The future of CHP - the Danish perspective

Berlin 27/10 2016

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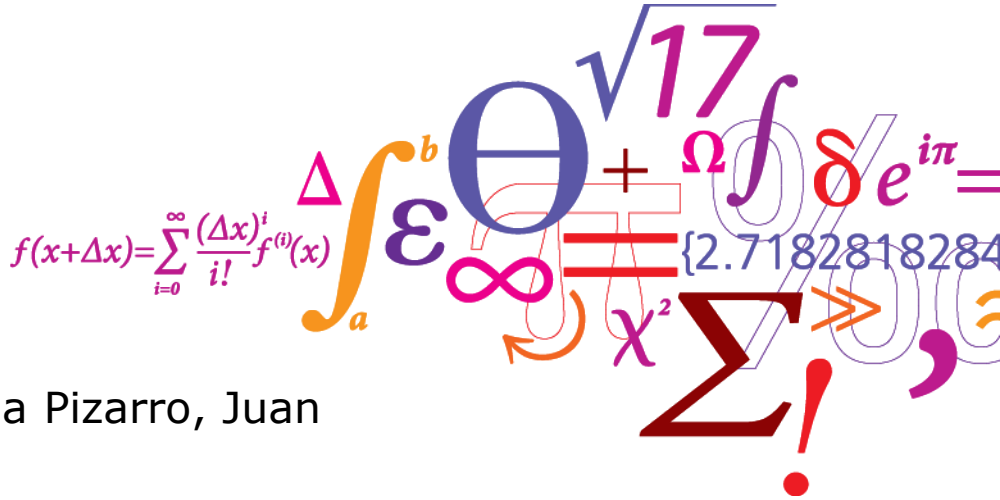
Senior Researcher
System Analysis Division



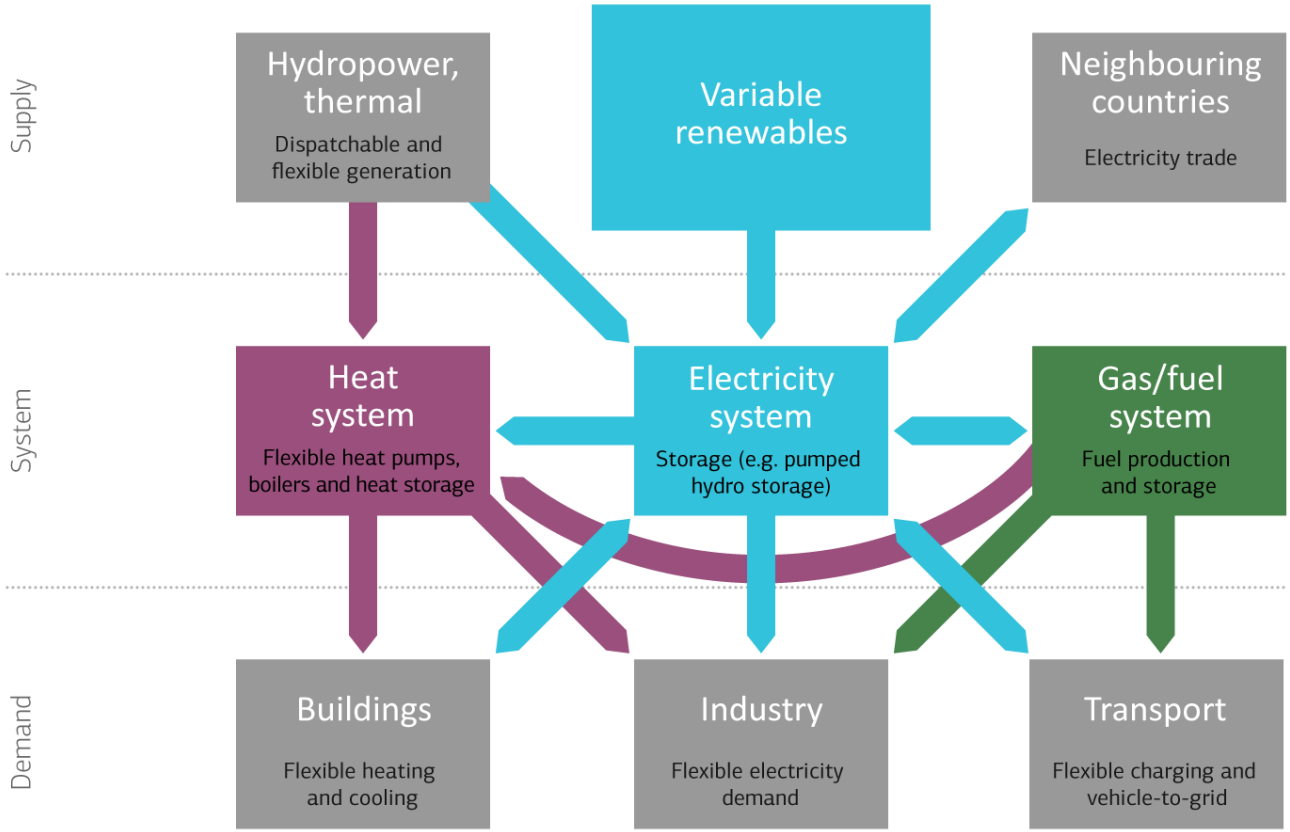
Inputs from Kenneth Karlsson, Amalia Pizarro, Juan Bermudez and PlanEnergi

DTU Management Engineering
Department of Management Engineering

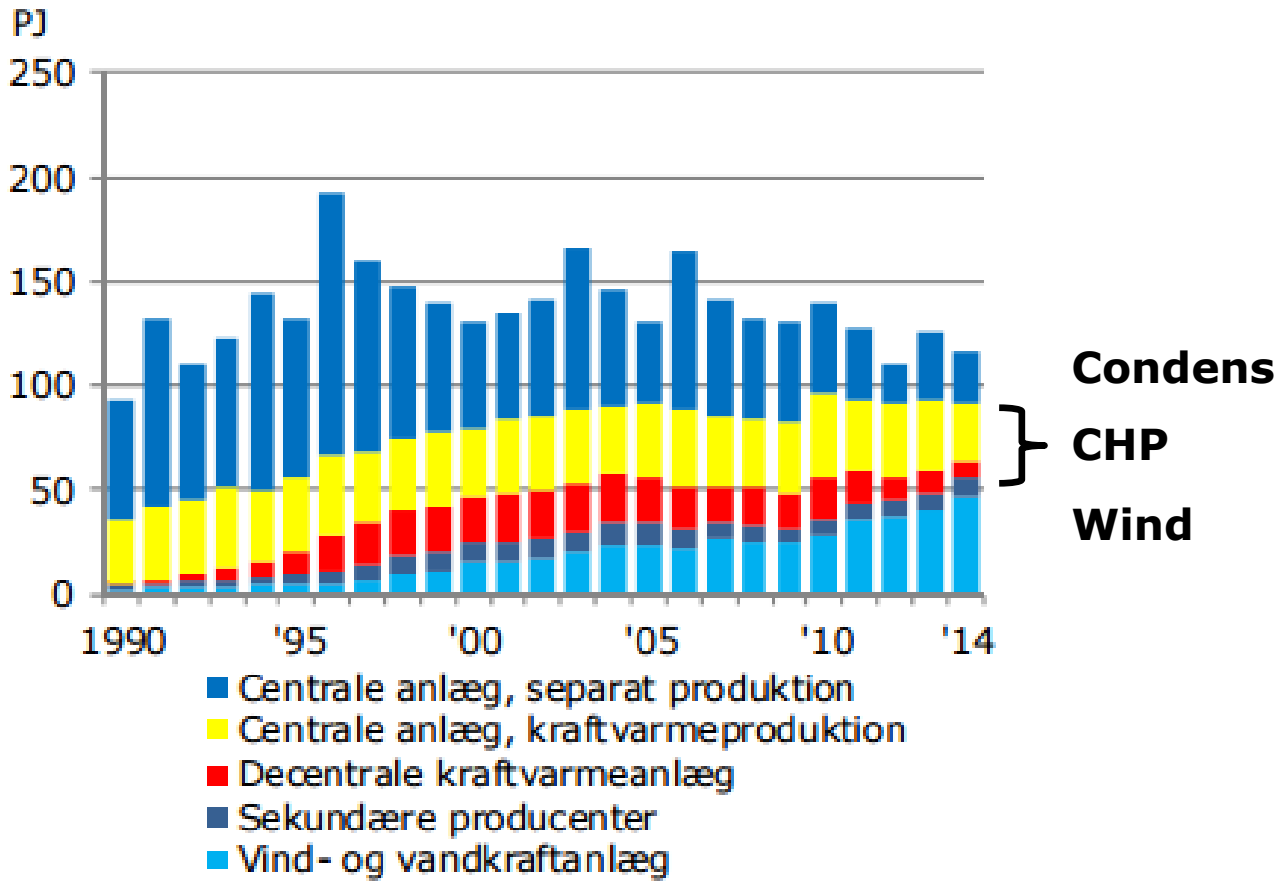
Outline

- Historical development
- Future energy production
  - Waste to Energy
  - Heat Pumps
  - Solar Heating
- Conclusions

Future integrated flexible energy system



Development of Power Production in DK
Plant type



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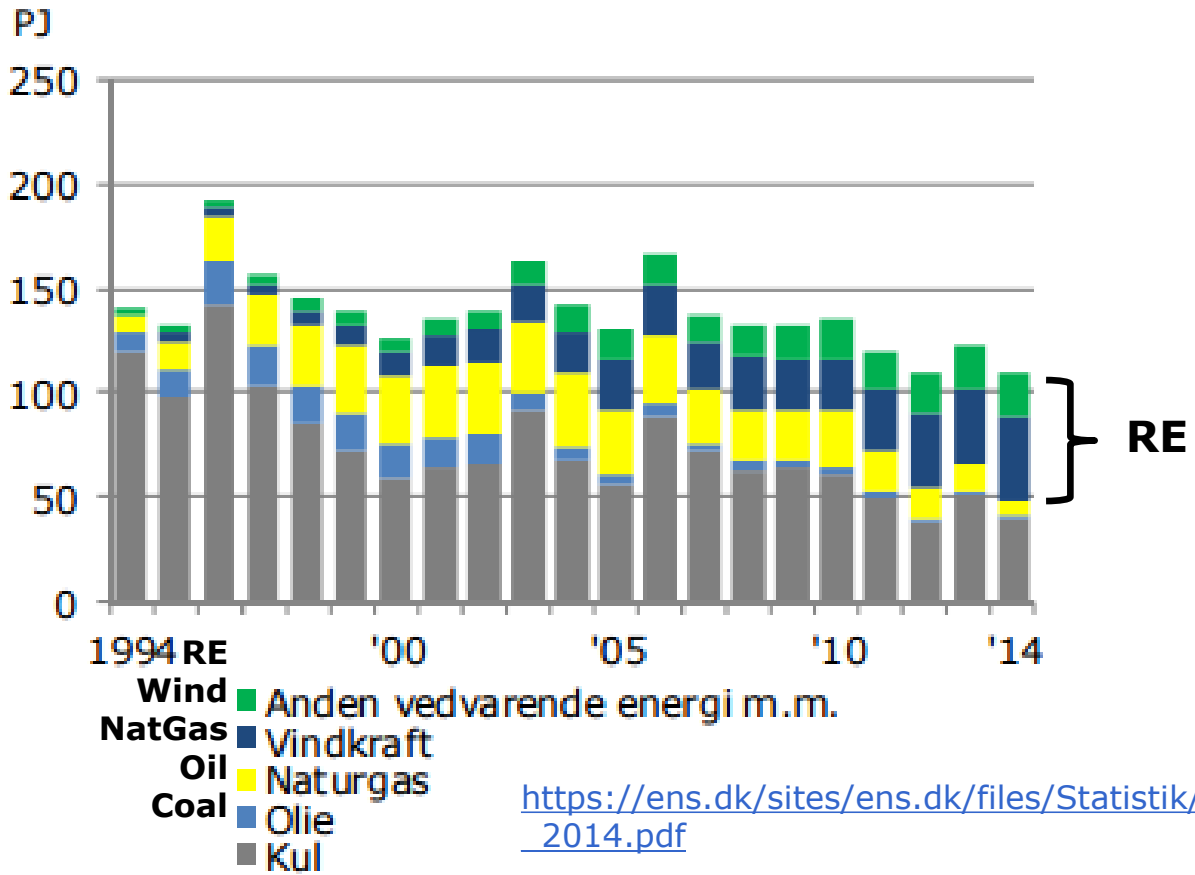
Power production
Fuel type

Windpower above 40% of electricity consumption



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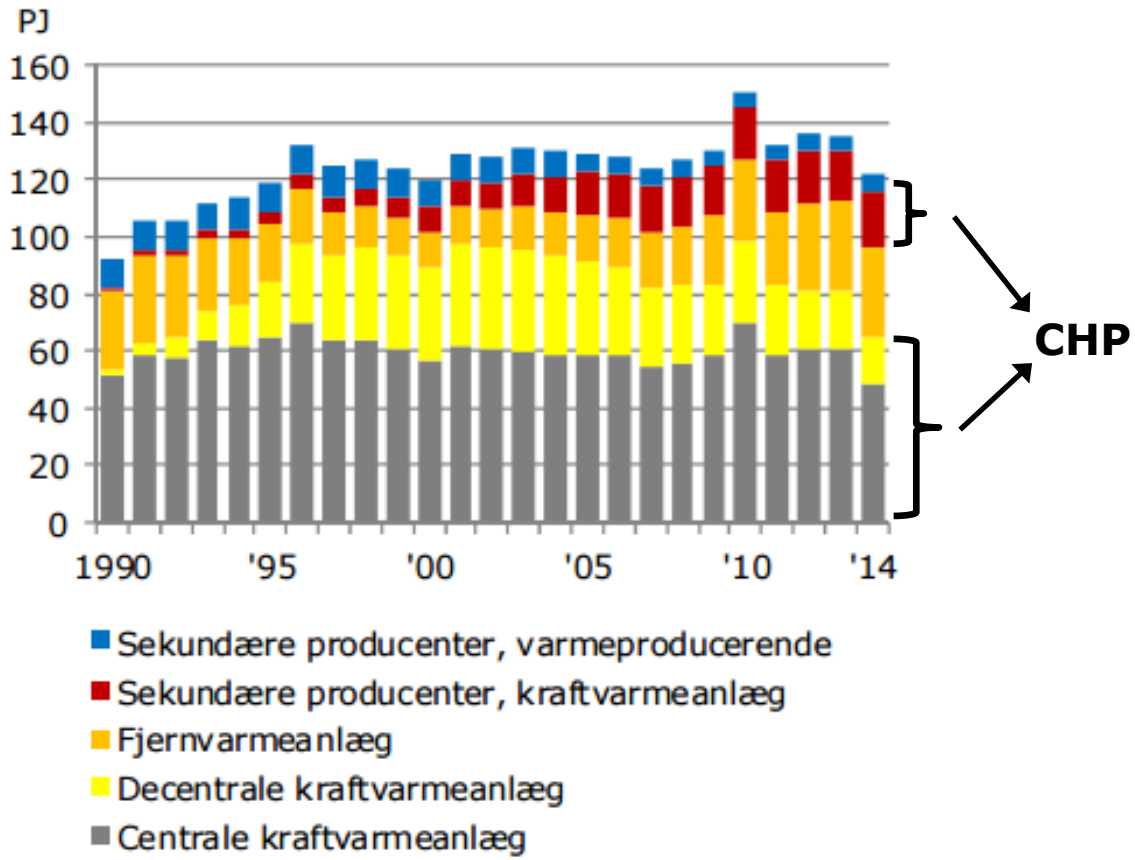
Development of District Heating in DK
Plant type

~50% of heat demand



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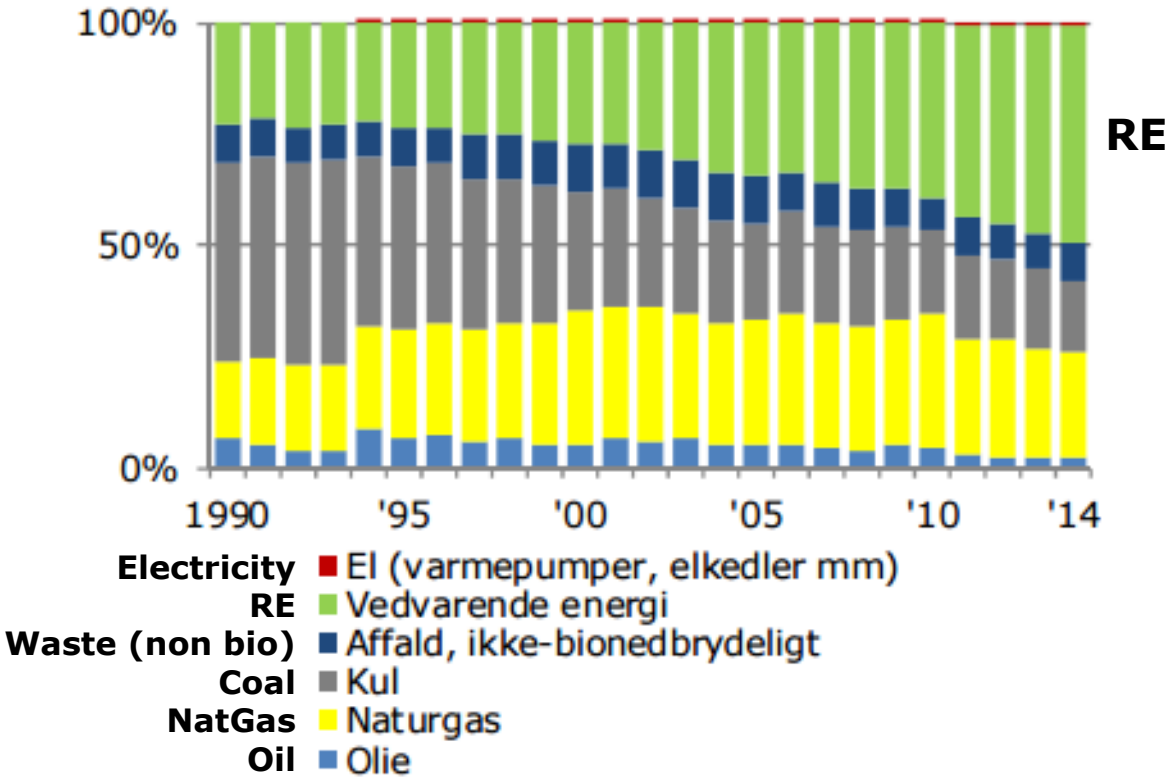
Development of District Heating in DK
Fuel type

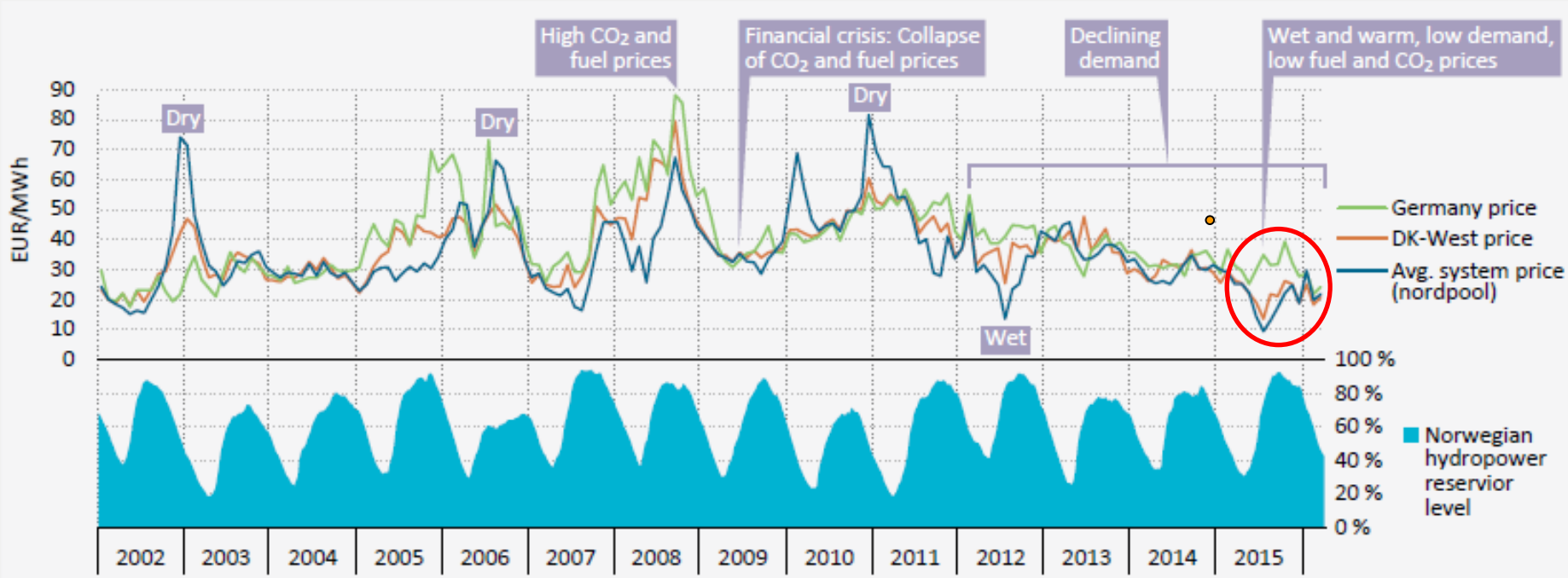


https://ens.dk/sites/ens.dk/files/Statistik/energistatistik_2014.pdf

Development of Electricity prices in DK

Depends on

- Hydro power availability (dry/wet years)
- CO2 quota prices and fuel prices
- Electricity (and heat) demand



http://www.nordicenergy.org/wp-content/uploads/2016/04/Nordic-Energy-Technology-Perspectives-2016.pdf

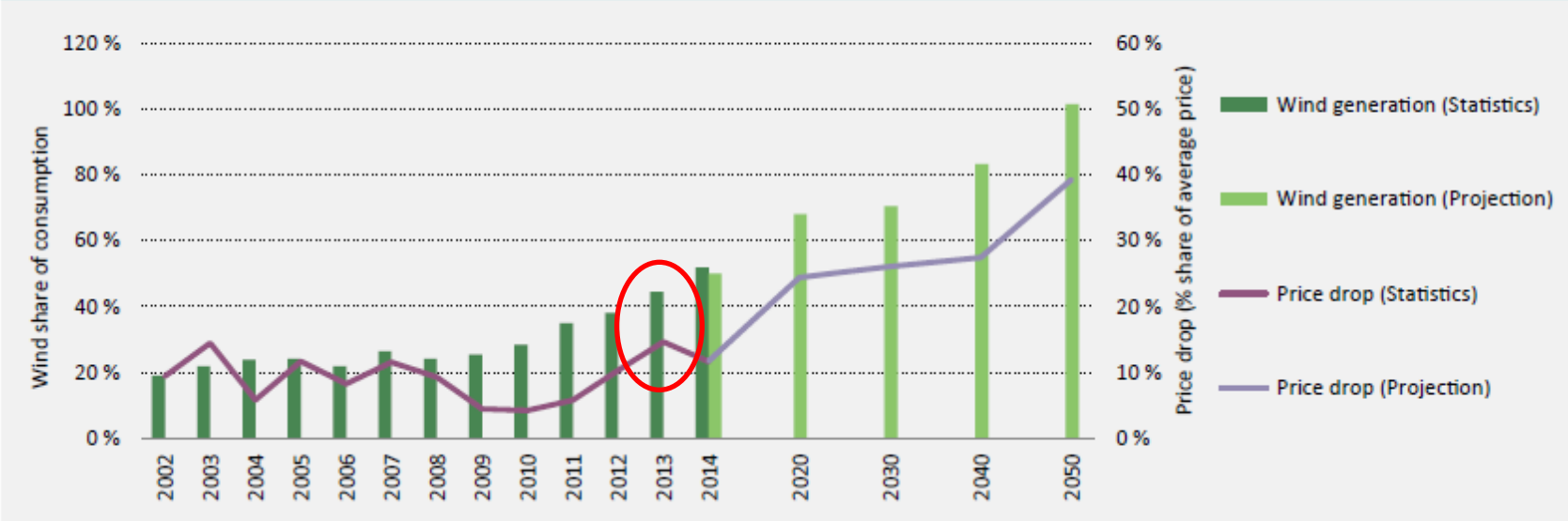
Future electricity prices in DK

Prices may get even lower in the future

Depends on

- Windpower share
- Available electricity transmission (bottle necks?, net import?)
- Flexible electricity consumption (e.g. Power to heat, EV's, Power to gas)

Figure 3.18 Price drop compared to the wind share in Western Denmark, statistical and model results, CNS-B



http://www.nordicenergy.org/wp-content/uploads/2016/04/Nordic-Energy-Technology-Perspectives-2016.pdf

Short run marginal heat production cost

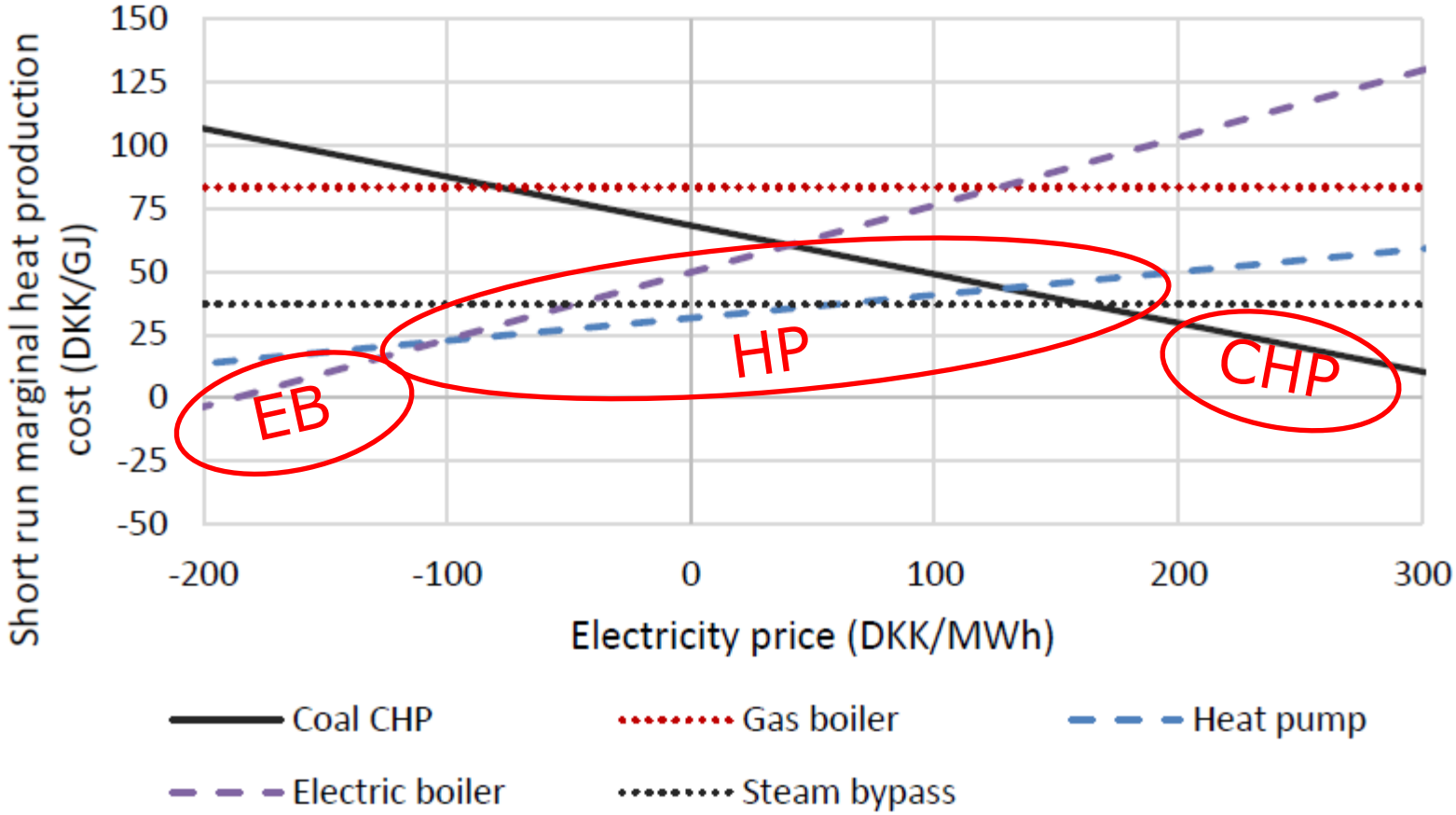


Figure 28: Short run marginal heat production cost for different units depending on the electricity price. Illustrative example. Actual costs will depend on fuel prices, emission prices, taxes and subsidies. Source: Own figure.

(EA 2015. *The Danish Experience with Integrating Variable Renewable Energy: Lessons Learned and Options for Improvement*)

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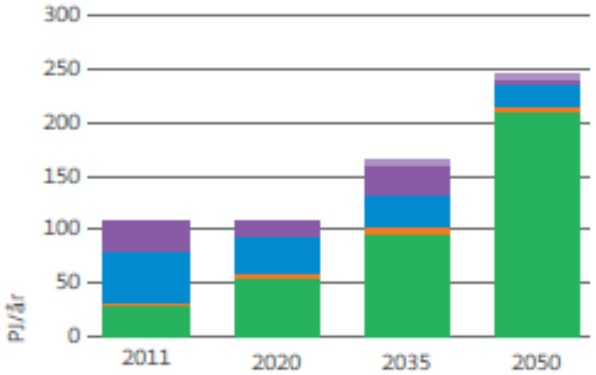
Future Electricity Production in DK

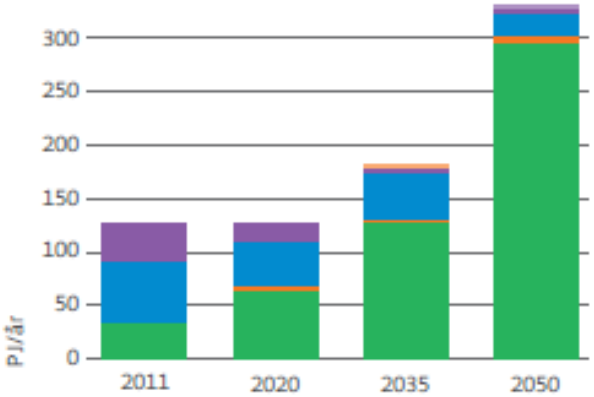
Danish Energy Agency Scenarios

100% RE in power and heat in 2035

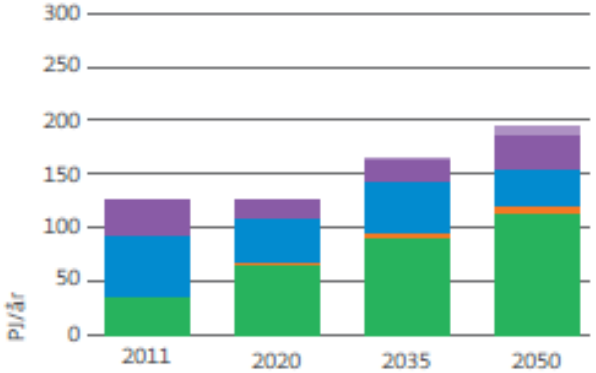
100% RE in 2050



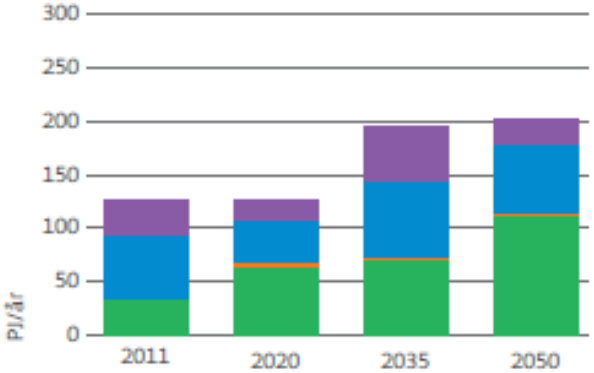
Figur 12.8. Udvikling i elproduktionen i vindscenariet.



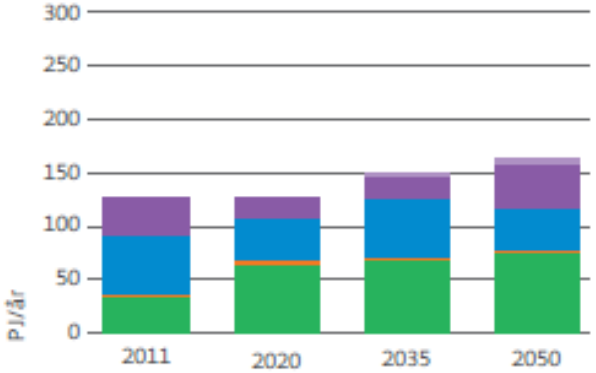
Figur 12.11. Udvikling i elproduktionen i brintscenariet.



Figur 12.9. Udvikling i elproduktionen i biomassescenariet.



Figur 12.12. Udvikling i elproduktionen i det fossile scenarie.



Figur 12.10. Udvikling i elproduktionen i bio+ scenariet.

https://ens.dk/sites/ens.dk/files/Basisfremskrivning/energiscenarier_-_analyse_2014_web.pdf

Vindkraft
Biobrændstoffabrik
Solceller
Kraftvarme
Kondens

PV

Heat Roadmap Europe

Heat savings (30-50%) and DH expansion (~50%)

Key Conclusions

- **Energy Efficiency:** heat savings are a key component in the decarbonisation of the EU energy system. The total heat demand in Europe should be reduced by approximately 30-50%, which is similar to the conclusion presented by the European Insulation Manufacturers Association, Eurima. However, after this point the price of sustainable heat supply is likely to be lower than the price of further heat savings.

- **District Heating:** There is currently more heat being wasted in Europe than is required to heat all of the buildings. District heating can capture this excess heat and move it into the buildings. District heating should be increased from today's level of ~10% up to ~50% in 2050. It should increase in urban areas, where the heat densities have been estimated based on the pan-EU heat atlas.

- **Individual Heat Pumps:** in rural areas, individual ground and air-sourced heat pumps should replace existing oil boilers. Heat pumps connect cheap renewable electricity production (such as wind and solar) with efficient renewable heat production (due to their COP).

- **Energy System:** heat savings, district heating, and individual heat pumps are key components in a future low-carbon EU energy system. They are fundamental to the technical and economic viability of the Smart Energy System.

http://www.heatroadmap.eu/

Future Danish DH potentials

- Today covering ~**50%** of heat consumption

- In the future:

  – **between 55-57%**

  (Münster et al 2012. *The role of district heating in the future Danish energy system*)

  – **between 50-70%**

  (Lund et al. 2010 *The role of district heating in future renewable energy systems*)

Future DH

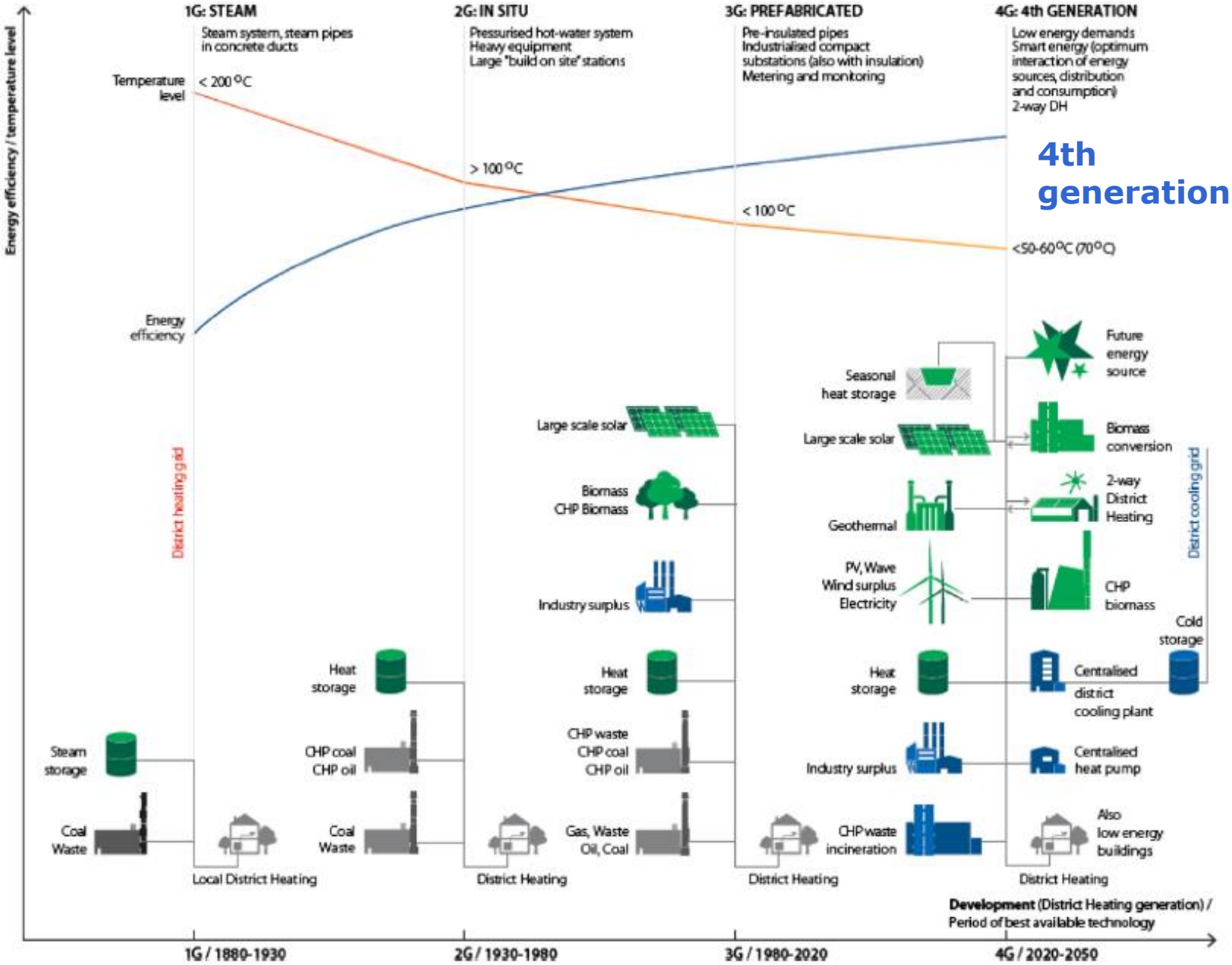
Why expansion potential?

- Increasing connection rate in DH areas and expanding close by
- Increasing efficiency by lowering supply temperatures
- Ability to utilise central heat sources (e.g. from industry and incineration)
- Economy of scale of supply and storage technologies

Potential heat supply?

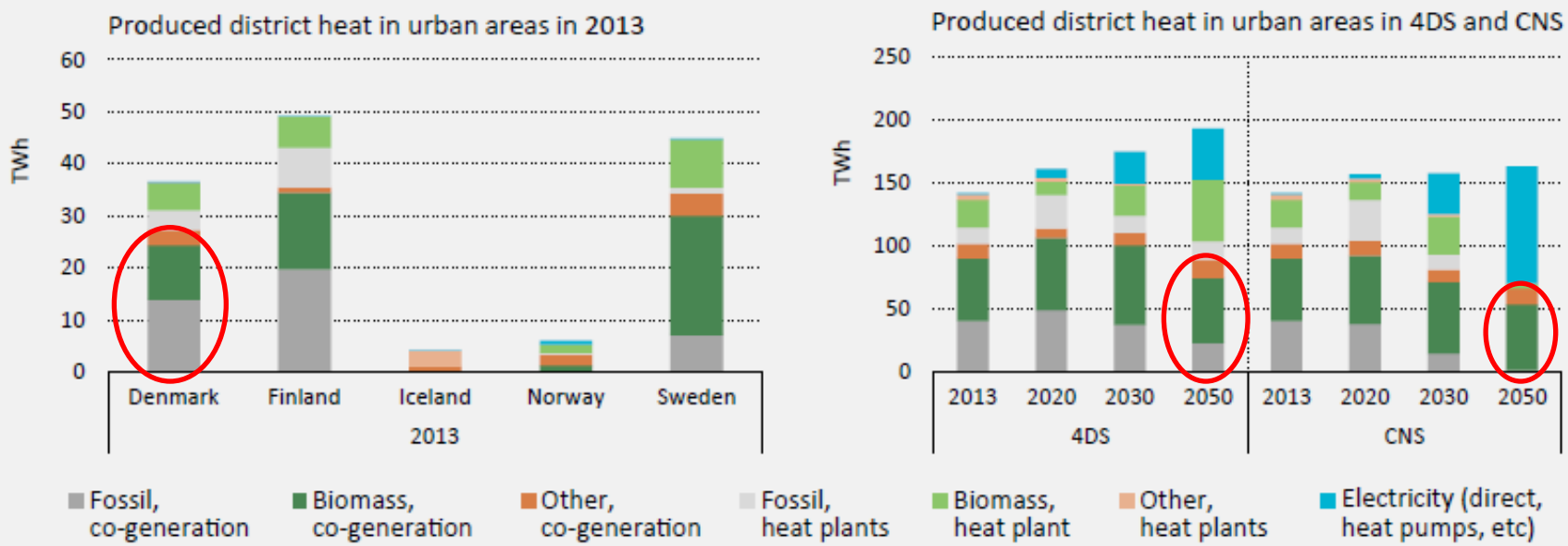
- Excess heat (industry and biorefineries)
- CHP (biomass and waste)
- Heat pumps (geothermal and ambient heat)
- Solar thermal

Lund et al. Energy 68 (2014) 1-11. 4th Generation District Heating (4GDH)
Integrating smart thermal grids into future sustainable energy systems



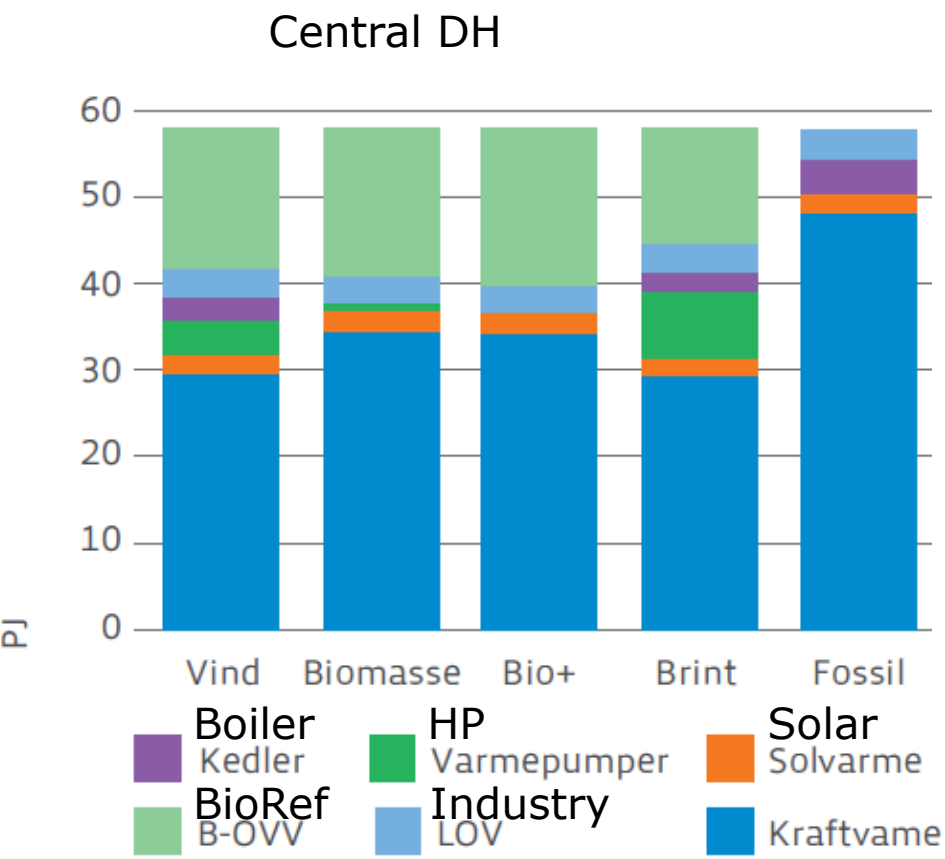
Future District Heating in the Nordic countries

Figure 2.7 Production of district heat by fuel and technology in 2013 (left) and 2013-50 in scenarios (right)

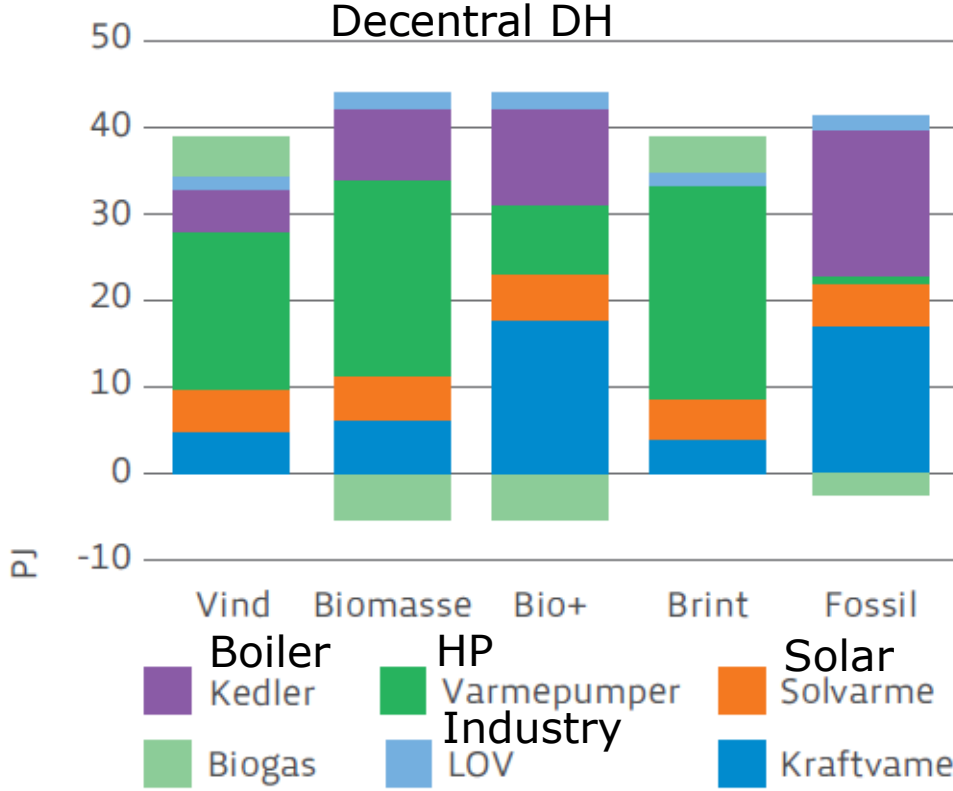


http://www.nordicenergy.org/wp-content/uploads/2016/04/Nordic-Energy-Technology-Perspectives-2016.pdf

Future DH production



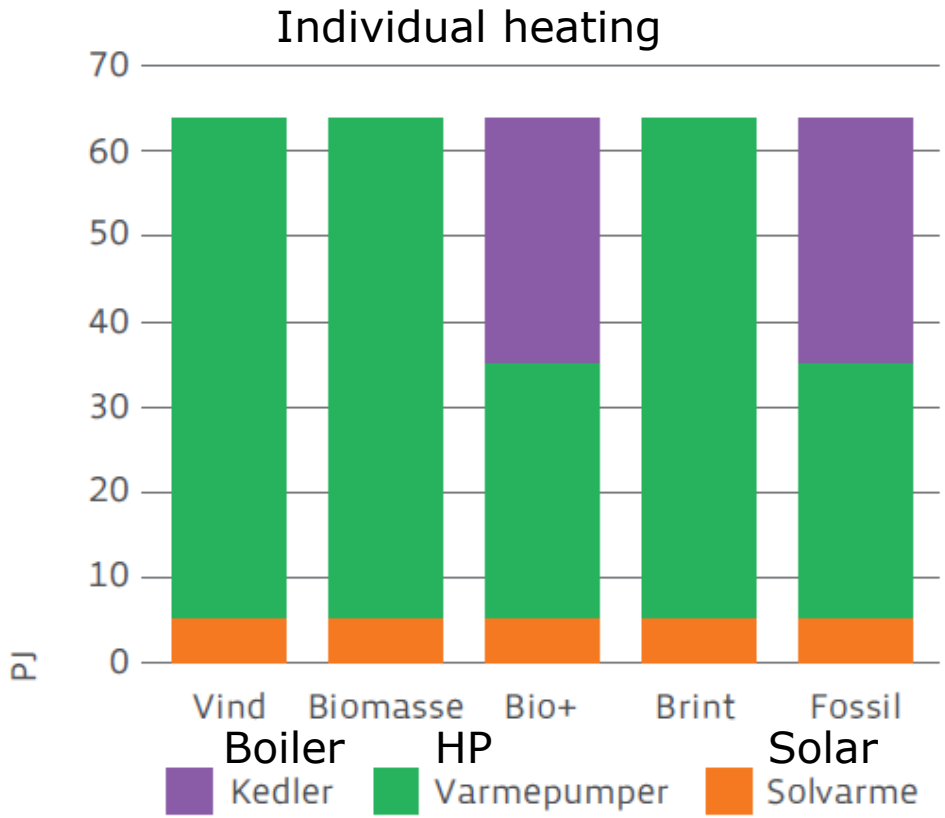
Figur 11.9. Produktion af central fjernvarme 2050. Grafisk illustration af tabel 11.3.



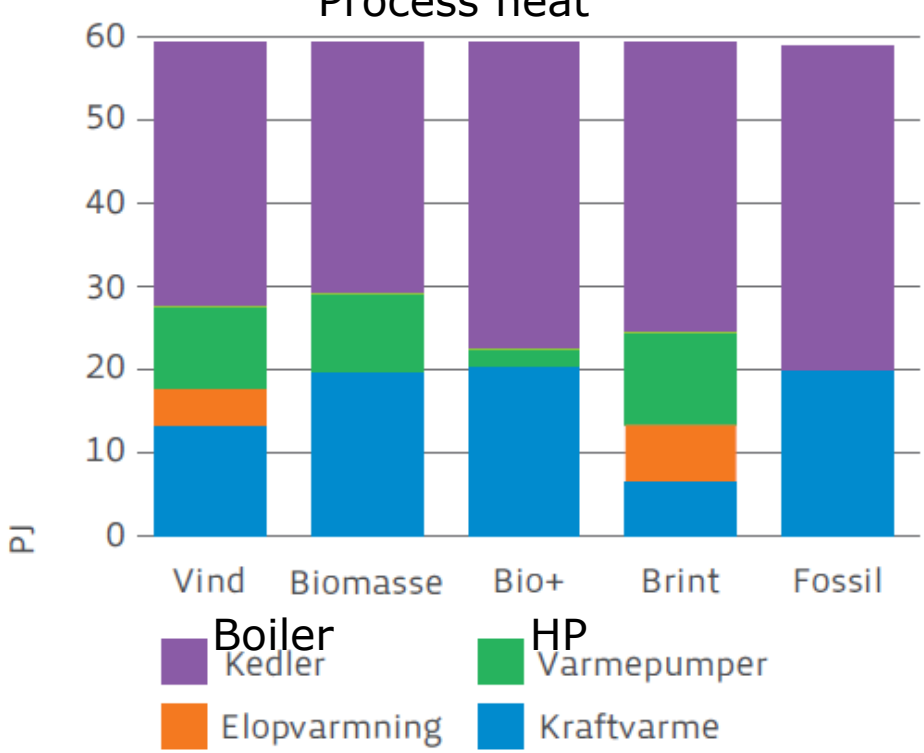
Figur 11.10. Produktion af decentral fjernvarme 2050. Grafisk illustration af tabel 11.4. Bemærk, at den negative produktion i biomasse- og bio+ scenariet skyldes procesvarmeforbrug i biogasanlæggene.

http://www.ens.dk/sites/ens.dk/files/undergrund-forsyning/el-naturgas-varmeforsyning/Energianalyser/nyeste/energiscenarier_-_analyse_2014_web.pdf

Future heat production



Figur 11.8. Individuel varmeproduktionen 2050. Grafisk illustration af tabel 11.2.



Figur 11.6. Procesvarmeproduktionen 2050 i de fem scenarier fordelt på opvarmningsformer. Grafisk illustration af tabel 11.1.

http://www.ens.dk/sites/ens.dk/files/undergrund-forsyning/el-naturgas-varmeforsyning/Energianalyser/nyeste/energiscenarier_-_analyse_2014_web.pdf

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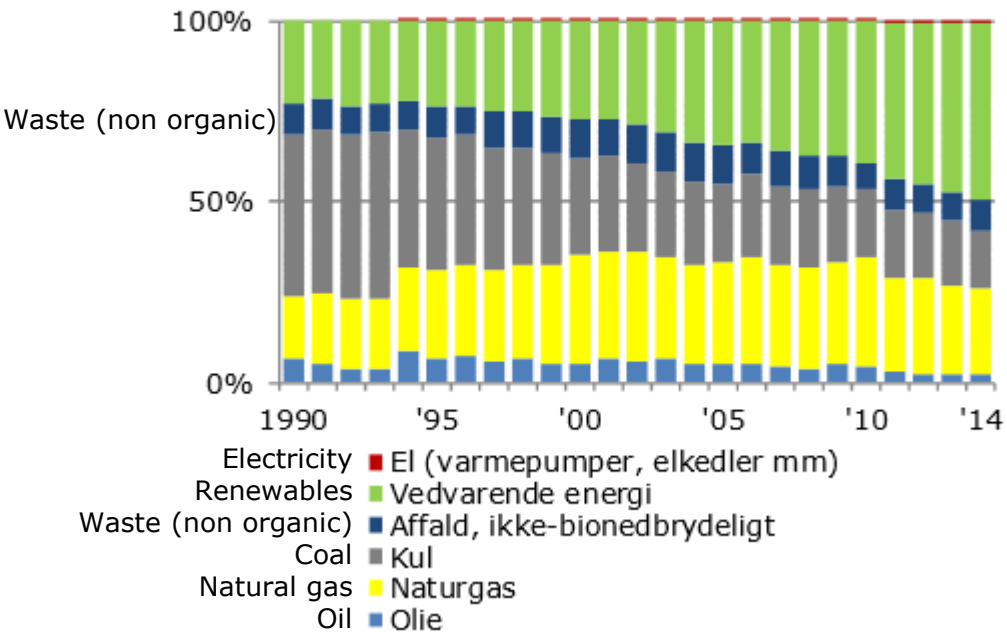
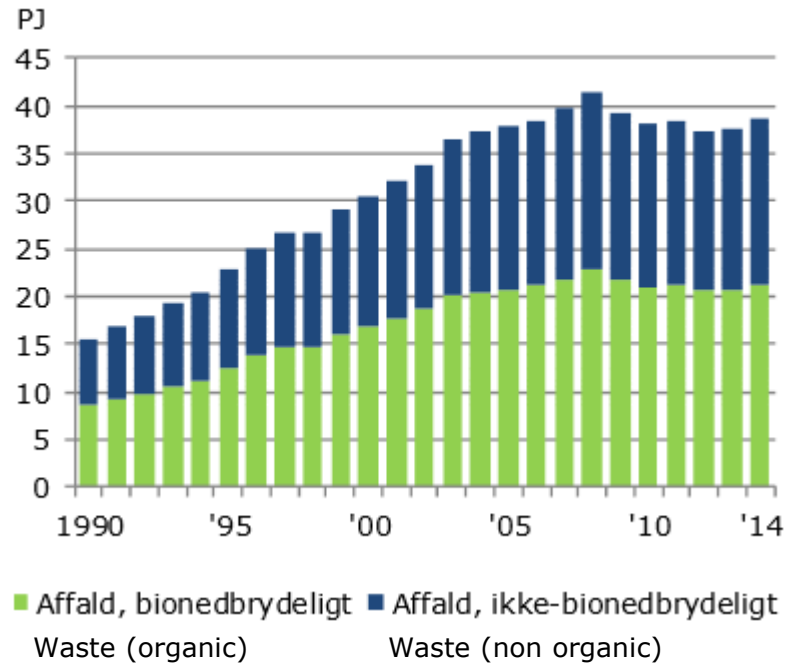
Waste for DH

- 5% of electricity production
- 21% of DH production

Fuel consumption for DH production



Use of waste for incineration



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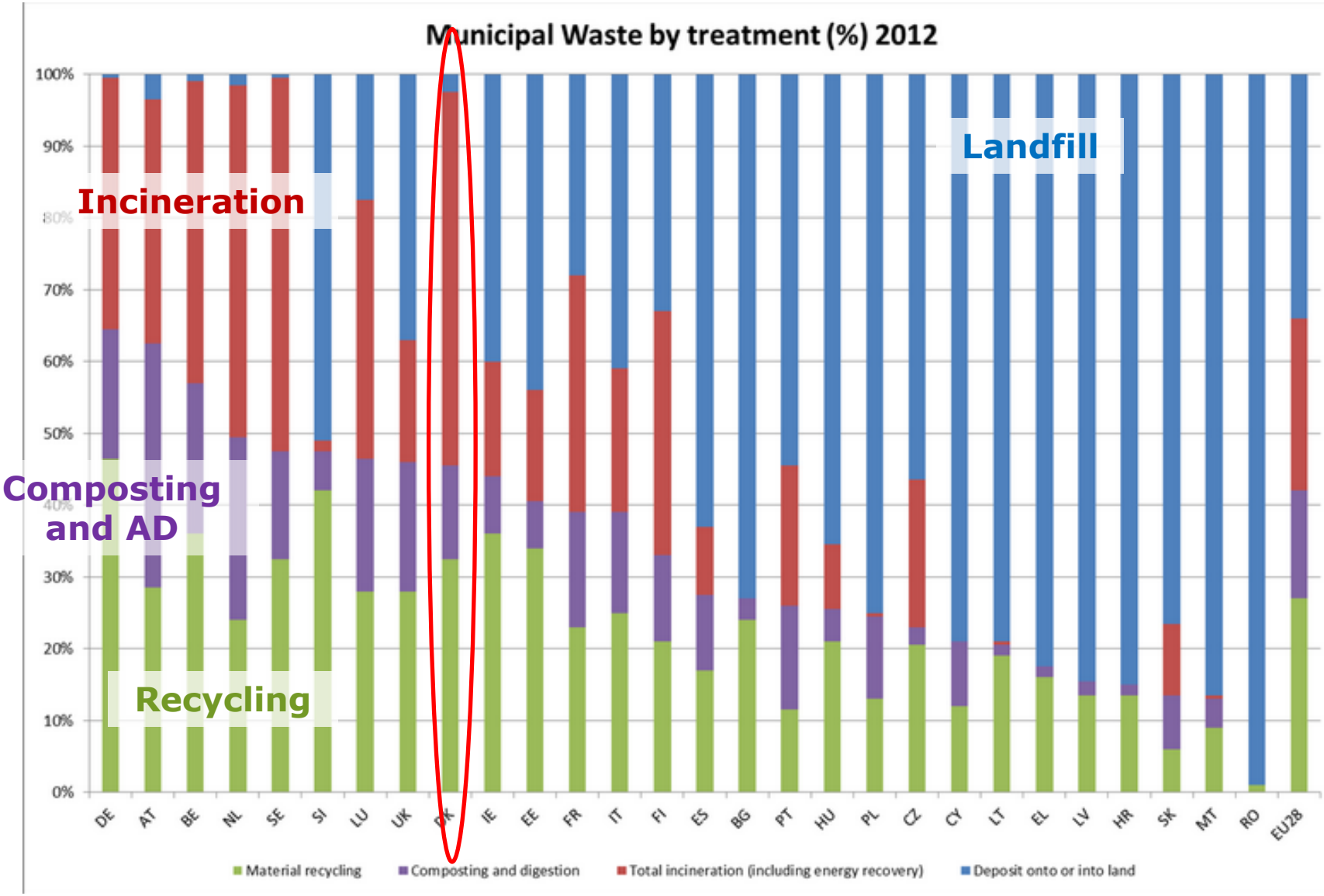
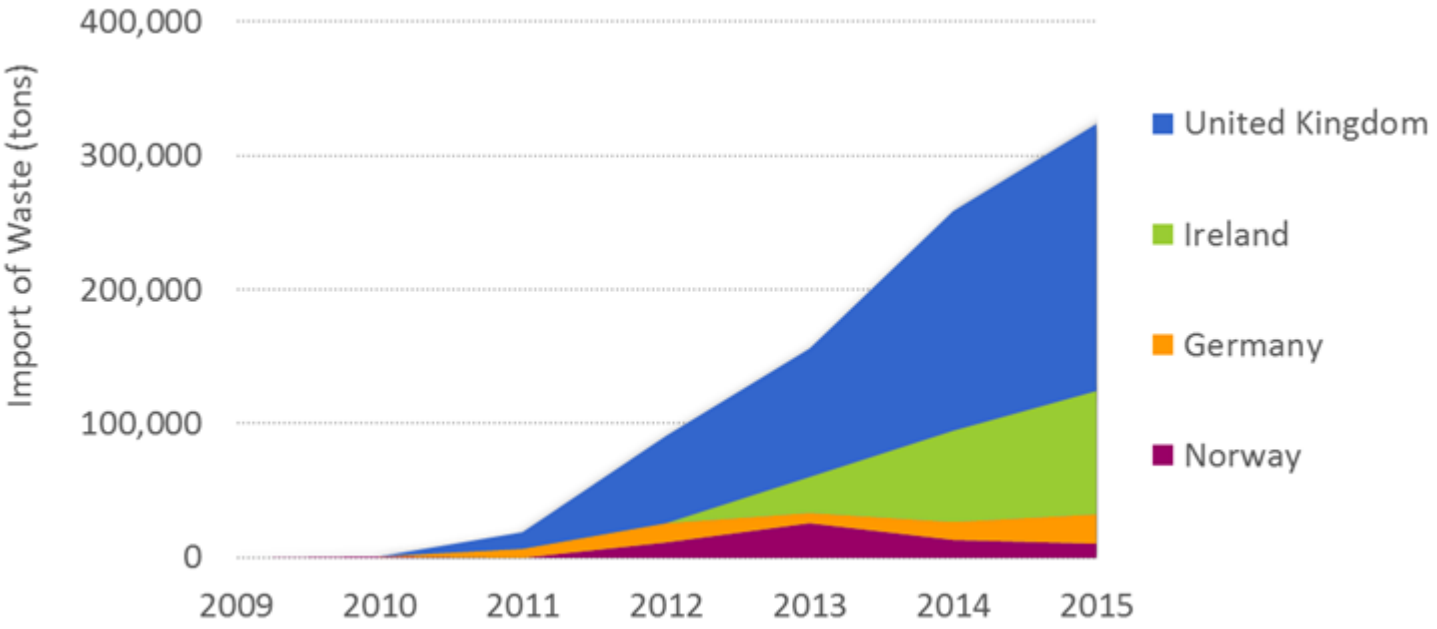

Municipal Waste by treatment (%) 2012
100%
90%
80%
70%
60%
50%
40%
30%
20%
10%
0%
Incineration
Landfill
Composting and AD
Recycling
DE
AT
BE
NL
SE
SI
LU
UK
DK
IE
EE
FR
IT
FI
ES
BG
PT
HU
PL
CZ
CY
LT
EL
LV
HR
SK
MT
RO
EU28
Material recycling
Composting and digestion
Total incineration (including energy recovery)
Deposit onto or into land

Import of waste

Image: BIG-Bjarke Ingels Group/Glessner and Amager Ressourcecenter



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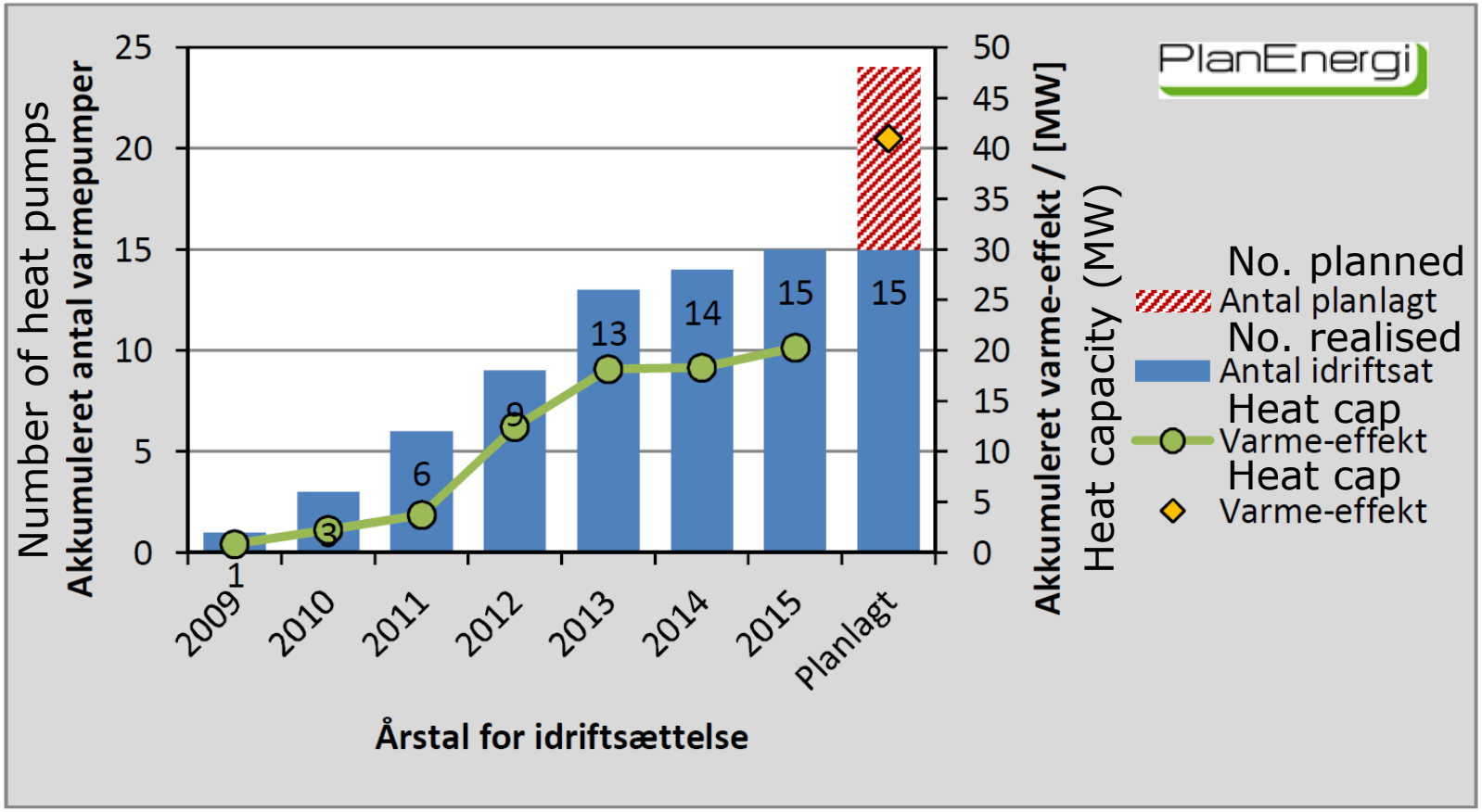
Electric DH Heat pump in DK

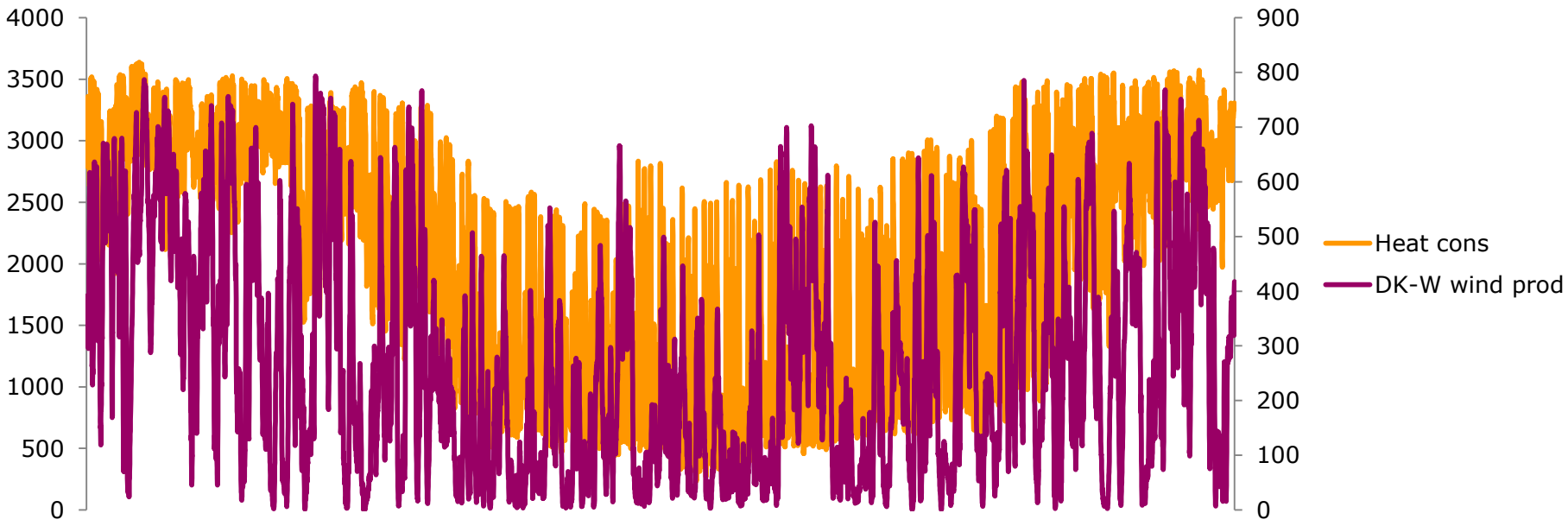


Heat sources today: flue gas, solar heat, excess heat, ground water, waste water

Planned: as above plus sea water and lake water

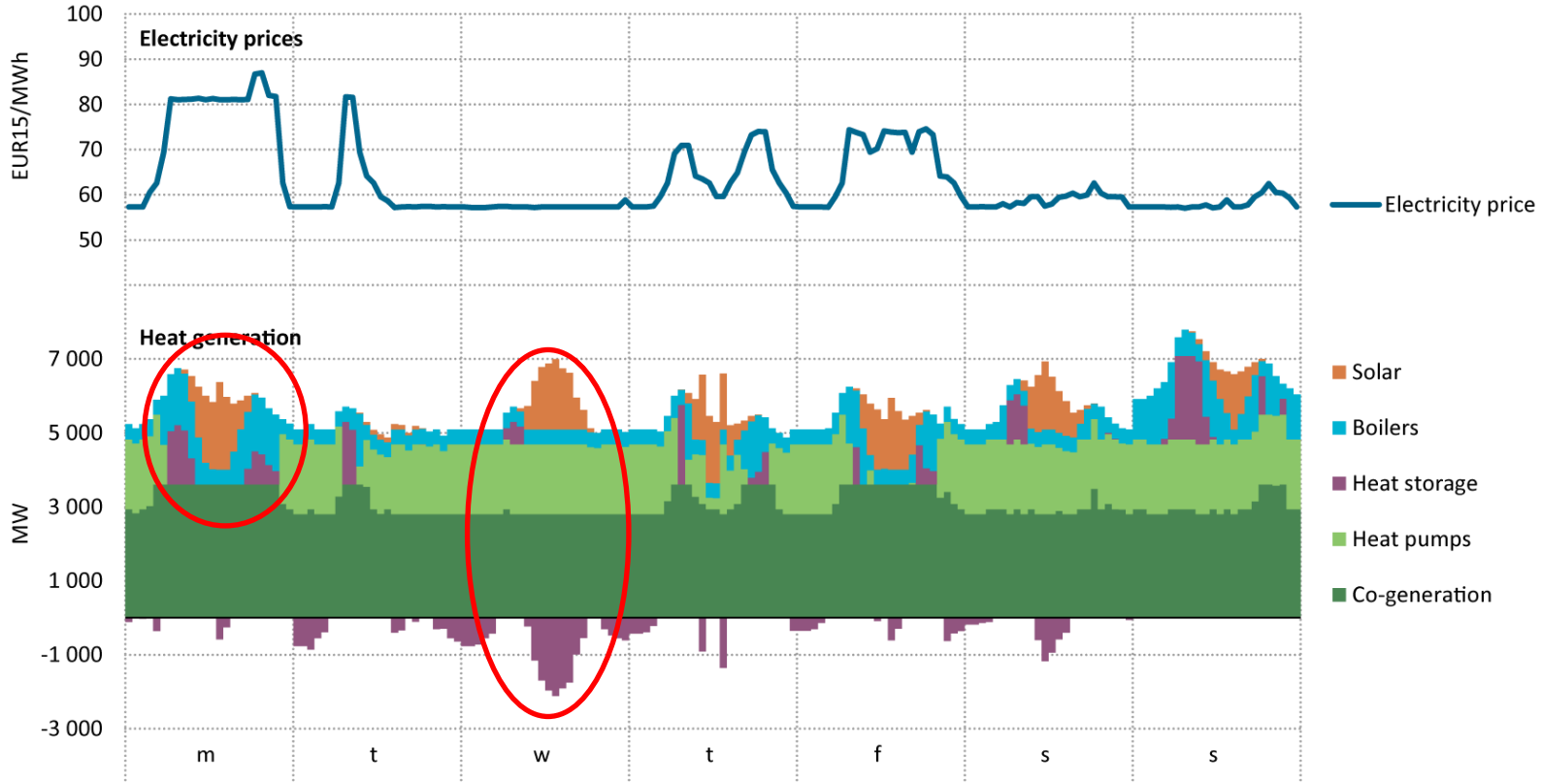
www.planenergi.dk

Wind production and heat consumption



(STREAM and Energinet.dk market data)

Flexible use of large heat pumps in district heating systems - simulation year 2030 district heating area in Sweden



Power to heat potential

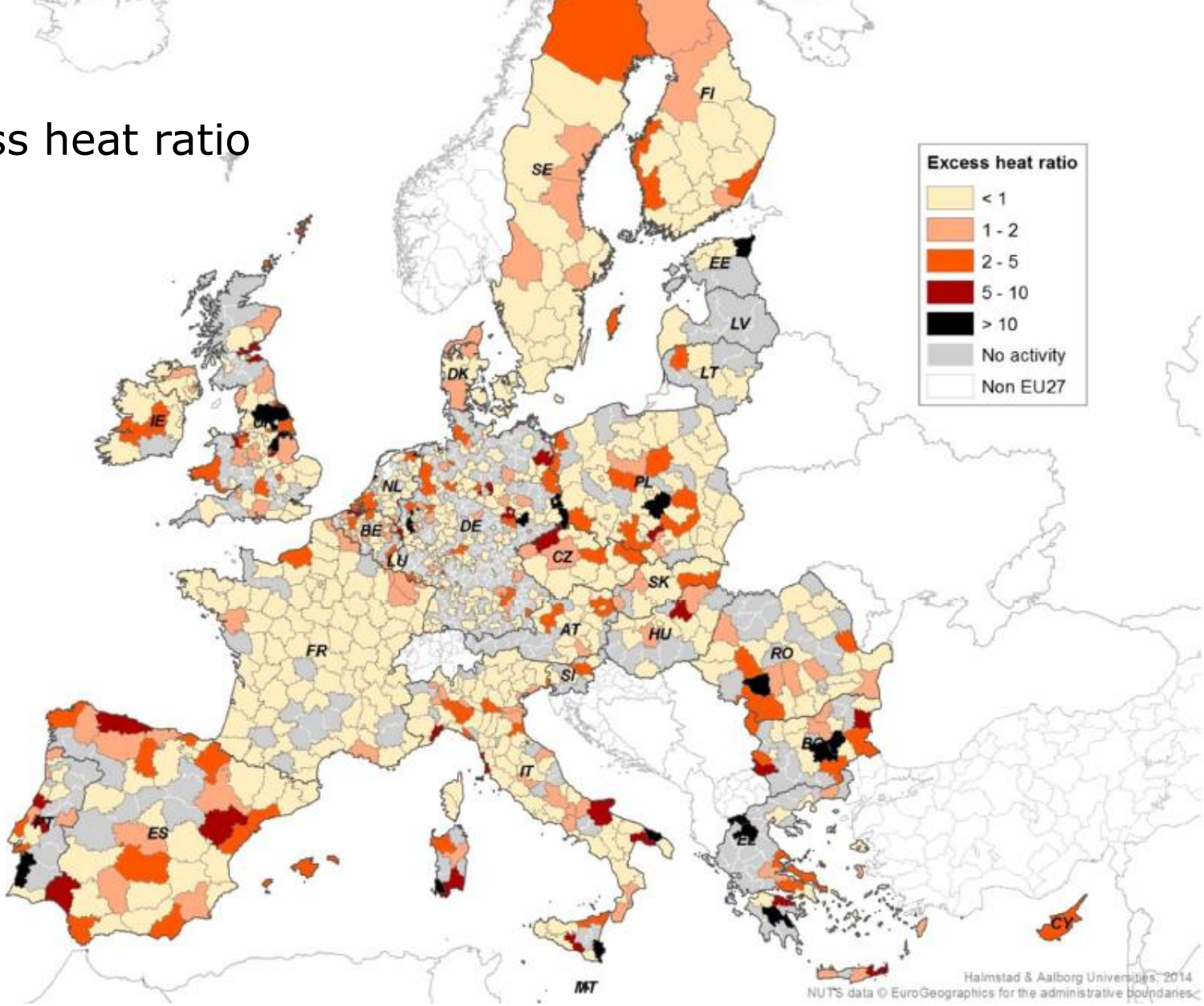
- ***Existing flexibility measures***
- Interconnectors to Norway and Sweden 4.1 GW
- Interconnectors to Germany 2.4 GW

- ***Examples of options towards 2030***
- Heat pumps in DH 0.6 GWe
- Additional electric boilers in DH 1.0 GWe
- Heat pumps in individual houses 0.15 GWe (1.5 GWe)

Total power to heat potential **2.2-3.5 GWe**

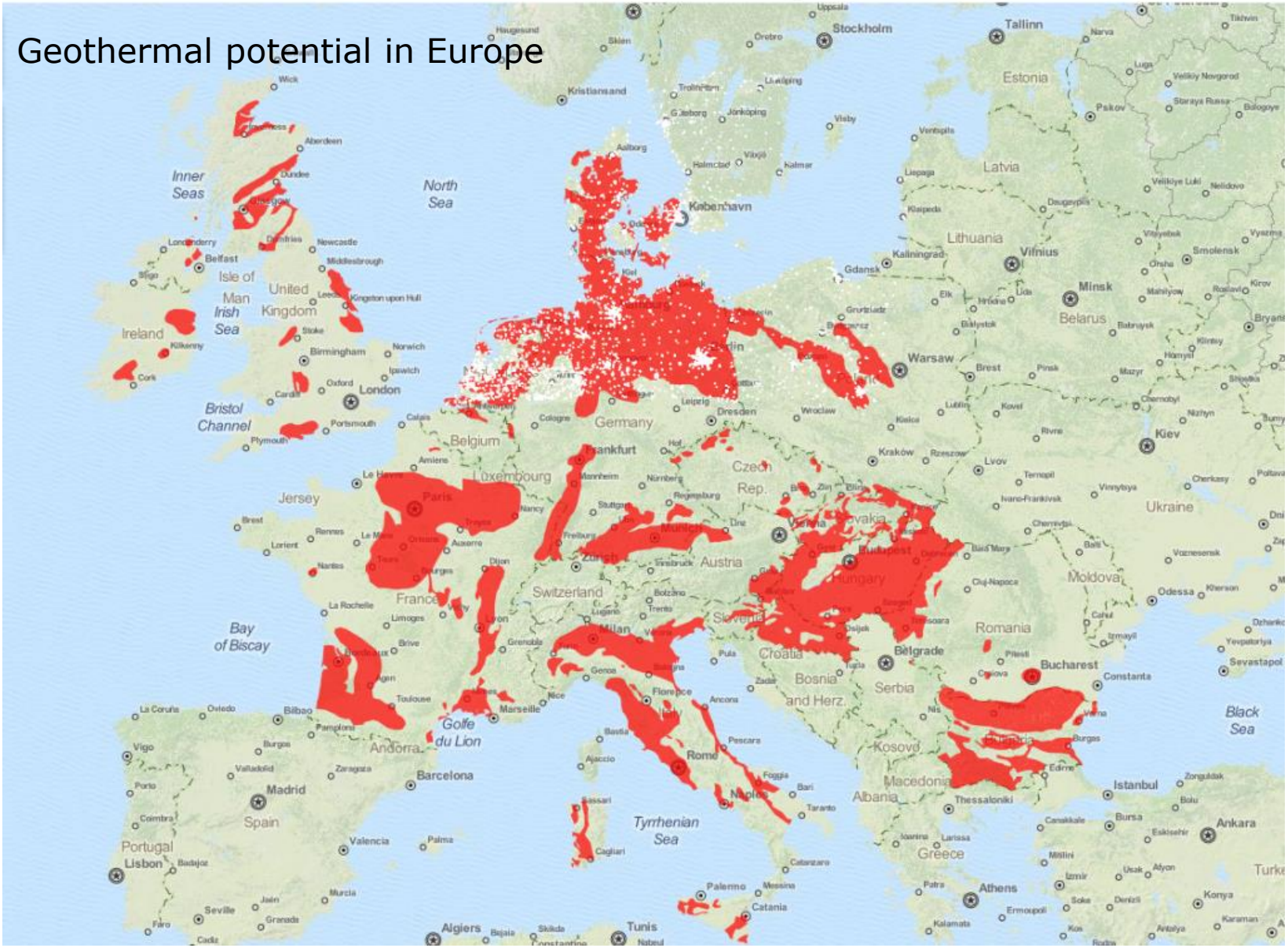
(EA 2015. *The Danish Experience with Integrating Variable Renewable Energy: Lessons Learned and Options for Improvement*)

Excess heat ratio



Persson,U.,etal.,HeatRoadmapEurope:Identifyingstrategicheatsynergyregions.EnergyPolicy(2014), http://dx.doi.org/10.1016/j.enpol.2014.07.015

Geothermal potential in Europe



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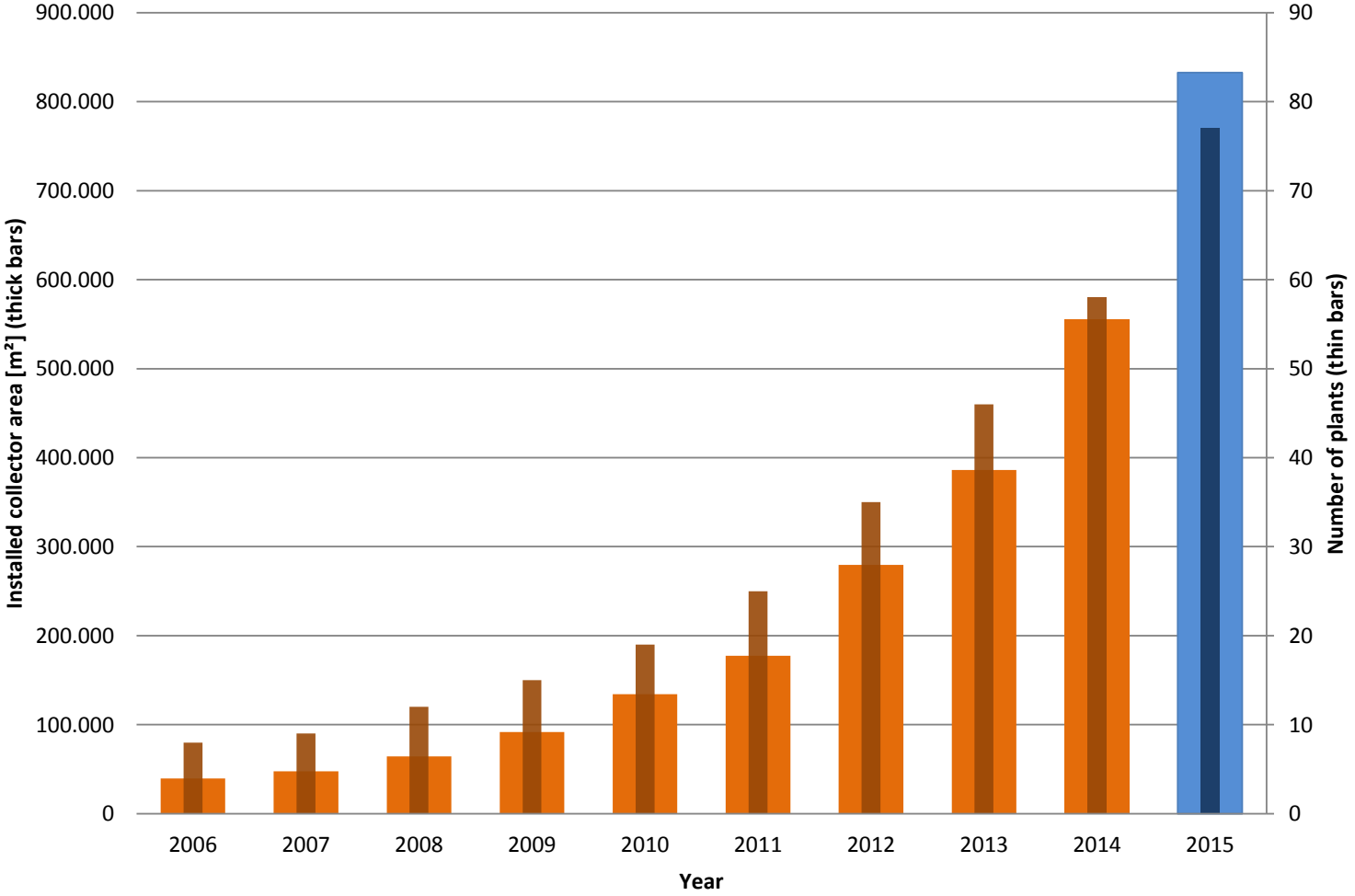
Solar heating

DH can cut down the use of fuels
by using **solar thermal, seasonal heat storages and heat pumps**

Dronninglund solar heating plant www.planenergi.dk

Solar District Heating in Denmark

Sum of collector area and the number of operating and upcoming plants



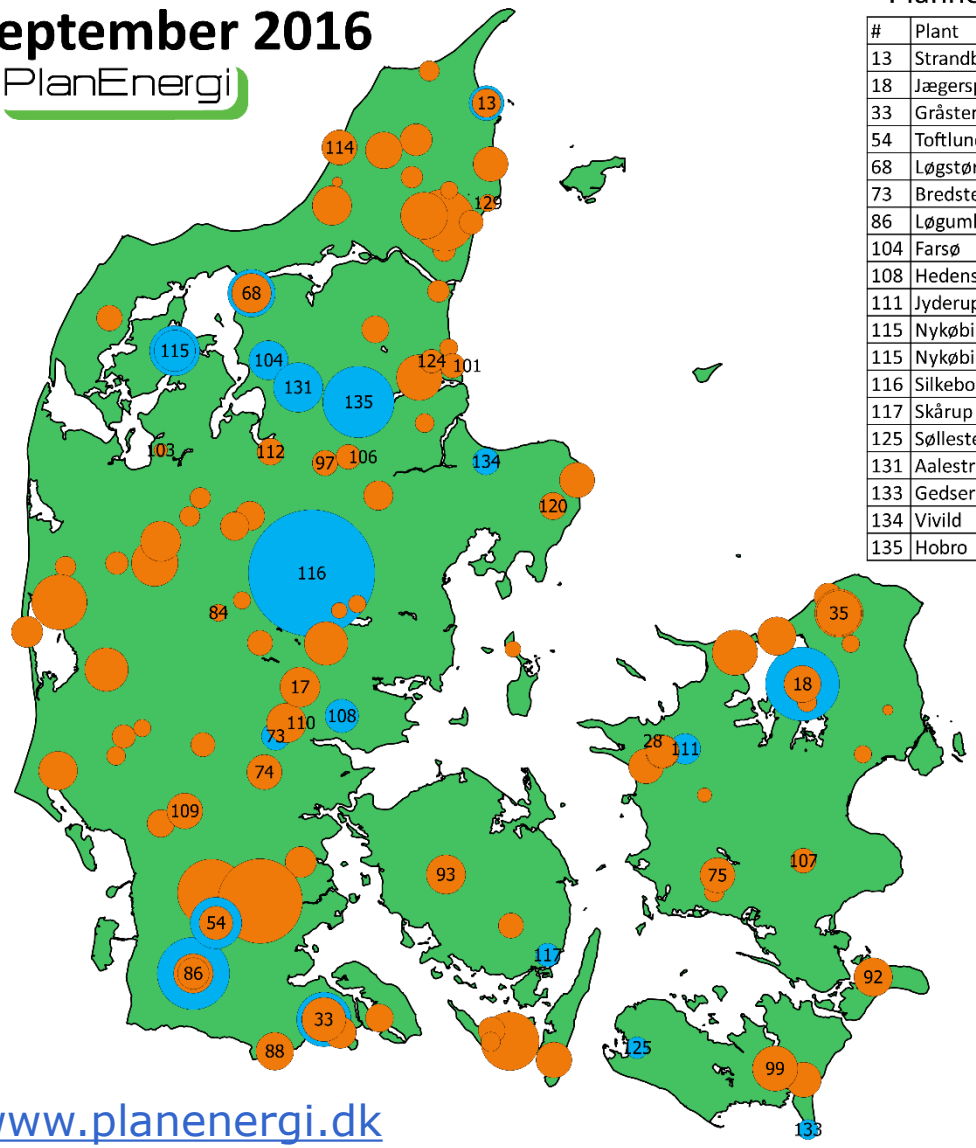
www.planenergi.dk

Solar thermal for DH

More than 1.000.000 m2 in operation!

September 2016

PlanEnergi



Planned new & expansions

#	Plant	Collector area (m2)
13	Strandby	(8019)+4000
18	Jægerspris	(10000+3405)+40000
33	Gråsten	(19024)+10000
54	Toftlund	(11000)+15000
68	Løgstør	(15208)+7000
73	Bredsten - Balle	7800
86	Løgumkloster	(9699+5576)+36000
104	Farsø	15120
108	Hedensted	11000
111	Jyderup	9239
115	Nykøbing Mors	16708
115	Nykøbing Mors	(16708)+8000
116	Silkeborg	156694
117	Skårup (Sydfyn)	5418
125	Søllested	4701
131	Aalestrup	24129
133	Gedser	4000
134	Vivild	7000
135	Hobro	50000

New plants & expansions in operation

#	Plant	Collector area (m2)
17	Tørring	(7284)+8467
28	Svebølle-Visking.	(7035+3000)+1000
35	Helsinge	(4733+14855)+3276
74	Egtved	12000
75	Fuglebjerg	12000
84	Kølkær	2873
86	Løgumkloster	(9699)+5576
88	Padborg	13961
92	Stege	14515
93	Tommerup	15000
97	Ørum	6375
99	Øster Toreby	20000
101	Als (Mariagerfj.)	5947
103	Ejsing	1800
106	Hammershøj	6000
107	Haslev	6010
109	Holsted	12500
110	Jelling	15290
112	Løgstrup	7031
114	Løkken	12096
120	Trustrup-Lyngby	7245
124	Veddum (VSV)	5500
129	Voerså	2873

In operation

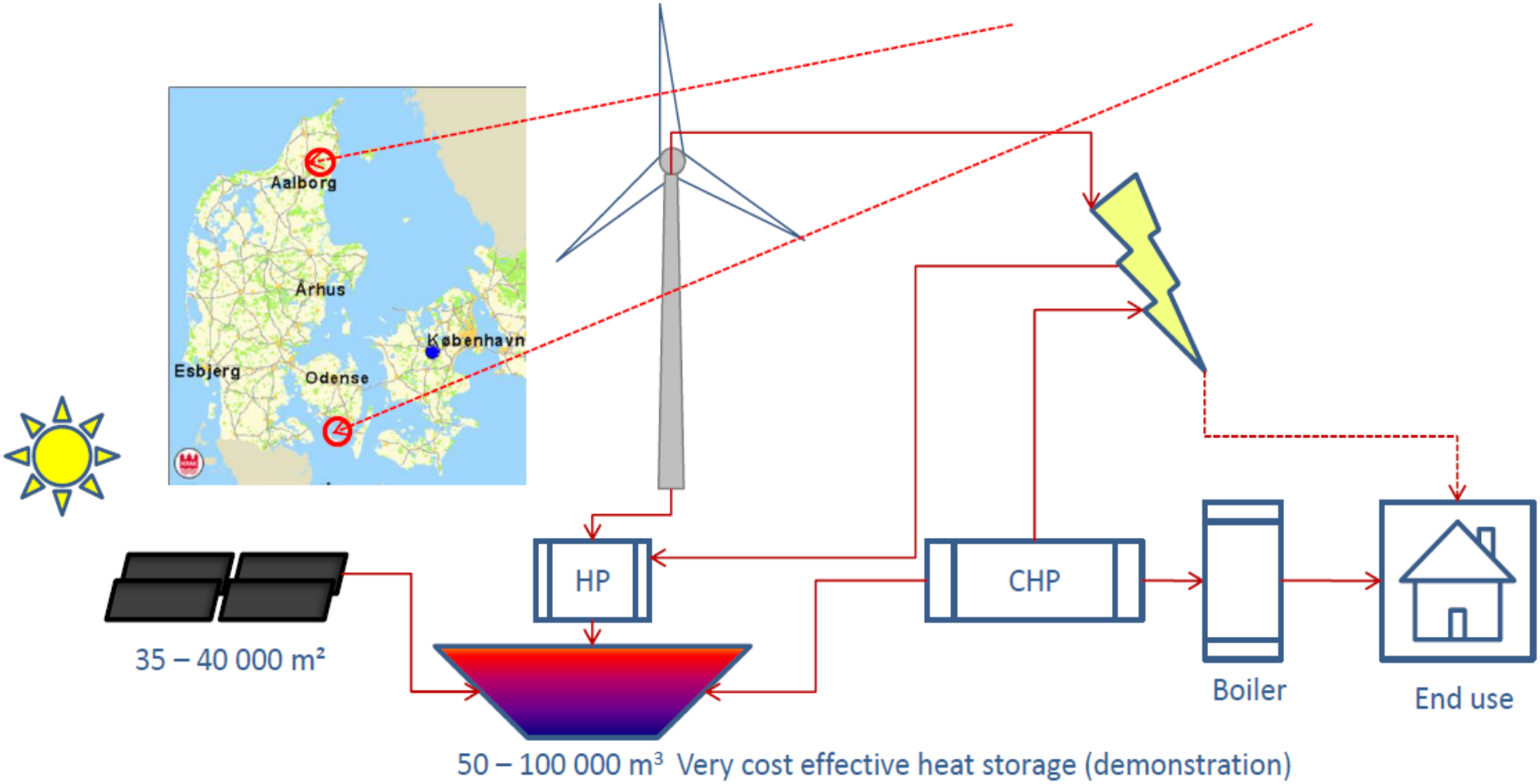
Planned / planned expansion

Total collector area (in operation): 1 003 024 m^2

Total collector area (planned): 431 809 m^2

www.planenergi.dk

The SUNSTORE® Concept
Examples Dronninglund and Marstal



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Conclusion

- **CHP** is an important efficient bridging technology
- Also as local thermal power production to supplement wind and import

- **4th generation DH** can play an important role in future green energy systems - given the right regulation

- Apart from **excess heat, residual waste and biomass**, fuelfree solutions are promising:

- **Solar heating and geothermal energy** can be an important ressources for district heating
- **Heat storages** even-out timeshifts between heat production and heat demand
- **Heat pumps** provide flexible power consumption that utilizes low temperature heat sources
- Less risk from fluctuating fuel and CO2 prices

Thank you for your attention!

Questions or comments?

maem@dtu.dk

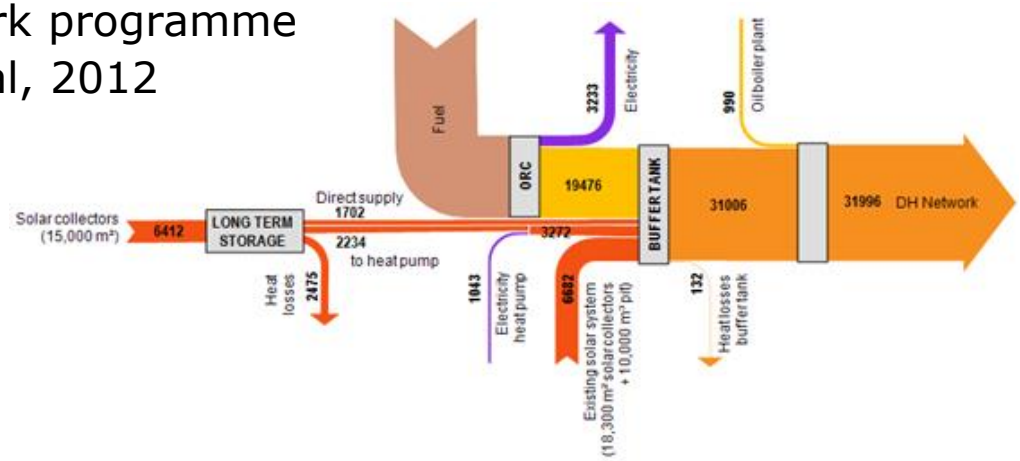
Extras

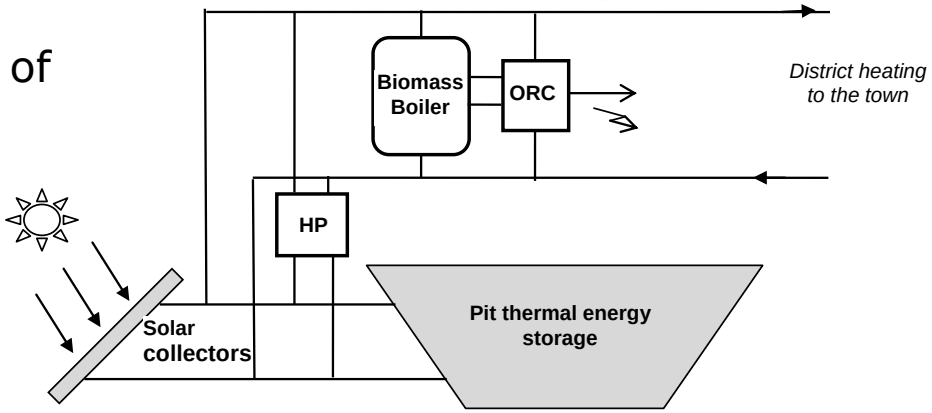
SUNSTORE 4 demonstration plant in Marstal

- The SUNSTORE 4 project
  - Supported by EC 7th framework programme
  - Demonstration plant in Marstal, 2012

- A district heating system with
  - 100% RE
  - > 50% solar thermal
  - A seasonal heat storage
  - A heat pump

- District heating system consisting of
  - 33,300 m^2 solar plant
  - 75,000 m^3 pit heat storage
  - 1.5 MW_{th} heat pump
  - 4 MW wood chip boiler
  - 750 kW_e ORC





www.planenergi.dk

4DH - Danish research centre

4th generation district heating (4GDH)

Hypothesis:

- 4GDH systems and technologies will play a big part in future cost-effective sustainable energy systems and are likely to replace the import of fossil fuels and create jobs and economic growth in Denmark and in Europe.

- Collaboration between industry, universities and the public sector

1) District Heat Grids and Components,
2) District Heating Production and System Integration,
3) District Heating Planning and Implementation

http://www.4dh.dk/

progRESsHEAT

http://www.progressheat.eu/

About progRESsHEAT

Goal:

- assisting local, regional, national and EU political leaders in **developing policy and strategies** to ensure a quick and efficient deployment of renewables in heating and cooling networks
- applying **model-based** quantitative impact assessment of local, regional and national policies up to 2050 (Local: EnergyPro, National: TIMES)

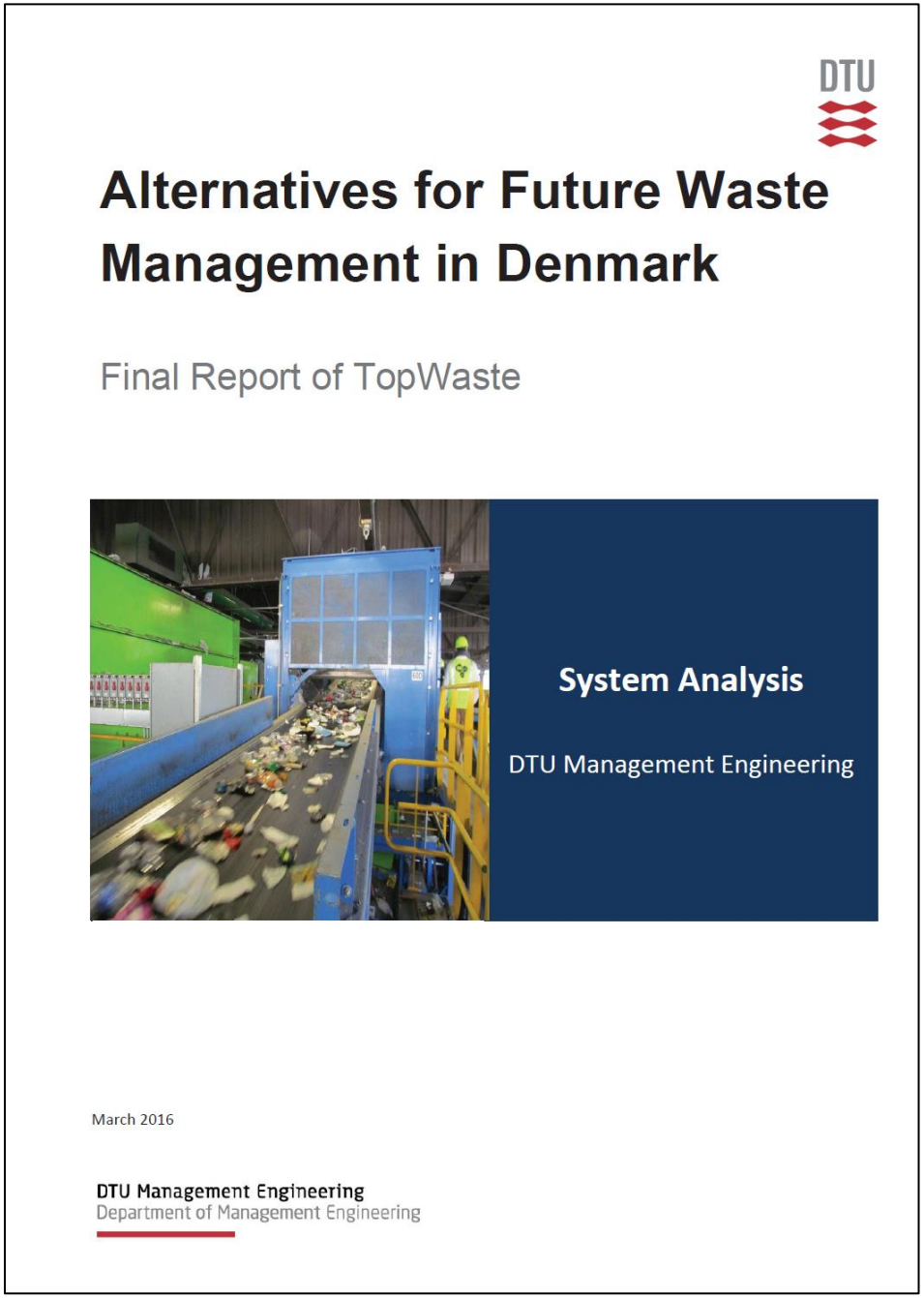
Running from March 2015 to October 2017. The project is supported by the Horizon 2020 programme

PARTNERS IN THE PROJECT

Institute for Energy Systems and Electric Drives, Vienna University of Technology - TU-Wien (Austria) // Fraunhofer Institute for Systems and Innovation Research ISI (Germany) // Technical University of Denmark - DTU (Denmark) // Institute for Resource Efficiency and Energy Strategies - IREES GmbH (Germany) // OÖ Energiesparverband - ESV (Austria) // ee energy engineers GmbH (Germany) // Gate 21 (Denmark) // Instituto de Engenharia Mecanica e Gestao Industrial - INEGI (Portugal) // Agentia Pentru Management ul Energiei si Protectia Mediului Brasov - ABMEE (Romania) // City of Litoměřice (Czech Republic) // Energy Cities (France)

TOPWASTE
Research project
2011-2015

Main purpose:

- to contribute to **improved use of waste for energy or material recycling** integrating economic and environmental considerations including resource scarcity.

www.topwaste.dk