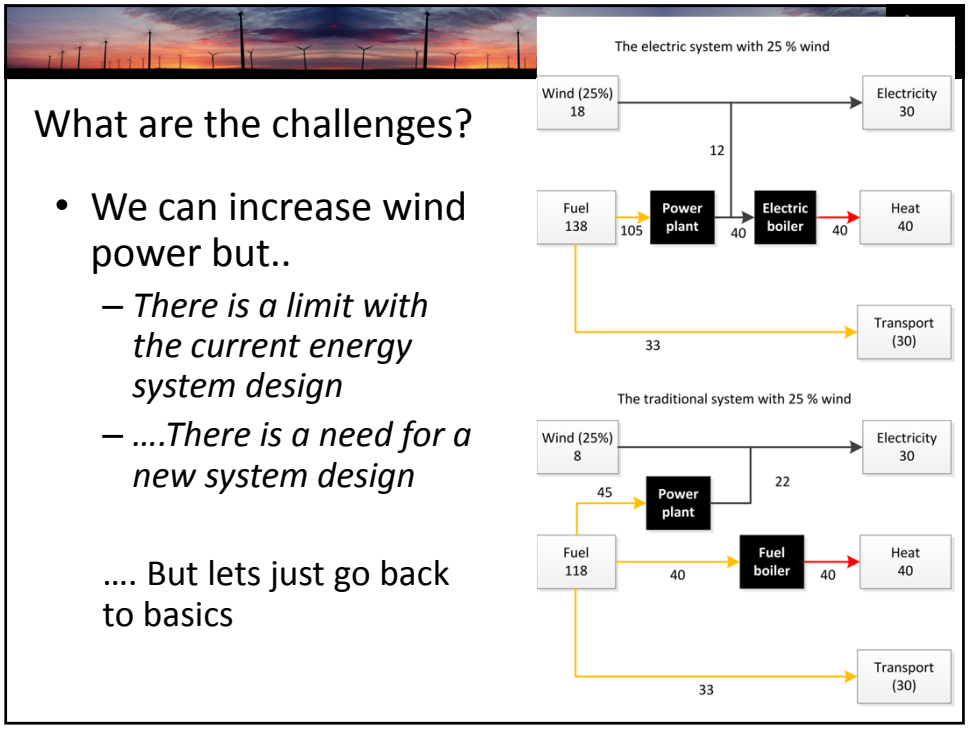
SUSTAINABLE ENERGY PLANNING RESEARCH GROUP
DEPARTMENT OF DEVELOPMENT AND PLANNING

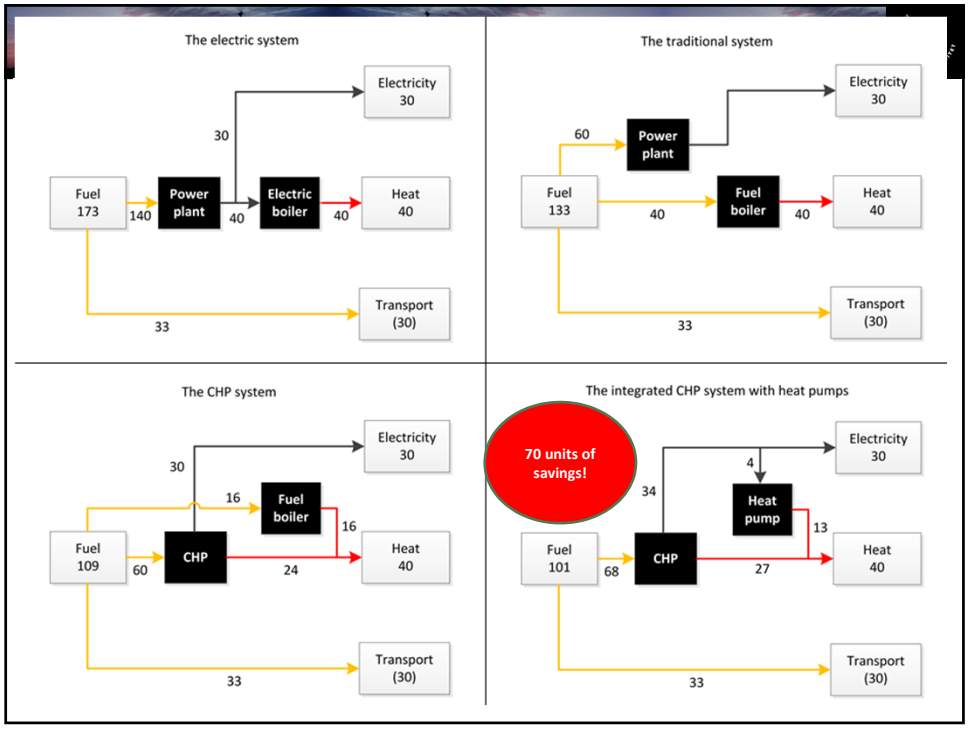
AALBORG UNIVERSITY
DENMARK

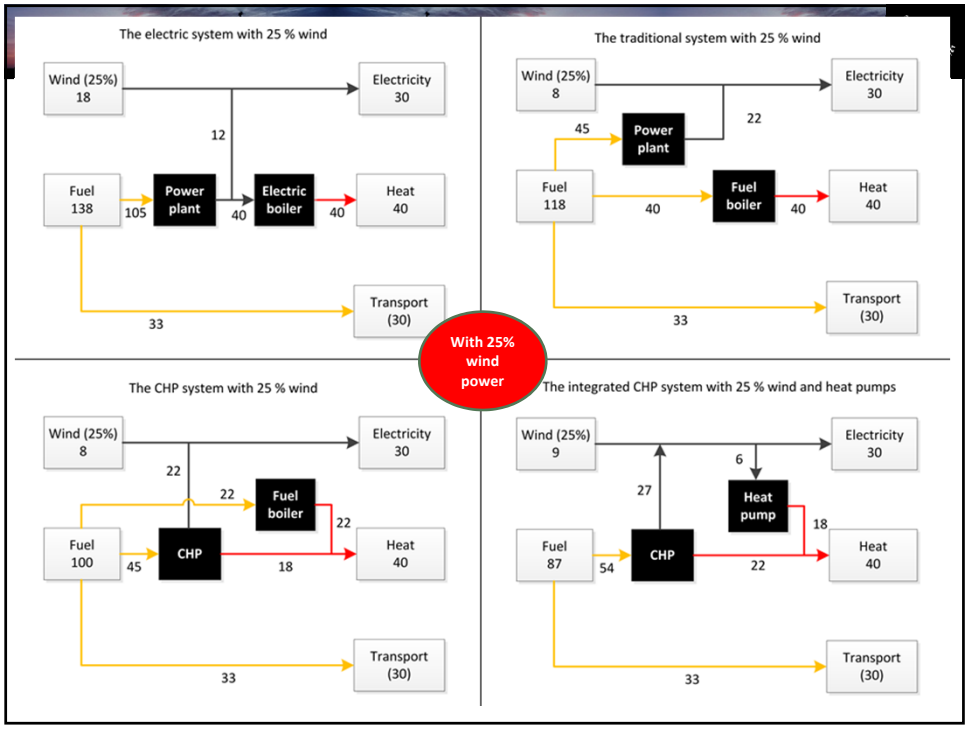
Agenda

- The challenges of the current energy systems
- What are smart energy systems?
- A case study bringing Smart energy systems to life

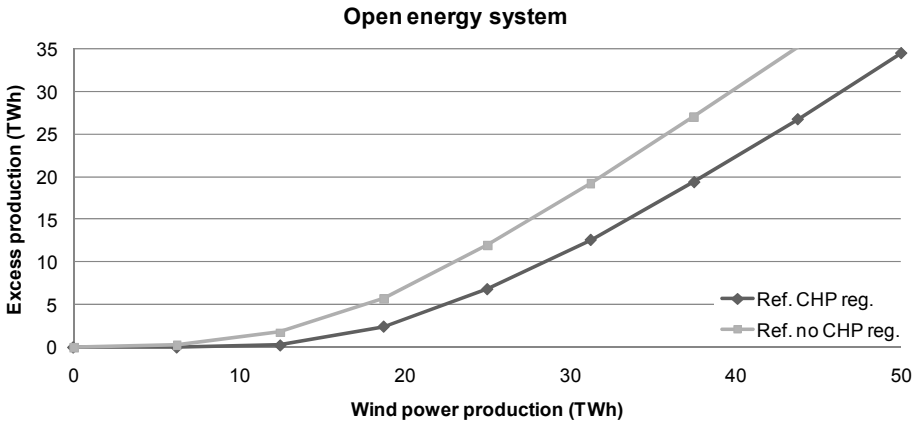

The electric system
Electricity
30
30
Fuel
173
140
Power
plant
40
Electric
boiler
40
Heat
40
Transport
(30)
33
The traditional system
Electricity
30
60
Power
plant
Fuel
133
40
Fuel
boiler
40
Heat
40
Transport
(30)
33
What are the challenges?
• We want to decrease the use of fossil fuels but:
1. The current system is extremely flexible…
2. We cannot replace these with biomass only…
3. We need to use intermittent renewable ressources!
3


What are the challenges?
• We can increase wind power but..
– There is a limit with the current energy system design
– ….There is a need for a new system design
…. But lets just go back to basics
The electric system with 25 % wind
Wind (25%)
18
Electricity
30
12
Fuel
138
105
Power
plant
Electric
boiler
40
40
Heat
40
Transport
(30)
33
The traditional system with 25 % wind
Wind (25%)
8
Electricity
30
22
45
Power
plant
Fuel
118
40
Fuel
boiler
40
Heat
40
Transport
(30)
33


The electric system
Electricity 30
30
Fuel 173
140
Power plant
40
Electric boiler
40
Heat 40
Transport (30)
33
The traditional system
Electricity 30
60
Power plant
Fuel 133
40
Fuel boiler
40
Heat 40
Transport (30)
33
The CHP system
Electricity 30
30
16
Fuel boiler
16
Fuel 109
60
CHP
24
Heat 40
Transport (30)
33
The integrated CHP system with heat pumps
70 units of savings!
Electricity 30
4
34
Heat pump
13
Fuel 101
68
CHP
27
Heat 40
Transport (30)
33


The electric system with 25 % wind
Wind (25%) 18
Electricity 30
12
Fuel 138
105
Power plant
40
Electric boiler
40
Heat 40
Transport (30)
33
The traditional system with 25 % wind
Wind (25%) 8
Electricity 30
22
45
Power plant
Fuel 118
40
Fuel boiler
40
Heat 40
Transport (30)
33
With 25% wind power
The CHP system with 25 % wind
Wind (25%) 8
Electricity 30
22
22
Fuel boiler
22
Fuel 100
45
CHP
18
Heat 40
Transport (30)
33
The integrated CHP system with 25 % wind and heat pumps
Wind (25%) 9
Electricity 30
6
27
Heat pump
18
Fuel 87
54
CHP
22
Heat 40
Transport (30)
33

Example of technology study: Seven system integration options



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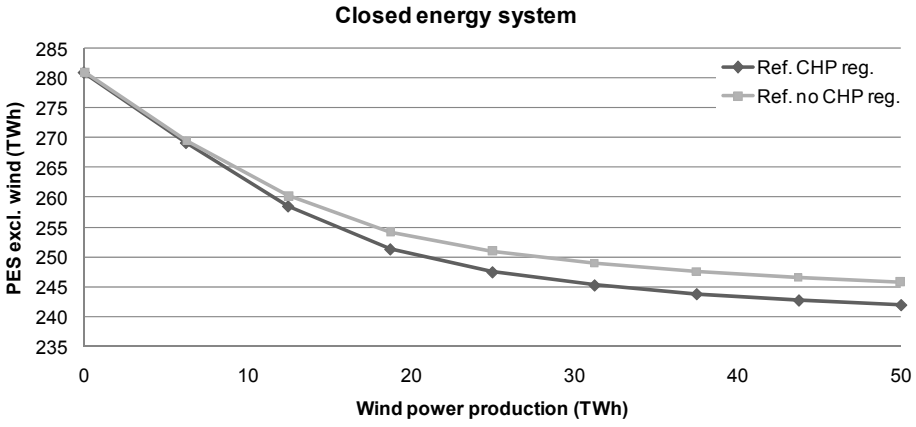
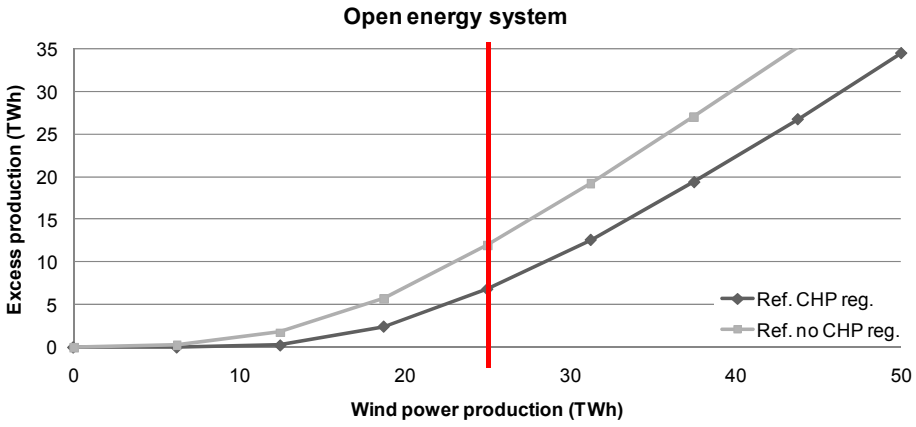
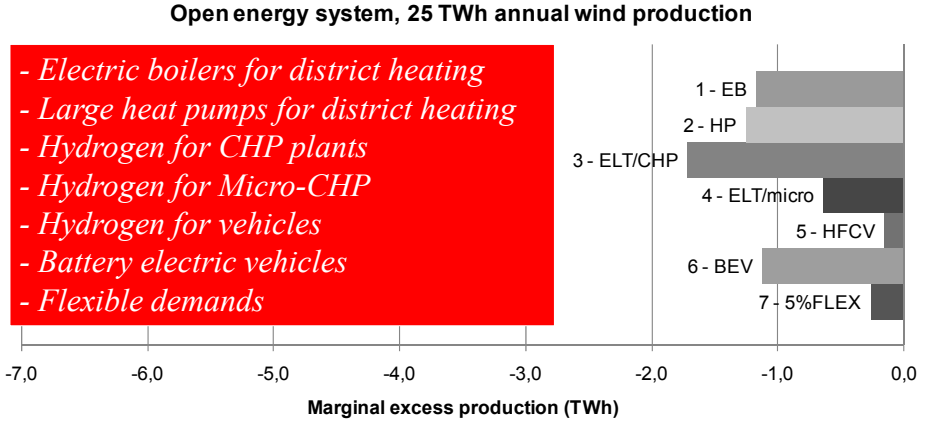


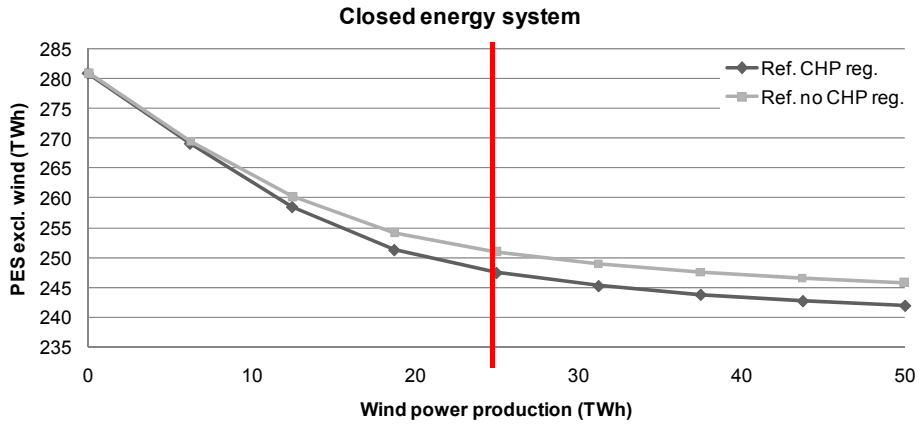
Example of technology study: Seven system integration options



Example of technology study: Seven system integration options



Example of technology study: Seven system integration options



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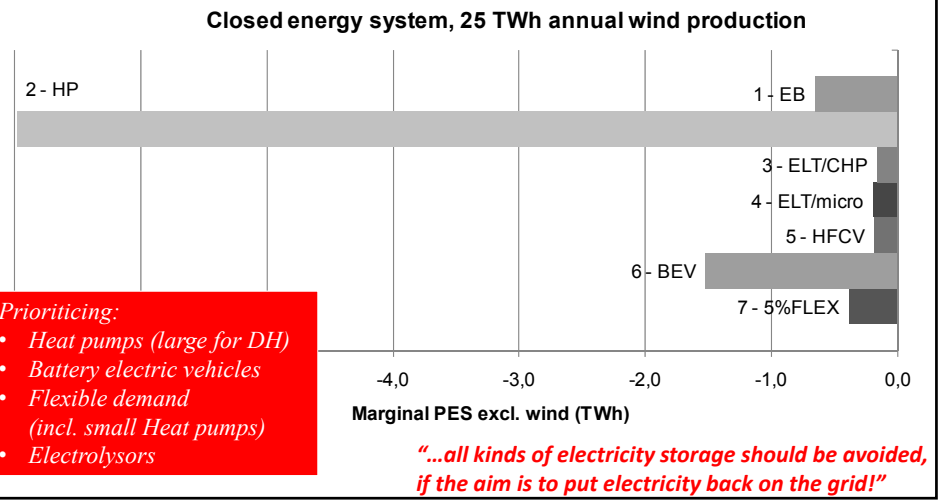
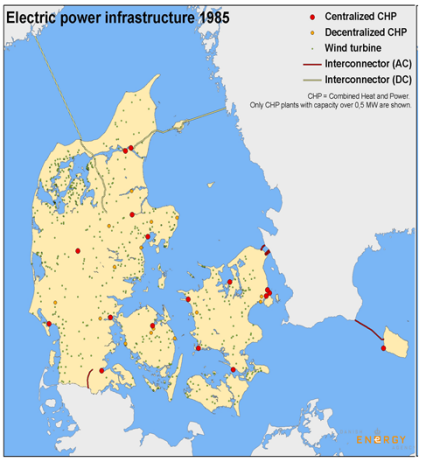


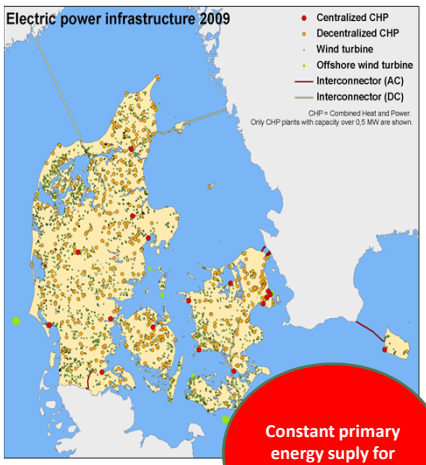
Prioriticing:

- *Heat pumps (large for DH)*
- *Battery electric vehicles*
- *Flexible demand (incl. small Heat pumps)*
- *Electrolysors*

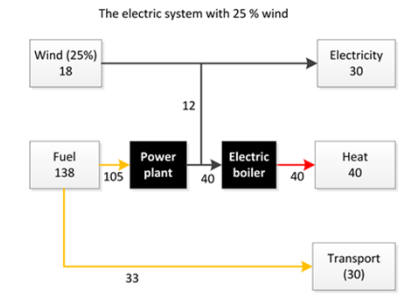
"…all kinds of electricity storage should be avoided, if the aim is to put electricity back on the grid!"

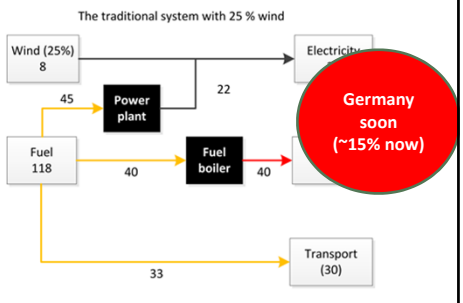
Transition from a hierarchal centralised to a semi-decentralised energy system – Status



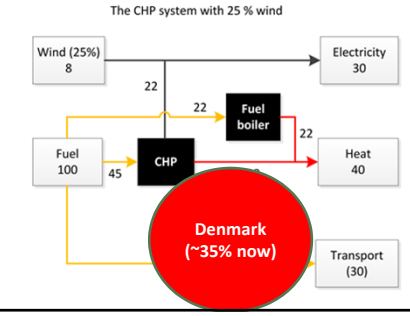


Constant primary energy suply for 40 years

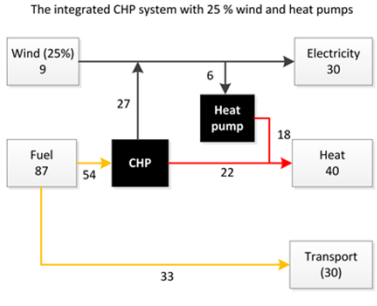




Germany soon (~15% now)



Denmark (~35% now)



Example of a scenario study:
Heating technologies and renewable ergny

Heat Plan Denmark

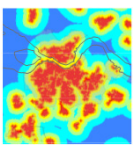
2008: Technical and economic analyses
2010: Implementation and Public Regulation

- How should we heat the houses in Denmark ??
  - What to do in a **short-term** perspective in which we want to decrease CO2-emissions and energy consumptions.
  - And what to do in a **long-term** perspective in which we want to convert to a 100% Renewable Energy System.

Example of a scenario study:
Heating technologies and renewable ergny

The reasonable solutions seems to be to combine:

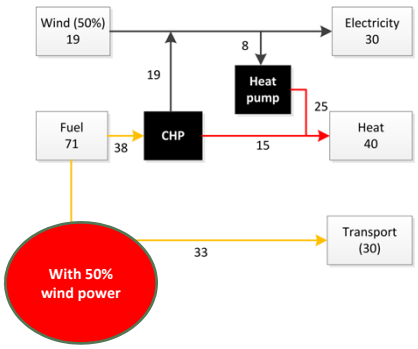
- Gradually increasing District Heating from now 46% to somewhere in between 63% and 70%
- Individual Heat Pumps in the rest of the buildings
- Focus on synergies with regards to increasing the efficiencies of district heating networks (essential)
- District heating can integrate more renewable energy sources
  - And no micro-CHP; especially not in combination with hydrogen…



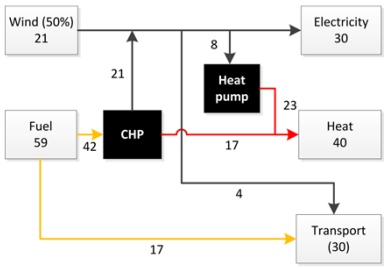
"…the integration of the electricity sector and the heating sector should be done with CHP plants and large heat pumps with heat storages in district heating systems where possible"

The next step?

The integrated CHP system with 50 % wind and heat pumps



The integrated system with 50 % wind
& electric vehicles



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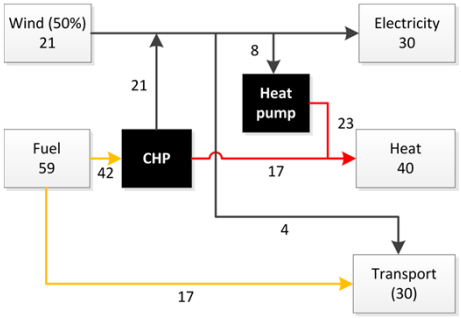
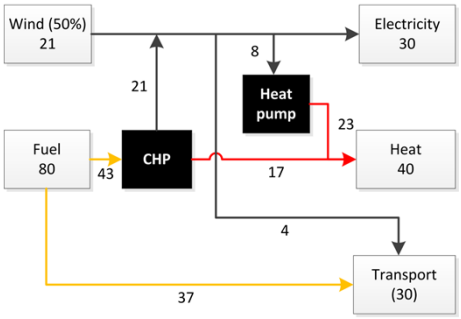
The dilemme - Fuels for the hard part of transport?

The integrated system with 50 % wind, electric vehicles and 1. generation bio-fuels



The integrated system with 50 % wind, electric vehicles and 2. generation bio-fuels



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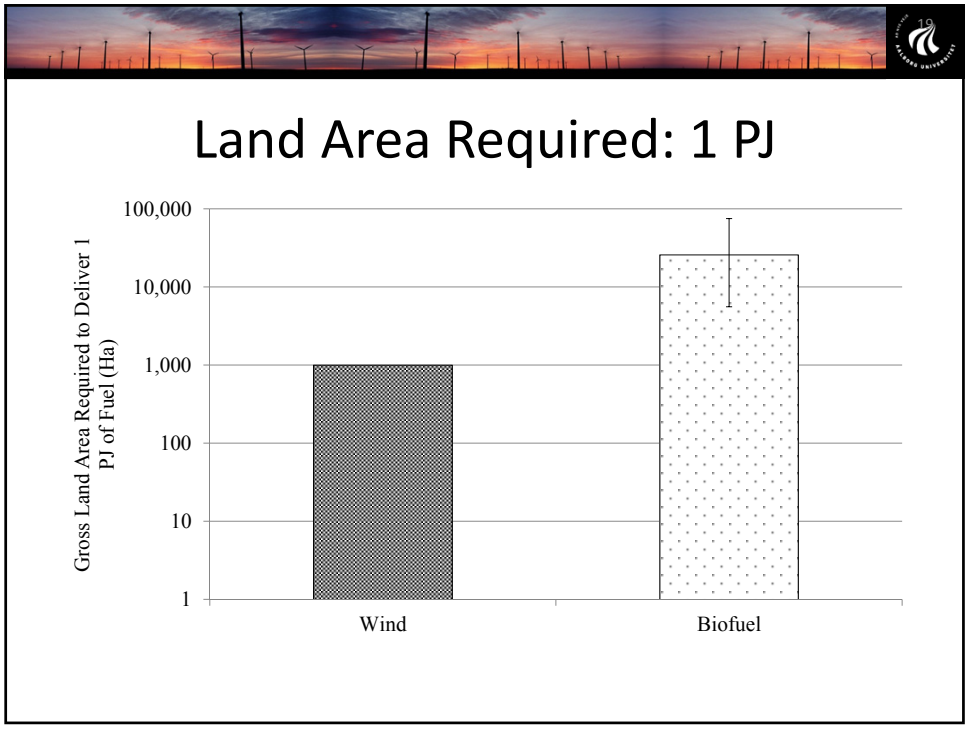
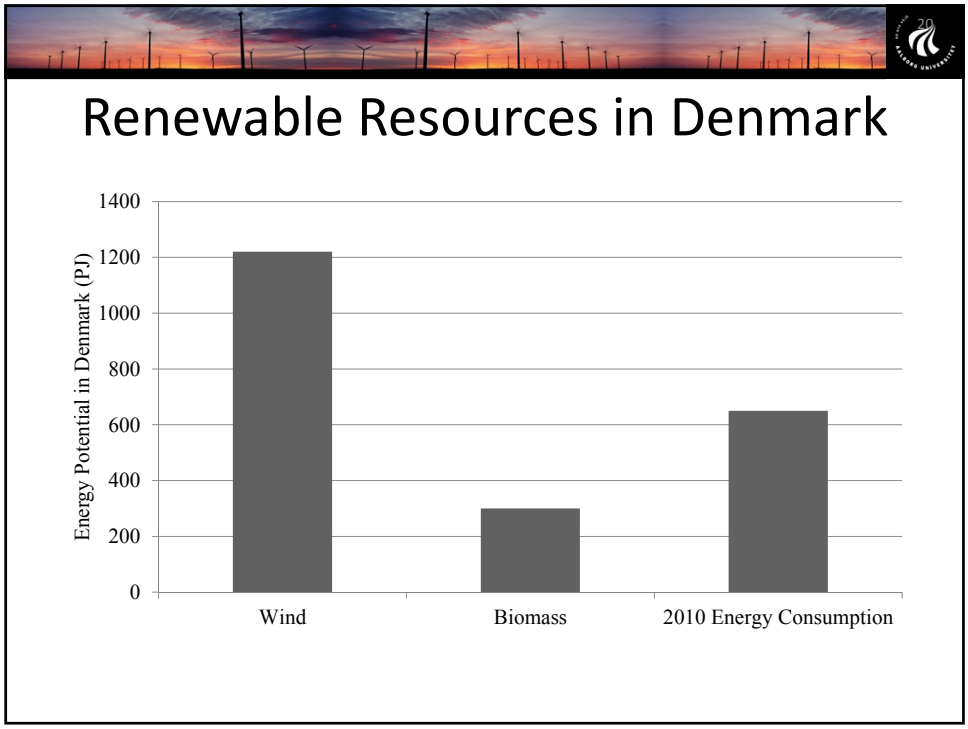
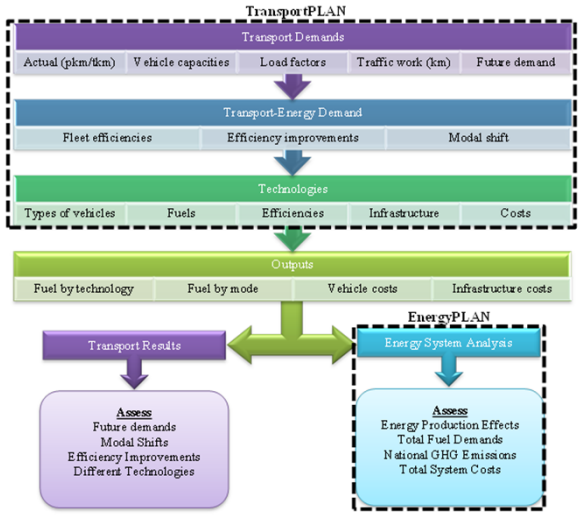

19
Land Area Required: 1 PJ
Gross Land Area Required to Deliver 1 PJ of Fuel (Ha)
100,000
10,000
1,000
100
10
1
Wind
Biofuel

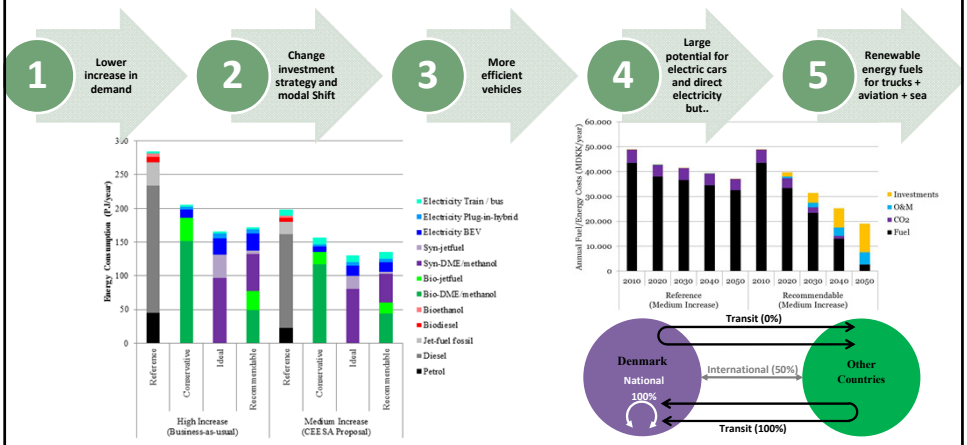

20
Renewable Resources in Denmark
Energy Potential in Denmark (PJ)
1400
1200
1000
800
600
400
200
0
Wind
Biomass
2010 Energy Consumption

TransportPLAN modeling and profiling in CEESA

- Particular focus due to large challenges:
  - >95% reliant on oil
  - High increase historically
  - Large potential for electric cars and direct electricity but..
  - Specific challenges in bringing in electricity in sea, aviation and good transport



It is possible to transform the Danish transport system to 100% renewable energy

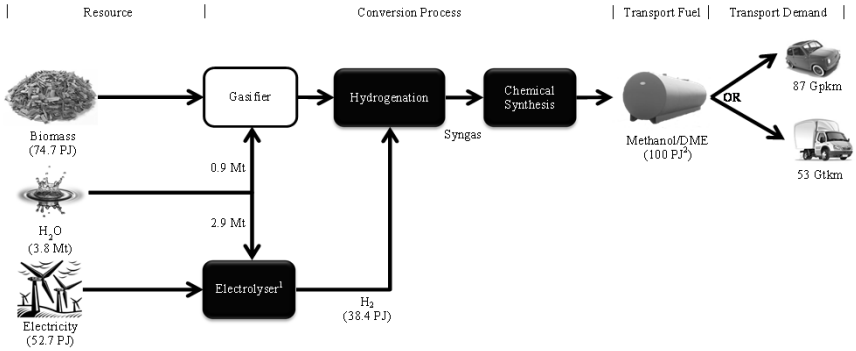


Creating Liquid Fuels for Transport

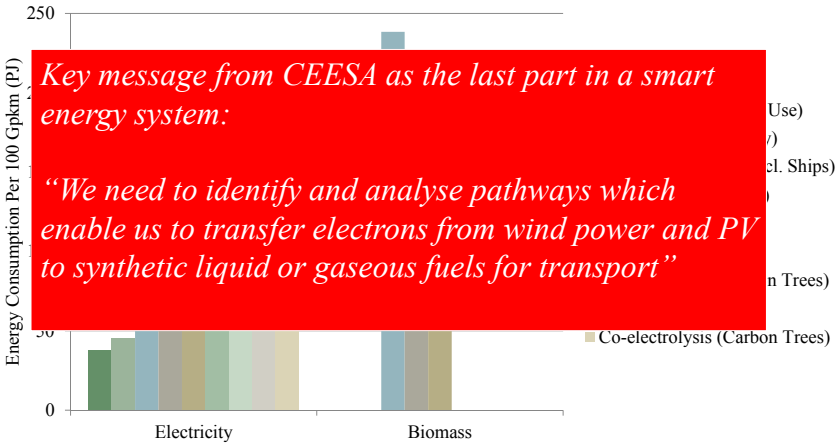
- 4 Principal Options:
  1. Fermentation (and hydrogenation of residues)
  2. Gasification of biomass and hydrogenation
  3. Steam electrolyses and CO2 hydrogenation (No biomass)
  4. Combined steam and CO2 electrolysis (No biomass)

- These pathways were assessed to quantify how much biomass and electricity are required to supply the same transport demand using these pathways

Hydrogenation of gasified biomass

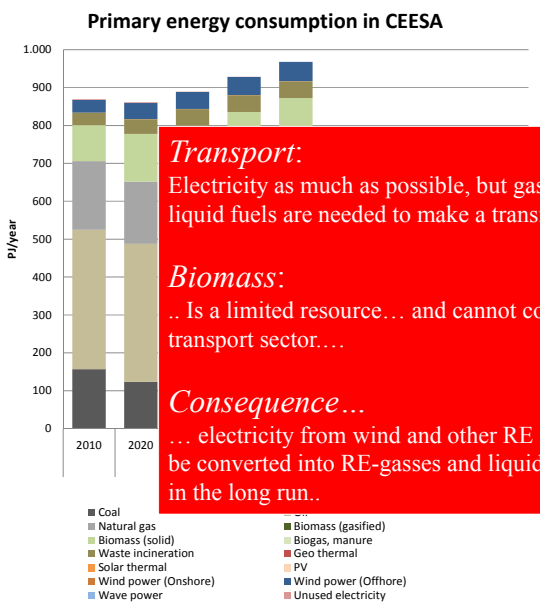


Passenger Transport



Key message from CEESA as the last part in a smart energy system:

"We need to identify and analyse pathways which enable us to transfer electrons from wind power and PV to synthetic liquid or gaseous fuels for transport"



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..

100 % renewable energy scenarios

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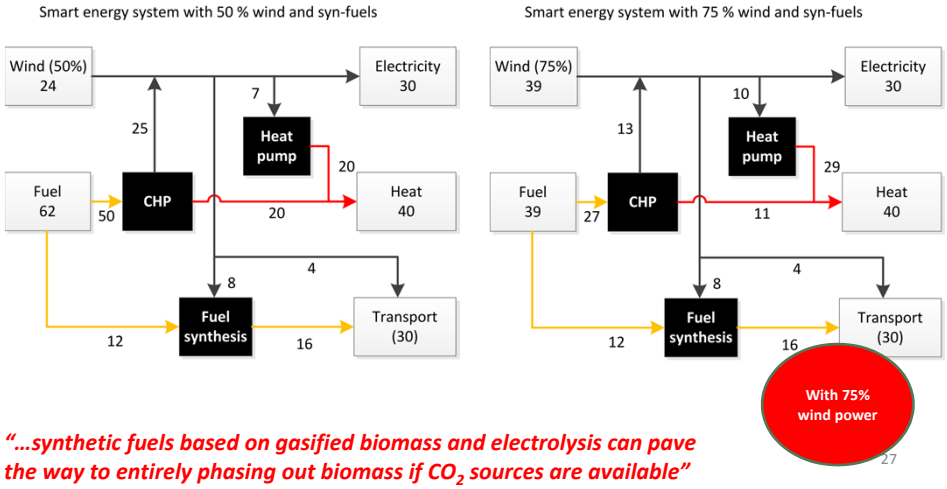
nsumption will
ange
quires smart energy
stems

Towards Smart Energy Systems



"…synthetic fuels based on gasified biomass and electrolysis can pave the way to entirely phasing out biomass if CO_2 sources are available"

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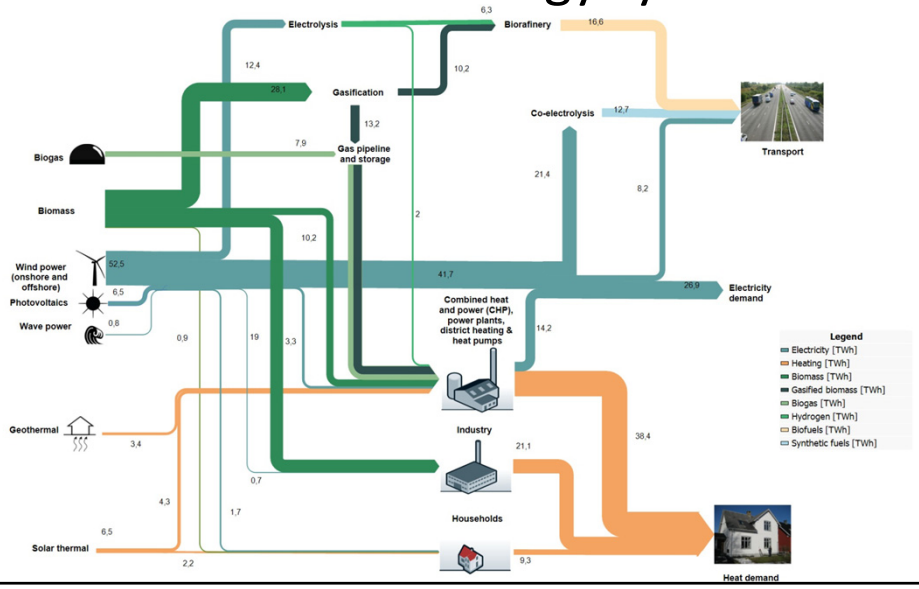
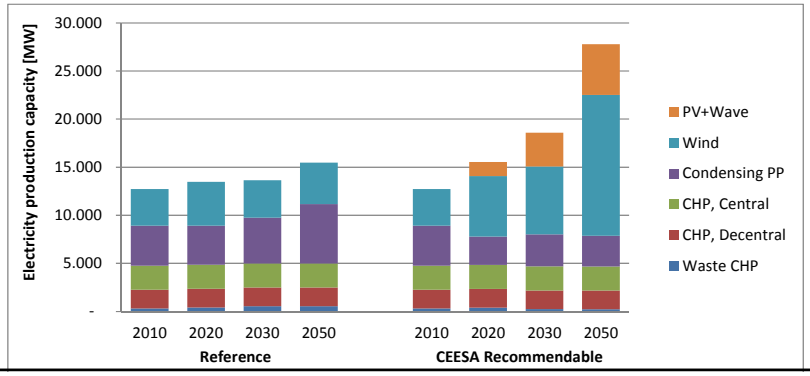
CEESA – smart energy system



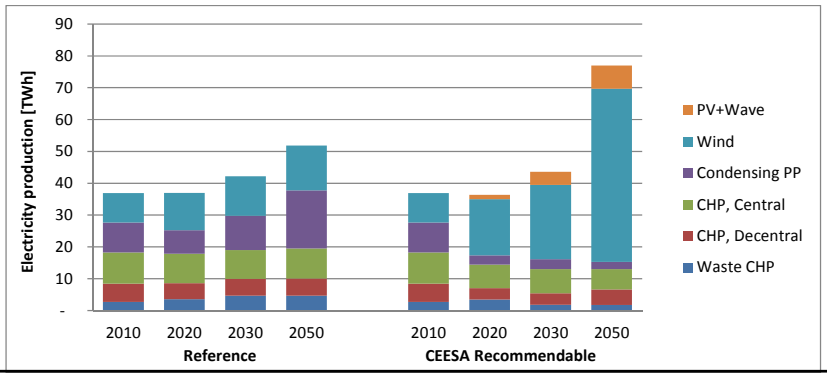
Development of the electricity system

- Increase of RE capacity
- Constant CHP capacity
- Need for high flexibility in CHP production

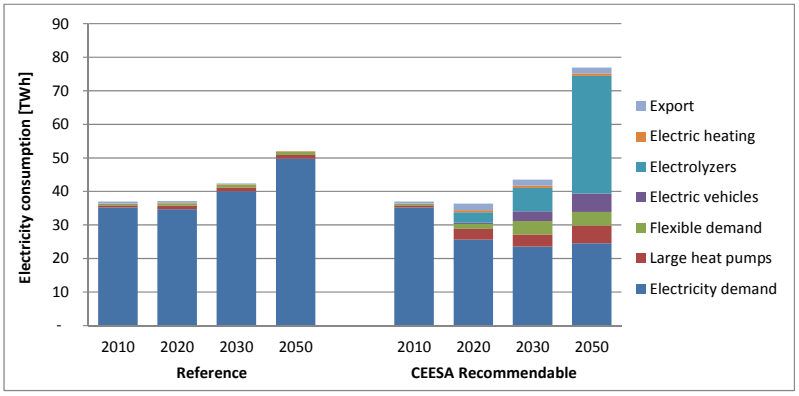


Development of the electricity system

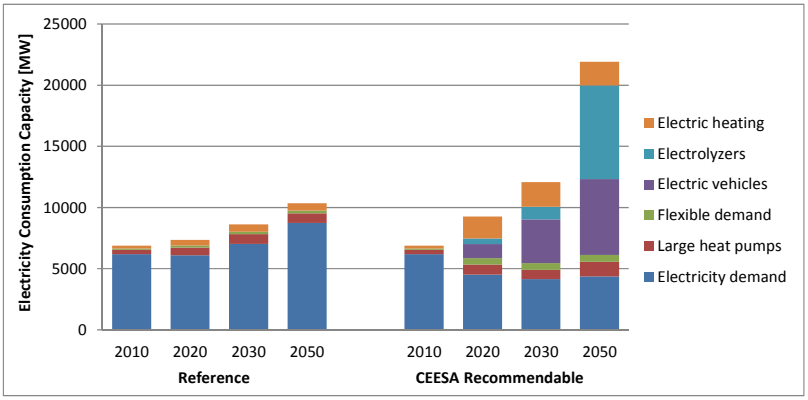
- Decreased production from CHP
- Increase of total production
- 80% from wind, PV and wave power



Potential development in electricity consumption



Potential development in electricity consumption capacity



The need for flexibility on the production side

- Larger gas turbines
  - 10% of full load pr. min
  - Good part-load efficiencies
  - Best efficiencies in base load
  - Quick start-up
  - From Natural gas to biogas and gasified biomass
  - Low investment costs
  - Fuel cells may eventually perform better.
- New demands for wind turbines
  - Can be used in the regulation power markets
  - +5MW/min/200MW or 2,5% incr./min of full load

What can we do on the demand side?

- **Smart Electricity Grids** and infrastructure
  - Connects to storage with flexible electricity demands such as heat pumps and electric vehicles to the intermittent renewable resources such as wind and solar power.
- **Smart Thermal Grids** - District Heating and Cooling infrastructure
  - connects electricity & heating sectors.
  - Enables thermal storage and other heat sources in the energy system to be used.
- **Smart Gas Grids** and infrastructures
  - Connects the electricity, heating, and transport sectors. This enables gas storage to be utilised for creating additional flexibility. (Liquid fuel storages can also be utilised)

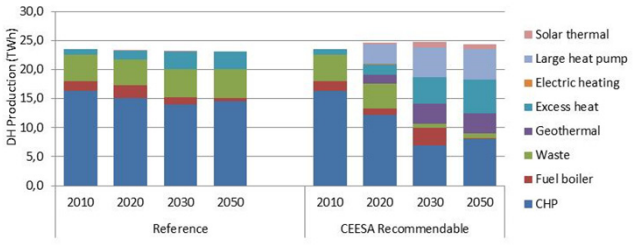
District heating production capacities

- Traditional thermal capacities will be reduced to half
- Several new capacities to supplement these
- Electric efficiencies of CHP will increase which causes lower heat production capacities at the CHP plants

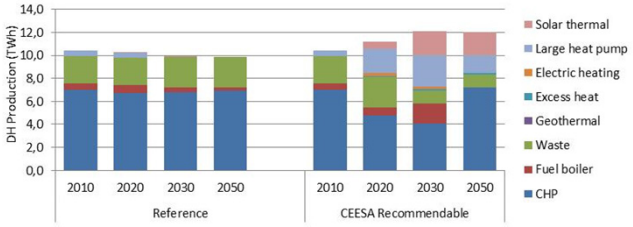
District heating production capacities

<u>CHP areas:</u>

- Central

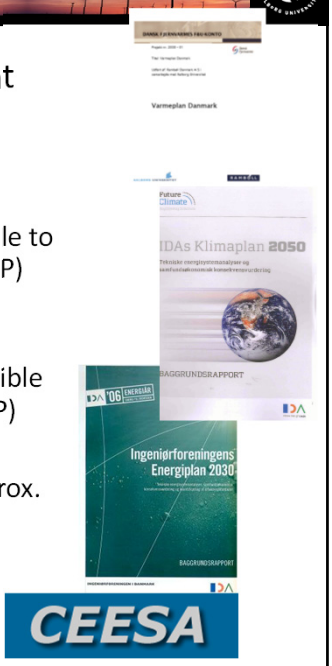


- Local



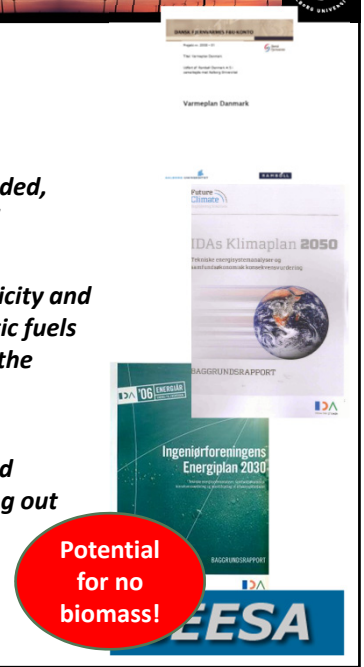
Large scale integration of intermittent resources require integration:

- Regulation of CHP and heat storage (implemented in DK in 2004): Makes possible to integrate 20-25% 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

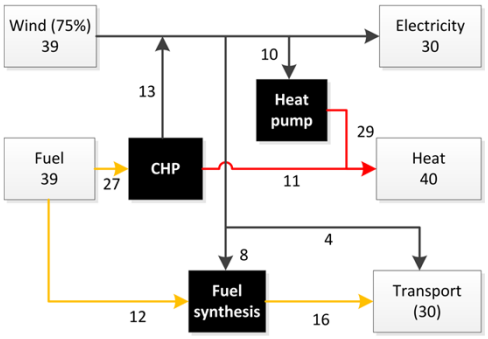


…and also

- ***"…all kinds of electricity storage should be avoided, if the aim is to put electricity back on the grid!"***
- ***"…transport demands should be meet by electricity and where direct electricity cannot be used, synthetic fuels using renewable energy should be used due to the limitations in the biomass resources."***
- ***"…synthetic fuels based on gasified biomass and electrolysis can pave the way to entirely phasing out biomass if CO_2 sources are available"***



Smart energy system with 75 % wind and syn-fuels



What are the challenges?

- We want to decrease the use of fossil fuels but:
  1. *The current system is extremely flexible…*
  2. *We cannot replace these with biomass only…*
  3. *We need to use intermittent renewable ressources!*

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Solution

Smart energy systems are crucial in 100% renewable energy systems

– **Smart Electricity Grids** to connect flexible electricity demands such as heat pumps and electric vehicles to the intermittent renewable resources such as wind and solar power.

– **Smart Thermal Grids** (District Heating and Cooling) to connect the electricity and heating sectors. This enables thermal storage to be utilised for creating additional flexibility and heat losses in the energy system to be recycled.

– **Smart Gas Grids** to connect the electricity, heating, and transport sectors. This enables gas storage to be utilised for creating additional flexibility. If the gas is refined to a liquid fuel, then liquid fuel storages can also be utilised.


Thank you for attention
Brian Vad Mathiesen
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http://people.plan.aau.dk/~bvm/
AALBORG UNIVERSITY
DENMARK
Remember –
3 EnergyPLAN
Special sessions
today and
tommorrow