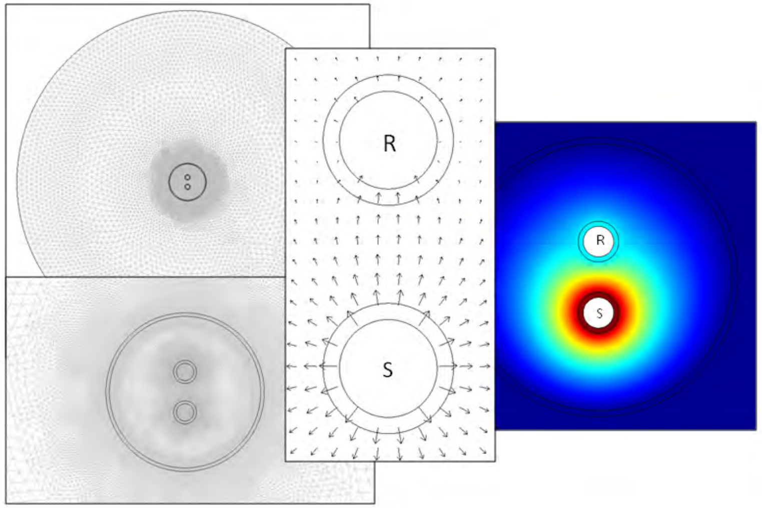
Low-Temperature District Heating for Energy-Efficient Communities

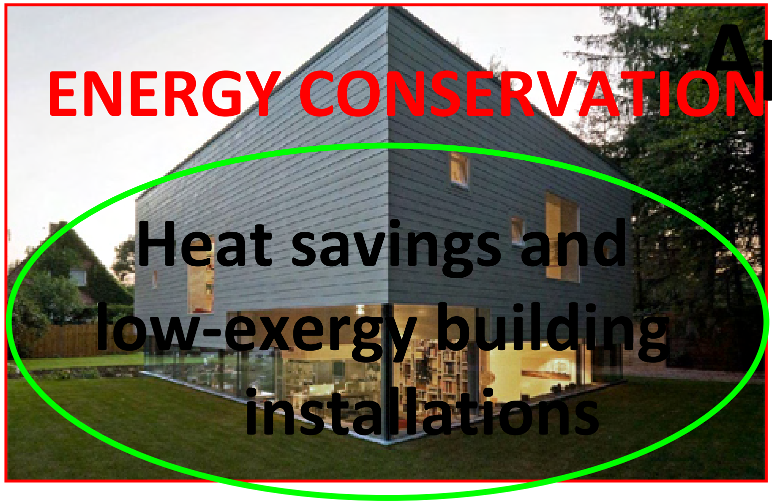
Alessandro Dalla Rosa

Technical University of Denmark

3rd October 2012, Salzburg, Austria



The Heating Sector: Integrated and Holistic Approach



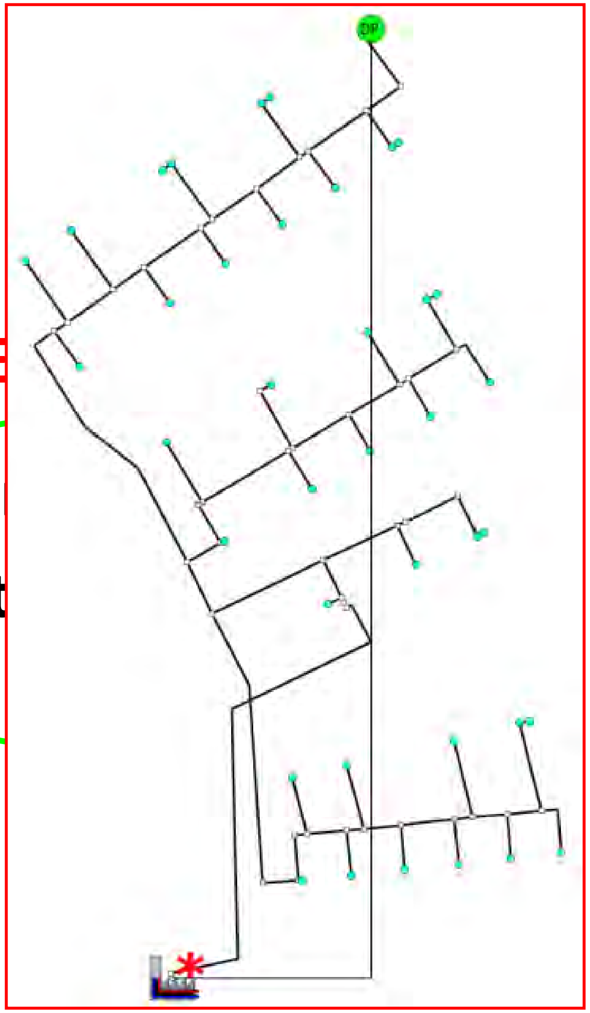
ENERGY CONSERVATION

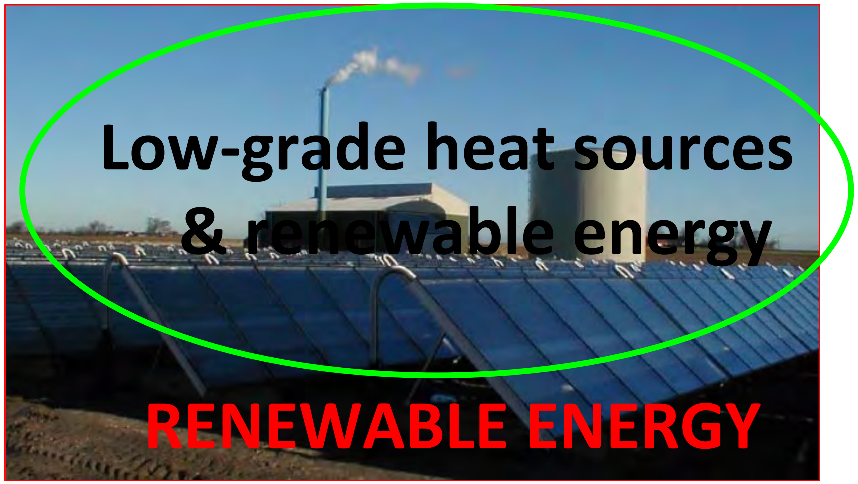
Heat savings and low-exergy building installations

ENE

Ene

heat





Low-grade heat sources & renewable energy

RENEWABLE ENERGY

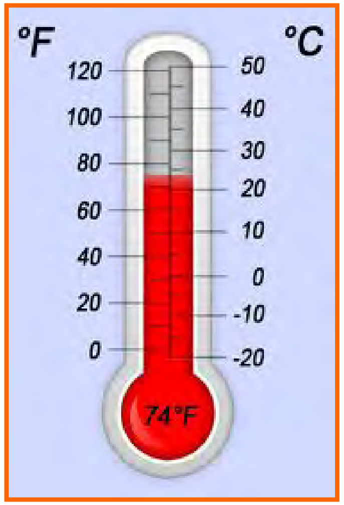
Definitions

1st Generation District Heating (DH): Steam systems

$T_{\text{supply}} > 120^\circ\text{C}$

2nd Generation DH: High-Temperature Water

$T_{\text{supply}} > 100^\circ\text{C}$



3rd Generation DH: Medium-Temperature Water

$70^\circ\text{C} \leq T_{\text{supply}} \leq 100^\circ\text{C}$

4th Generation DH: Low-Temperature Water

$T_{\text{supply}} \leq 60^\circ\text{C}$

Supply of “green” energy to energy-efficient buildings

District Heating (DH) in Denmark (2010)

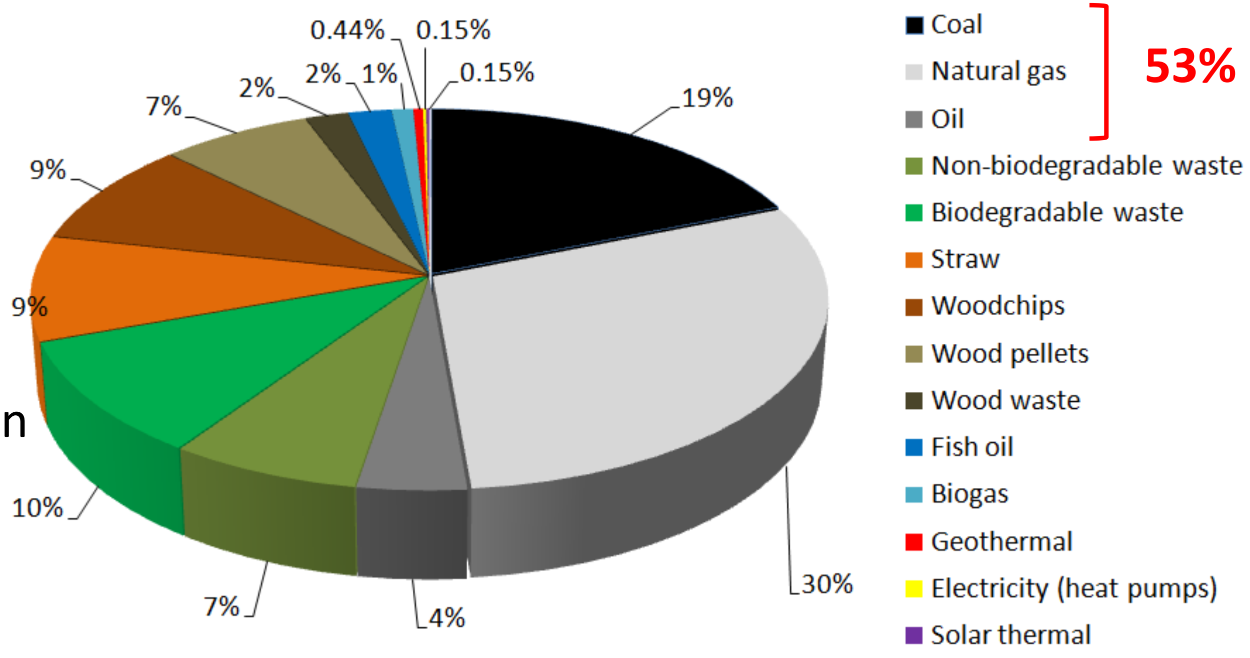
- Approx. 450 DH systems

- 27,000 km of pipelines

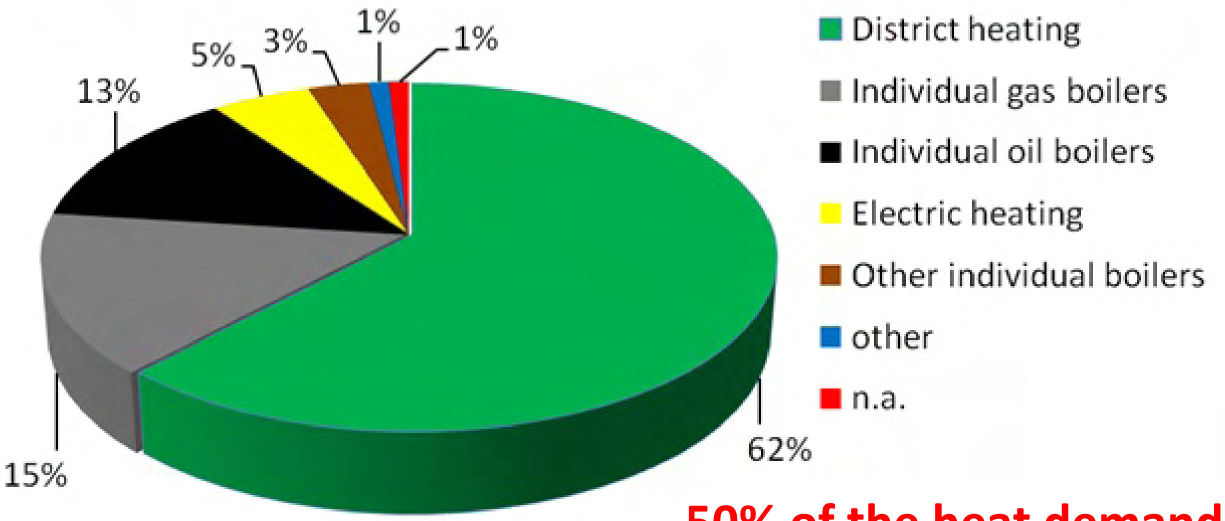
- 77% of heat from cogeneration

- Heating season:
T_{supply} = 78.7°C, T_{return} = 41.4°C

- Non-heating season:
T_{supply} = 73.3°C, T_{return} = 44.1 °C

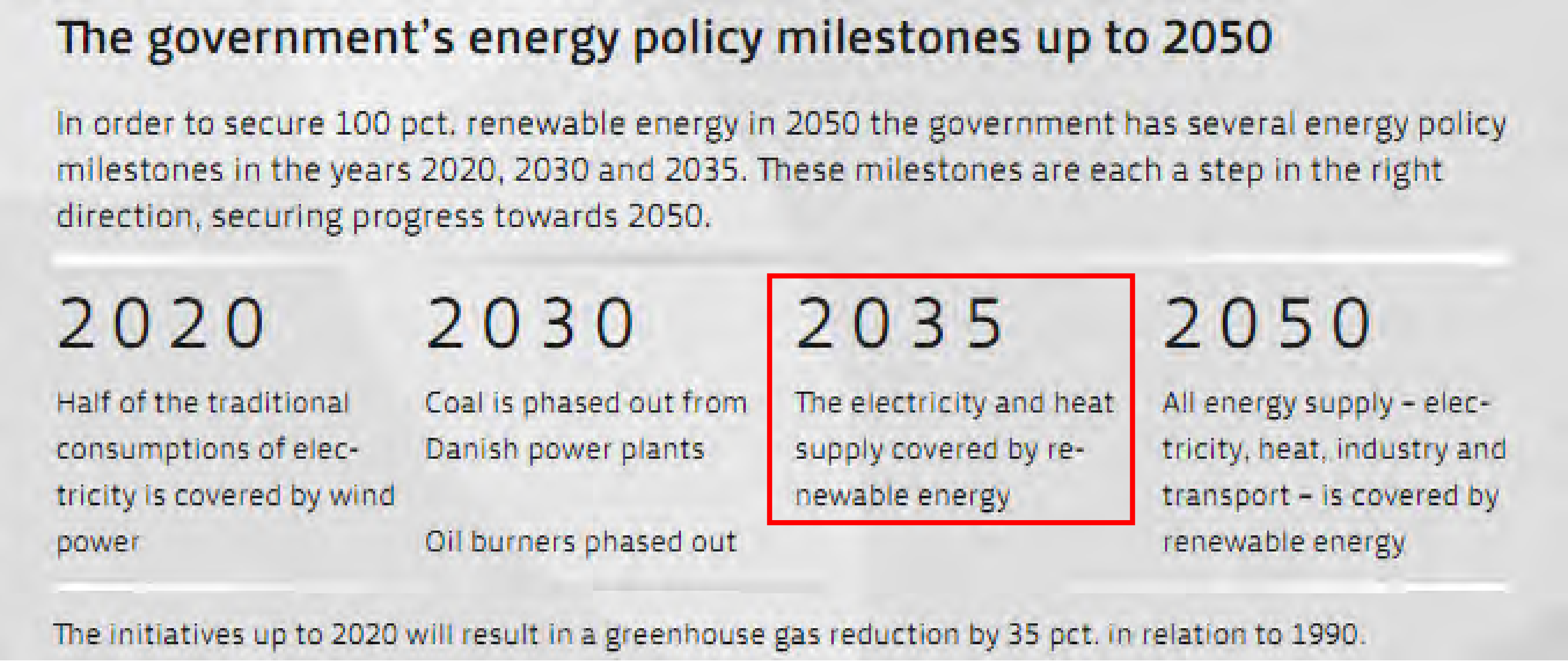


53%



50% of the heat demand

The Roadmap in Denmark



The government's energy policy milestones up to 2050

In order to secure 100 pct. renewable energy in 2050 the government has several energy policy milestones in the years 2020, 2030 and 2035. These milestones are each a step in the right direction, securing progress towards 2050.

2020	2030	2035	2050
Half of the traditional consumptions of electricity is covered by wind power	Coal is phased out from Danish power plants Oil burners phased out	The electricity and heat supply covered by renewable energy	All energy supply – electricity, heat, industry and transport – is covered by renewable energy

The initiatives up to 2020 will result in a greenhouse gas reduction by 35 pct. in relation to 1990.

Source: "Our Future Energy", the Danish Parliament, Nov. 2011

100% share of RE in the heating sector by 2035

The “Heat Plan Denmark”

Energy savings

Approx. 40% reduction of the space heating demand (reference 2010)

Low-temperature

Reduction of yearly-averaged DH return temperature to 35°C

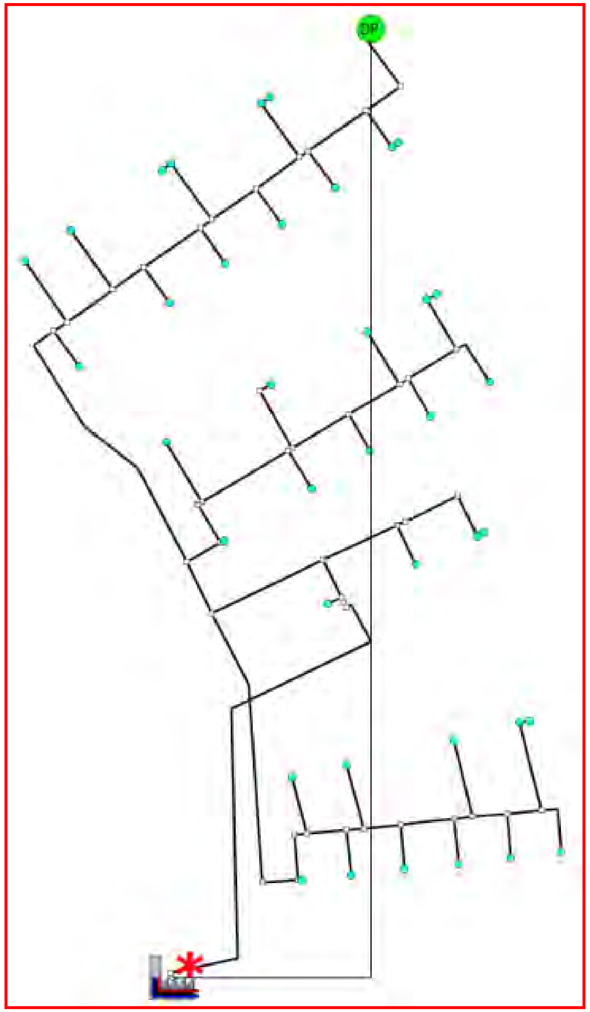
DH expansion

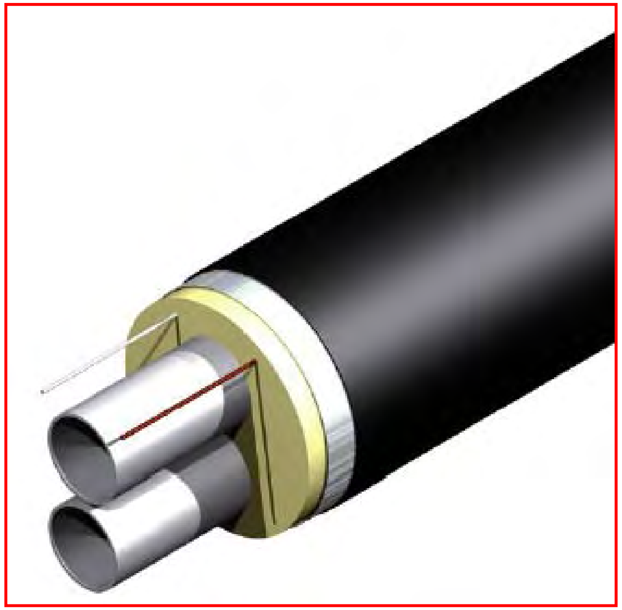
Expansion of DH to supply 70% of the heat demand

Low-Energy District Heating in Energy-Efficient Building Areas

Case-studies in Denmark

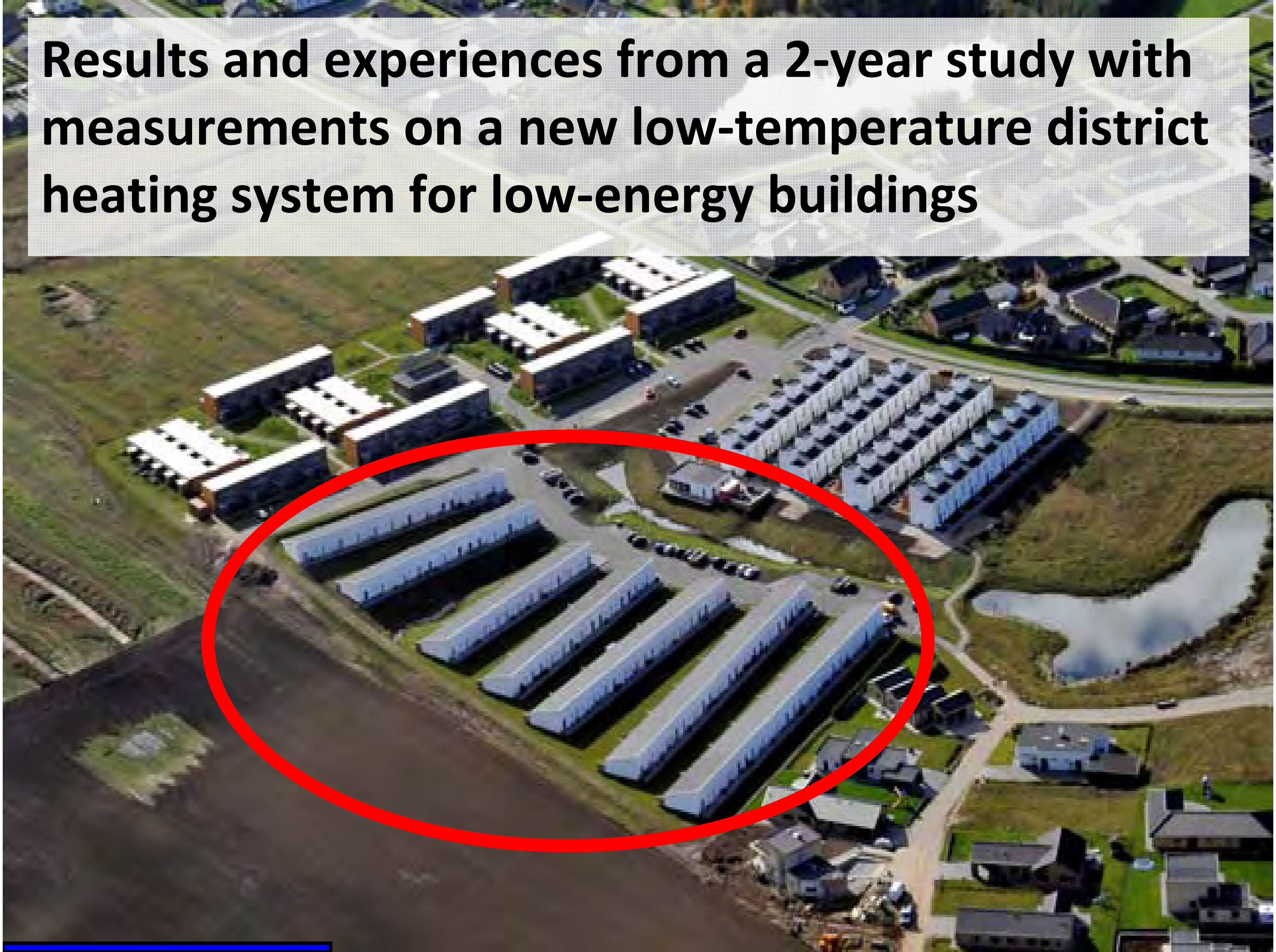
- settlement with 41 low-energy houses





$T_{supply} = 55°C$
$T_{return} = 25°C$

Results and experiences from a 2-year study with measurements on a new low-temperature district heating system for low-energy buildings



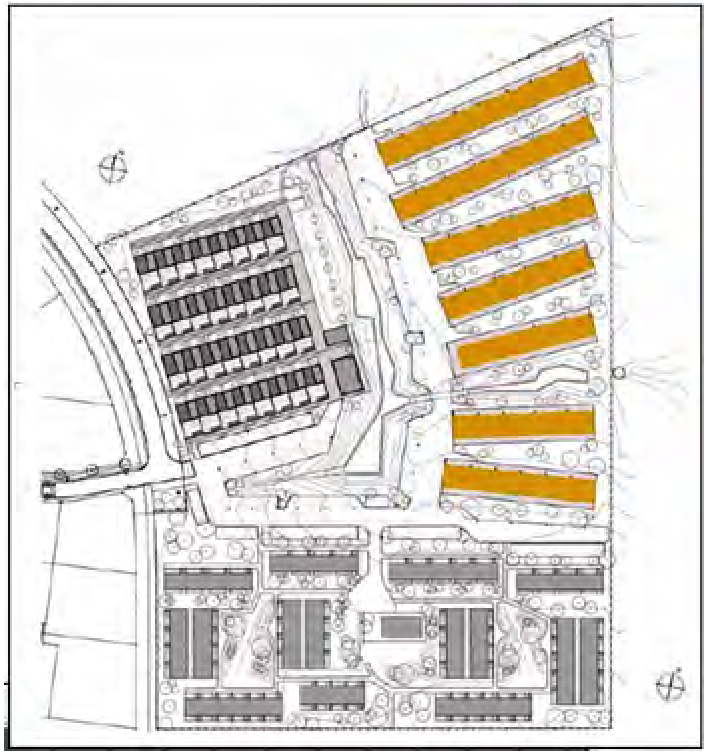
The challenge: 100% renewable energy in the heating sector

- Heat demand is decreasing because of tighter building codes and retrofitting of the existing building stock. Energy Performance of Building Directive describes **”nearly zero energy buildings” from 2020**
- **Development of community energy systems in Europe** includes going into areas with **lower heat density than before**
- **Integration of more renewables and low temperature surplus heat**
- Part of the solution: **Low temperature district heating systems for low heat density areas**

	Today	**Tomorrow**
Heat demand for DH	75-150 kWh/m^2	40 kWh/m^2
Design temperatures, Winther	70/40 °C	55/25 °C
Design temperatures, Summer	60/40 °C	50/25 °C
Distribution heat losses	15-30%	15-20%

Demonstration site: Lystrup (Aarhus), Denmark

- Owner: **Housing association Boligforeningen Ringgården**
- Year of construction: **2008-2010**
- Building units: **40 terraced houses + 1 communal building**
- Total heated area: **4115 m²**
- Calculated building code specific design heat demand for space heating and domestic hot water: **43.1 kWh/m²**
- Heating system: **Radiators and Floor heating in bathrooms**



Distribution pipes

- Twin pipes in all dimension
- Insulation class: Series 2
- PUR foam: λ = 0,023 W/(mK)
- Cell gas diffusion barrier in outer casing
- Diffusion-tight flexible carrier pipe (AluPEX)

Pipe dimensions	[m tracé]
Alx 14/14-110 (16-16/110)	115
Alx 20/20-110	187
Alx 26/26-125	163
Alx 32/32-125	127
TWS-DN32 (42-42 /180)	89
TWS-DN40 (48-48/180)	34
TWS-DN50 (60-60/225)	8
I alt	723

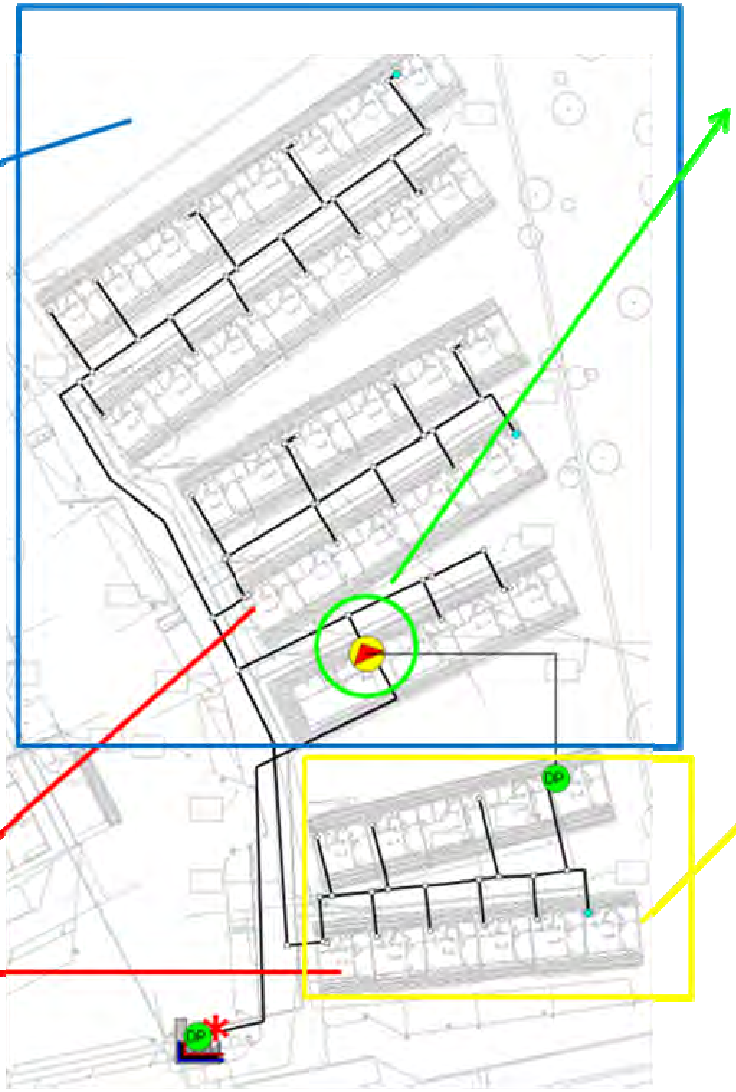
Alx: AluPEX pipes

TWS: Steel pipes

Distribution network & meters

Main design criteria

- Reduced length when possible
- Maximum pressure level: 10 bar(g)
- Holding pressure: 2 bar
- Maximum velocities: 2 m/s
- Minimum difference pressure: 0.3 bar



Instantaneous Heat Exchanger Unit (IHEU)

Flow rate meter:
0.01-0.38 m³/h

Pumping station
Flow rate meter:
0.8-12 m³/h

District Heating Storage Unit (DHSU)

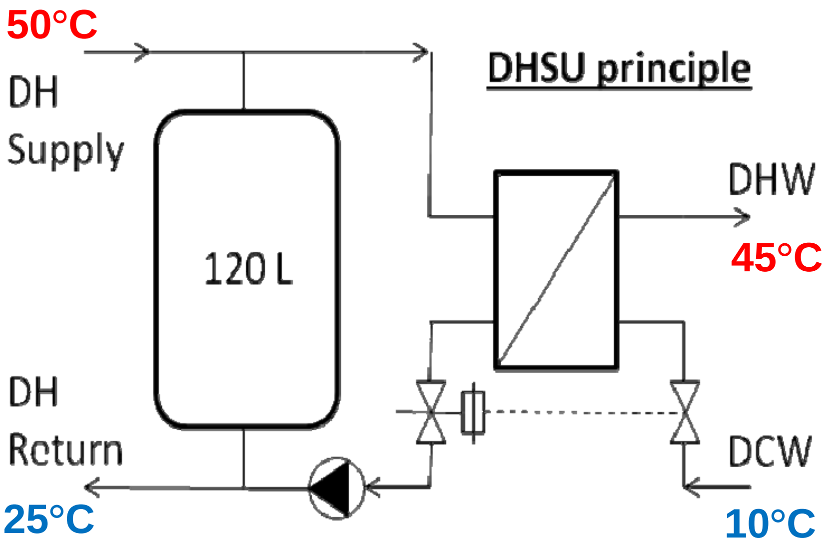
Flow rate meter:
0.01-0.09 m³/h

Flow rate meter (street):
0.26-3.4 m³/h

Building substations

Design loads:

3 kW

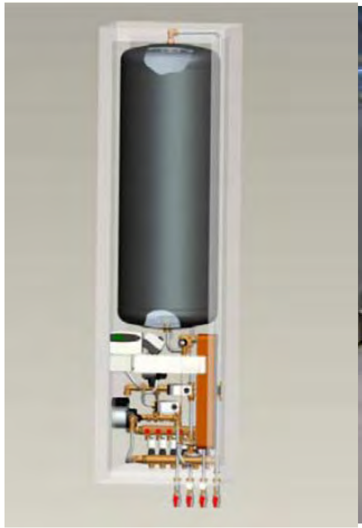


50°C

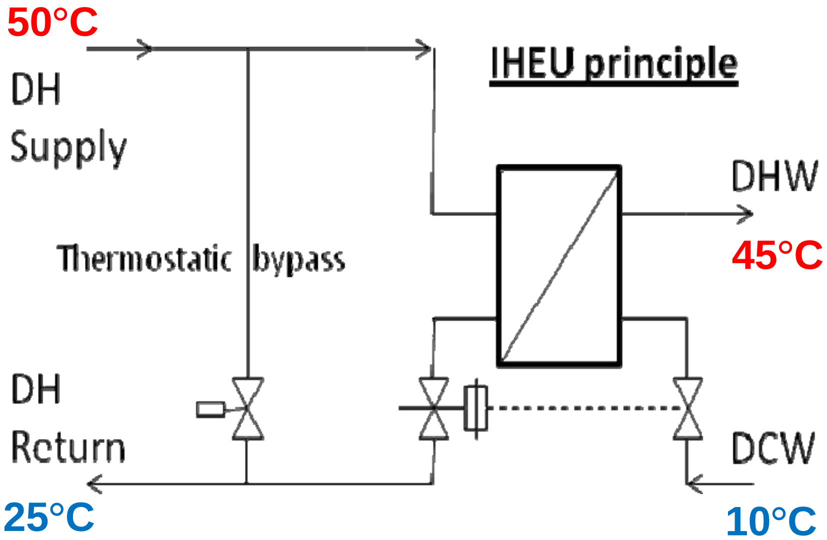
45°C

25°C

10°C



32.3 kW



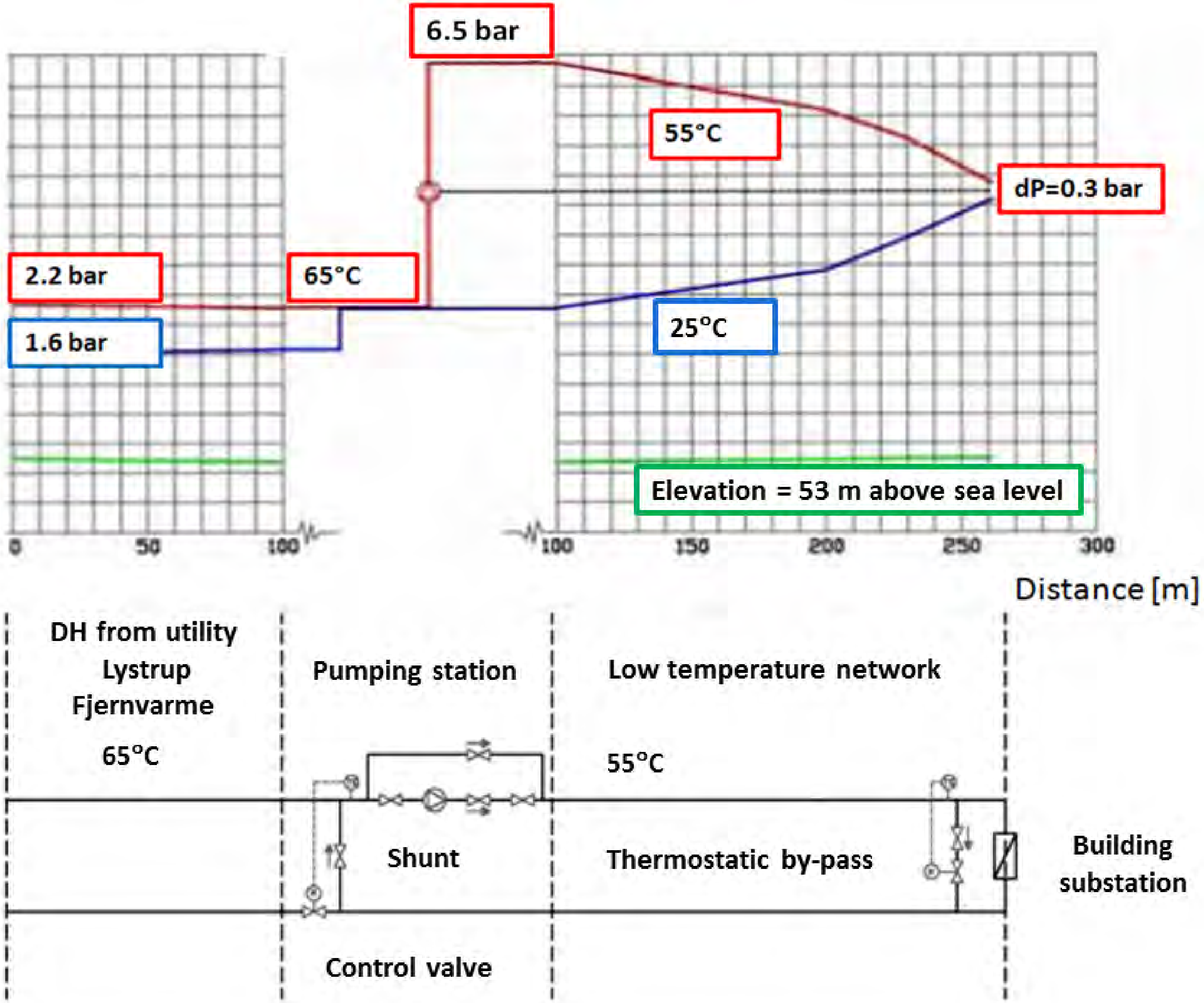
50°C

45°C

25°C

10°C

Pumping station and shunt



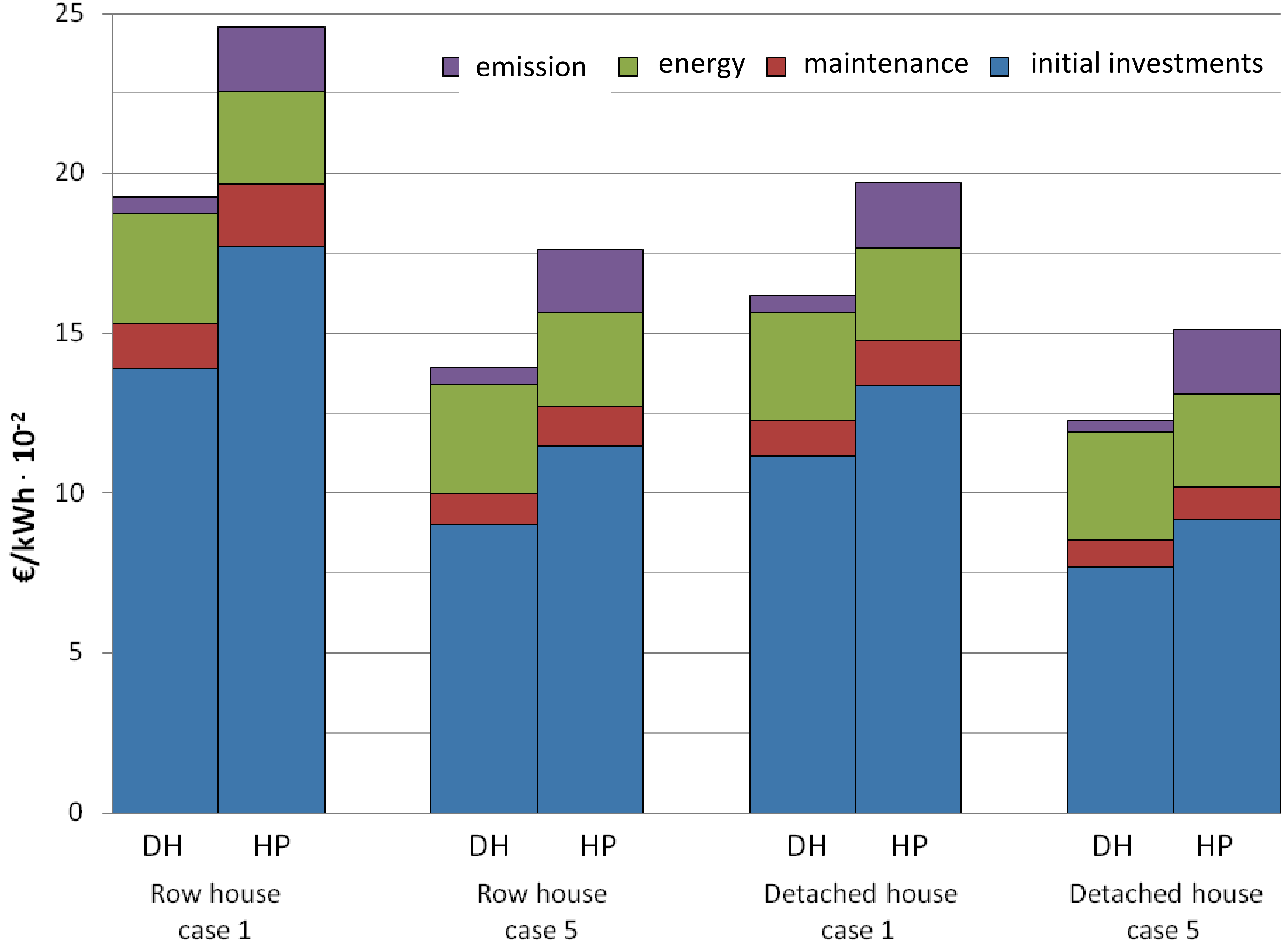
Results: Summary

Year		**DK ref** (calc.)	**2011** (meas.)
Total heat delivered to LTDH network	MWh	287.2	273.9
Heat demand	MWh	238.1	219.4
Distribution heat loss	MWh	49.1	54.5
Distribution heat loss	%	17.1	19.9
Heat power, yearly avg.	kW	-	31.3
Supply temperature, DH	°C	-	67.4
Supply temperature, LTDH	°C	55	52.7
Return temperature DH	°C	30	34.1
Electricity use,pumping station	kWh	2600	2556

- Heat consumption 5.8 MWh per house **(58 kWh/m²)**
- Heat loss from distribution network: 1.2 MWh per house **(12 kWh/m²)**
- Total district heating consumption: 7.0 MWh per house **(70 kWh/m²)**

With traditional pair of pipes (single pipes) and DH temperatures 80°C/40°C heat loss from distribution network would have been about 4 times higher

District Heating (DH) vs. Ground Source Heat Pumps (HP)

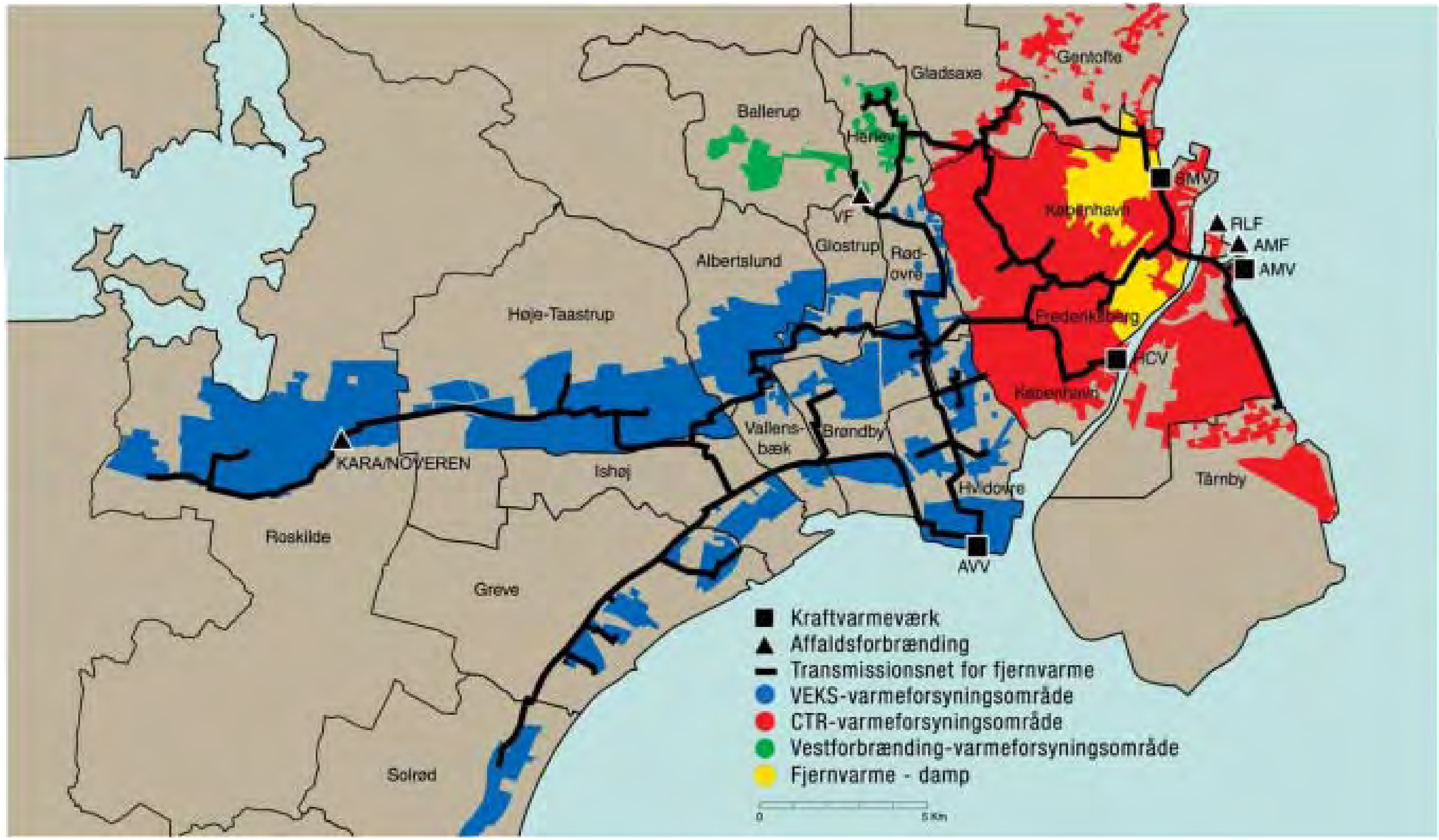


Conclusions

- The optimised low-temperature district heating concept works
- 50°C in supply temperature at the consumers can be sufficient
- Low network heat loss (down to 15-20%) despite the low heat demand in low-energy buildings.
- The design and operation details are getting important!
- Demonstration projects in Denmark are paving the way:
  - Lystrup: 40 terraced houses, Low energy buildings
  - Taastrup: 75 detached houses with underfloor heating, from the 90ties (uses return water from nearby network)
  - Tilst: 8 detached houses (1 street) with radiators, from the 70ties

Planning of the District Heating System in Copenhagen in the Future

Existing district heating in the Copenhagen area

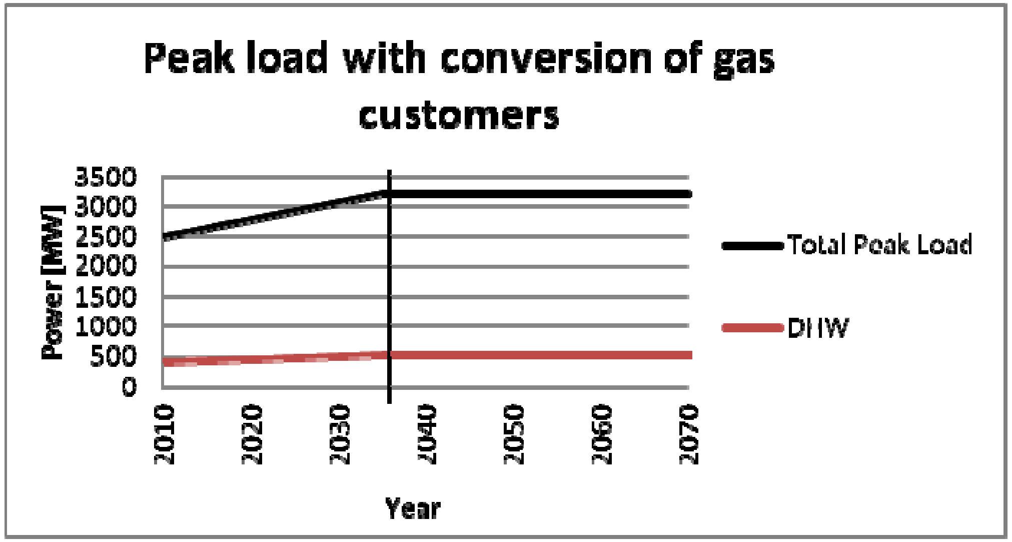


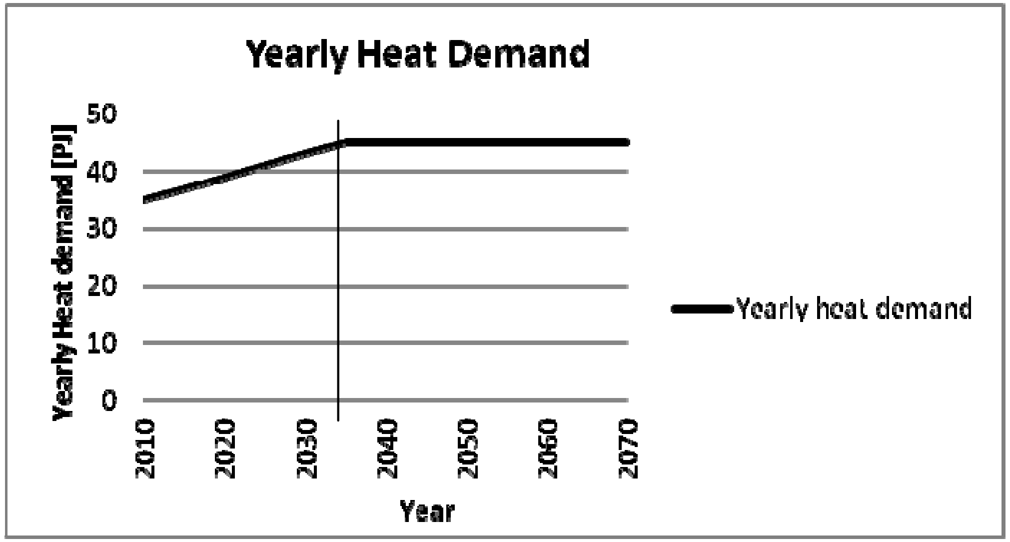
Present and Future Heat Demand

- Heat demand (2010):
  - Peak load: 2500 MW
  - Yearly heat demand: 35 PJ

- Potential for converting costumers supplied by natural gas to district heating: 10 PJ
  - Peak load: 3200 MW
  - Yearly heat demand: 45 PJ

→ Linear conversion is assumed until 2035





Assumptions for the Investigation

- Biomass is not a long-term solution for heating purposes

- When biomass will be phased out from DH large investment in a new technology will take place
  - Geothermal heat has been in focus in this investigation.
  - Other technologies could be solar heat with storage, heat pumps, surplus heat, etc.

- Assumptions for the model:
  - Heat from waste incineration decreases by 1/3 (recycling+biofuels)
  - Coal and gas will be phased out in CHP plants before 2025
  - Biomass will be phased in before 2025
  - The biomass is moved to the other energy sector before 2040
  - Geothermal heating plants will be phased in before 2040

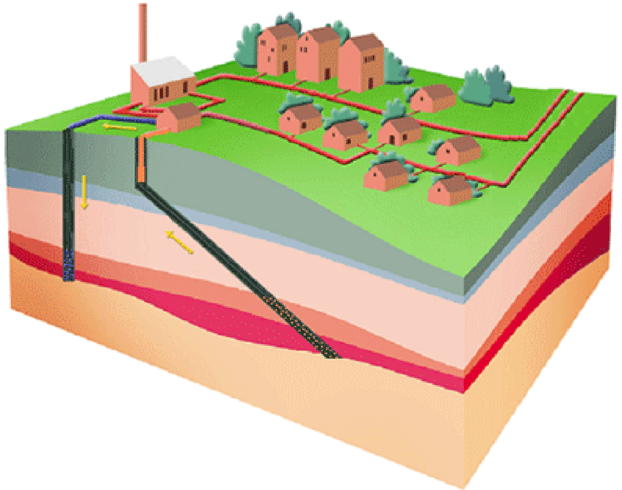
- Low temperature district heating is implemented widely

- Priority of resources when present

  1.Waste, 2.Geothermal, 3.Biomass, 4.Fossil fuels

Geothermal potential under Copenhagen

- Recent studies have estimated the potential under Copenhagen: 60,000 PJ
  - Cover heat demand for more than 1000 years
- Temperature drawn from the ground at 73°C



Low temperature district heating

- Normal operating temperatures
  supply: 50-55°C, Return: 25-30°C
- Heat losses from the distribution pipes can be reduced drastically
- Better utilisation of renewable resources
- Better utilisation of supply if return temperature is low

3 Scenarios

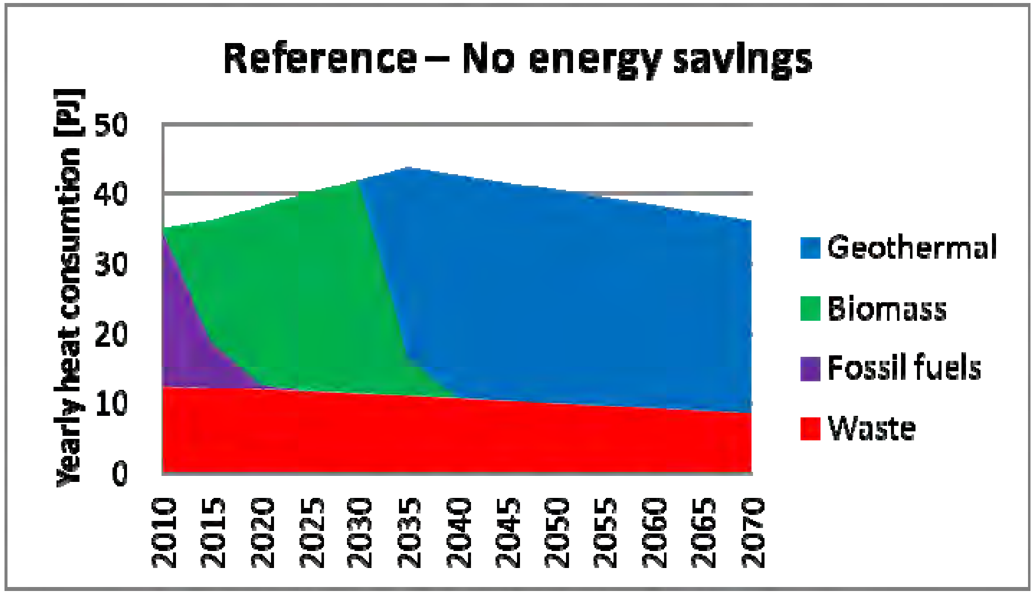
- All scenarios contain a natural replacement of 1% of the existing building mass with newly constructed buildings.

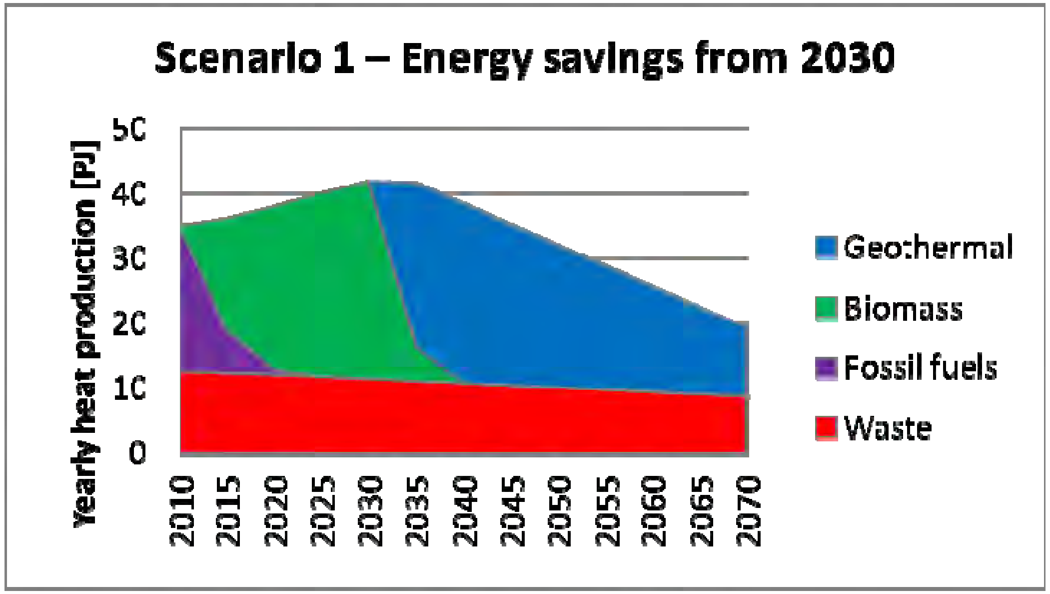
- **Reference scenario - No heat savings**
  - *Represents the extreme case where nothing is done. Supply for the full unchanged heat demand.*

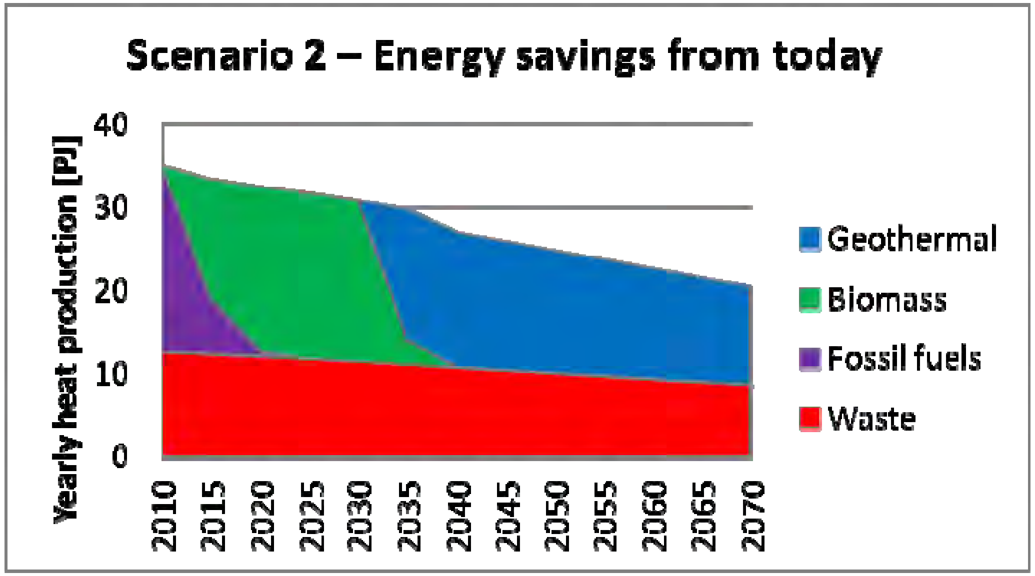
- **Scenario 1 - Accelerated energy renovation from 2030-2070 (65 %)**
  - *Nothing is done in the near future due to low DH-supply prices. Investment in new capacity will increase the supply price and as a consequence heat savings are carried out.*

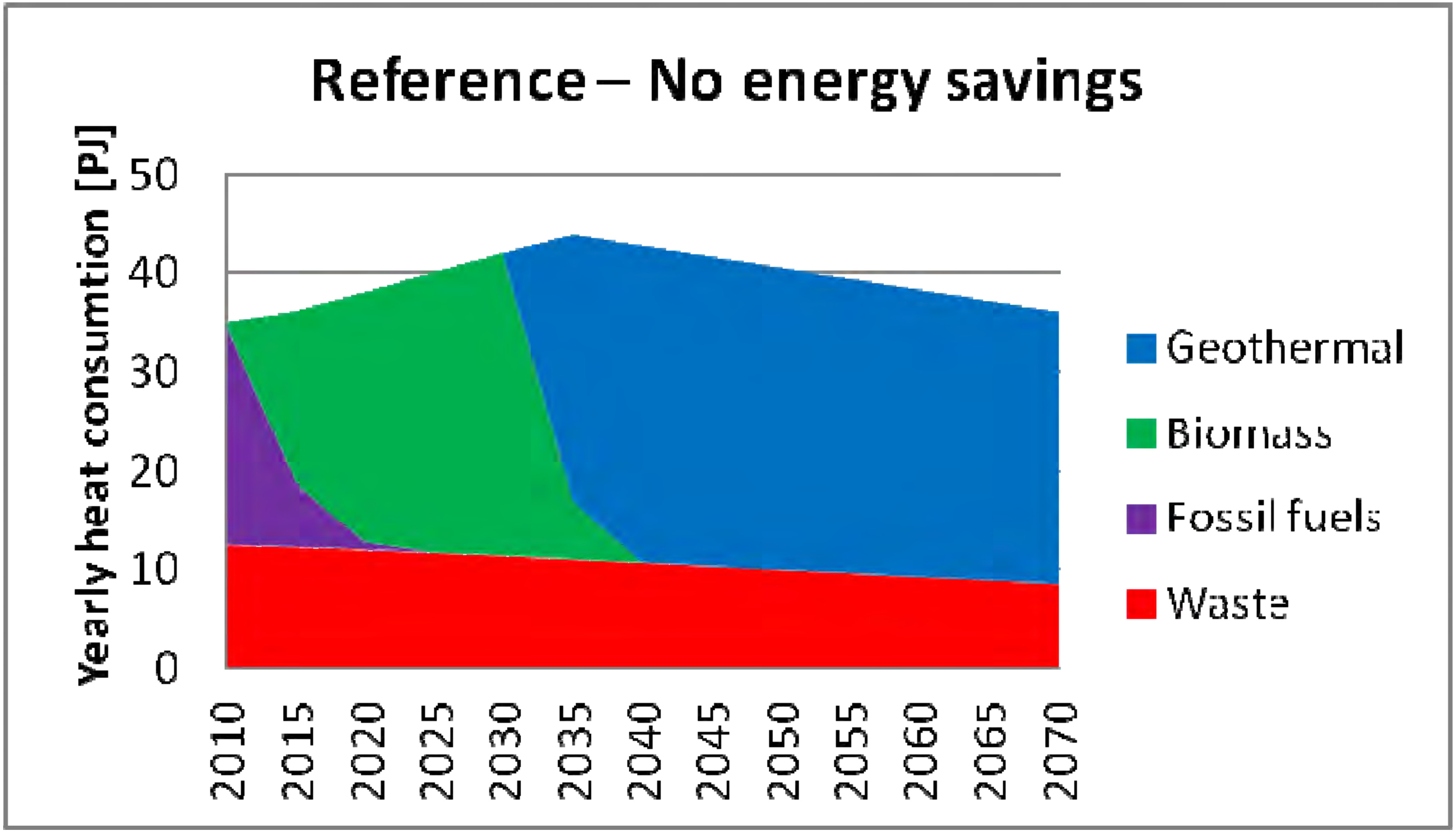
- **Scenario 2 - Accelerating energy renovations from today (65%)**
  - *Heat savings are implemented from today, resulting in decreased heat demand before investment in new capacity.*

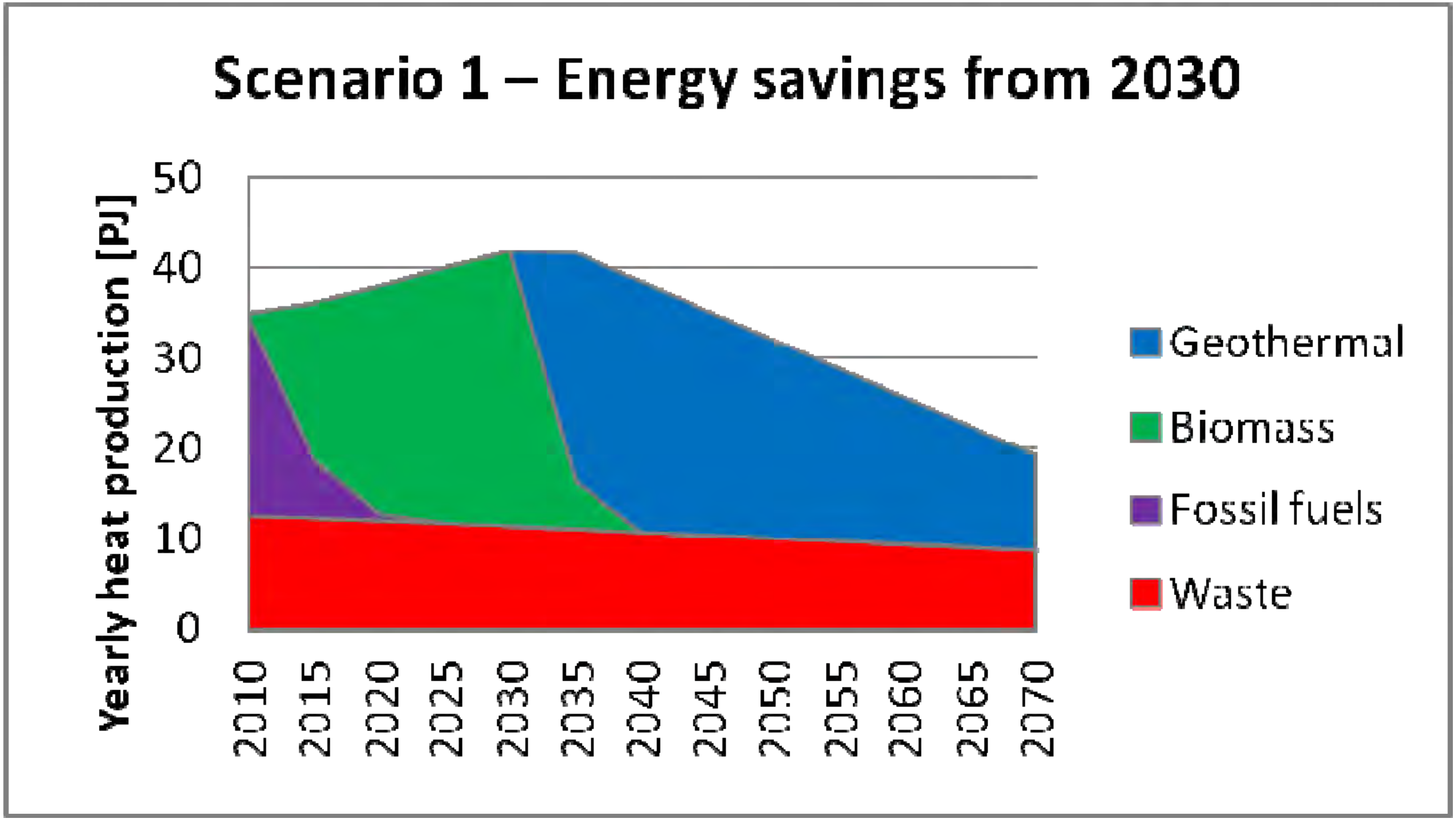
Yearly heat production (Scenarios 2010 – 2070)



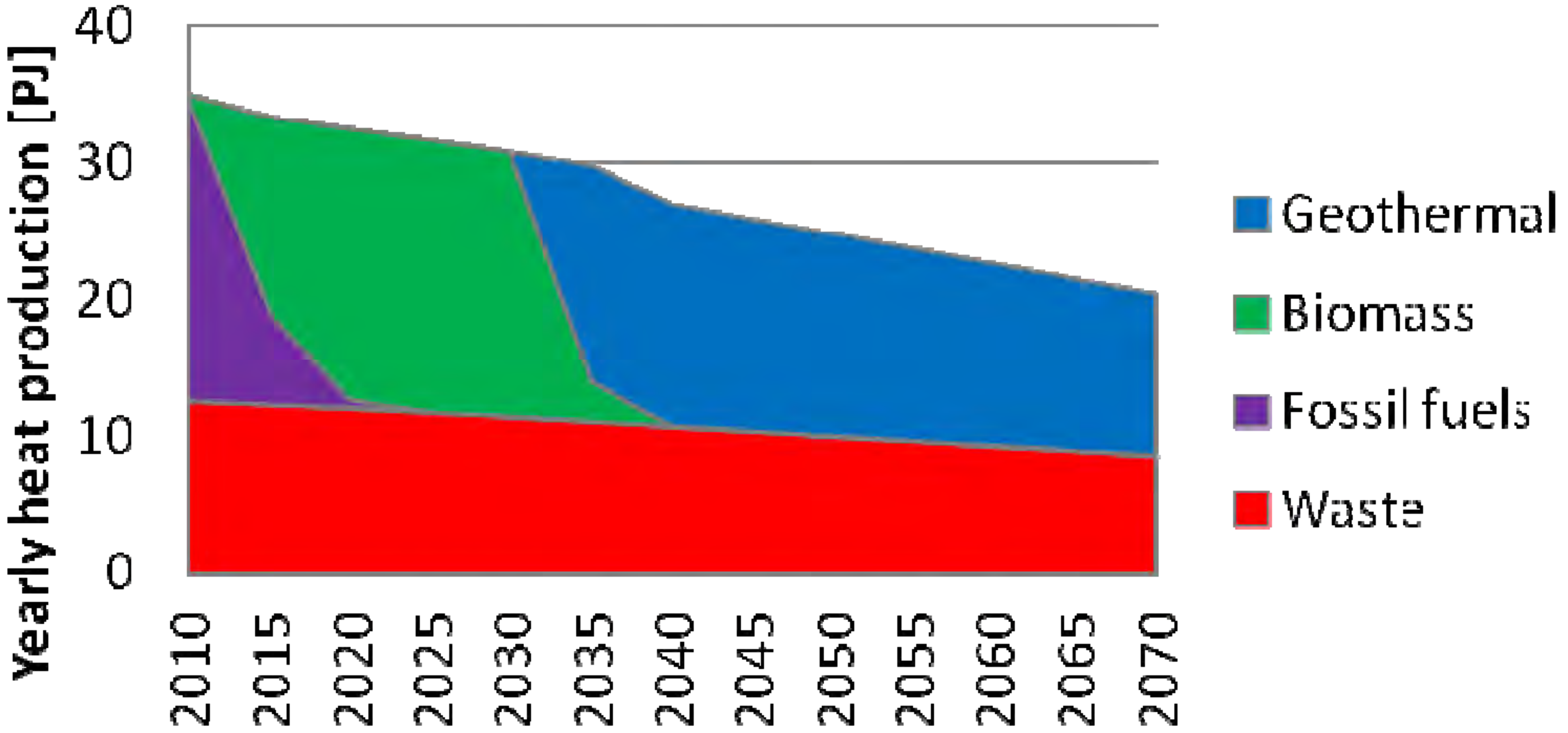





Reference – No energy savings
Yearly heat consumtion [PJ]
50
40
30
20
10
0
2010
2015
2020
2025
2030
2035
2040
2045
2050
2055
2060
2065
2070
Geothermal
Biomass
Fossil fuels
Waste


Scenario 1 – Energy savings from 2030
Yearly heat production [PJ]
0
10
20
30
40
50
2010
2015
2020
2025
2030
2035
2040
2045
2050
2055
2060
2065
2070
Geothermal
Biomass
Fossil fuels
Waste

Scenario 2 – Energy savings from today



Costs

Investment in heat capacity: - 50%
If energy savings are carried out, starting now

		Reference	Scenarie 1	Scenarie 2
Geothermal				
Capacity	[MW]	2793	2464	1207
Capital investment	[mil €]	7498	6614	3241
DH-system				
Total DH -production in 60 years	[PJ]	2379	2114	1656
Geothermal production in 40 years	[PJ]	1110	838	543
Total costs for DH	[mil €]	12162	10521	6227
Renovation				
PJ saved by energy renovating (65%)	[PJ]	-	265	723
Cost for energy renovation	[mil €]	-	2205	6021
Total cost for each scenario	[Bil €]	26	29	25

Conclusions

- It is fundamental to reduce the heat demand by means of energy saving measures, starting today!
    - *Save 50% of the capital investment in new thermal capacity*
    - *Better utilisation of the heating plants*
- The “hidden value” of energy conservation policies: reduction of investment risks, future-proof policy, increase lifetime of the buildings and improved comfort
- RE-based heat supply is technical and economically feasible
- Both the quantity of the investments and the timing for their implementing are decisive factors

Conclusions

- Low-temperature DH systems are a competitive technology to supply energy-efficient buildings.
  Min. linear heat density: ~ 0.20 MWh/(m·yr) (in Denmark)

- The optimal design methodology for DH systems in urban areas of countries without a well-developed DH infrastructure might be based on medium-temperature systems which envisage the future upgrade to low-temperature systems

- The application of low-temperature DH through consistent, long-term energy plans is strategic towards energy sustainable communities

More information – Ongoing projects

- A. Dalla Rosa, “The Development of a New District Heating Concept”, PhD thesis, Technical University of Denmark

- Research Center for 4th Generation District Heating Technologies and Systems www.4dh.dk (13 PhD projects, international partners)

- EUDP 2010-II: “Full-Scale Demonstration of Low-Temperature District Heating in Existing Buildings”. www.ens.dk

- IEA-DHC Annex X: “Towards Fourth Generation District Heating. Experiences with and Potential of Low-Temperature District Heating” www.iea-dhc.org

THANK YOU FOR YOUR ATTENTION

Alessandro Dalla Rosa, Ph.D.
dalla@byg.dtu.dk

Svend Svendsen, Prof.
ss@byg.dtu.dk