4DH Forum International Conference
Friday 20 October in Tokyo

Smart Energy System and 4GDH for decarbonization

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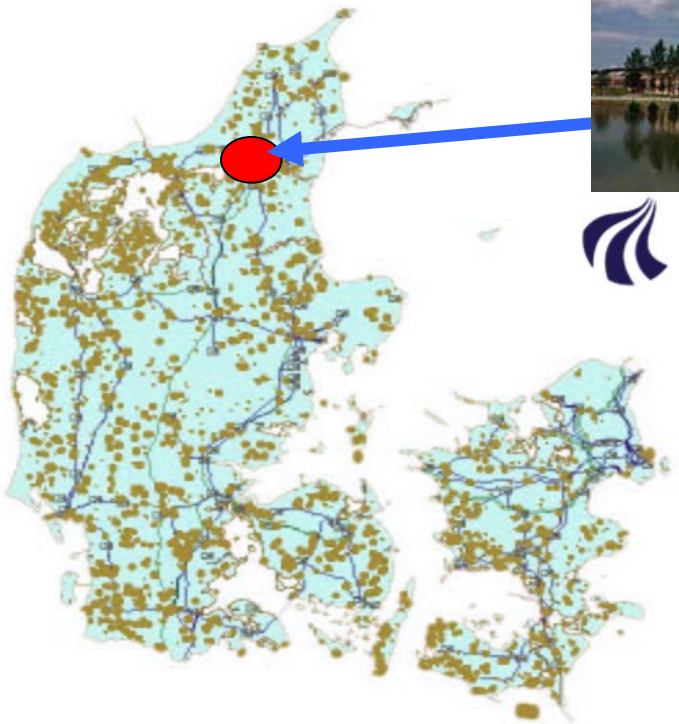
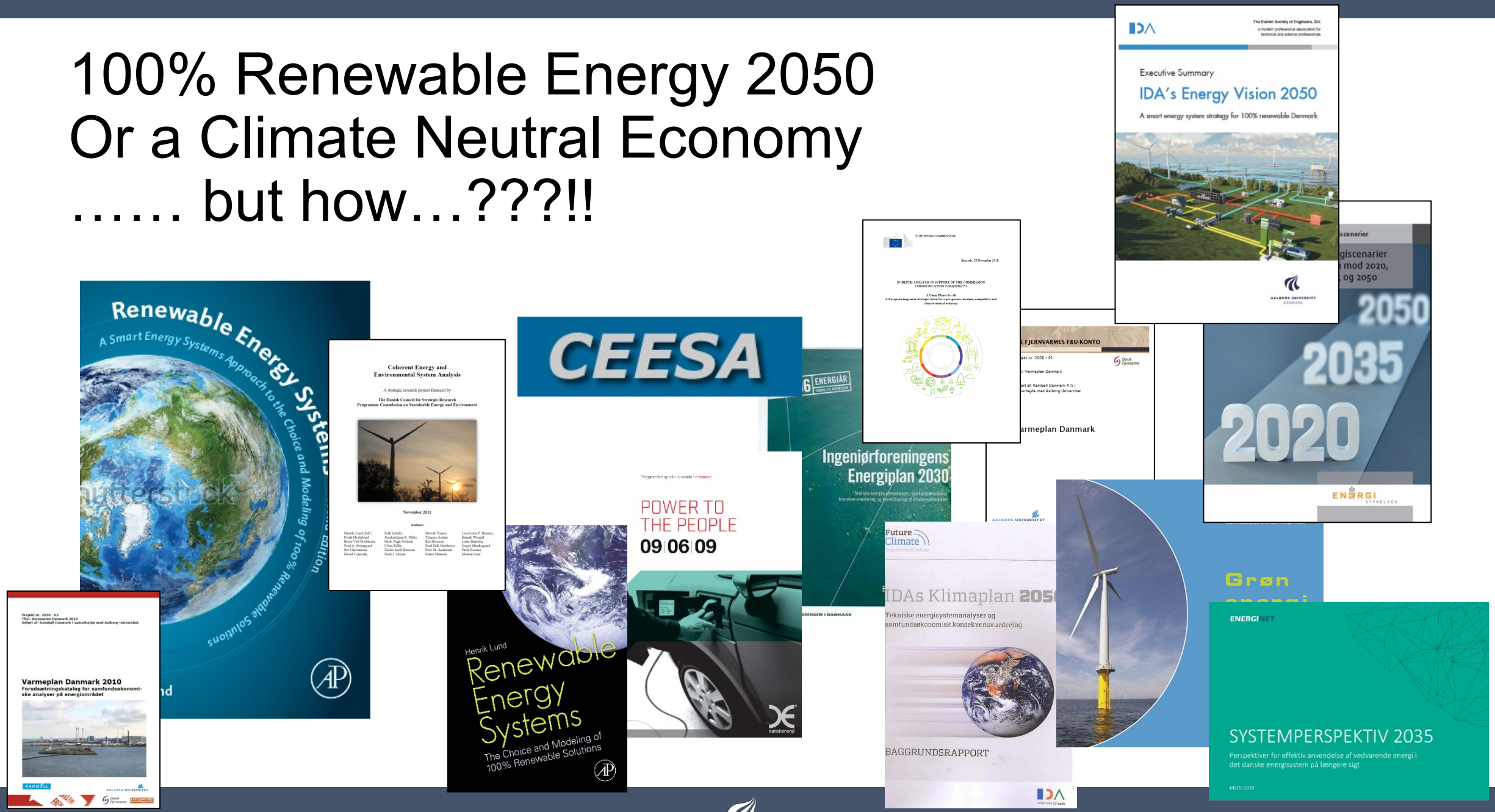


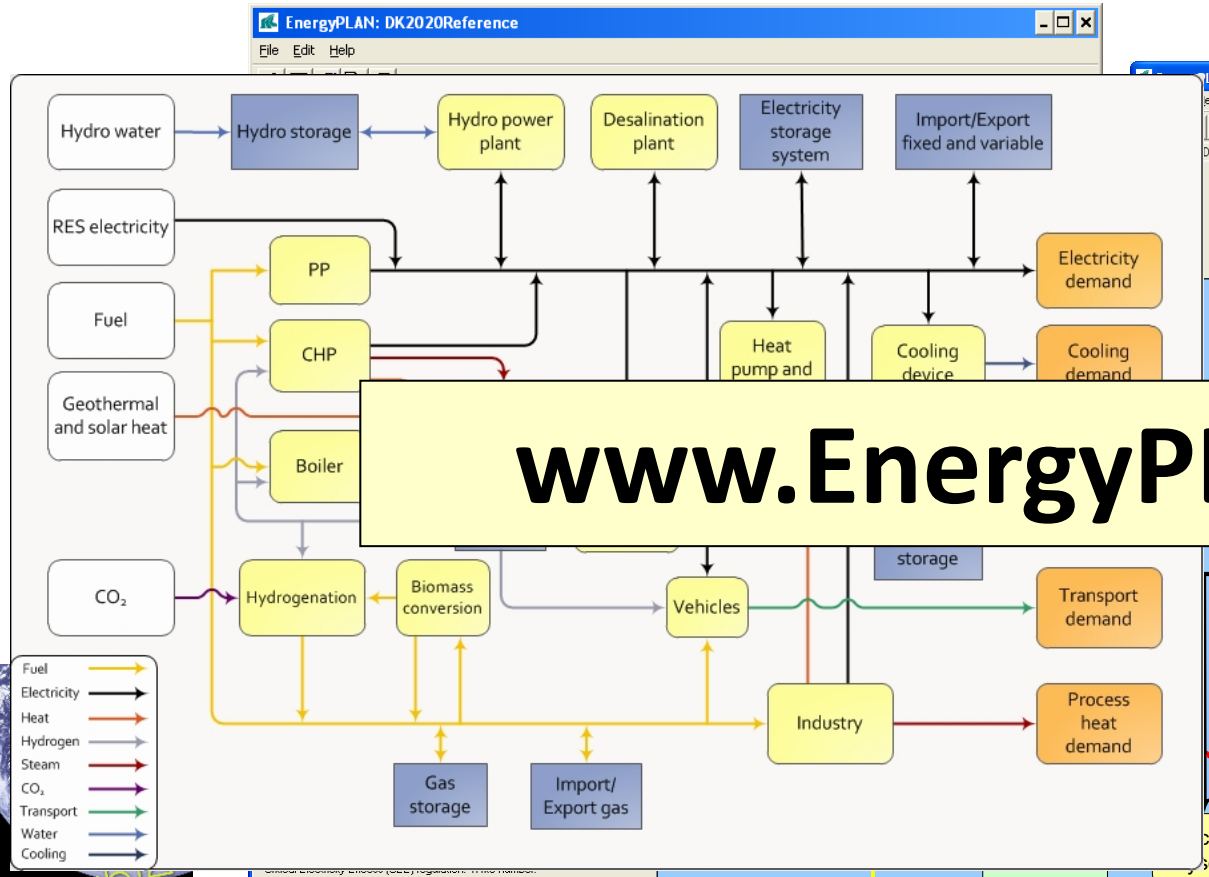
Jutland/Denmark (2022):

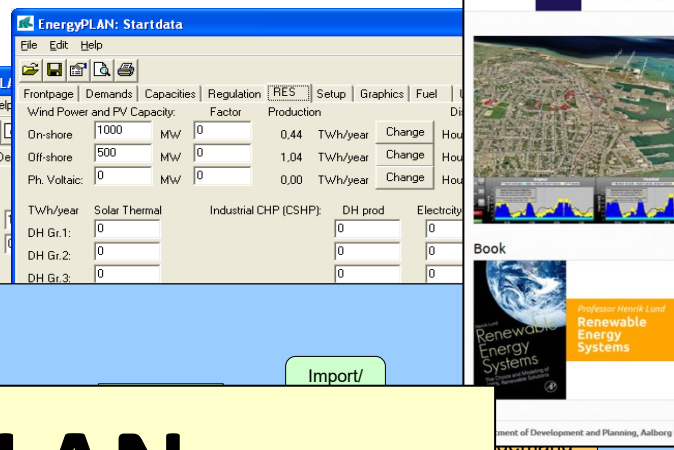
- approx. 50% wind power
- High share of the world's offshore power
- 30-50% of electricity supplied by CHP
- >50% District Heating
- > 30% Biogas in the natural gas supply

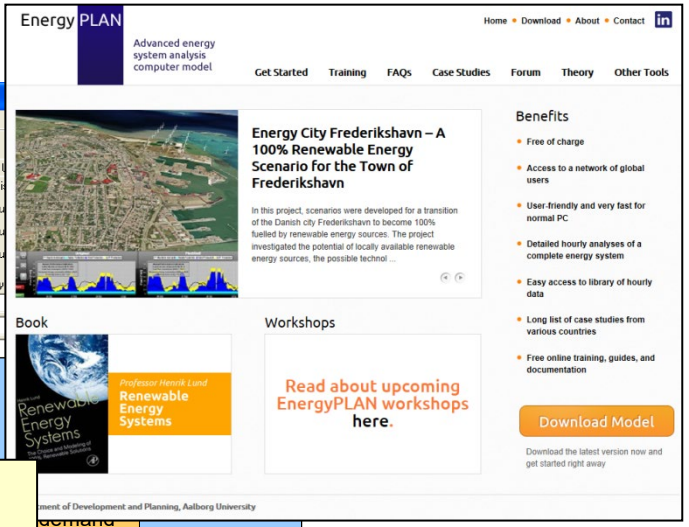
100% Renewable Energy 2050
Or a Climate Neutral Economy
..... but how…???!!



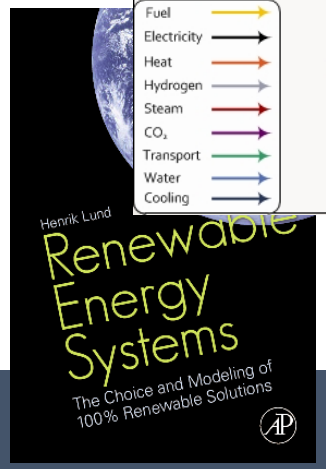
Energi System Analyse Model

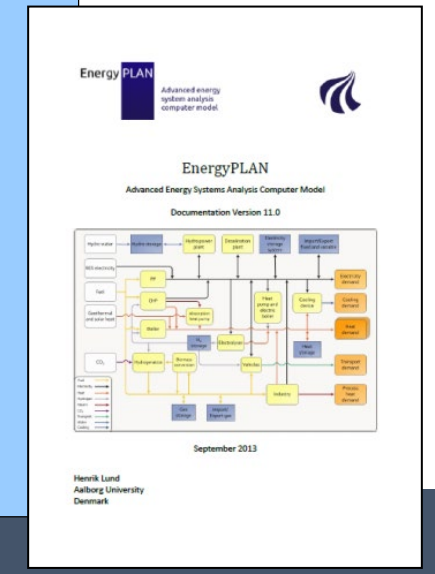




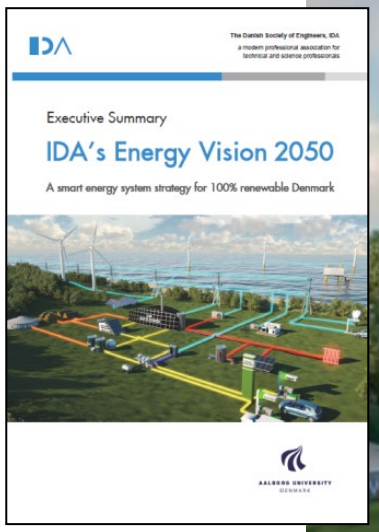


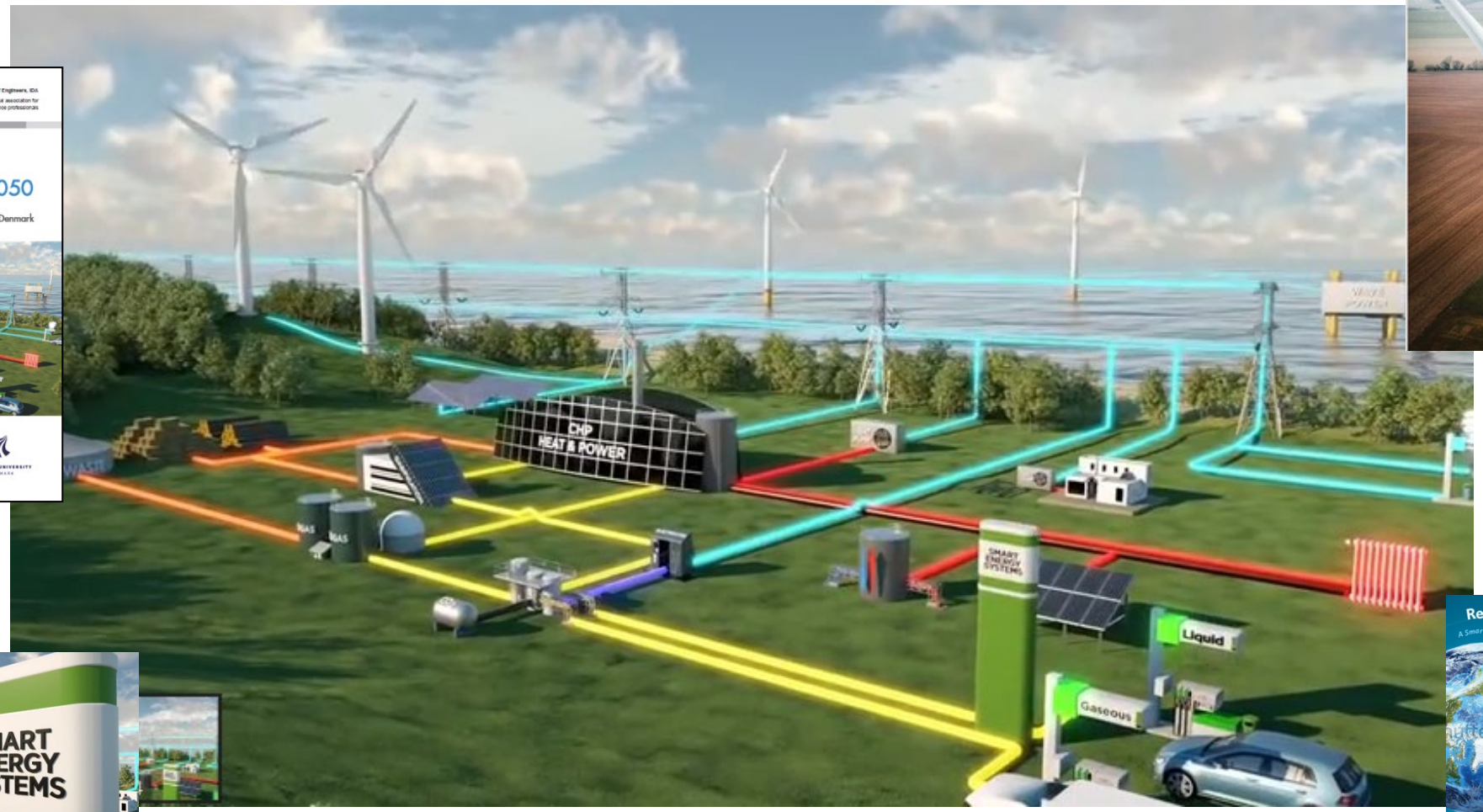
www.EnergyPLAN.eu

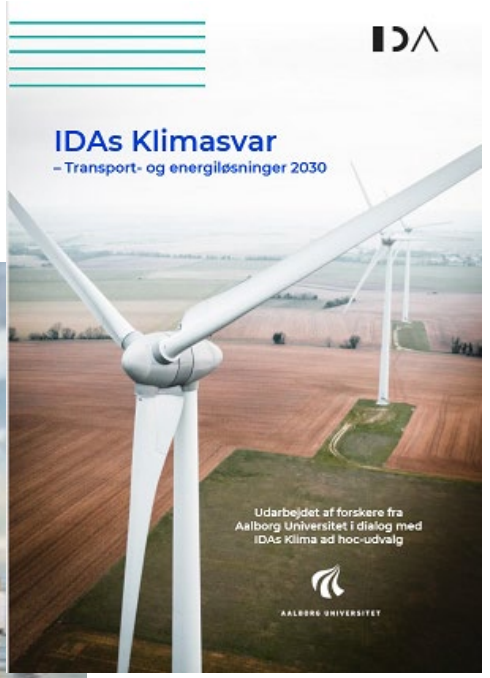


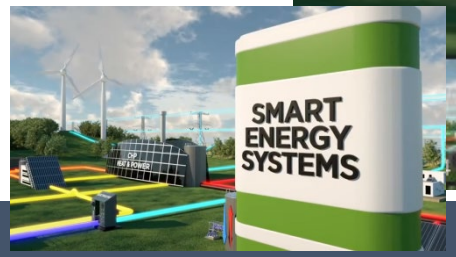


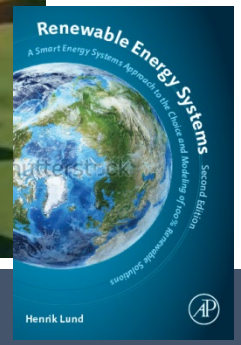
A Holistic Smart Energy Systems Approach

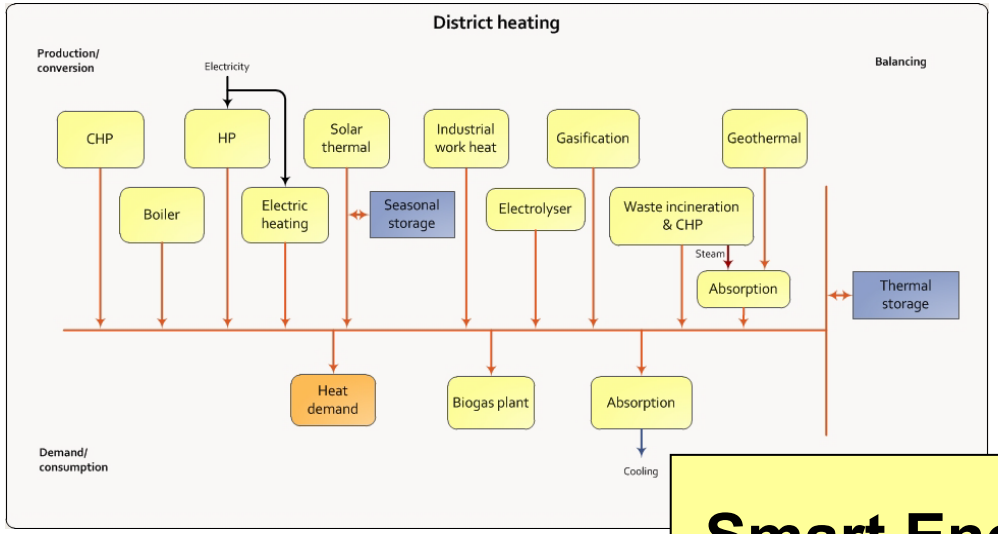


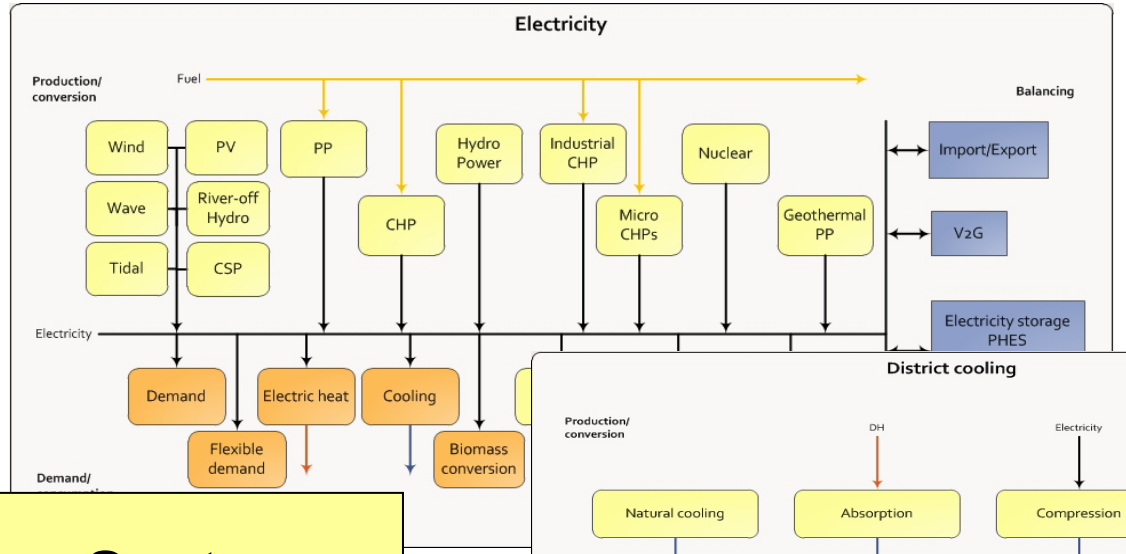


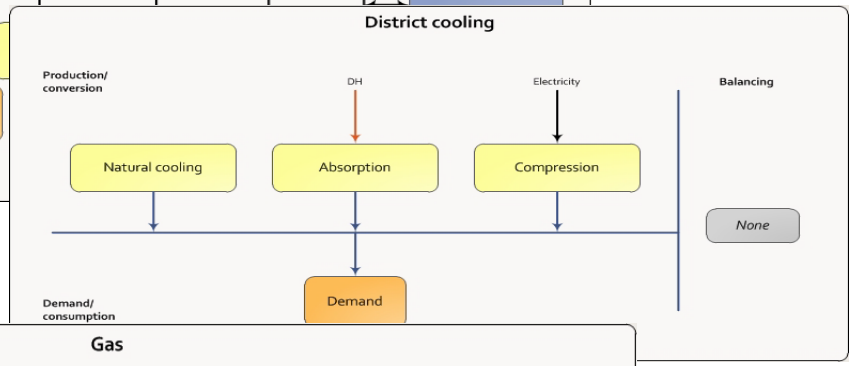






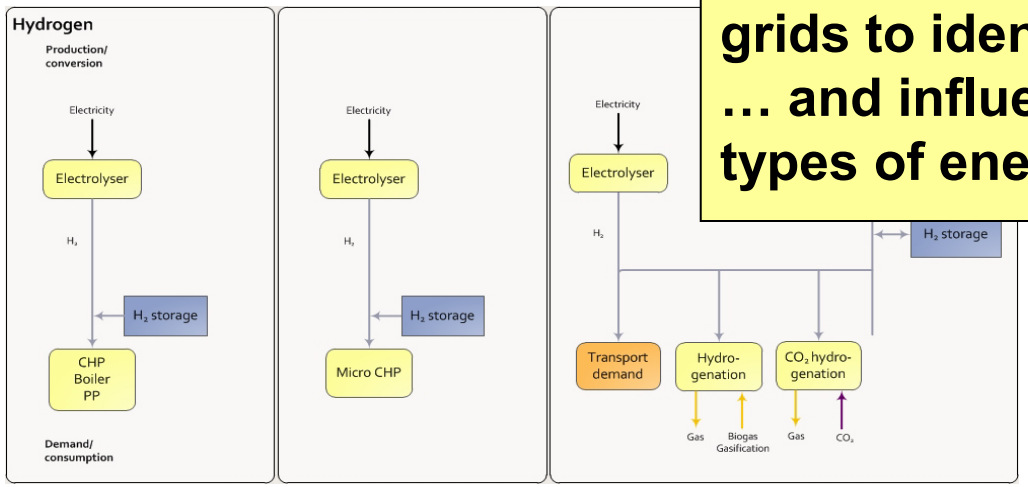


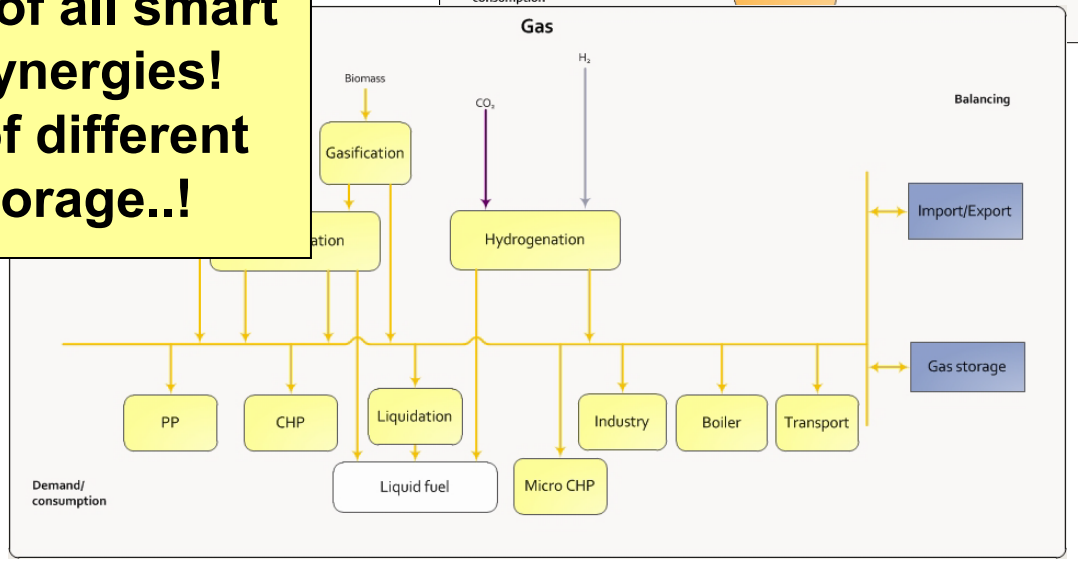




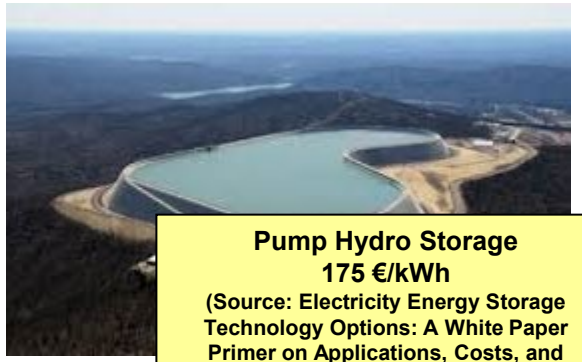
Smart Energy Systems:

Hourly modelling of all smart grids to identify synergies! … and influence of different types of energy storage..!



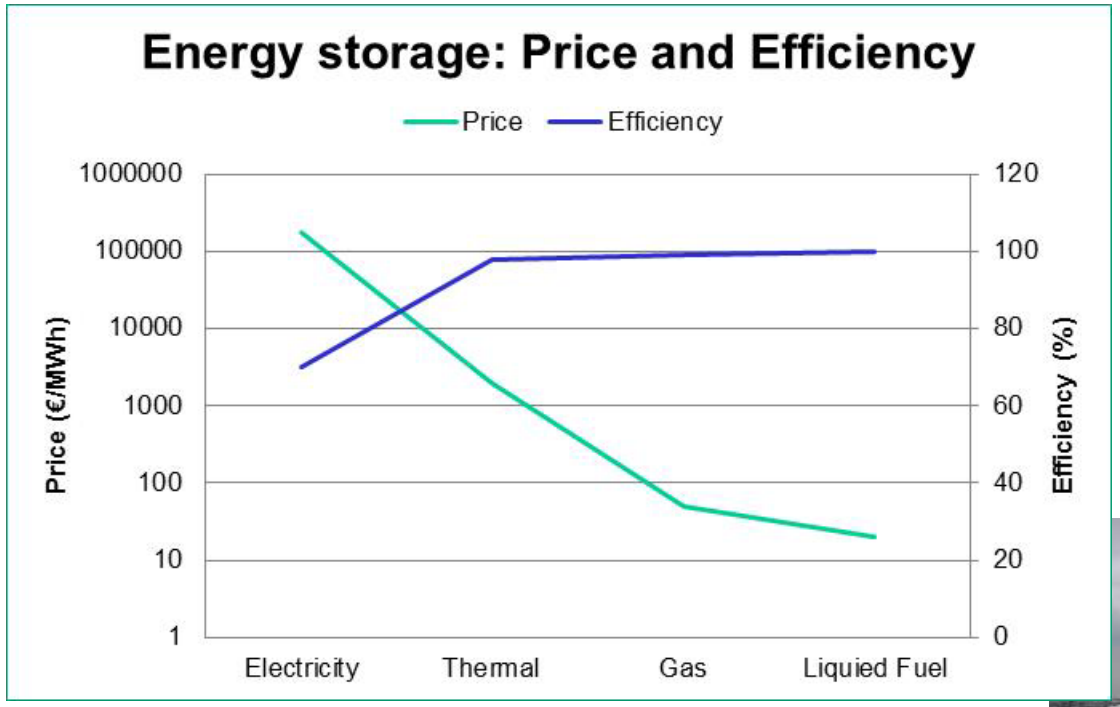


Energy Storage



Pump Hydro Storage
175 €/kWh
(Source: Electricity Energy Storage Technology Options: A White Paper Primer on Applications, Costs, and Benefits. Electric Power Research Institute, 2010)

Natural Gas Underground Storage
0.05 €/kWh
(Source: Current State Of and Issues Concerning Underground Natural Gas Storage. Federal Energy Regulatory Commission, 2004)



Thermal Storage
1-4 €/kWh
(Source: Danish Technology Catalogue, 2012)

Oil Tank
0.02 €/kWh
(Source: Dahl KH, Oil tanking Copenhagen A/S, 2013: Oil Storage Tank. 2013)

Energy Storage Capacities in Denmark

Danish Oil Storage
~50 TWh

Danish Gas Storage
~11 TWh

Danish
Thermal Storage
~0.090 TWh

Energy Storage Capacities in 100 % RES Denmark 2050 (IDA)

Danish Oil Storage
~50 TWh

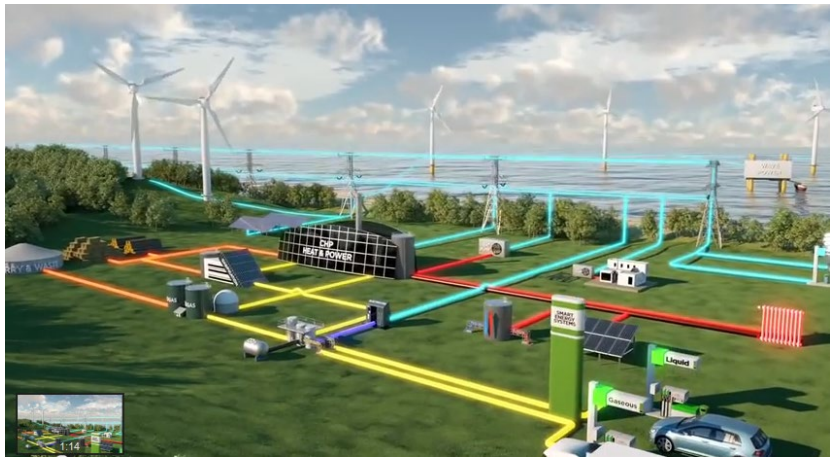
Danish Gas Storage
~11 TWh

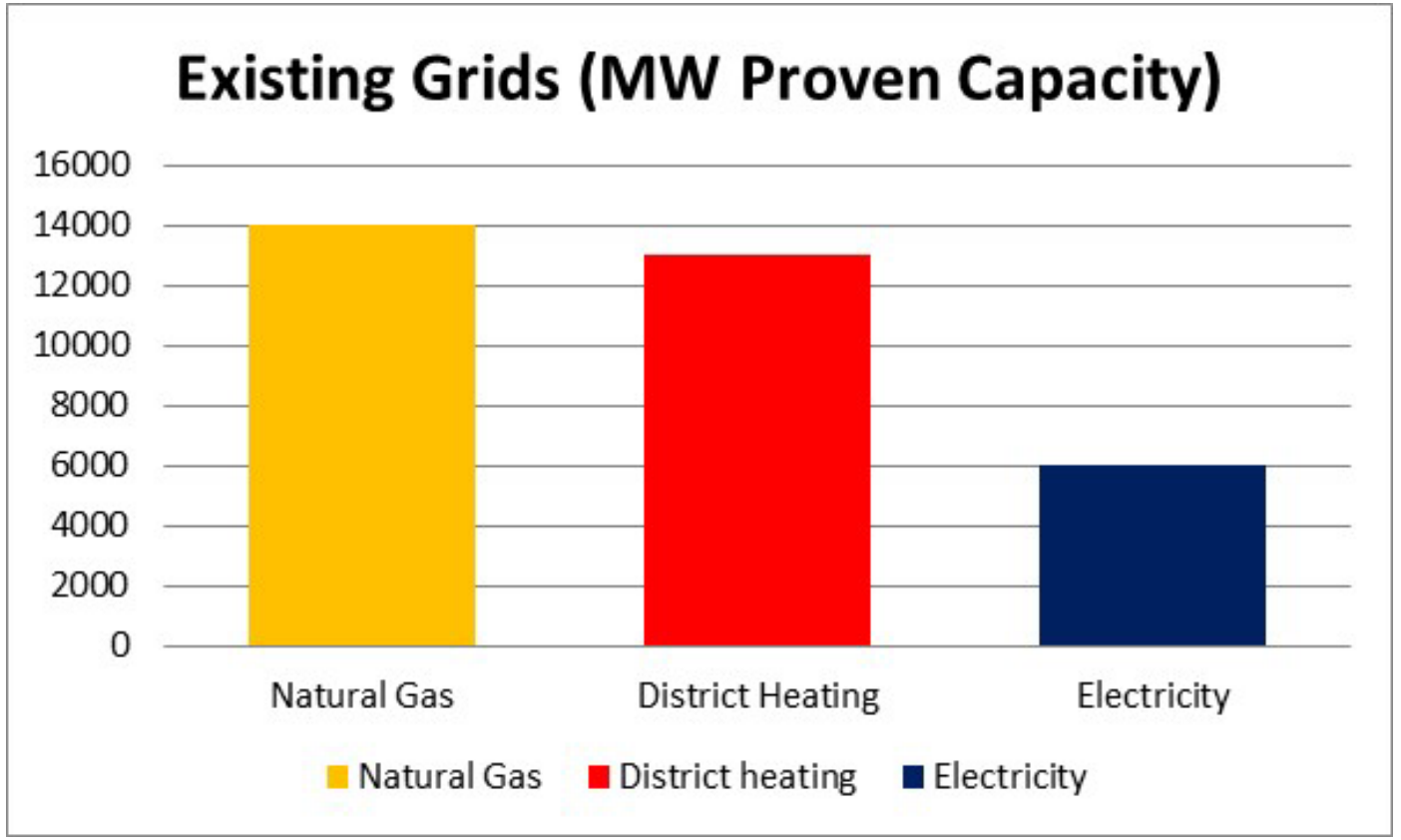
Danish
H_2 Storage
~0.550 TWh

Danish
Thermal Storage
~0.200 TWh

Danish
Electricity Storage
~0.015 TWh

Existing distribution grids

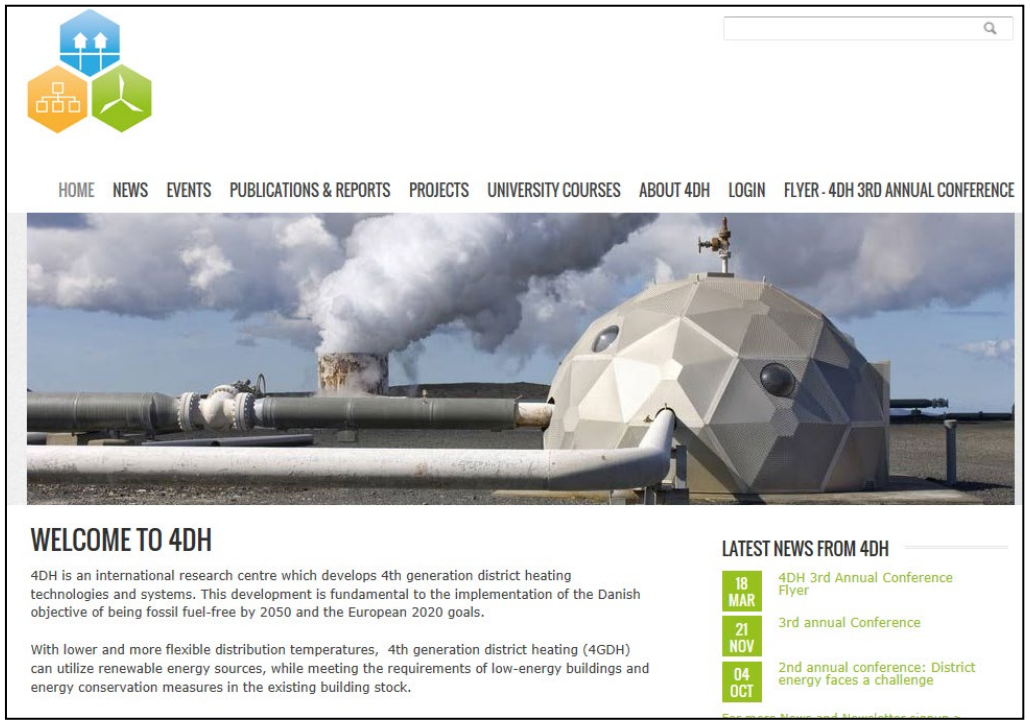




www.4DH.dk

4DH

4th Generation District Heating Technologies and Systems



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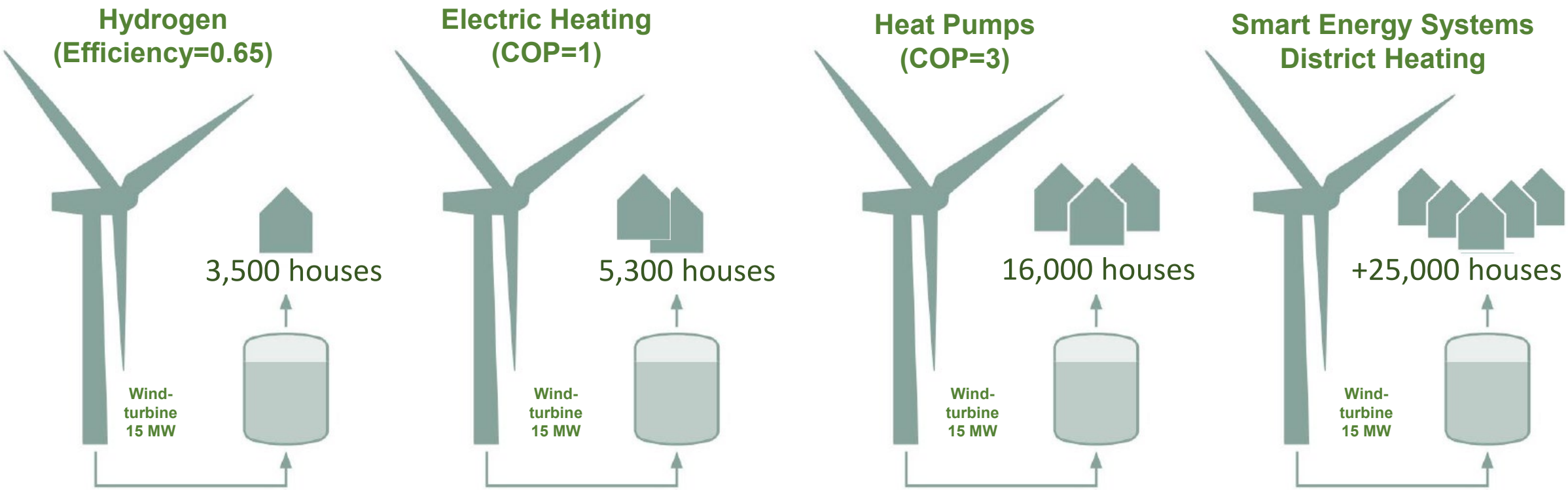
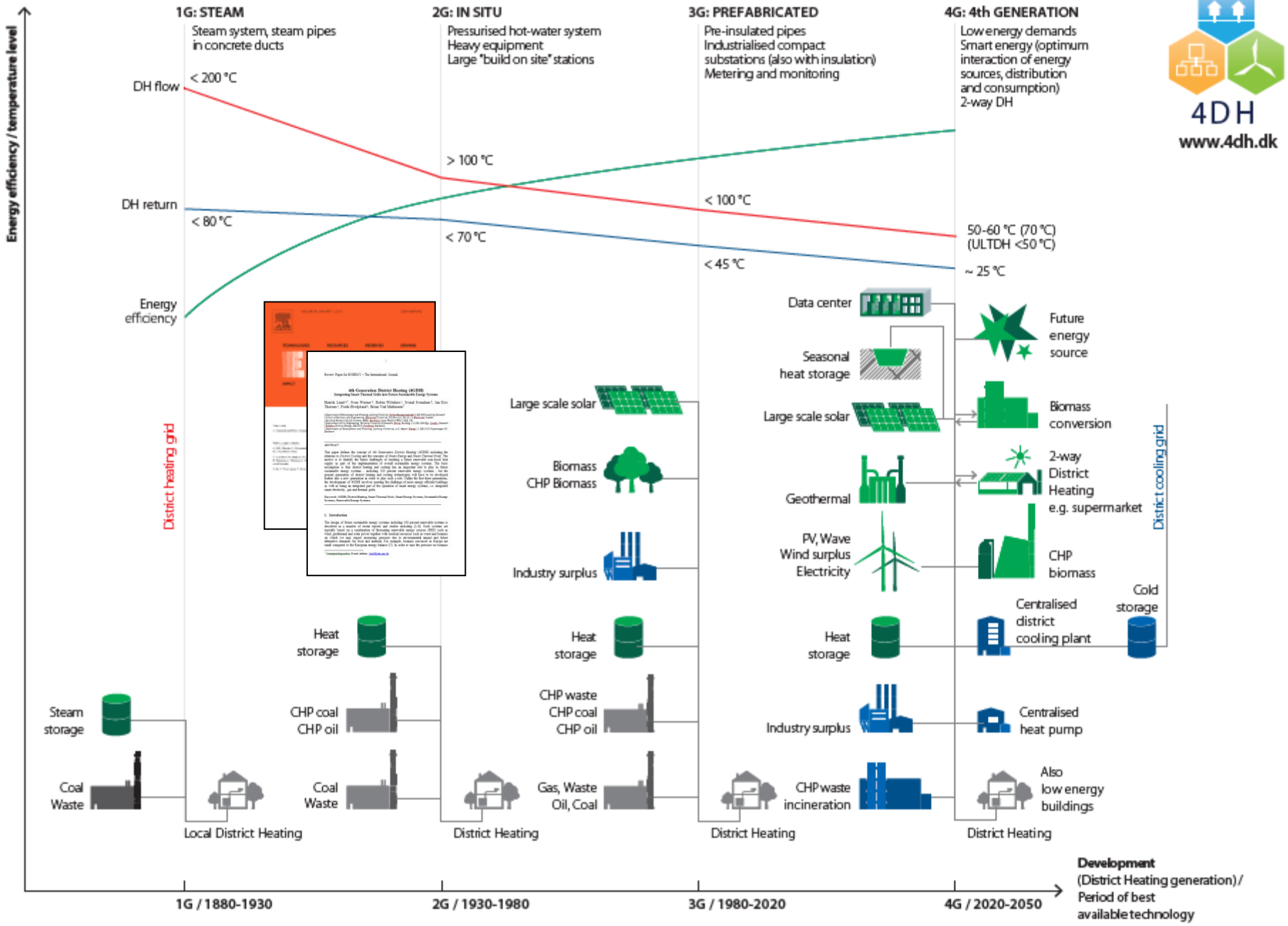
Innovation Fund Denmark
RESEARCH, TECHNOLOGY & GROWTH

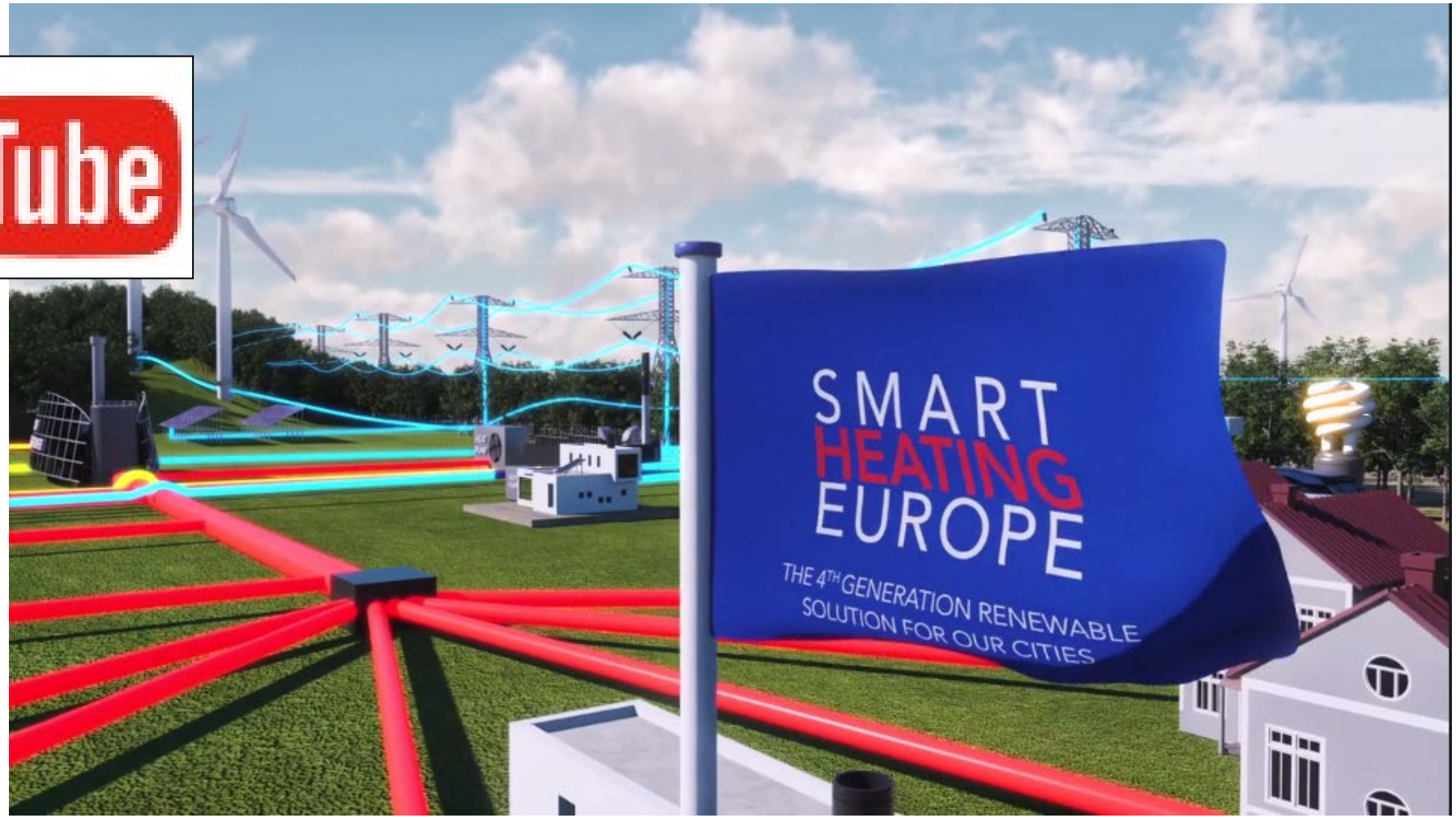
Hydrogen for heating of houses..???



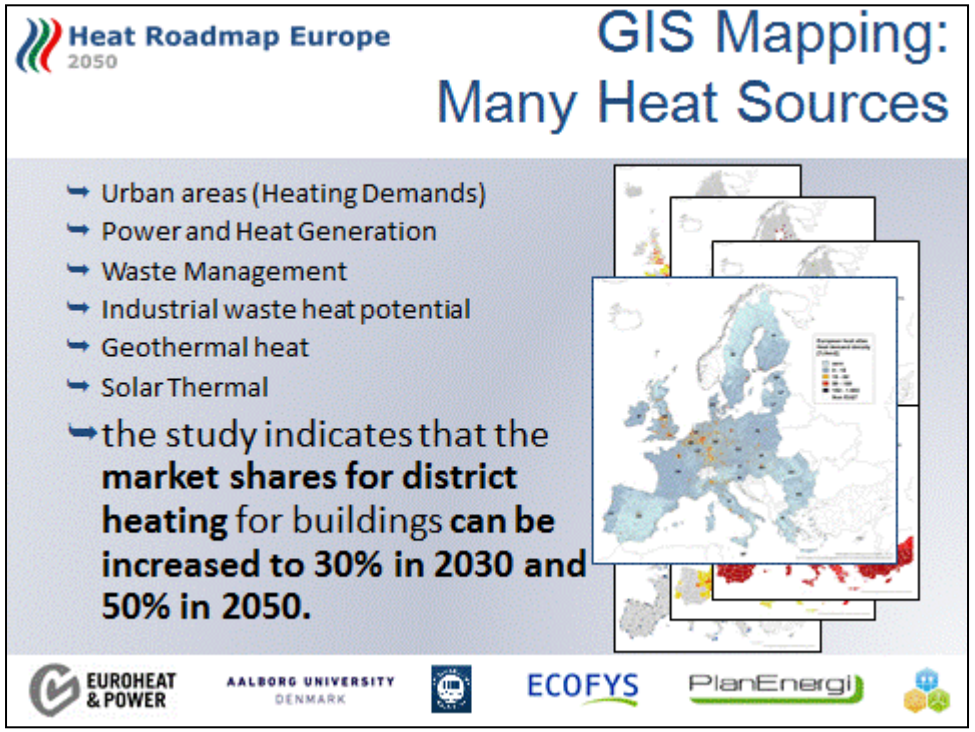

1G: STEAM
Steam system, steam pipes in concrete ducts
2G: IN SITU
Pressurised hot-water system
Heavy equipment
Large "build on site" stations
3G: PREFABRICATED
Pre-insulated pipes
Industrialised compact substations (also with insulation)
Metering and monitoring
4G: 4th GENERATION
Low energy demands
Smart energy (optimum interaction of energy sources, distribution and consumption)
2-way DH
4DH
www.4dh.dk
Energy efficiency / temperature level
DH flow
< 200 °C
> 100 °C
< 100 °C
50-60 °C (70 °C)
(ULTDH <50 °C)
DH return
< 80 °C
< 70 °C
< 45 °C
~ 25 °C
Energy efficiency
District heating grid
District cooling grid
Data center
Seasonal heat storage
Large scale solar
Future energy source
Biomass conversion
2-way District Heating
e.g. supermarket
Geothermal
PV, Wave Wind surplus Electricity
CHP biomass
Cold storage
Centralised district cooling plant
Heat storage
Industry surplus
Centralised heat pump
CHP waste incineration
Also low energy buildings
Large scale solar
Biomass CHP Biomass
Industry surplus
Heat storage
CHP waste CHP coal CHP oil
Gas, Waste Oil, Coal
Heat storage
CHP coal CHP oil
Coal Waste
Steam storage
Coal Waste
Local District Heating
District Heating
District Heating
District Heating
1G / 1880-1930
2G / 1930-1980
3G / 1980-2020
4G / 2020-2050
Development
(District Heating generation) / Period of best available technology

DENMARK

Smart Heating Europe



Heat Roadmap Europe



4DH
4th Generation District Heating Technologies and Systems

ECOFYS
sustainable energy for everyone

PlanEnergi

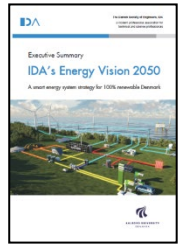
HÖGSKOLAN HALMSTAD

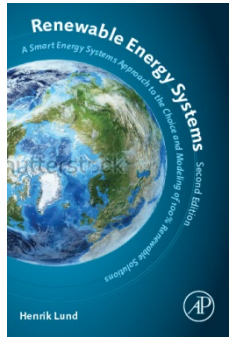
IDAs Climate Response: In a European context

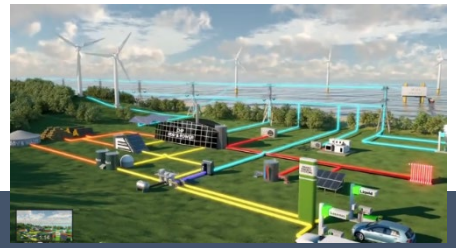
Denmark should fulfill its objective of renewable energy and CO2-reductions in a way, so it fits well into a context in which the rest of Europe - and the world - will do the same.

Therefore:

- Denmark should include the Danish share of ***international aviation and shipping*** even though it is not included yet in the UN way of calculating the Danish CO2 emissions.
- Denmark should not exceed our share of ***sustainable use of biomass*** in the world.
- Denmark should make our contribution in terms of ***flexibility and reserve capacity*** to integrate wind and solar into the ***European electricity supply***.



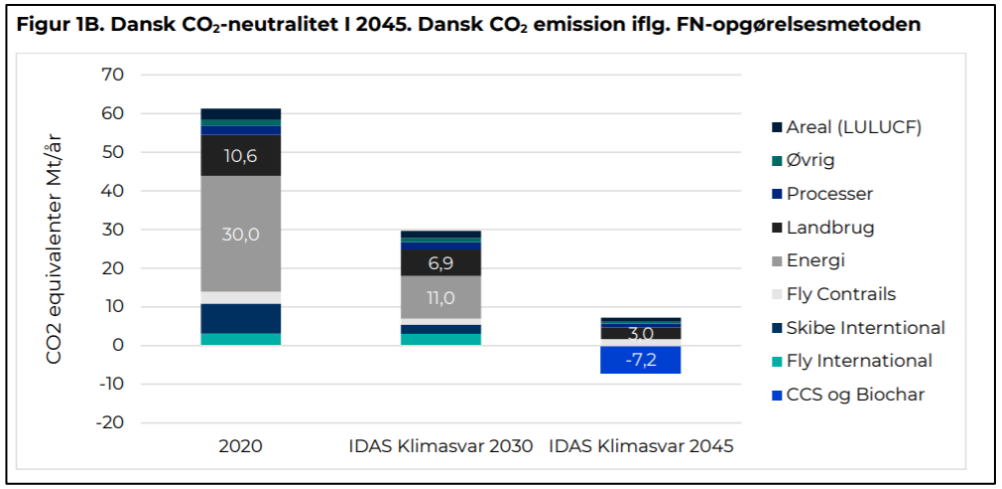


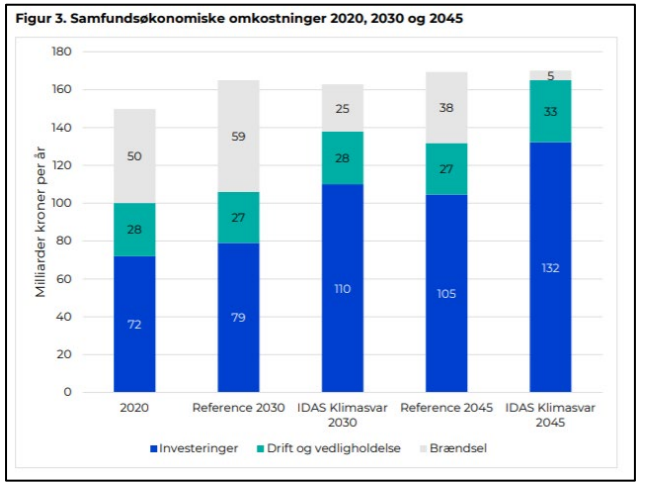


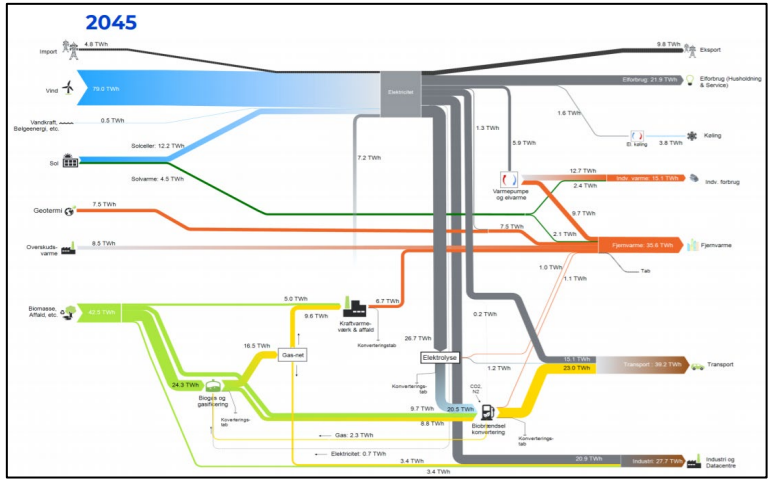
IDA´s Climate Response 2045

How Denmark Can Become Climate Neutral

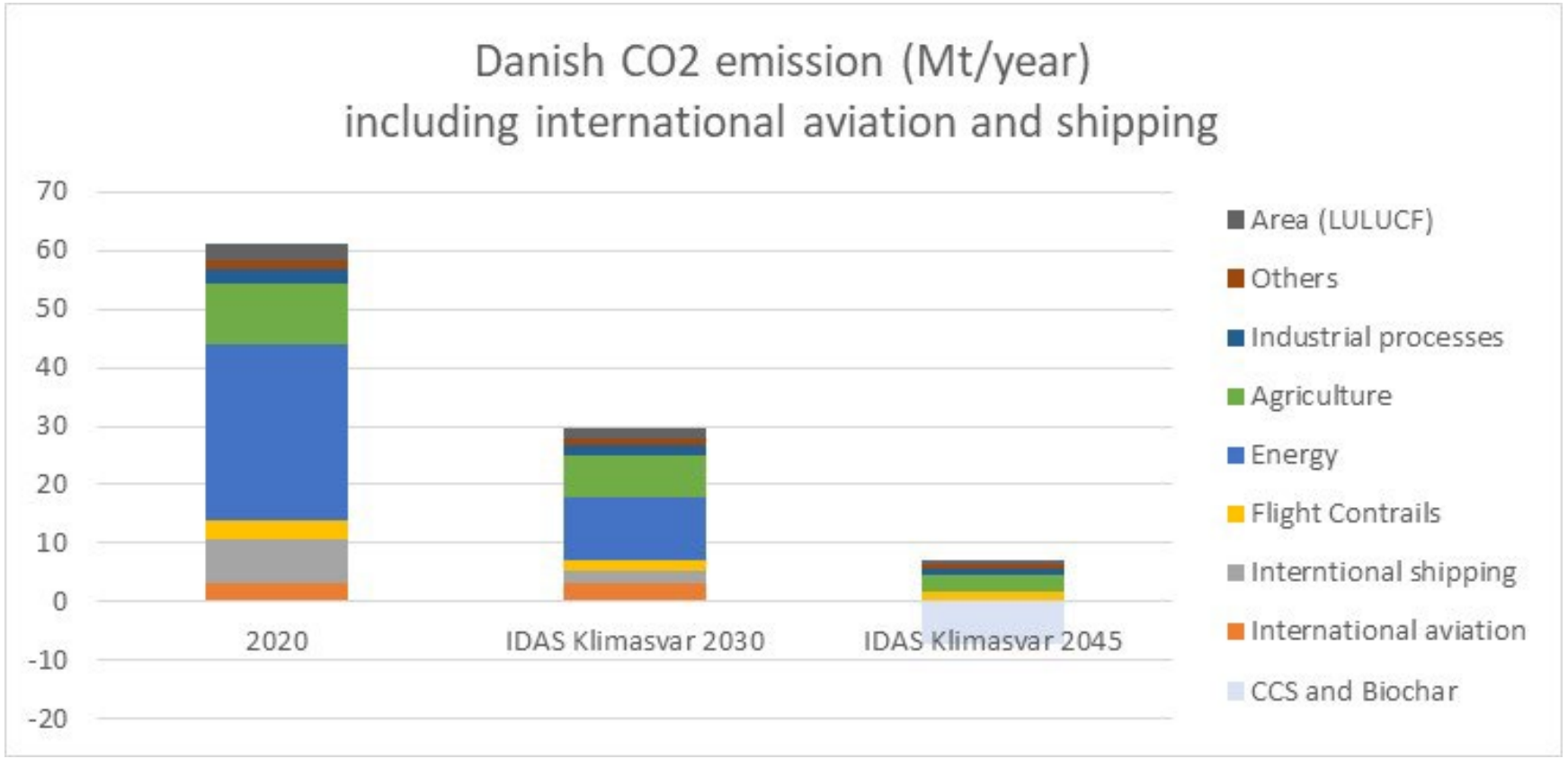
- Include Danish Share of International Aviation and Shipping
- Within the Danish share of Global Sustainable Biomass resources
- Reach the 2050 climate neutral goal already in 2045
- Coordinated with actions within agriculture, LULUFC and processes

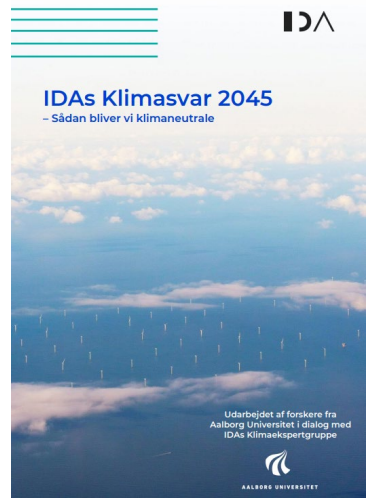






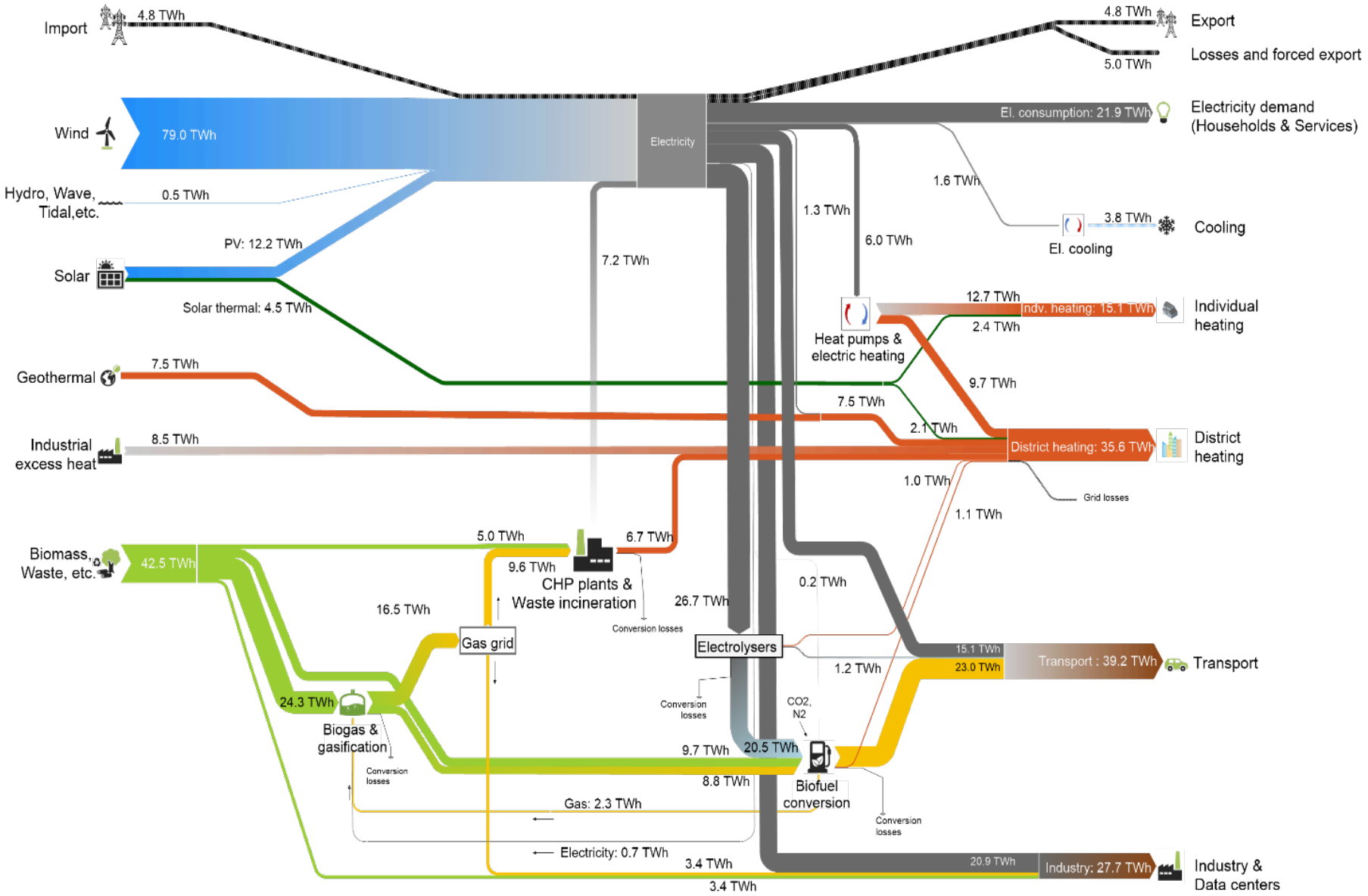
A fully decarbonized Denmark 2045





2045

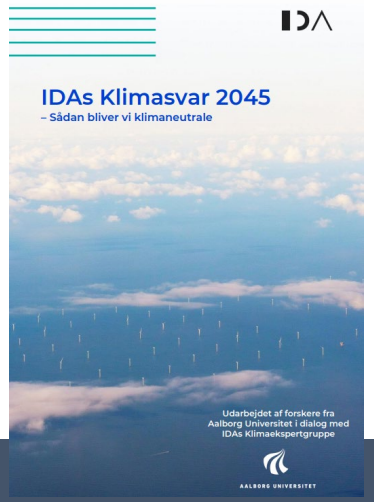

IDAs Klimasvar
– Transport- og energiløsninger 2030
IDAs Klimasvar 2045
– Sådan bliver vi klimaneutrale

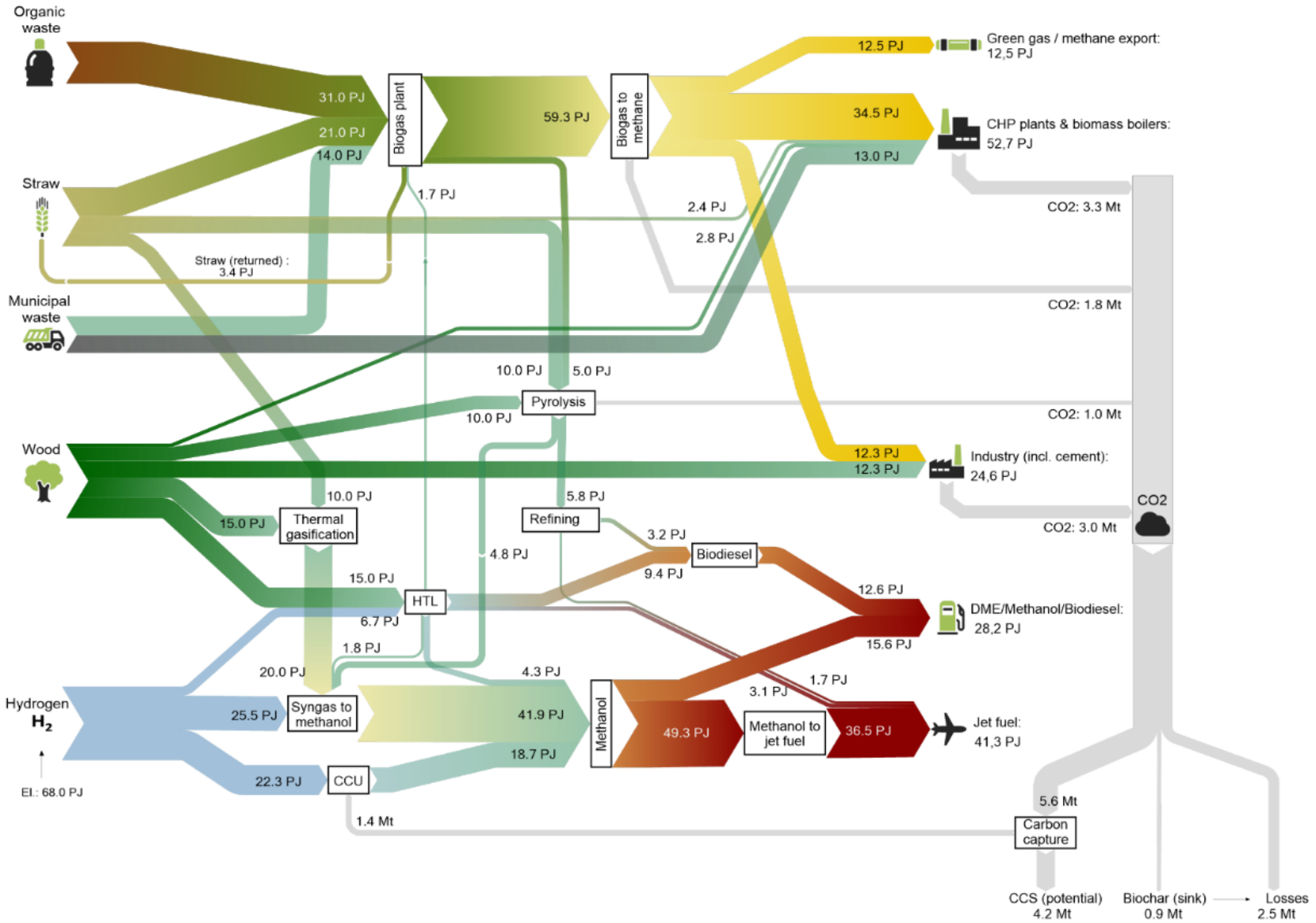

Import
4.8 TWh
4.8 TWh
Export
5.0 TWh
Losses and forced export
Wind
79.0 TWh
Electricity
El. consumption: 21.9 TWh
Electricity demand (Households & Services)
Hydro, Wave, Tidal,etc.
0.5 TWh
1.6 TWh
1.3 TWh
6.0 TWh
3.8 TWh
Cooling
El. cooling
PV: 12.2 TWh
Solar
7.2 TWh
Solar thermal: 4.5 TWh
12.7 TWh
Indv. heating: 15.1 TWh
Individual heating
2.4 TWh
Heat pumps & electric heating
9.7 TWh
7.5 TWh
Geothermal
7.5 TWh
2.1 TWh
Industrial excess heat
8.5 TWh
District heating: 35.6 TWh
District heating
1.0 TWh
Grid losses
1.1 TWh
5.0 TWh
6.7 TWh
Biomass, Waste, etc.
42.5 TWh
9.6 TWh
CHP plants & Waste incineration
26.7 TWh
Conversion losses
0.2 TWh
16.5 TWh
Gas grid
Electrolysers
15.1 TWh
Transport : 39.2 TWh
Transport
1.2 TWh
23.0 TWh
24.3 TWh
Conversion losses
CO2, N2
Biogas & gasification
9.7 TWh
20.5 TWh
Conversion losses
8.8 TWh
Biofuel conversion
Gas: 2.3 TWh
Electricity: 0.7 TWh
3.4 TWh
20.9 TWh
Industry: 27.7 TWh
Industry & Data centers
3.4 TWh

Biomasse 2045

Overview:

(153 PJ minus eksport 13 PJ = 140 PJ svarende til 23 GJ/capita)





Heat Plan Denmark 2021

Varmeplan Danmark 2021

Brian Vad Mathiesen, Henrik Lund, Steffen Nielsen, Peter Sorknæs, Diana Carolina Moreno Saltos og Jakob Z. Thellufsen

Aalborg Universitet

Why Heat Plan Denmark 2021?

How can the heating sector best support the political goals?

- 70% reduction in greenhouse gases by 2030
- Climate-neutral Denmark in 2050

Key questions:

- Where is the balance between heat savings and heat supply?
- Where should there be district heating and where should it be individual?
- What should the individual heat supply be based on?
- Where should the district heating come from?
- What are the innovative challenges e.g. 4th generation district heating, smart meters, digitization, power2X, data centers, geothermal, etc.
- How does the heating sector best help in terms of flexibility in the entire energy supply?

Four main points

- ***Energy savings in the building stock are important****. A good balance between energy savings and renewable energy must be achieved to have low costs and low fuel consumption. This means that a continued focus on energy renovation in buildings is important to implement savings of 32-36%.*

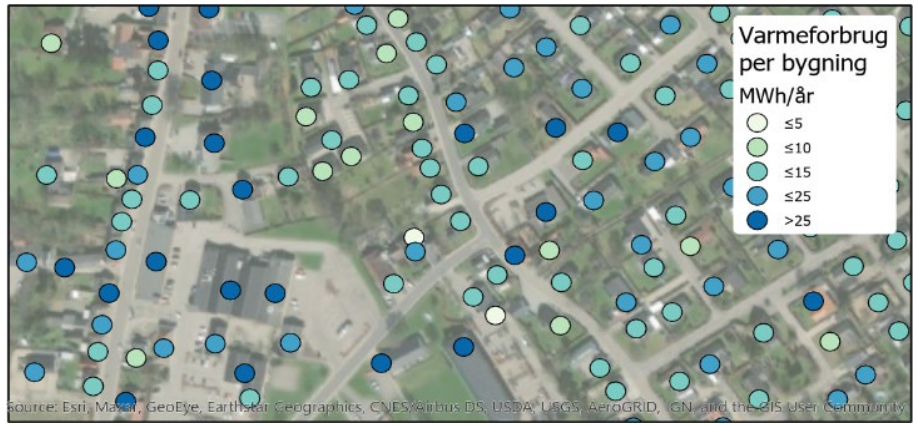
- ***District heating should be expanded to cover 63-70% of the heat market*** *as individual natural gas and oil-fired boilers are phased out in existing urban areas and as new urban areas emerge. Outside the district heating areas, the heat should come from* ***individual heat pumps*** *supplemented by solar thermal. This combination provides the most energy efficient and flexible solution.*

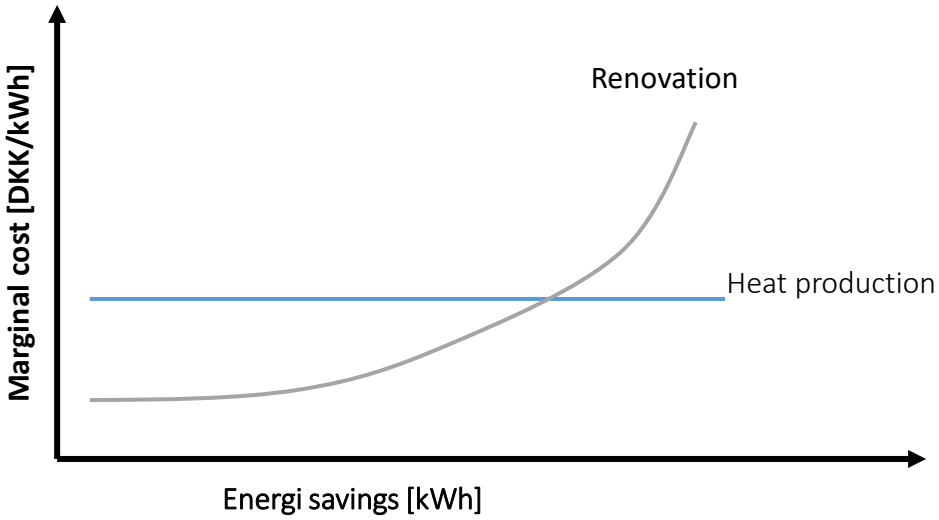
- *In district heating, a* ***targeted focus should be placed on a transition to 4th generation district heating*** *with lower temperatures. It provides the lowest cost and most efficient use of geothermal heat, waste heat, and large heat pumps.*

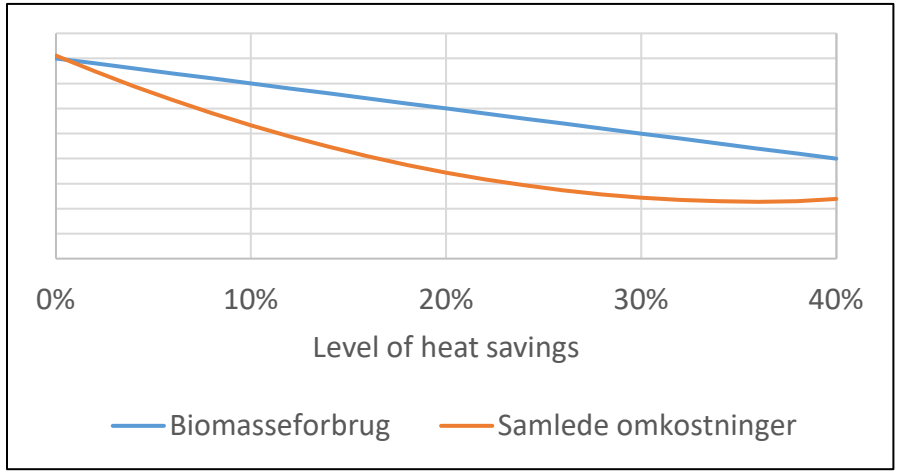
- *In future low-carbon energy systems there is* ***great potential for utilizing geothermal and waste heat*** *from industry, data centers, and Power-to-X. These opportunities should be exploited.*

36-40% energy savings in the building stock

- **Energy savings in the building stock are important.**
- **What is the right balance between energy savings and energy efficiencies and renewable energy.**
  - Financially, the balance is 36% (saving of DKK 1.1-1.3 billion / year)
  - The pressure on biomass can be reduced for a marginal extra cost by going to 40%

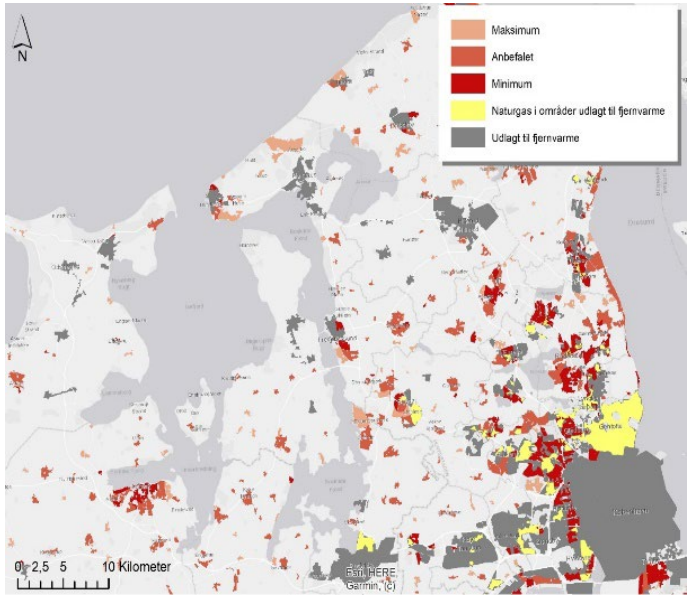


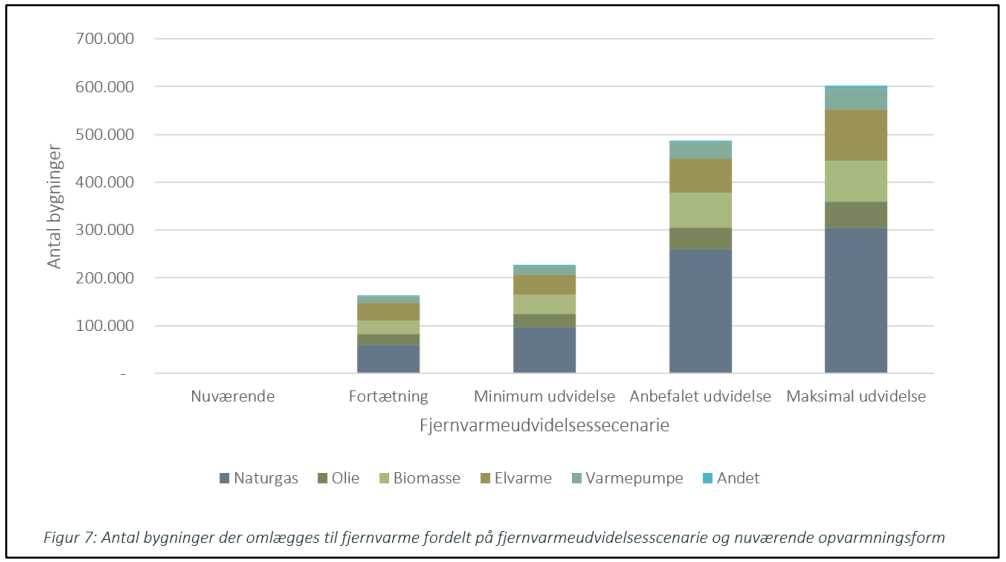




District heating should be expanded to 63-70%

- Current: Current buildings registered with district heating (~ 50%)
- Densification: All buildings in areas designated for district heating (~ 59%)
- Minimum expansion: Expansions to urban areas with heat density above 15 kWh/m^2 (~ 63%)
- **Recommended expansion**: Expansions to urban areas with heat density above 10 kWh/m^2 (~ 70%)
- Maximum expansion: Expansions to urban areas with heat density above 5 kWh/m^2 (~ 74%)





Figur 7: Antal bygninger der omlægges til fjernvarme fordelt på fjernvarmeudvidelsesscenarie og nuværende opvarmningsform

Natural gas conversion:

- 260,000 to district heating
- 115,000 to indv. heat pumps

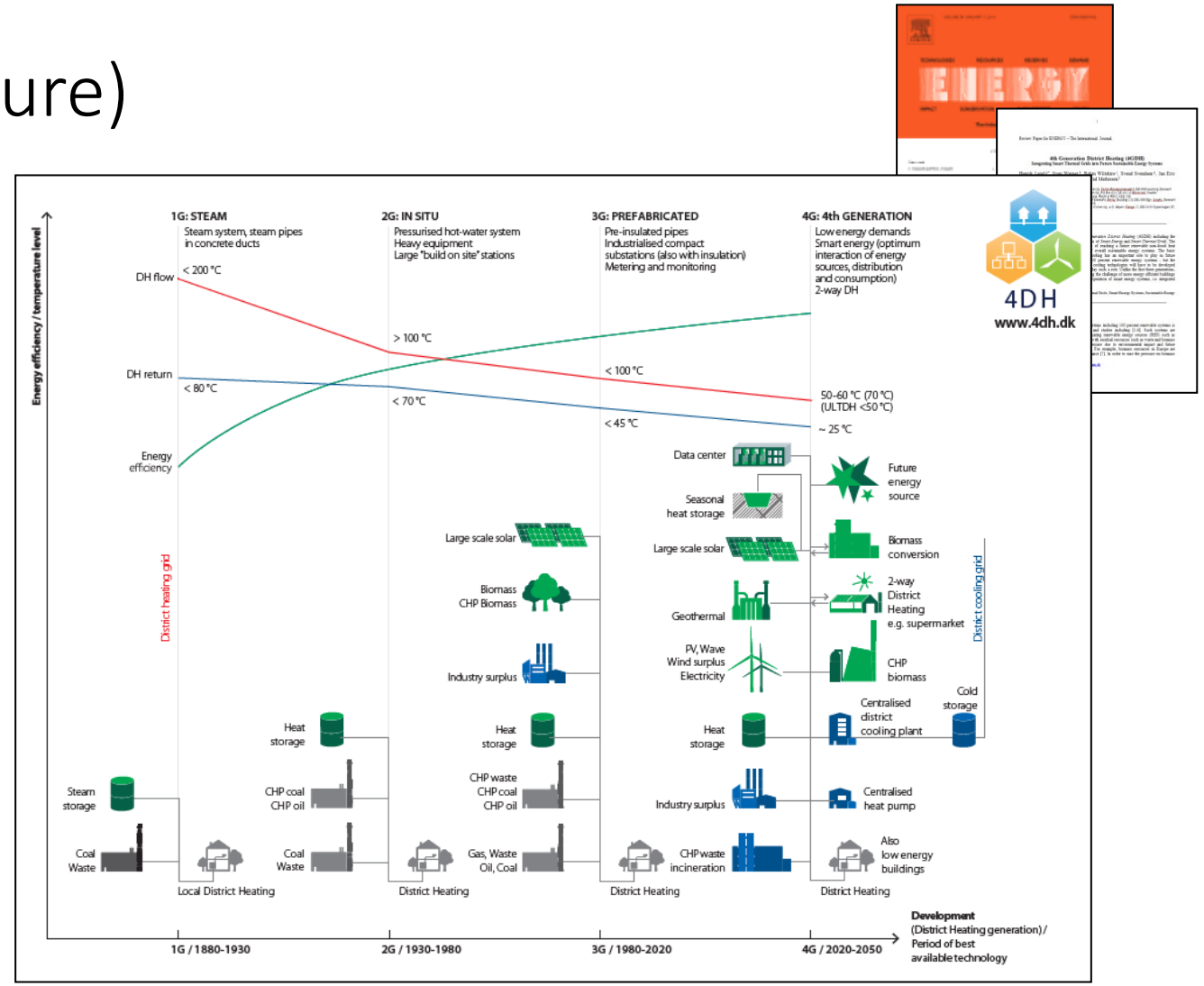
Oil boiler conversion:

- 44,000 to district heating
- 70,000 to indv. heat pumps

Biomass boiler conversion:

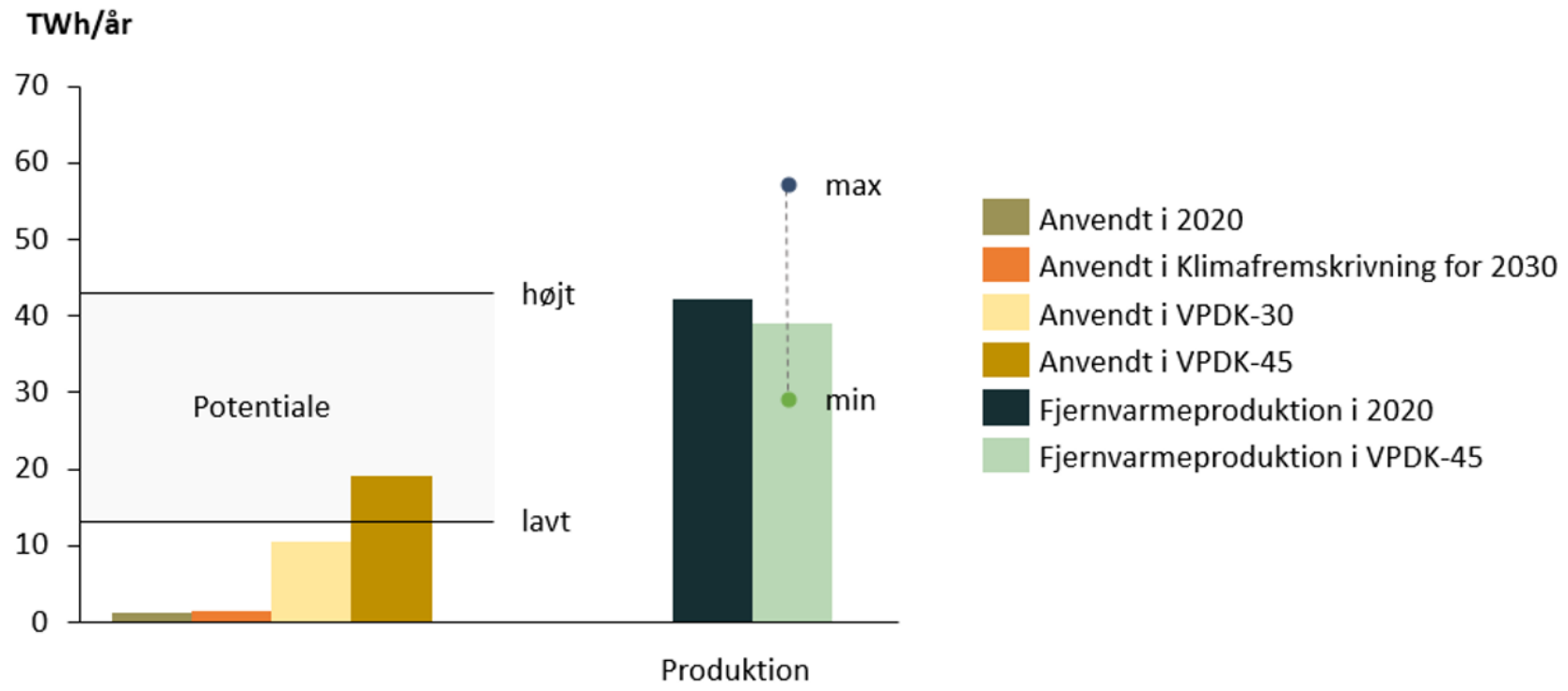
- 74,000 to district heating
- 183,000 to indv. heat pumps

4th generation (low temperature) district heating



In the district heating supply, a ***targeted focus should be placed on the transition to 4th generation district heating with lower temperatures***. It provides the lowest costs and the most efficient use of geothermal energy, waste heat, efficient electrification through large heat pumps and existing and new heat storages.

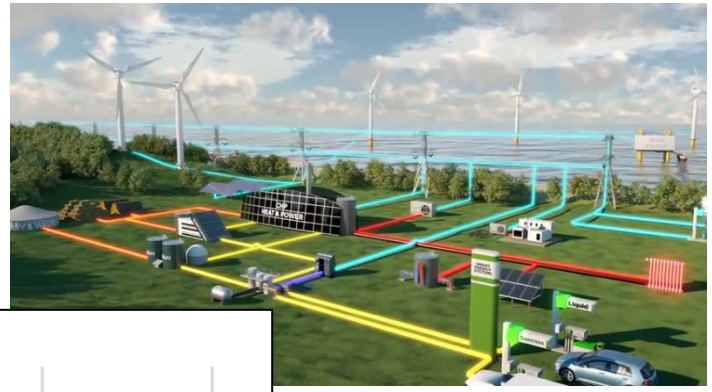
Large potentials for geothermal and excess heat

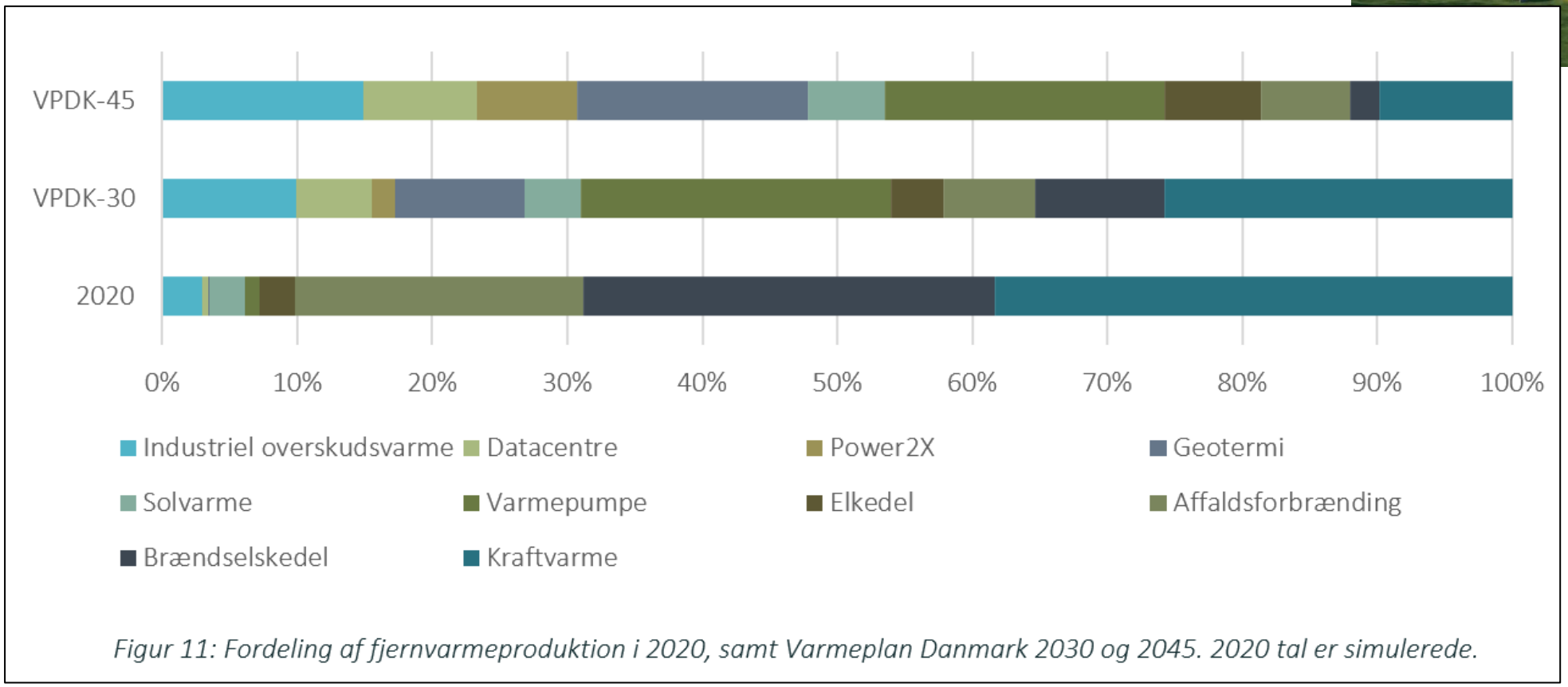


Figur 9: Fjernvarmebehov i 2020 og niveauer for fjernvarmebehov i 2045 (til venstre). Højt og lavt potentiale for overskudsvarme fra industri, datacentre og power2X samt geotermi. Anvendt industriel overskudsvarme i 2020, andel af potentialet anvendt i Klimafremskrivningen for 2030, samt i VPDK-30 og VPDK-45.

In the energy system of the future, there is ***great potential for geothermal and waste heat from industry, data centers and PtX.*** These opportunities should be exploited.

Part of an overall solution
A changing heating sector





Figur 11: Fordeling af fjernvarmeproduktion i 2020, samt Varmeplan Danmark 2030 og 2045. 2020 tal er simulerede.

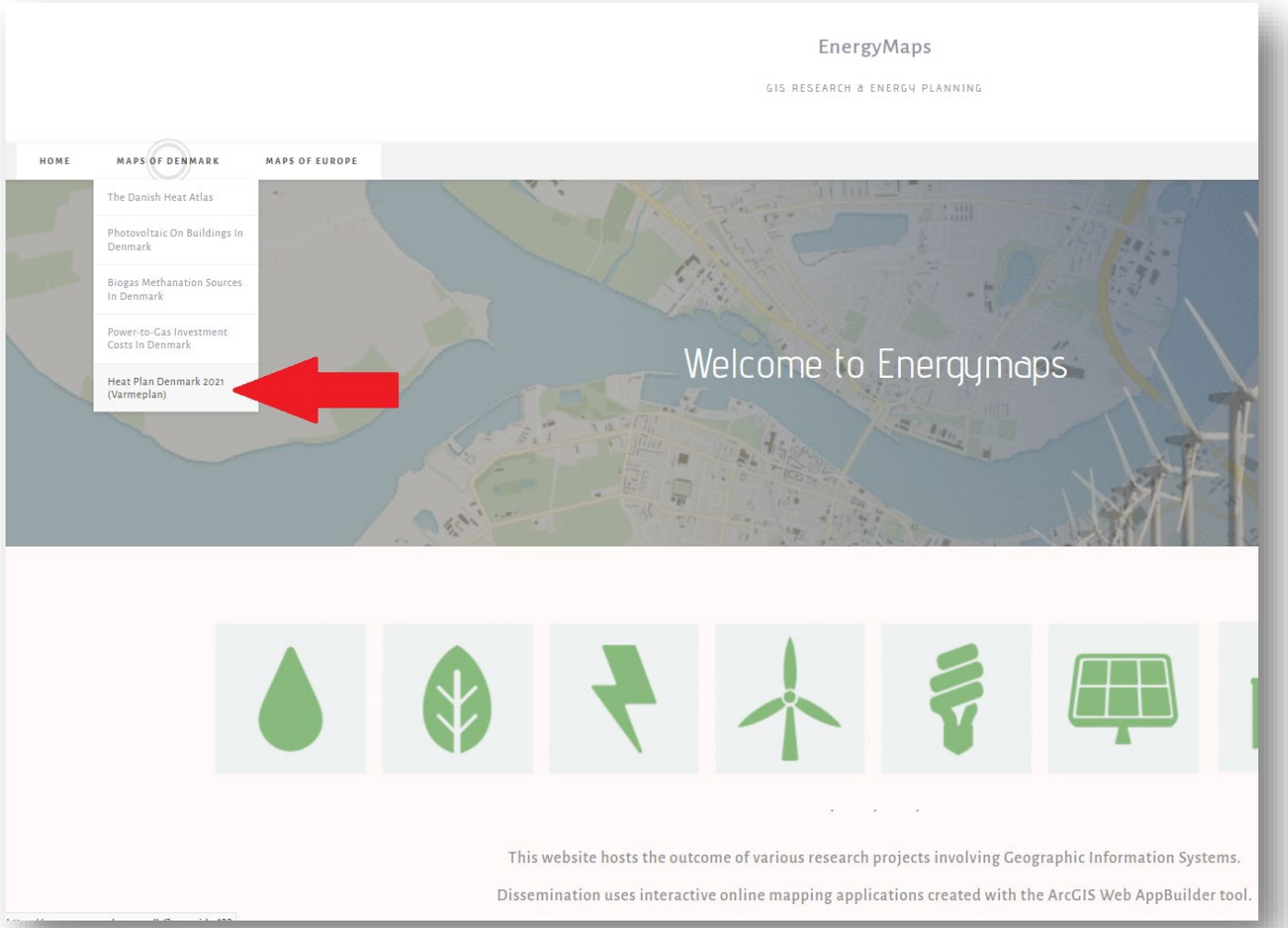
Maps from Heat Plan Denmark 2021 available online

Findes på hjemmesiden:

https://energymaps.plan.aau.dk/

Here are 4 different maps:

1. Heat consumption in urban areas
2. District heating expansion scenarios
3. Industrial waste heat
4. Map of "free" baseload in the district heating



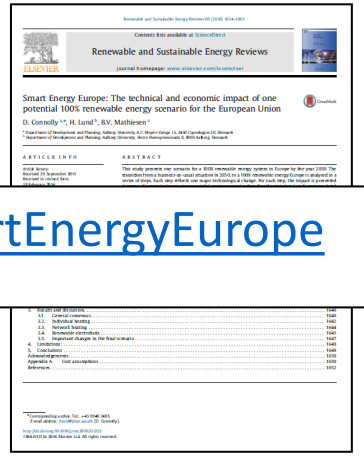
More information:

www.henriklund.eu

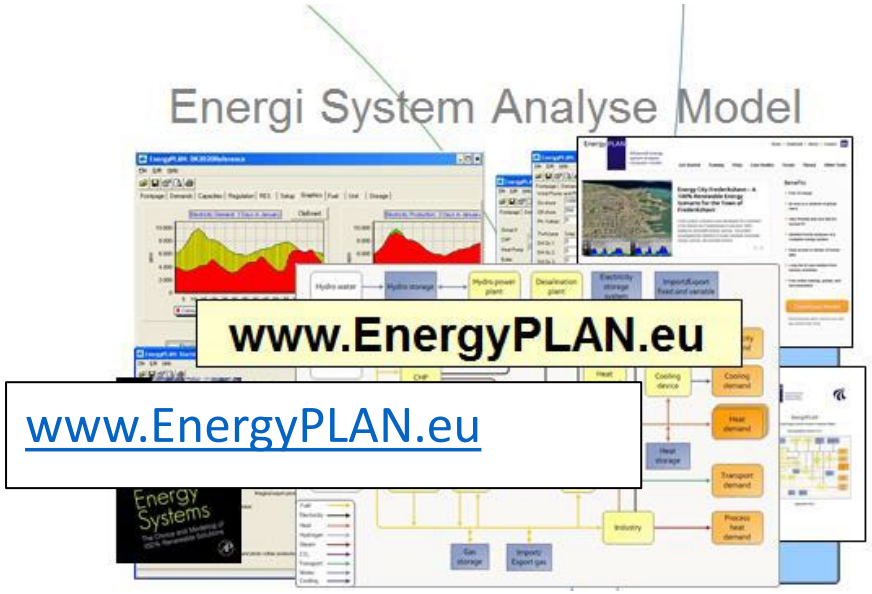
www.4DH.dk

4DH
4th Generation District Heating Technologies and Systems

https://www.energyplan.eu/book2/

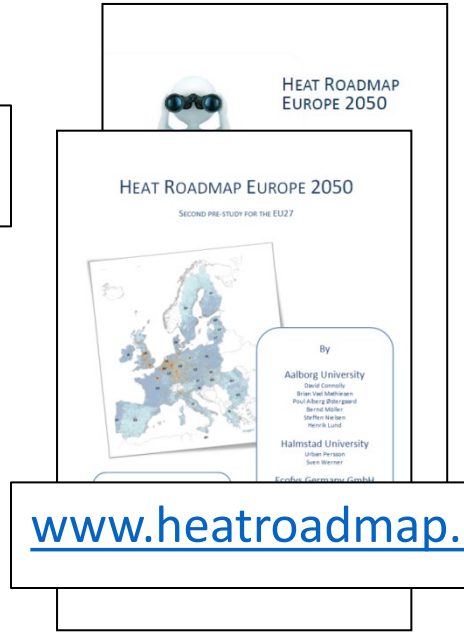


www.energyplan.eu/SmartEnergyEurope



www.EnergyPLAN.eu

www.energyplan.eu/smartenergysystems/



www.heatroadmap.eu