4th Generation District Heating Systems 4GDH

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4DH
4th Generation District Heating Technologies and Systems

Technical University of Denmark DTU

Presentation on 4GDH

4DH
4th Generation District Heating Technologies and Systems

- Relevance
- Concepts
- Technologies
- Demonstration
- Implementation plans

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What is 4GDH?

4DH
4th Generation District Heating
Technologies and Systems

- **Low temperature**
- **Renewable heat supply to**
- **Low energy buildings by**
- **Use of warm water grid (district heating)**

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What was the 1, 2, 3th

4DH
4th Generation District Heating
Technologies and Systems

First Generation (1880-1930):

Steam as heat carrier. Is today in use in e.g. Manhattan, Paris and partly in Copenhagen.

Second Generation (1930-1970):

Pressurised hot water as heat carrier with temperature above 100 C.

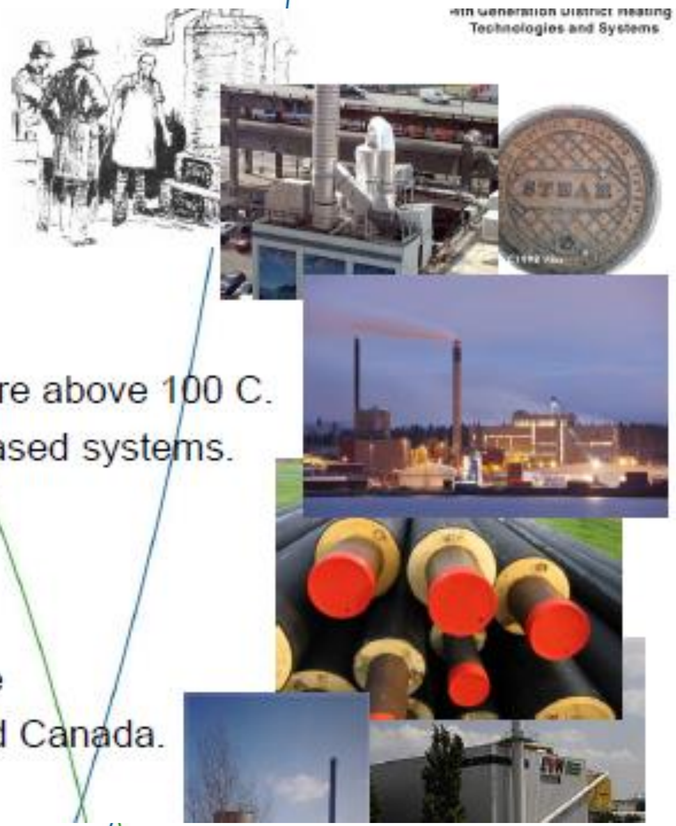
Can be found today in older parts of current water-based systems.

Third Generation (1970-present):

Pressurised water with temperatures below 100 C.

Used in replacements in Central and Eastern Europe

and all extensions in China, Korea, Europe, USA and Canada.



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Why 4GDH?
Relevant in EU due to:

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EU Policy on energy and buildings

EPBD recast:

All new buildings in the EU as from December 2020 (2018 for public buildings) will have to be **nearly zero energy buildings**

the ***nearly zero or very low amount of energy required should to*** a very significant level be covered by energy from **local renewable source**

Why 4GDH?
Relevant in DK due to:

4DH
4th Generation District Heating Technologies and Systems

Danish Energy Plan *

- **All buildings and electricity fossil free by 2035**
- **Transport and industry fossil free by 2050**

- **Based on:**
- **energy savings and**
- **renewable energy supply**

* http://www.ens.dk/Documents/Netboghandel%20-%20publikationer/2011/our_future_energy_%20web.pdf

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Why 4GDH?
Relevant due to:

4DH
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Overall optimization of energy system with Renewable energy for heating buildings

What are the best technologies?

- **RE-based District heating in cities**
- **RE-based Heat pumps outside cities**

Why 4GDH?
Relevant due to:

4DH
4th Generation District Heating Technologies and Systems

Optimization of fossil fuel free Energy system

What is the best combination of

- **Efficiency**
- **Geothermal heat**
- **Biomass**
- **Wind**
- **Solar**

4GDH - **How?**
Strategic Research Centre for
4^{th} Generation District Heating Systems
2012 - 2017

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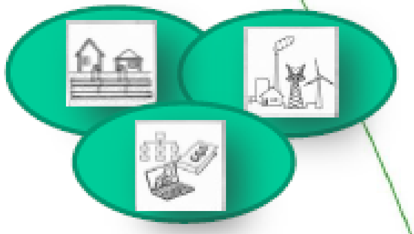
The **Aim** is to assist in the development of 4th Generation District Heating Technologies and Systems (4GDH).



Objectives:

- Scientific platform for research activities
- Societal understanding of the role of District Heating
- Further additional national and international projects

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4th Generation District Heating Technologies and Systems

Three pillars

Supply:

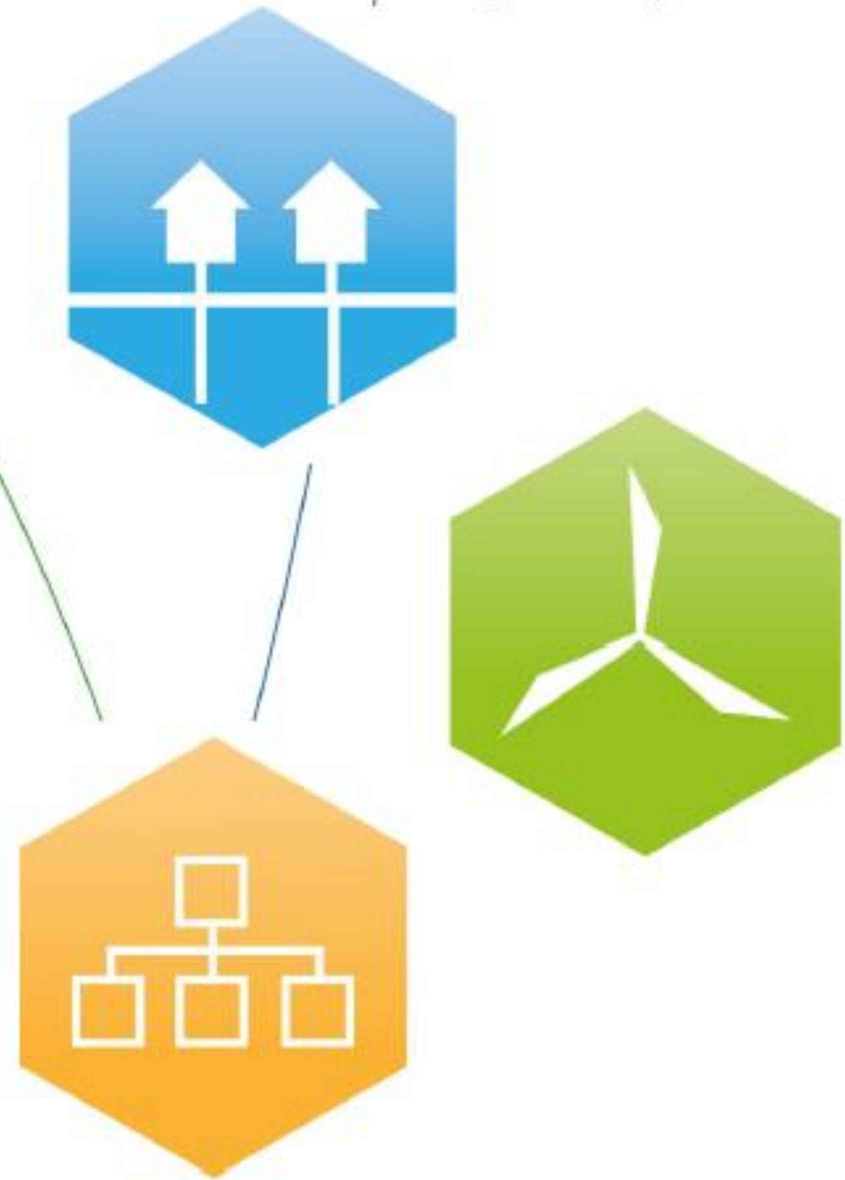
Low temperature District heating

Production:

Renewable Systems Integration

Organisation:

Planning and Implementation



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13 PhD projects

Strategic Research Centre for 4th Generation District Heating Technologies and Systems

PhD 1.1. Heating of existing buildings by low-temperature district heating

PhD 1.2. Supply of domestic hot water at comfort temperatures without Legionella

PhD 1.3. Conversion of existing district heating grids to low-temperature operation and extension to new areas of buildings

PhD 1.4 Minimising losses in the DH distribution grid

Ph.D. 2.1: Energy Scenarios for Denmark

Ph.D. 2.2 Thermal storage in district heating systems

Ph.D. 2.3 Distributed CHP-plants optimized across more electricity markets

Ph.D. 2.4 Low-temperature energy sources for district heating

Ph.D. 2.5 The role of district heating in the Chinese energy system

PhD 3.1: Strategic energy planning in a municipal and legal perspective

PhD 3.2: Price regulation, tariff models and ownership as elements of strategic energy pl

PhD 3.3: Geographical representations of heat demand, efficiency and supply

PhD 3.4: Geographical representations of renewable energy systems

Concept of 4GDH

4DH
4th Generation District Heating Technologies and Systems

Low temperature DH: Supply/return: 50C / 20C

Heat supply: No fossil fuels & no biomass fuels

Low temperature district heating necessary because:

- **more renewable heat produced at 50C than at 80C**
- **acceptable heat loss from grid (15%)**
  for low-energy buildings

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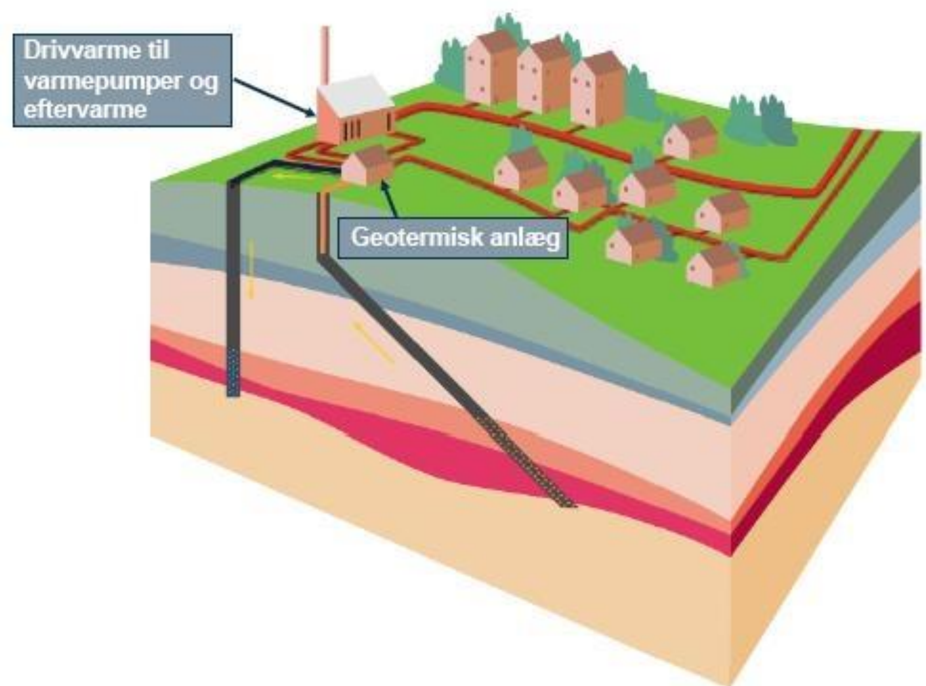
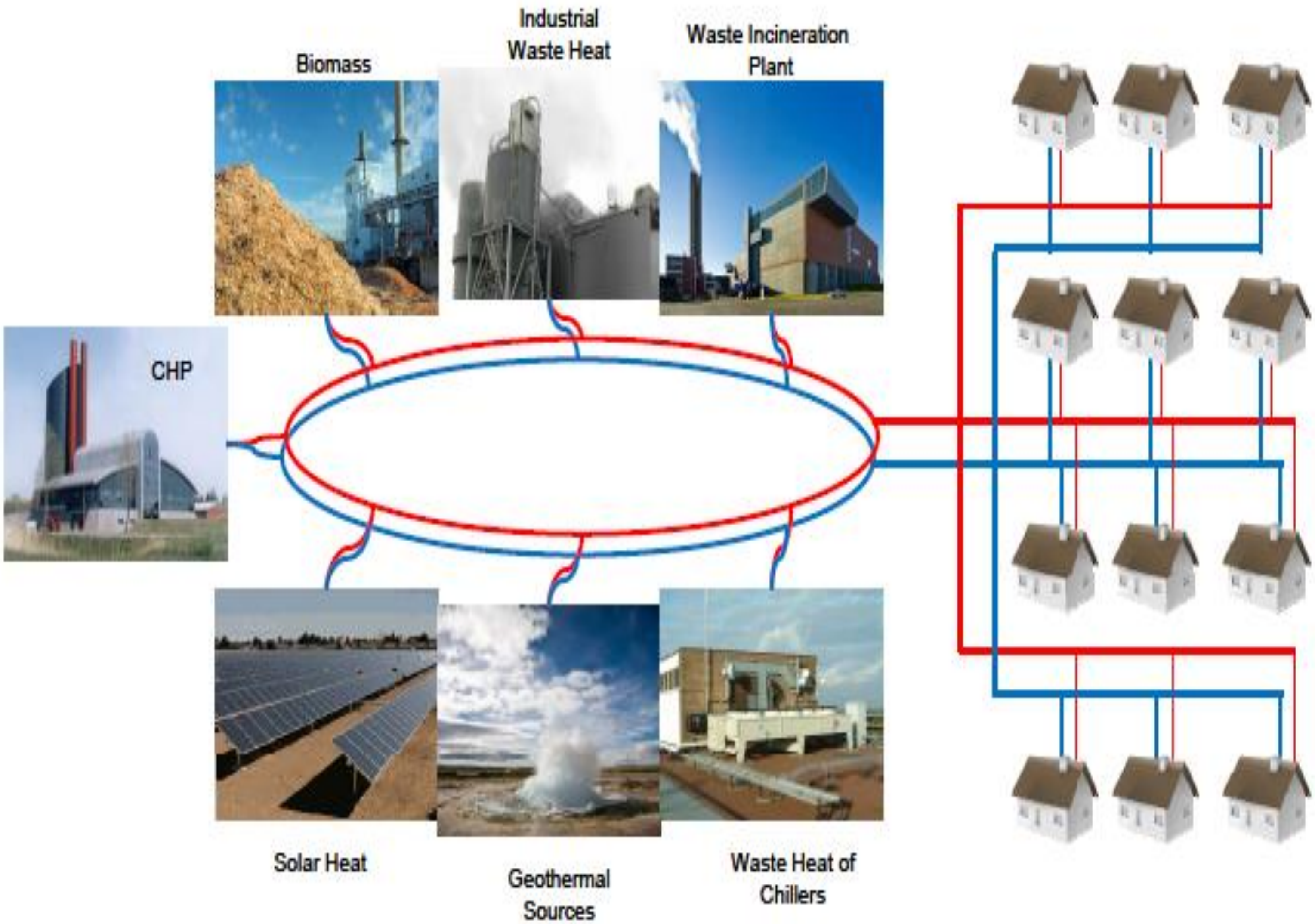
Technologies – Heat production

Fossil fuel based cogeneration replaced with Renewable energy



EFFICIENCY INCREASE OF EXISTING SOURCES
NEW LOW TEMPERATURE HEAT SOURCES



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Heat production in 4GDH

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Waste incineration

- Heat from waste in DK 67 %
- Producing 20% of district heating
- Producing 15% of all heat demand
- Less heat from waste in future for district heating

Heat production in 4GDH

Biomass : Wood chips, pellets. Straw

- **Major shift in DK from coal to biomass in cogeneration plants**
- Import today but to be sustainable: local production
- **Not biomass enough**
- **More valuable for transport then for heat**

Heat production in 4GDH

Solar thermal plants with seasonal storage

- **Example in Marstal:**

http://www.sunstore.dk/default.asp?id=94289

1400 buildings, 33000 m² solar collectors, 75000 m³ storage

50% solar

Heat production in 4GDH

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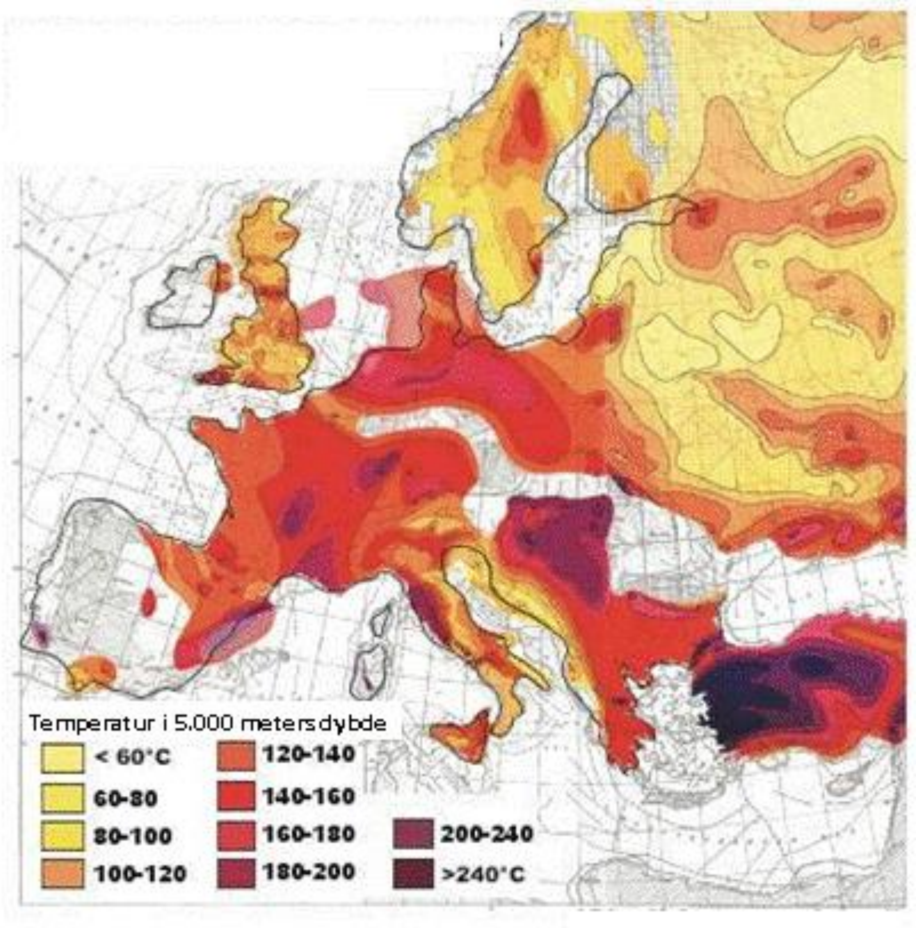
Geothermal heating

- Boreholes 2-5 km
- Temperature 60-70 C
- Porosity + Water
- Big resources
- Big investments
- Heat prices similar to prices for heat today.



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Heat production in 4GDH

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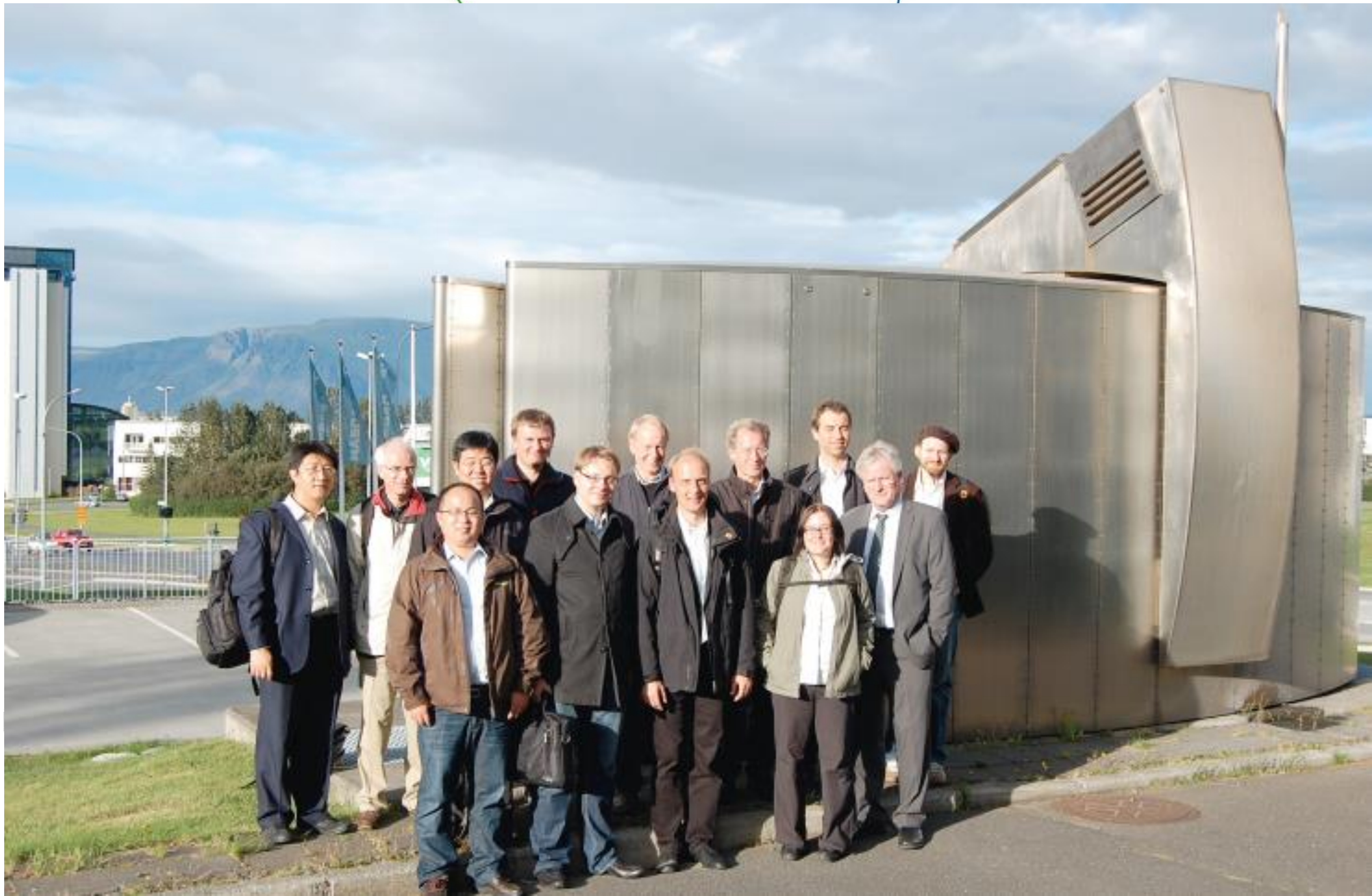
Geothermal heat: Pumping hut in Reykjavik Iceland



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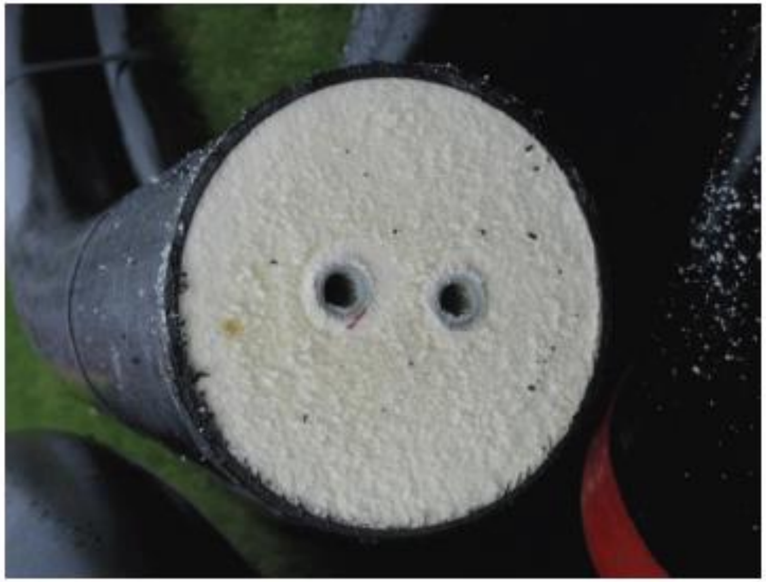
Distribution of heat in 4GDH

- Low temperatures:
- Supply at end user 50C
- Return at end user 20C

- Lower heat loss coefficient :
- Twinpipes with small diameter pipes (14mm) in service pipes



Figur 12 Tværsnit af det fremstillede prototyperør 14/14/110 mm

Distribution of heat in 4GDH

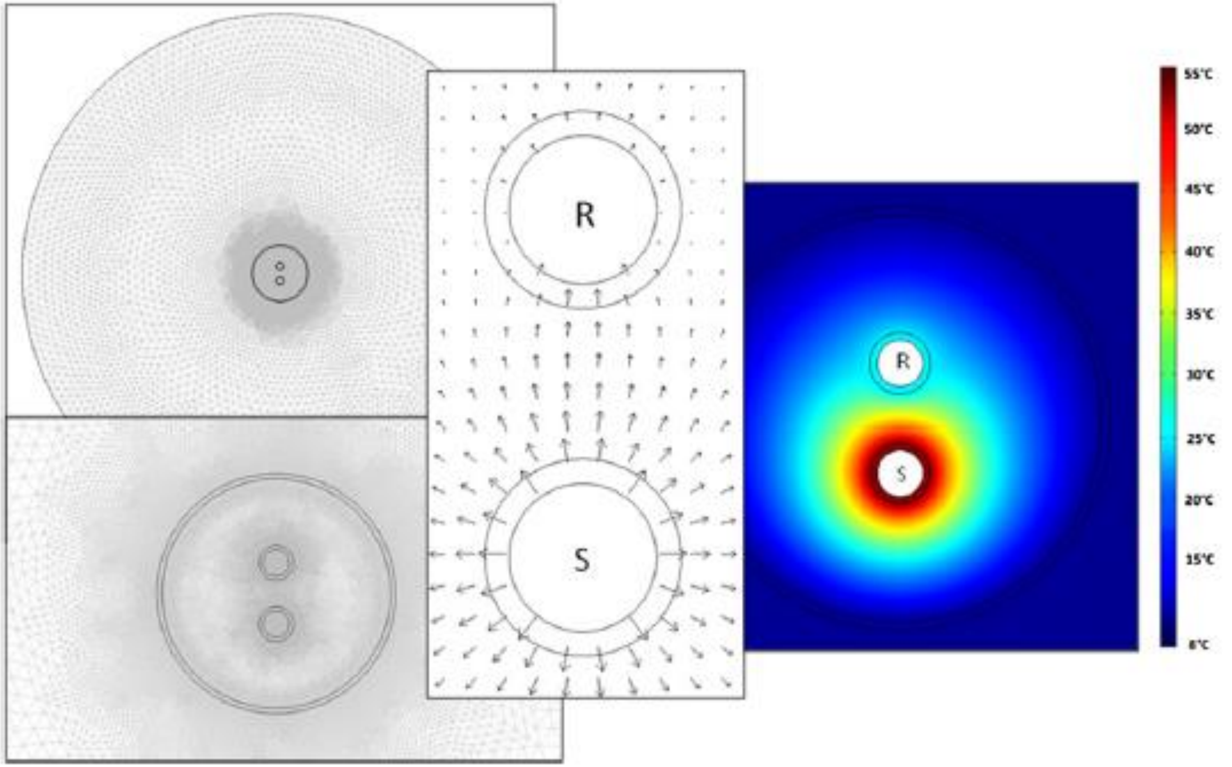
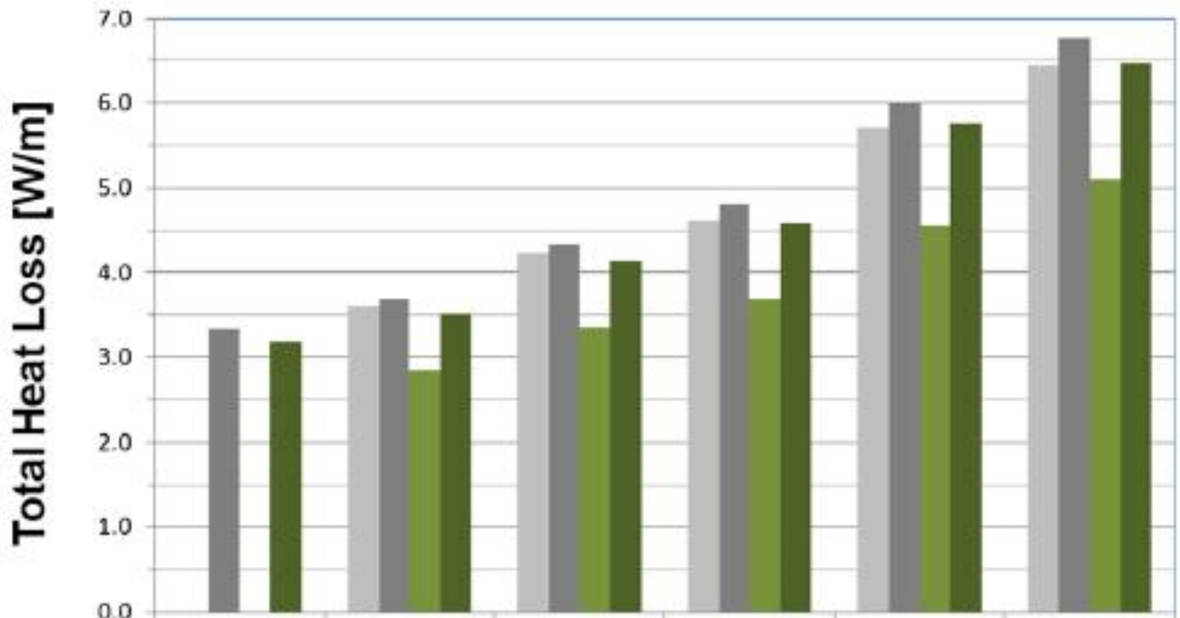


Fig. 5. Mesh model of a pre-insulated twin pipe buried in the ground (left). Heat flux between the media pipes (middle) and temperature field in Aluflex twin pipe 16–16/110 (right); temperature supply/return/ground: 55/25/8 °C.

Distribution of heat in 4GDH
Heat loss of 3-6 W/m



	DN 14	DN 16	DN 20	DN 26	DN 32	DN 40
Standard		3.61	4.24	4.62	5.71	6.45
FEM Standard	3.339	3.679	4.329	4.8	6.015	6.758
Advanced		2.86	3.36	3.69	4.55	5.1
FEM Advanced	3.187	3.513	4.135	4.587	5.753	6.466

Fig. 9. Comparison of 4 different approaches for steady-state heat loss calculation. Aluflex twin pipe series 2, supply/return/ground temperatures: 55/25/8 °C.

Distribution of heat in 4GDH
Central placing of supply pipe

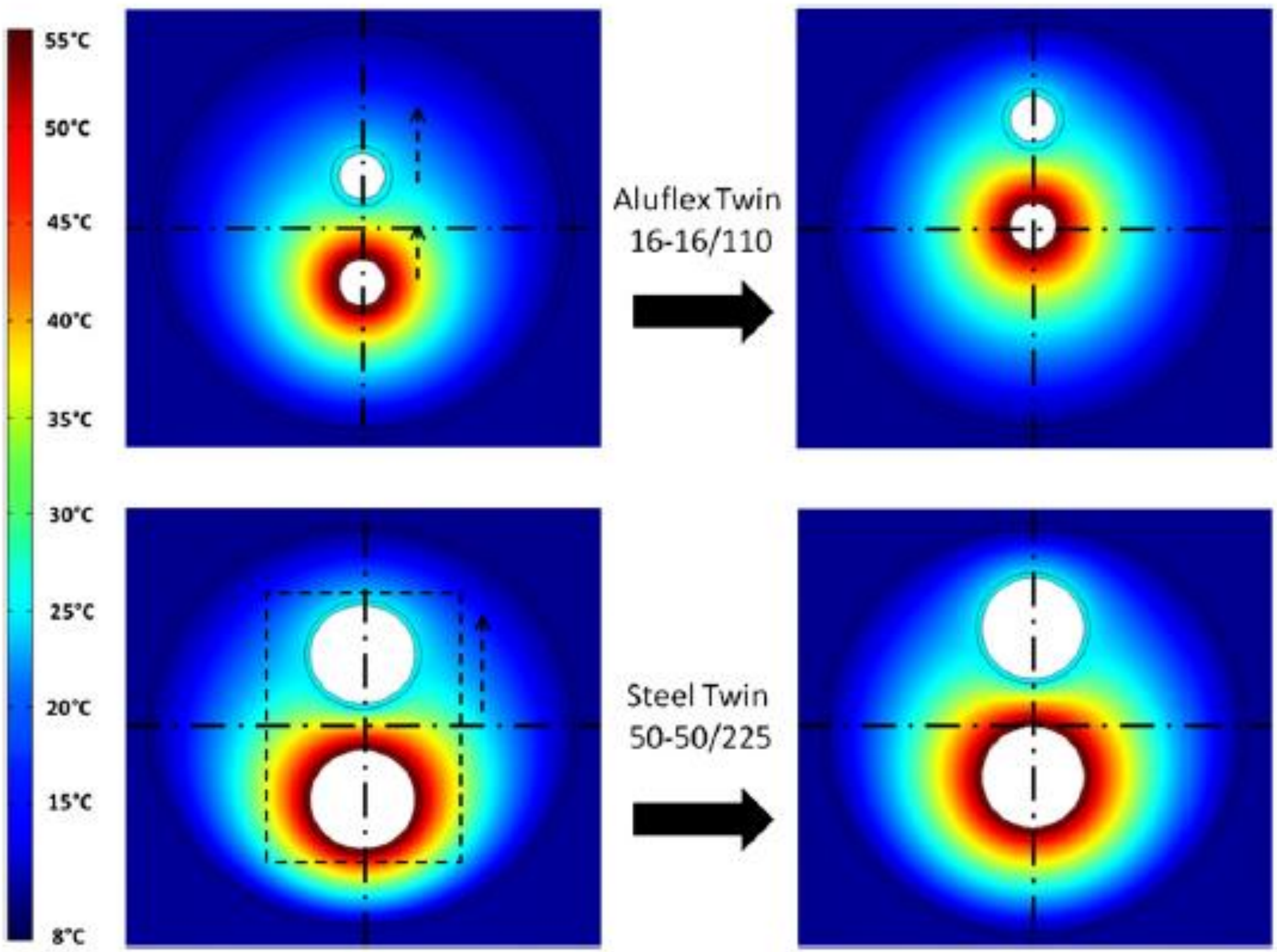


Fig. 10. Proposed modification in DH pipe design. Top: Aluflex Twin 16–16/110. Bottom: Steel Twin 50–50/225.

Distribution of heat in 4GDH

Pipe sizes proportional to local flow

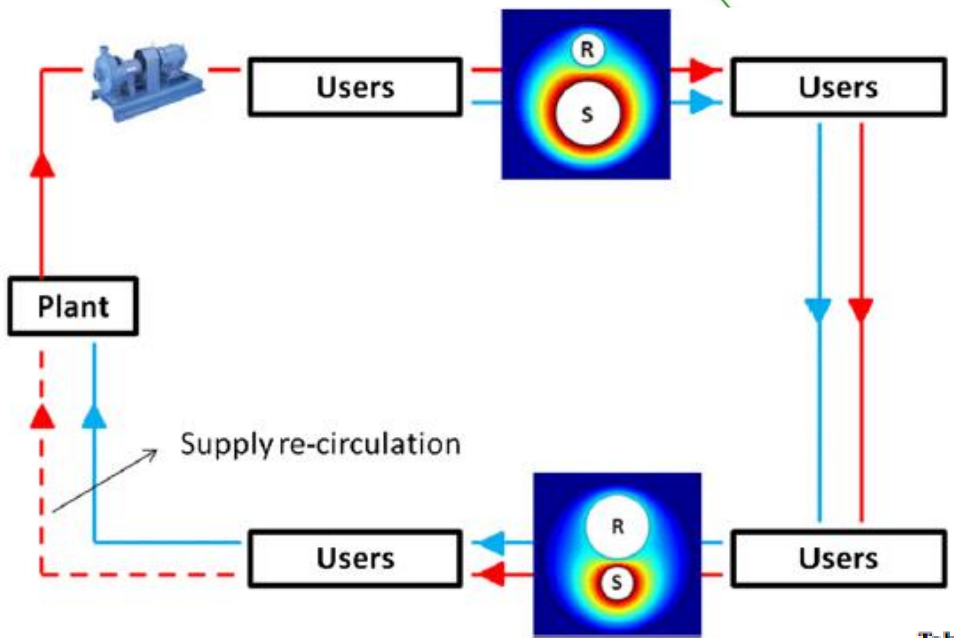


Fig. 11. Sketch of the possible application of the double pipe concept in a simple district heating network.

For info on products see:

http://www.logstor.com/

Table 10

Left: comparison between a distribution network based on twin pipes (DN40-40 and DN80-80) with a distribution network based on double pipes (DN40-80 and DN80-40). Right: comparison between a distribution network based on twin pipes (DN100-100 and DN200-200) with a distribution network based on double pipes (DN100-200 and DN200-100). Supply/return/ground temperature: 55/25/8 °C.

Size (DN)	Heat loss [W/m]			Total	[%]
	Supply	Return	Total		
40–40	−6.24	0.04	−6.20	Twin	6.1
80–80	−7.66	0.07	−7.59	−13.79	
40–80	−5.55	0.05	−5.58	Double	
80–40	−7.41	0.05	−7.36	−12.94	
100–100	−7.83	−0.55	−8.39	Twin	11.8
200–200	−8.92	0.24	−8.68	−17.06	
100–200	−6.4	0.08	−6.36	Double	
200–100	−8.07	−0.03	−8.69	−15.05	

Distribution of heat in 4GDH
Grid layouts

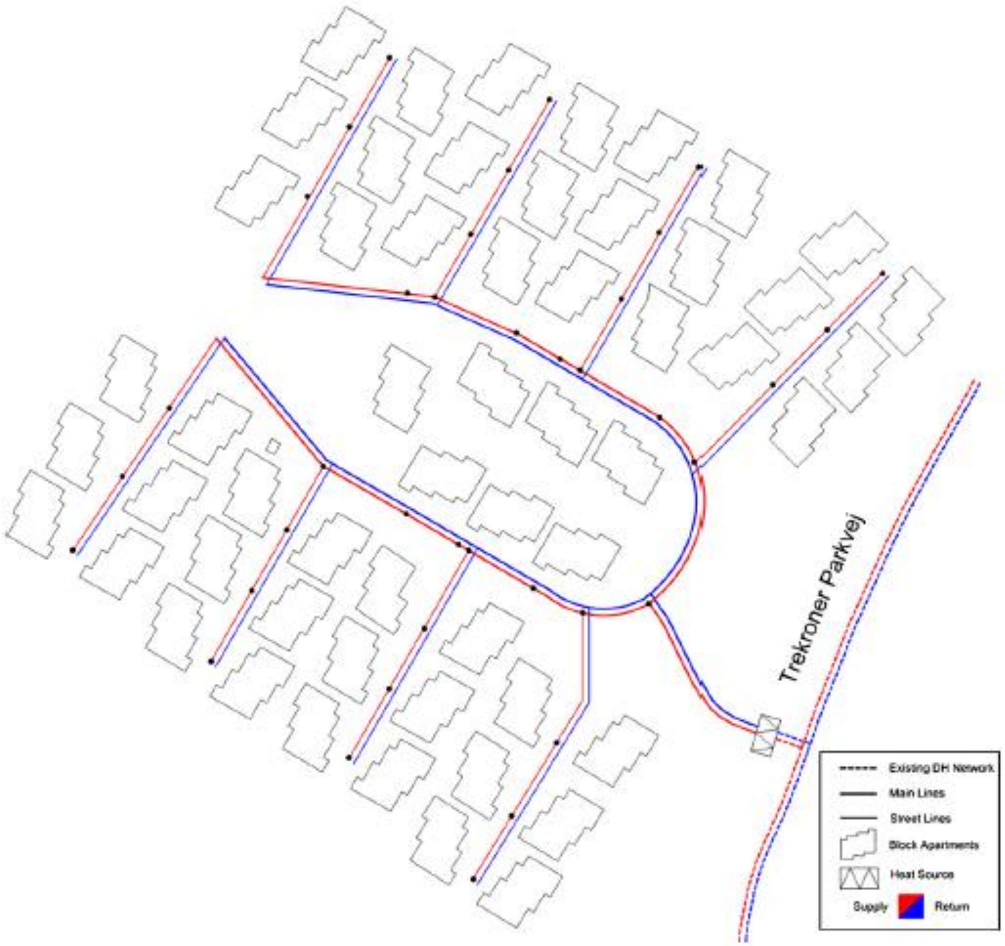
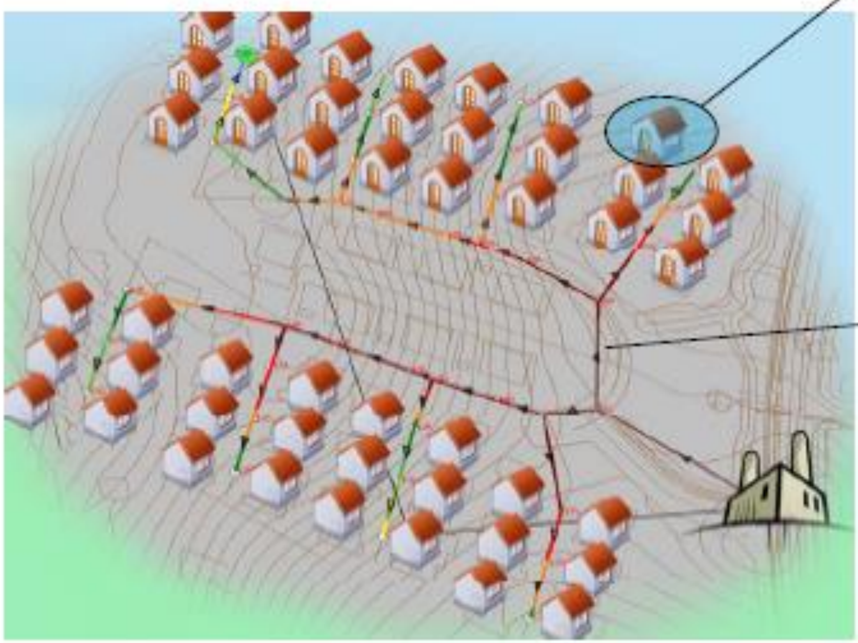


Fig. 1. Branched network layout considered for use in the Trekroner Area.

Distribution of heat in 4GDH
Grid optimization

TREKRONER LOW-ENERGY DH SYSTEM



SEMI-DETACHED SINGLE FAMILY HOUSES

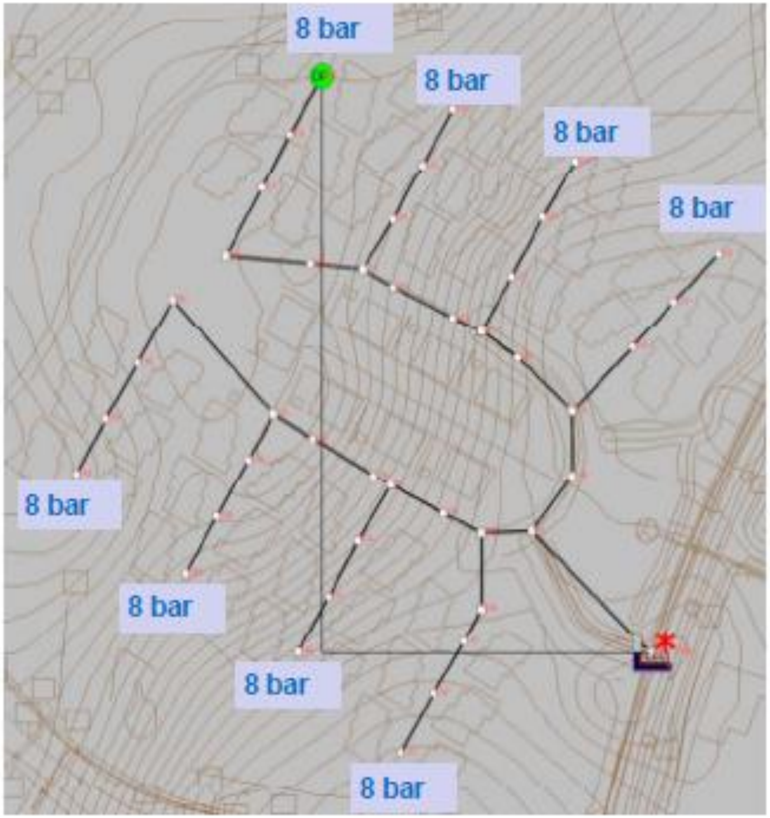
- Number of Houses
  - 165
- Low Energy House (Class I)
  - 3 kW Space Heating
  - 3 kW Domestic Hot Water (120 l buffer tank)

NEW LOW ENERGY DH SYSTEM

- Static Pressure
  - 10 bar
- Max Allowable Pressure Drop
  - 8 bar
- Total Length of Network
  - ~1 km
- Pipe Type (Class I)
  - AluFlex Twin Pipe
    - DN14 – DN32
  - Steel Twin Pipe
    - DN32 – DN80

Distribution of heat in 4GDH
Grid optimization

OPTIMIZATION METHOD



Nonlinear Constraint Function Optimization

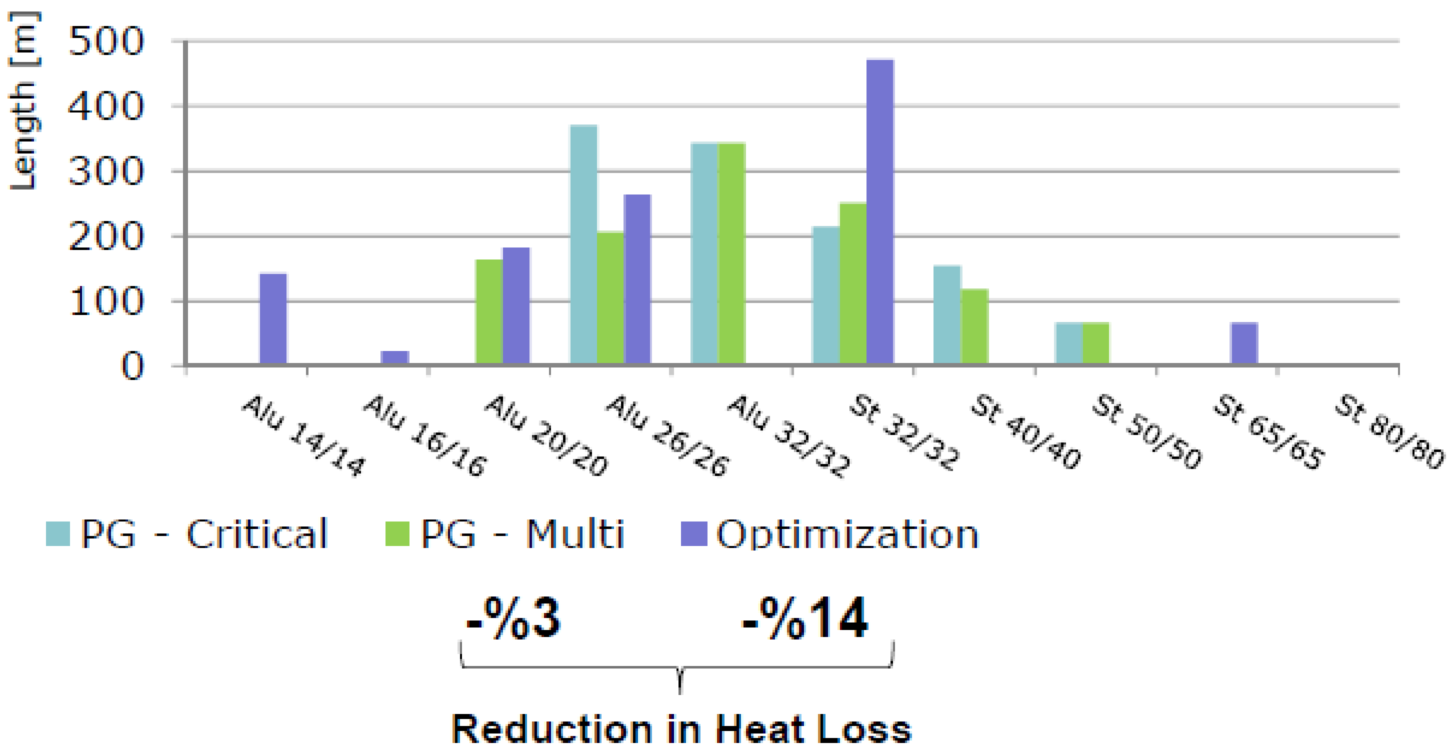
Objective Function:
Min Heat Loss from DH Network

By Means of:
Reducing Each Diameter

Constraint Functions:
Max Allowable Pressure Loss in each Route (8 bar)

Distribution of heat in 4GDH
Grid optimization

COMPARISON OF LENGTH OF PIPE TYPES



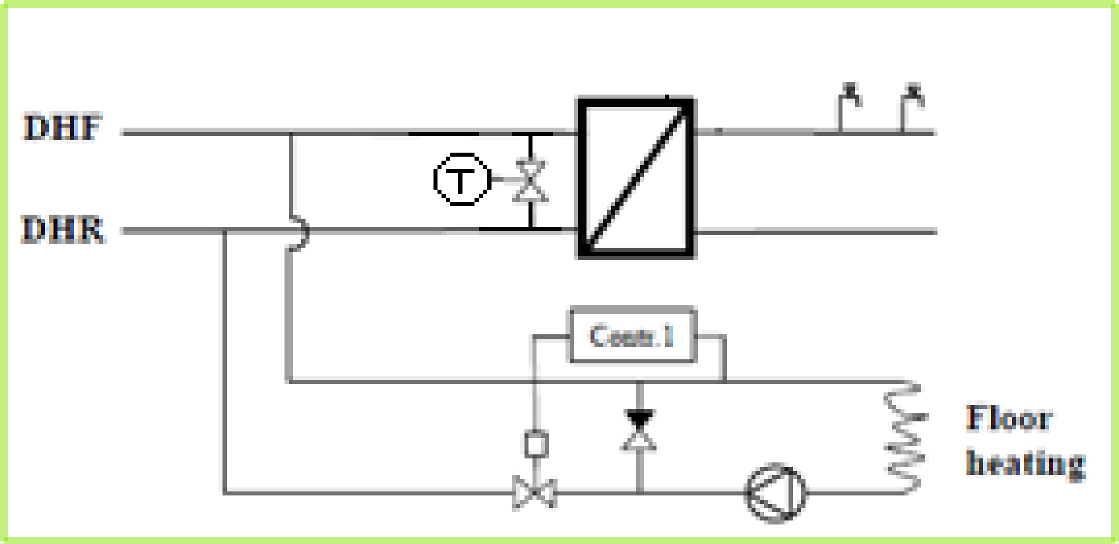
Distribution of heat in 4GDH

Substations - Heat exchanger for DHW

High efficiency –

Supply temp. district heating: 50 C

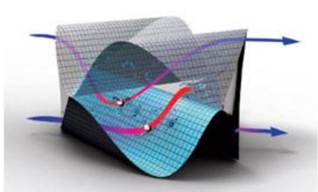
DHW : 45 C

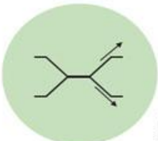


Distribution of heat in 4GDH

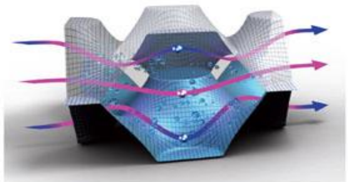
- Micro Plate Heat Exchanger from Danfoss (right)
- Heat exchanger for DHW: 33kW 52/20 -10/45
- Temperature differences of 5 C
- www.mphe.danfoss.com

Brazed plate heat exchangers only have a narrow brazing surface where the two 'peaks' of the plates touch.



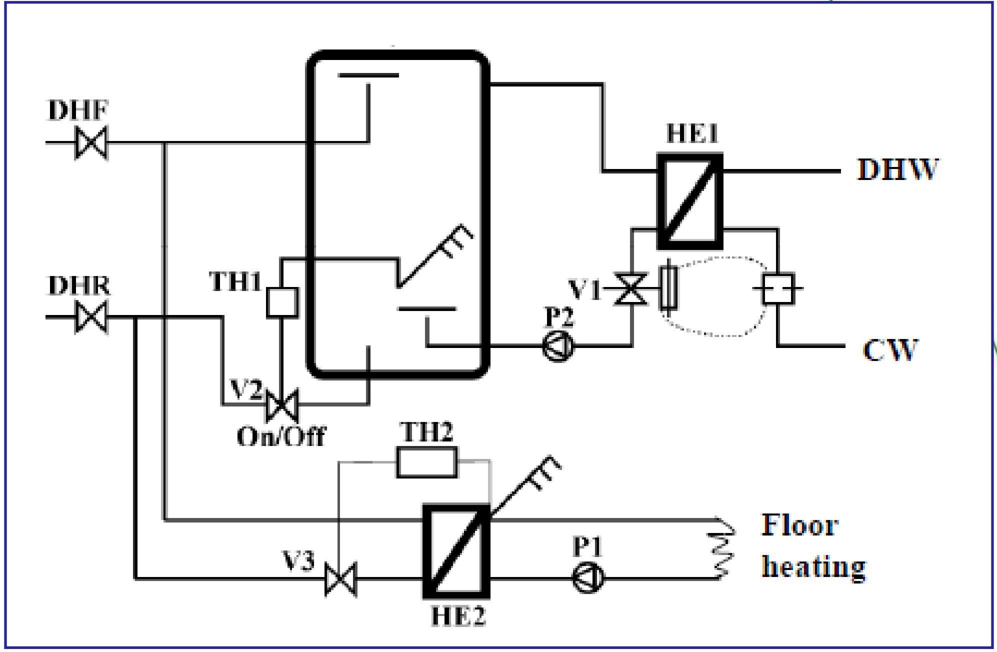


Micro Plate Heat Exchangers have a broad, flat brazing surface which adds stability to the construction.



Distribution of heat in 4GDH –
Substations – buffertank

Reduce peak load from DHW in DH



Distribution of heat in 4GDH –
DHW in large buildings with circulation
Thermal or UV /oxidation disinfection
Danfoss ThermoClean or Wallenius

Wallenius AOT 5 duo with sensor

Demonstration
EUDP - projects

- ***2001-2004**:* EFP-2001: District heating supply to low-energy areas
- ***2006-2009**:* EFP-2007: Development and demonstration of low-energy district heating for low energy buildings
- ***2008-2011**:* EUDP 2008-II: CO_2 reductions in low-energy buildings and communities by implementation of low-temperature district heating systems. Demonstration cases in EnergyFlexHouse and Boligforeningen Ringgården
- ***2011-2014** (expected completion):* EUDP 2010-II: Full-scale demonstration of the future low-temperature district heating in existing settlements. The project is ongoing.
- ***2011 – 2014** (expected completion):* EUDP – Heat Pumps in District Heating (HPinDH)

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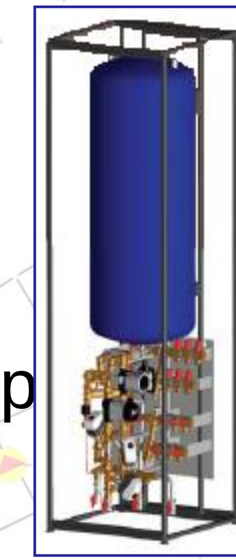
Demonstration in new LE-buildings - Lystrup [1,2]

- EFP/EUDP projects (2007, 2008, 2010)
- 40 row-houses class 1 (BR08) – 37 kWh/m^2·yr
- DH design parameters: 50/25°C, 10 bar
- District heating network
  - AluFlex Twin pipes (insulation series 2)
  - reduced pipe sizes -> higher pressure drop
  - annual distribution heat loss approx. 15%
- Development of two in-house substations concep
  - no problem with Legionella and comfort
- System runs already 2 years , no complaints



Demonstration of 4GDH

In new LE-buildings- Lystrup

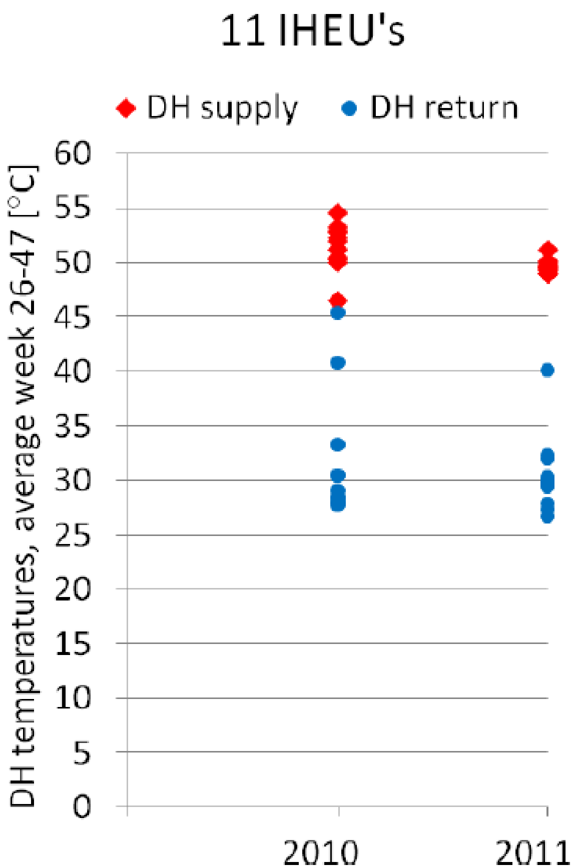


Figure 9: Supply and return temperatures for 11 IHEU's average of week 26-47, 2010/2011.

Table 5: Investment costs

	Costs (2010)		
Item	**[€/m]**	**[€/unit]**	**Total [€]**
Pipes*	120		65,000
Pipe fittings*	32		17,000
Pipe laying**	131		100,500
DHSU substation*		3,700	41,000
IHEU substation*		2,600	78,000
Substation installation**		1,000	41,000
Pump + frequency controller*		2,400+2,000	4,400
Total Cost			**346,900**
Cost per house			**8,460**

Demonstration of 4GDH In existing buildings

- How much we can reduce the supply temperature?
- Which renovation measures (if any) should be performed?
- Simulation of typical single-family house from 70s
  - radiators originally designed 70/40/20
  - influence of windows renovation

Case	windows properties	Energy demand for SH [MWh/year]	Peak power for SH [kW]	Supply temperature needed in radiators for:		
				Tout=-21°C	Tout=0°C HIGH	Tout=0°C LOW
no renovation	U-value: 2,5 W/m^{2}K g-value: 0,43	10 .49	5,8	65/43/20	60/29/20	50/34/20
new glazing	U- value: 1,4 W/m^{2}K g- value: 0,43	8.3	5,0	65/35/20	60/26/20	50/29/20
new windows	U- value: 0,9 W/m2K g- value: 0,35	7.55	4,5	65/32/20	52/25/20	50/26/20

Demonstration of 4GDH
In existing buildings
75 houses i DK gets low tempe-rature DH to reduce loss from grid

Implementation plans
Example: Pre study on energy renovation of buildings and 4GDH in Copenhagen
3 Scenarios

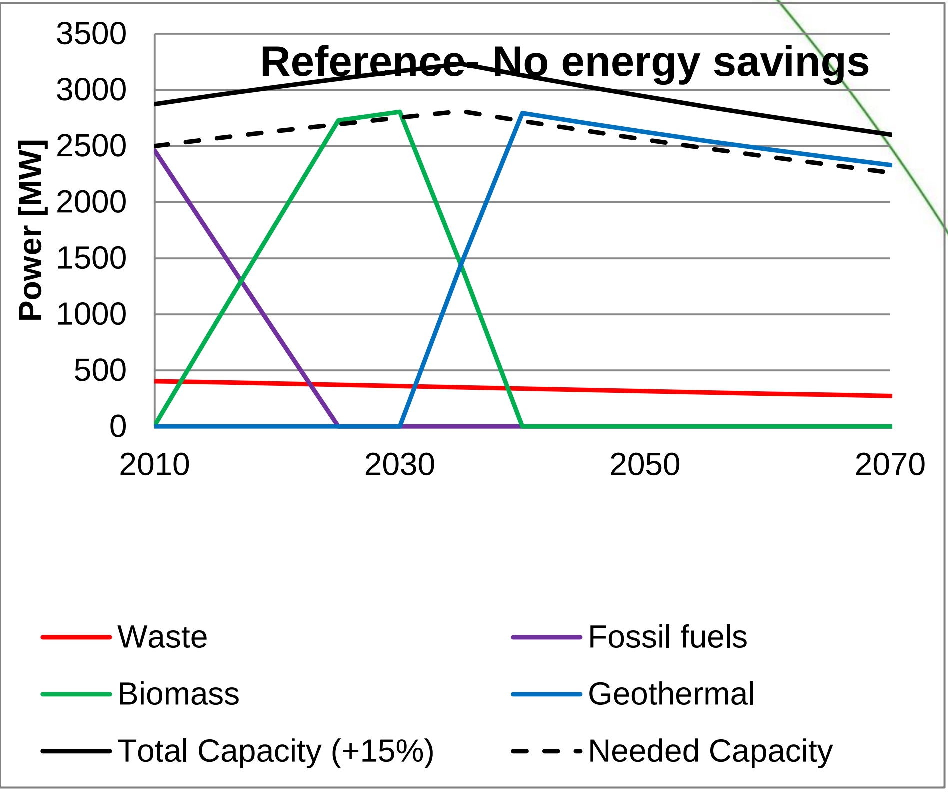
- All scenarios contain a natural replacement on 1% of the existing building mass with newly constructed buildings.

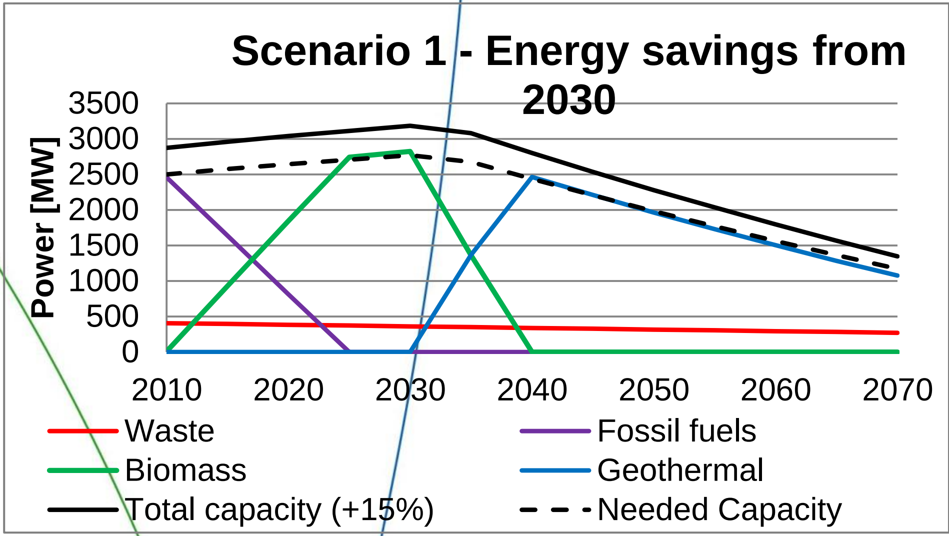
- **Reference scenario - No heat savings**
  - *Represents the extreme case where nothing is done. Supply for the full unchanged heat demand.*

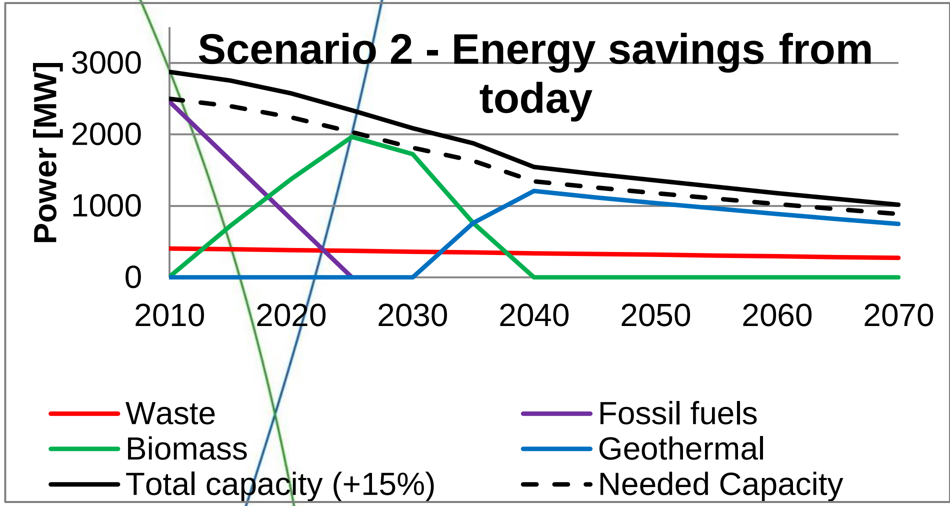
- **Scenario 1 - Accelerated energy renovation from 2030-2070 (65 %)**
  - *Nothing is done in the near future due to low DH-supply prices. Investment in new capacity will increase the supply price and as a consequence heat savings are carried out.*

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

Capacity – Peak loads







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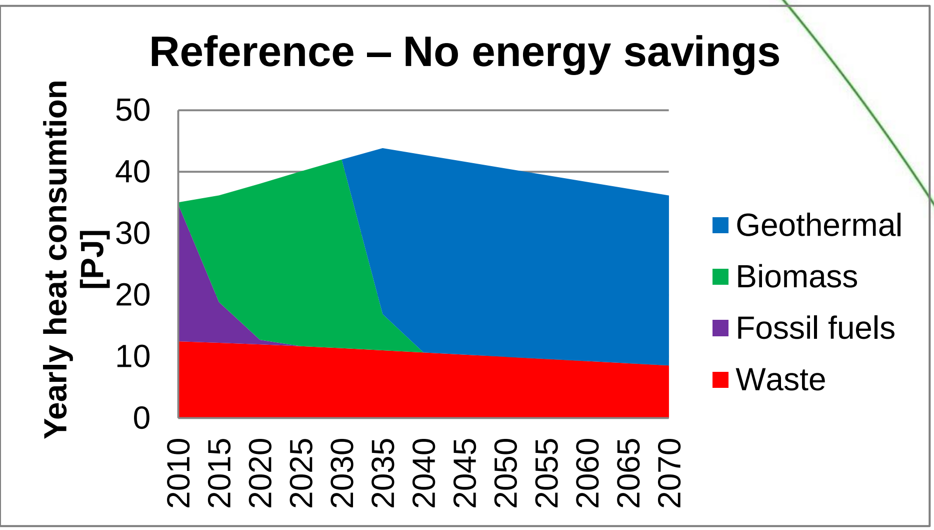
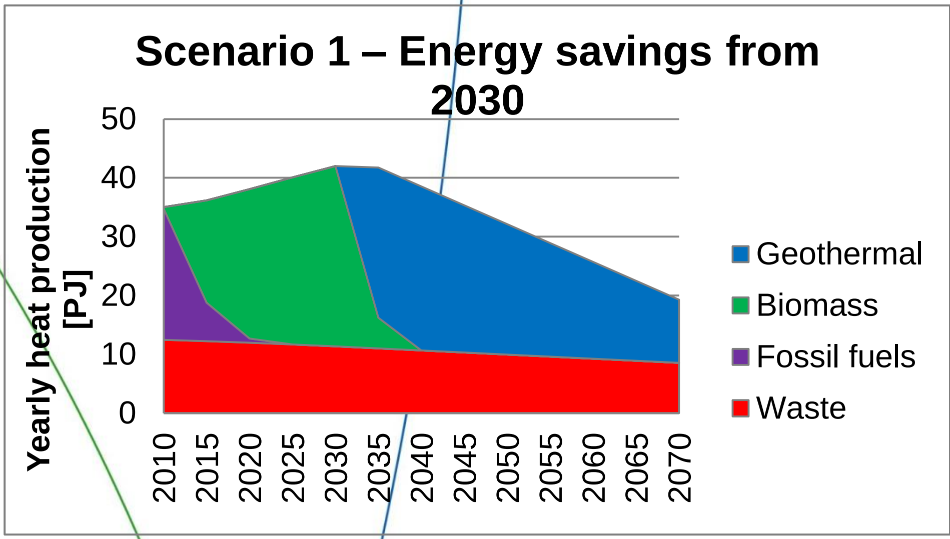
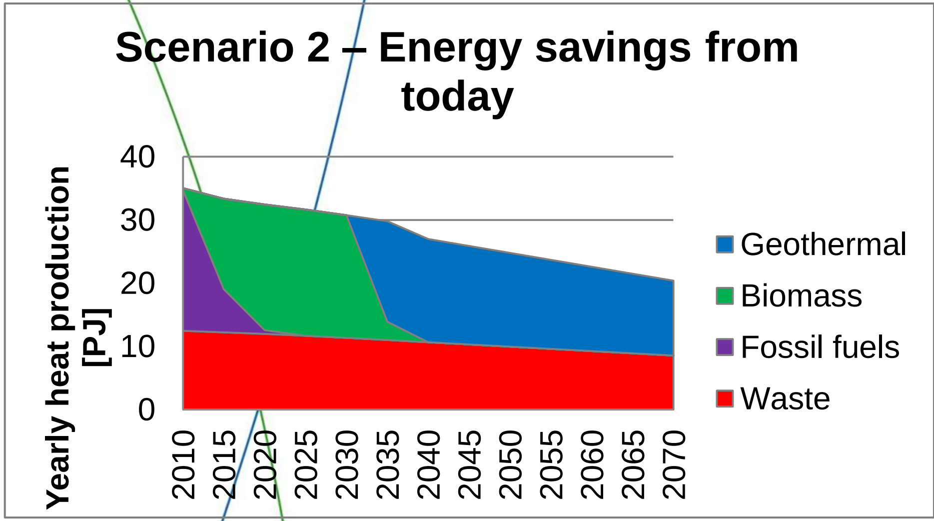
Yearly heat production 2010 - 2070







Costs

		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

Investment -50%
If energy savings are carried out now

Total costs are similar due to energy renovation is costly

Implementation plans - conclusions

4DH
4th Generation District Heating Technologies and Systems

Detailed investigations needed

- Based on new 4GDH technologies
- Based on an optimised energy system
  - Fossil free
  - No imported biomass for fuels

Optimal solutions

Political implementation needed

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