Exergy and cost analysis of heating systems with energy storage

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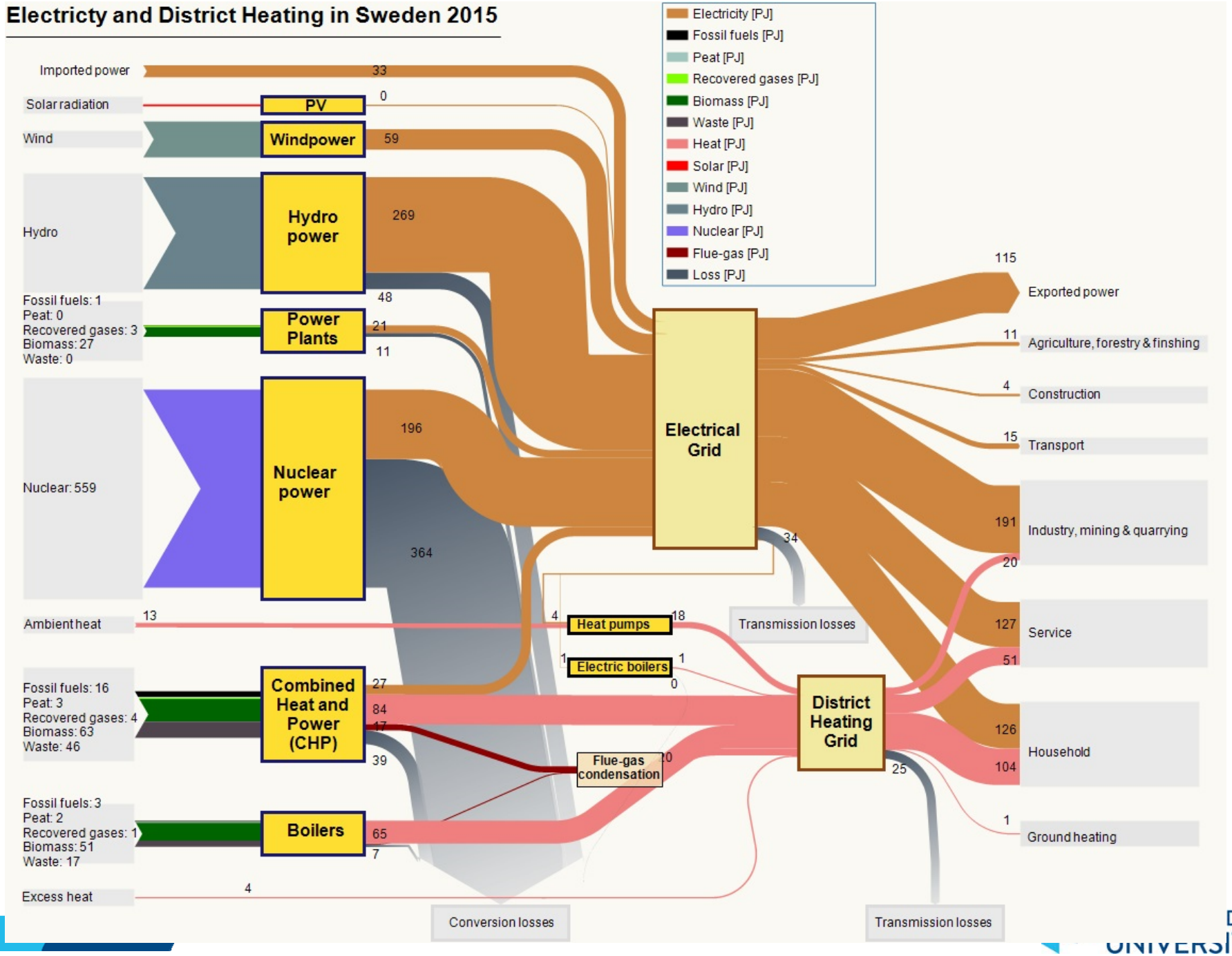
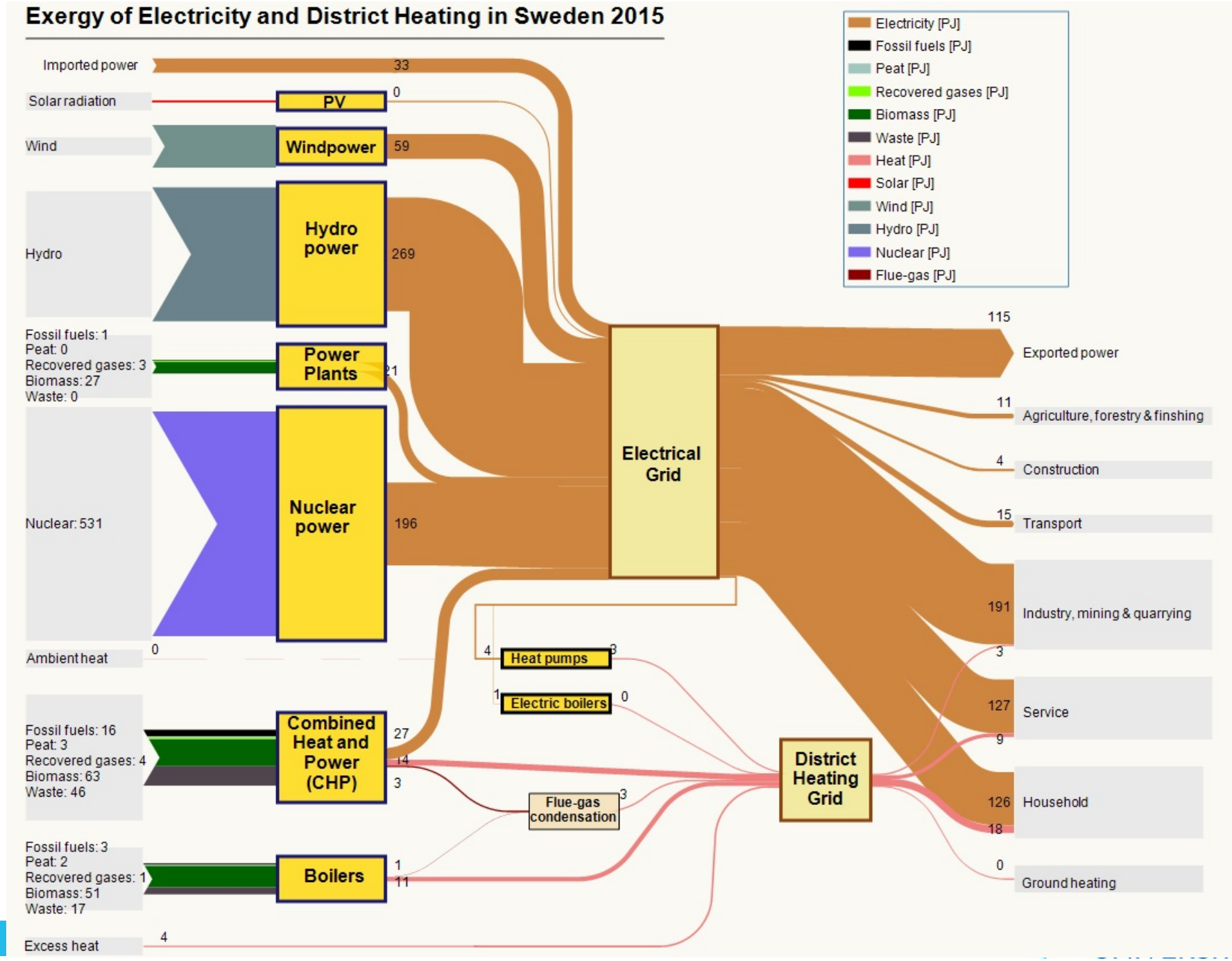
Outline

- Electricity and district heating in Sweden
- Heating method in service and household
- Heat price with district heat, electric boiler, and heat pump
- Thermal energy storages
- Summary


Electricty and District Heating in Sweden 2015
Electricity [PJ]
Fossil fuels [PJ]
Peat [PJ]
Recovered gases [PJ]
Biomass [PJ]
Waste [PJ]
Heat [PJ]
Solar [PJ]
Wind [PJ]
Hydro [PJ]
Nuclear [PJ]
Flue-gas [PJ]
Loss [PJ]
Imported power
33
Solar radiation
PV
0
Wind
Windpower
59
Hydro
Hydro power
269
48
Fossil fuels: 1
Peat: 0
Recovered gases: 3
Biomass: 27
Waste: 0
Power Plants
21
11
Nuclear: 559
Nuclear power
196
364
Ambient heat
13
4
Heat pumps
18
1
Electric boilers
1
0
Fossil fuels: 16
Peat: 3
Recovered gases: 4
Biomass: 63
Waste: 46
Combined Heat and Power (CHP)
27
84
17
39
Flue-gas condensation
20
Fossil fuels: 3
Peat: 2
Recovered gases: 1
Biomass: 51
Waste: 17
Boilers
65
7
Excess heat
4
Conversion losses
Electrical Grid
34
Transmission losses
District Heating Grid
25
Transmission losses
115
Exported power
11
Agriculture, forestry & finshing
4
Construction
15
Transport
191
Industry, mining & quarrying
20
127
Service
51
126
Household
104
1
Ground heating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Ground heating

The energy and exergy efficiencies in Sweden

Supplier	Energy efficiency	Exergy efficiency
CHP	97%	32%
Fuel boiler	93%	15%
Electric boiler	80%	13%
Heat pump	4 (COP)	69%

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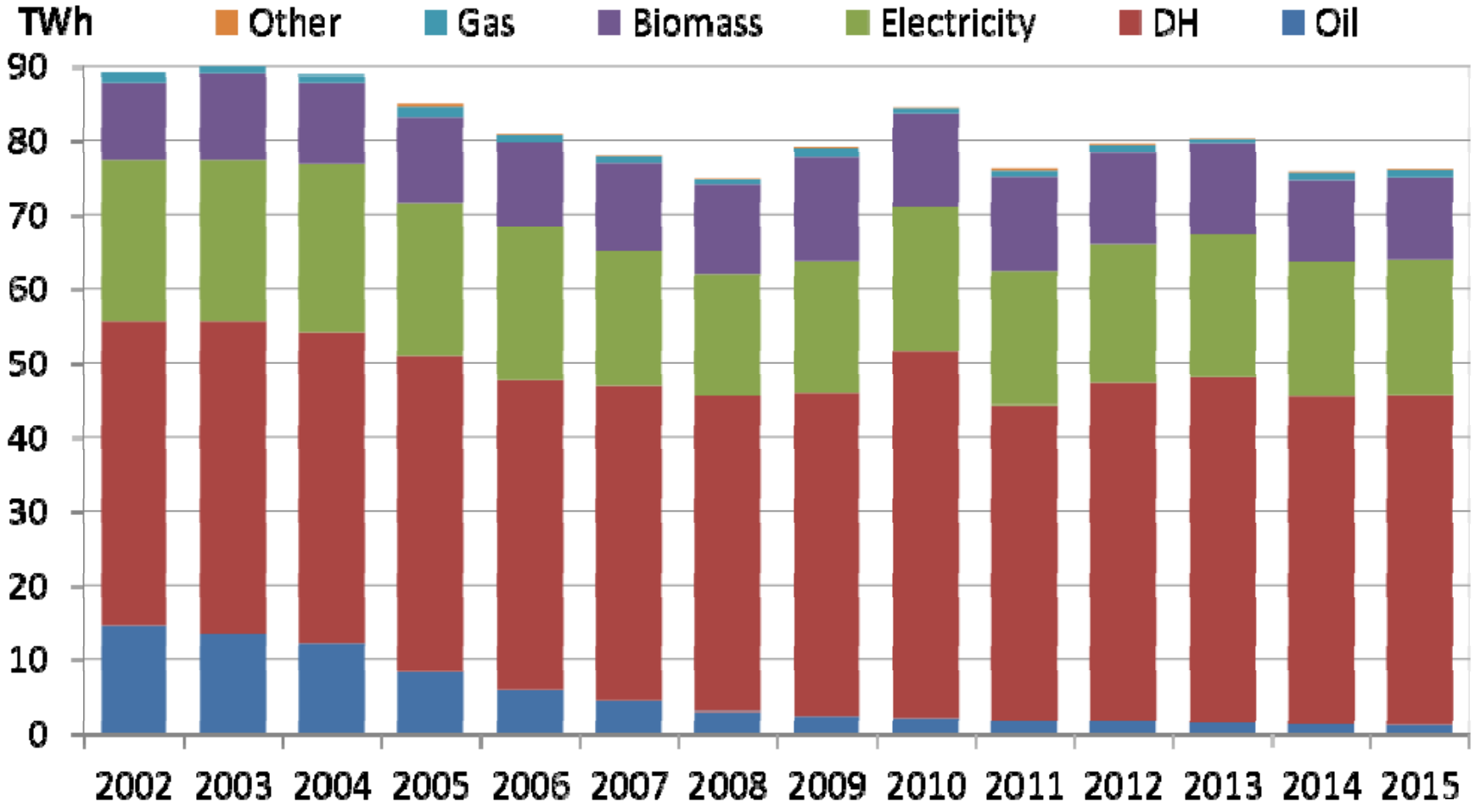
Heat for houses

Heating source for service and household



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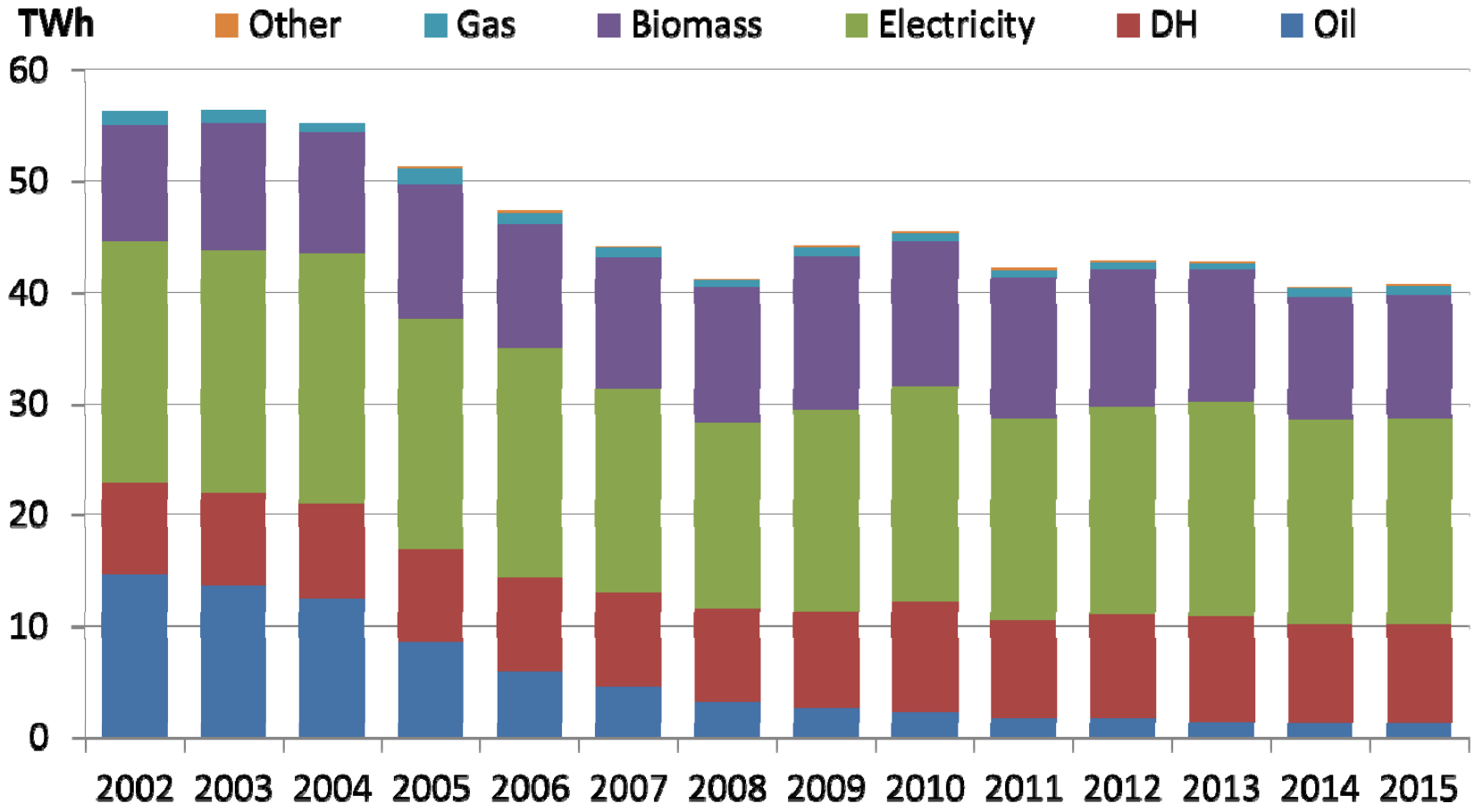
Heating source for service and household use in Exergy content



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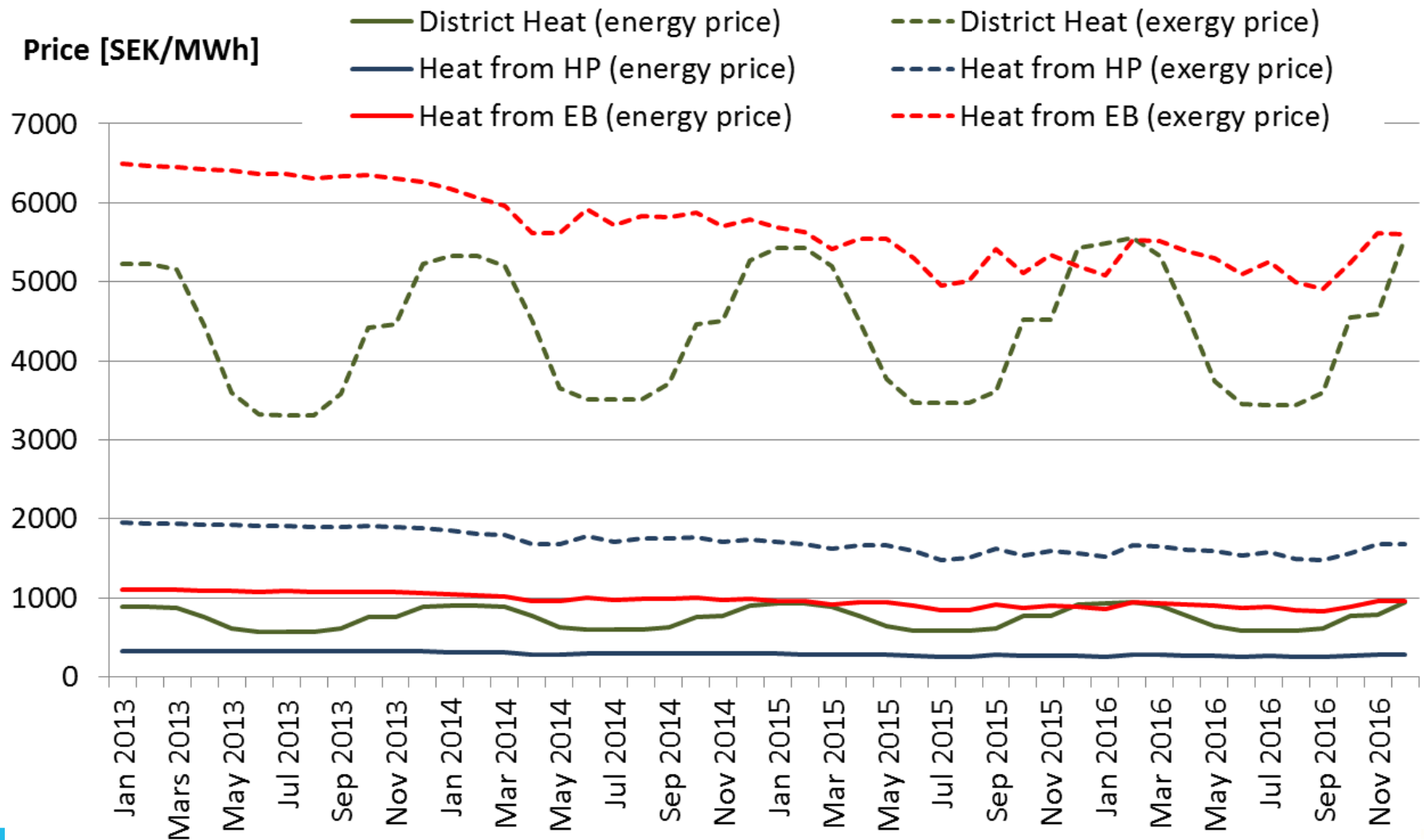
Methods for heating in service and household in Sweden

- District heating: about 54%
- Electric boiler/heater and heat pump: about 24%
- Biomass boiler: about 15%
- Other boiler and methods: about 7%

Heat cost including tax using district heat, electric boiler and heat pump



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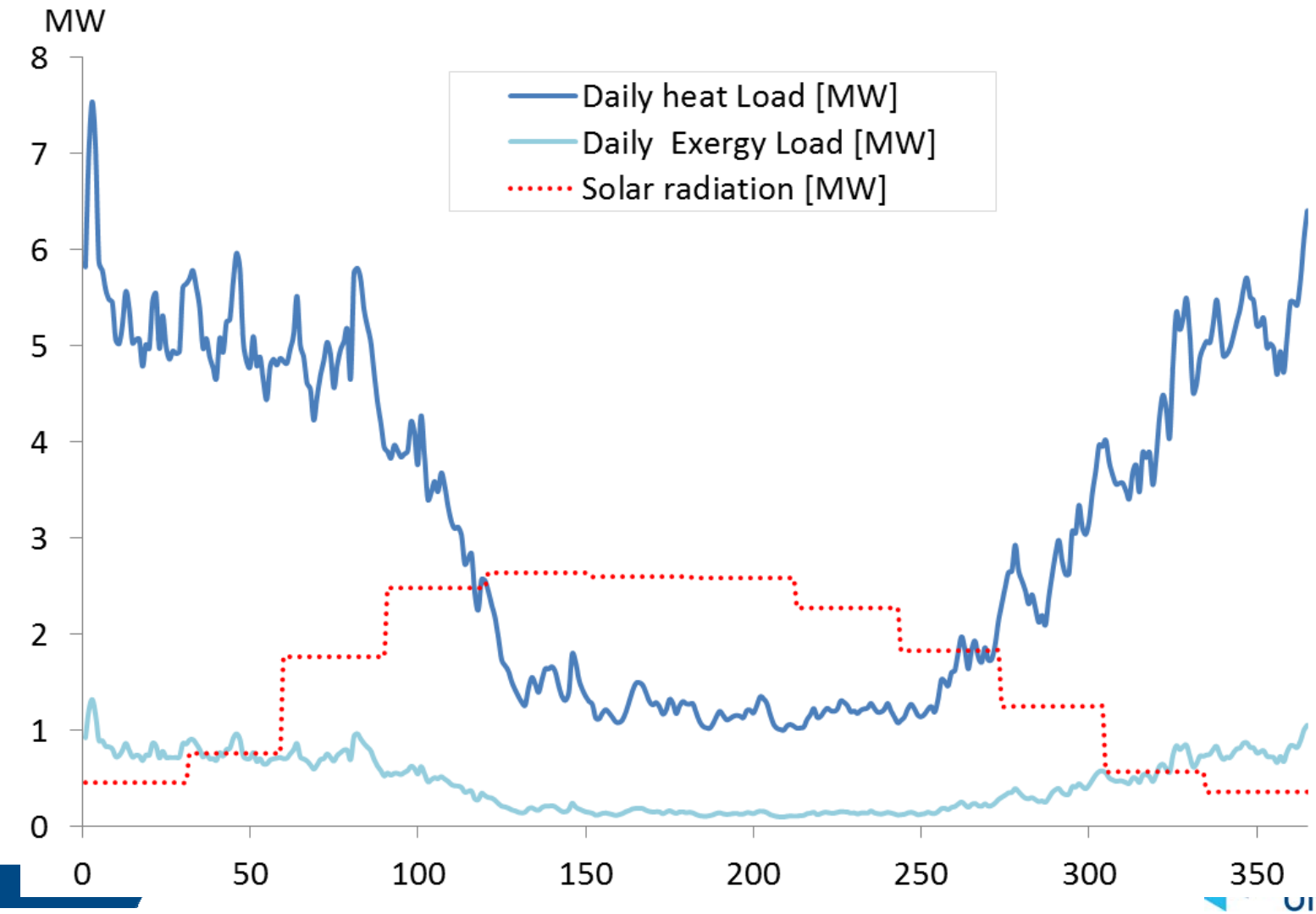
Thermal energy storage

Heat distributed to net during one year in a solar district heating system



Evaluation of thermal Storage

- $$\eta = \frac{\text{Total energy recovered} + \text{Accumulated energy in storage}}{\text{Total energy delivered}}$$
- $$= \frac{Q_r + Q_{acc}}{Q_c} = 1 - \frac{Q_{loss}}{Q_c}$$

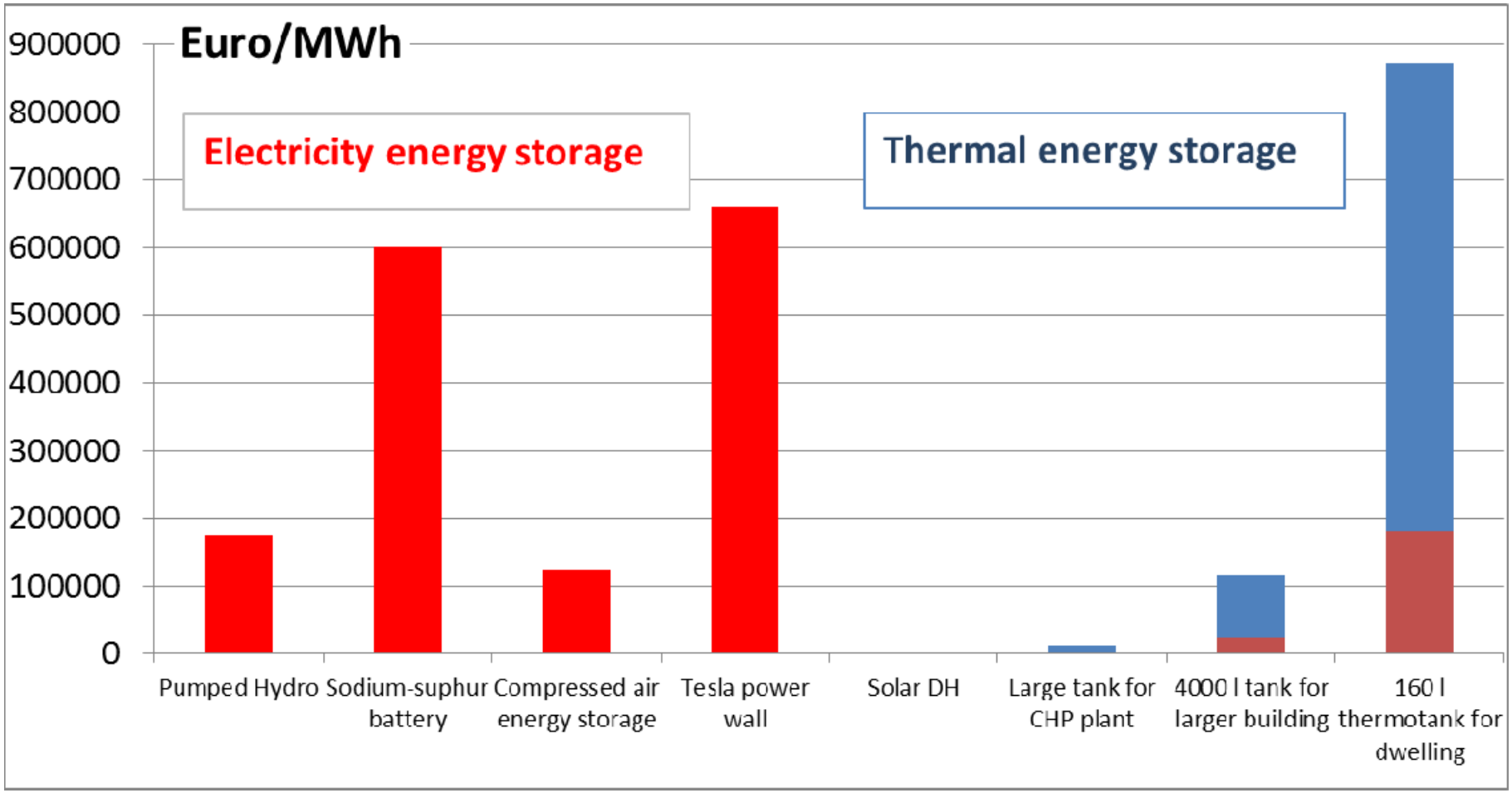
- $$\eta_{ex} = \frac{\text{Total exergy recovered} + \text{Accumulated exergy in storage}}{\text{Total exergy delivered}}$$
- $$= \frac{E_r + E_{acc}}{E_c} = 1 - \frac{E_{loss} + E_{destruction}}{E_c}$$

Energy Storage efficiency

- Overall energy efficiency of thermal storage : about 60%

- Overall exergy efficiency of thermal storage : about 19%

Investment cost of energy storage



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Summary

- Avoid to convert high quality energy sources to low quality energy sources, use low quality renewable energy resources
- Heat pump is good example combined low and high quality energy input, and price could complete with district heating at present
- Electricity storage is about 100 times more expensive than storage, in energy, and 20 times more in exergy

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Heat Roadmap Europe

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Thank for your attention!