ENGINEERING
TOMORROW

4GDH – The newest DH generation

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What is 4GDH?

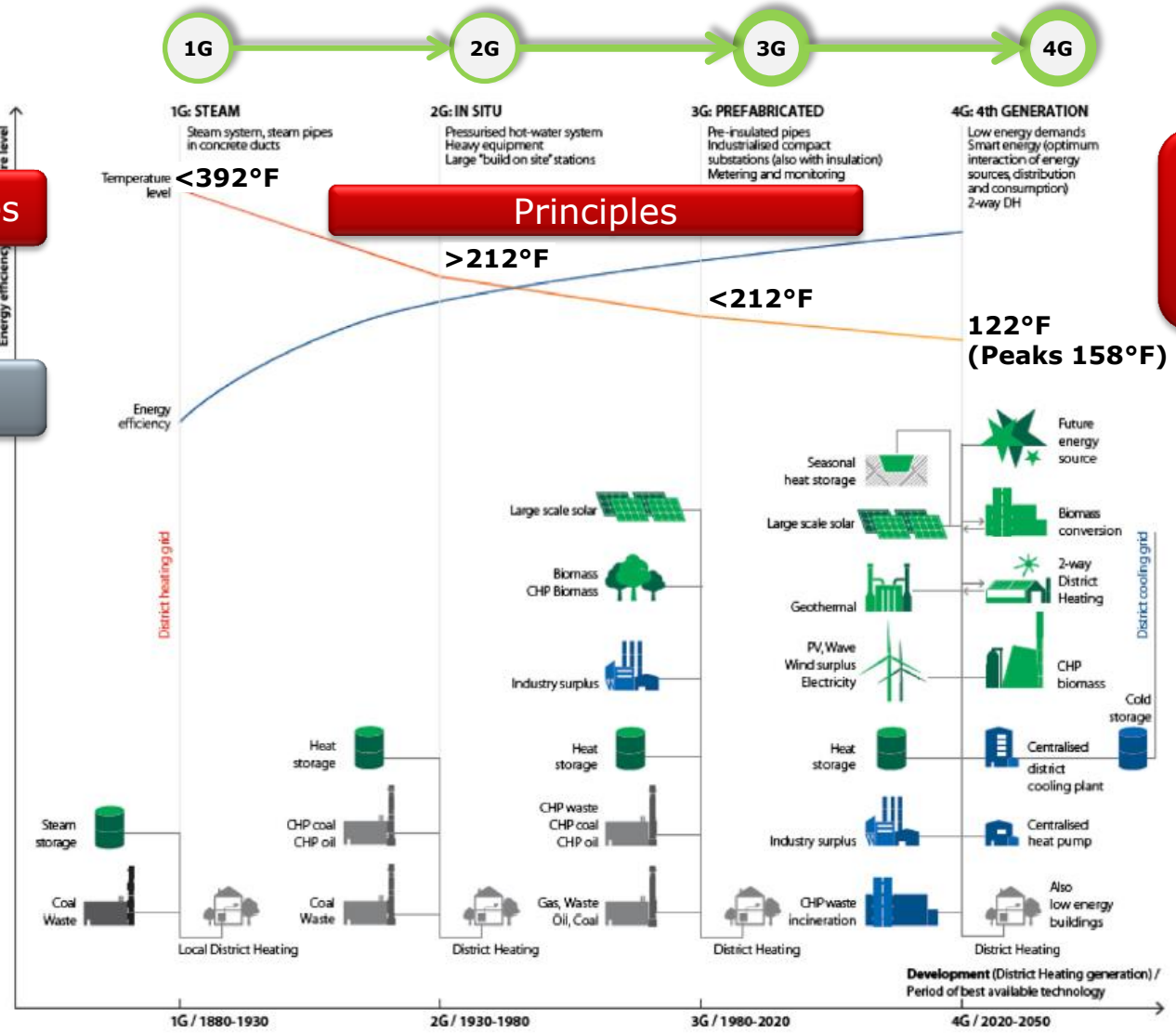
- From the start of district heating in the 1880s until today the technology has been developing

- The development can be categorized in 4 generations
  - 1st generation: Steam based systems (1880-1930)
  - 2nd generation: Pressurized super-heated water at temperatures above 212°F
    - ➢ stations built on site and pipe insulated on site (1930-1980)
  - 3rd generation: Pressurized water at temperatures typically below 212°F
    - ➢ Industrialized stations and pre-insulated pipes (1980-2010)
  - 4th generation: Pressurized water at temperatures of 122°F (peak 158°F)
    - ➢ Low energy demand and smart systems (2010+)

What are the district heating generations?

Temperatures

Efficiency

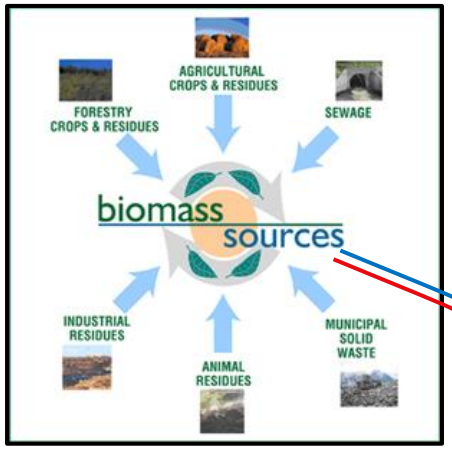


Principles

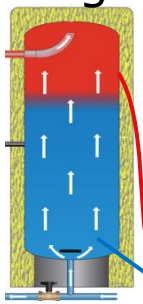
Same service but lower temperature and higher efficiency

Heat sources

Increased possibilities of renewable and surplus heat utilization

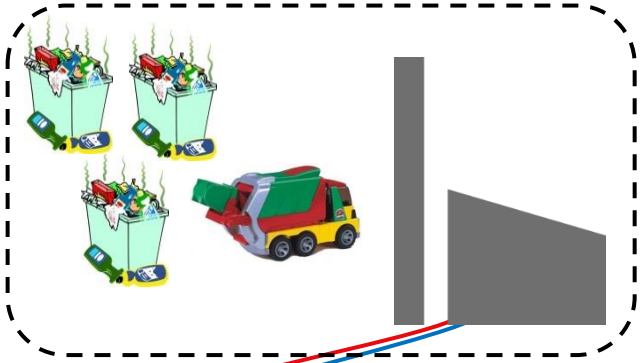


Large heat storage



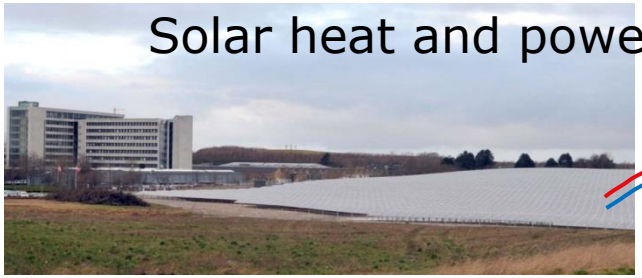
Supermarkets

Waste incineration



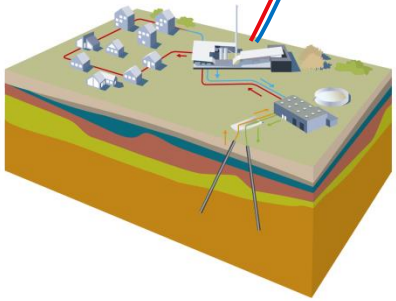
Industry

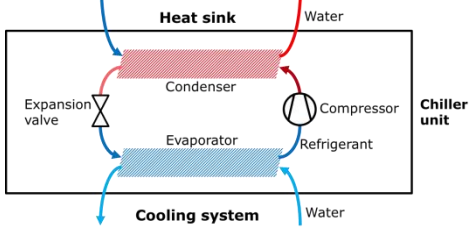
Solar heat and power



Surplus wind power

Geothermal

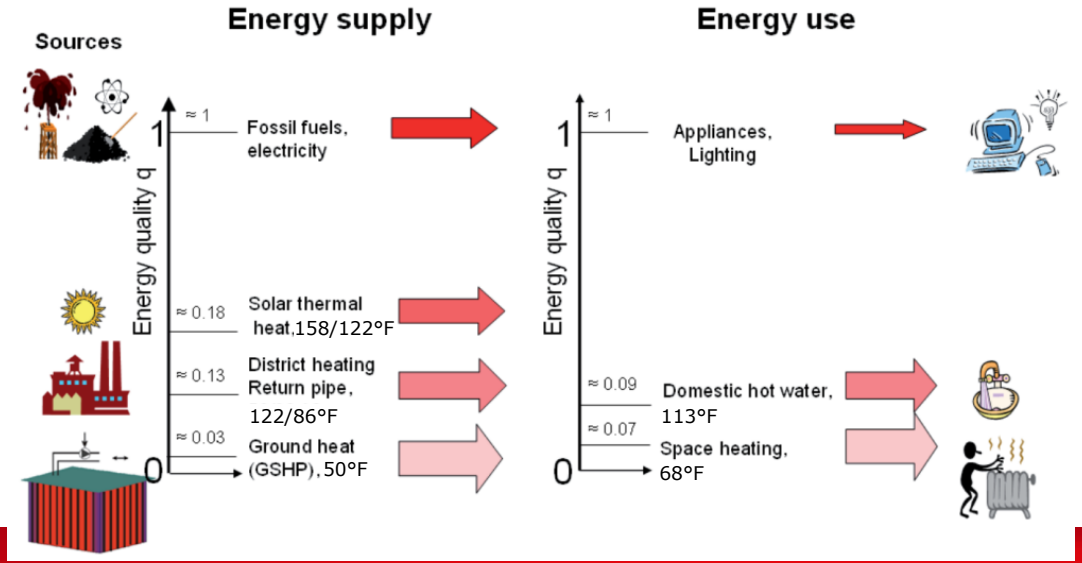




CHP

Other benefits of 4GDH systems to the energy infrastructure

- Increased CHP efficiency
  - Lower supply temperatures increase power generation efficiency
  - Lower return temperatures increase flue gas condensation
- Reduced distribution losses
  - Heat losses are linear dependent on the temperature
    - The lower the network temperatures are the less heat loss is experienced
- Better match of supplied energy quality and demanded energy quality



What impact has the 4GDH principles on currently applied technologies?

- **Distribution network**
  - Minimum pipe dimensions
  - Optimization in regards to pump power consumption and heat losses
  - The low supply temperature opens up for increased application of flexible pre-insulated plastic pipes
  - Fast installation
  - Cost efficient

Pictures from Thermaflex pipe manufacturer

Figure 2: Hengelo, NL: 10 houses connected to the heating grid (2 lines) in 1,5 hrs

Figure 3: Alkmaar, NL: 6 houses connected to District Heating in 1,5 hrs

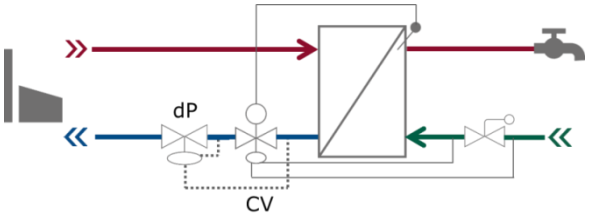
- **Space heating**
  - Heat emitters:
    - *Radiators:* need to be dimensioned for 131°F supply, 77°F return for 68°F indoor air temperature (131/77/68°F)
    - *Floor heating:* No impact as floor heating is designed for 113/77/68°F
  - Control equipment:
    - TRV's, return temperature limiters and dP controllers
    - High focus on smart controllers

What impact has the 4GDH principles on currently applied technologies?

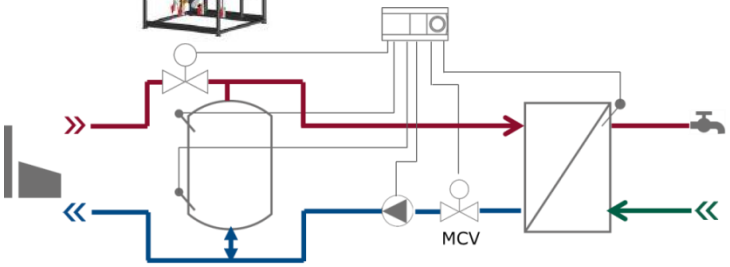
- 4GDH impacts the existing technologies due to the low supply temperature
- **Domestic hot water (DHW) preparation**
  - Due to the low supply temperature instantaneous DHW preparation using **high efficiency heat exchangers** and **high quality controls** are required to ensure good cooling of the supply and stable DHW temperatures
  - DHW piping volume should be less than 3 liters to limit Legionella growth
  - Special focus is needed during idling periods to limit the DHW waiting time and prevent high return temperatures

Improved heat exchanger technology

Instantaneous DHW preparation unit



Instantaneous DHW preparation unit with primary side storage



Why does 4GDH fit with future low energy buildings?

- **Low energy buildings:**
  - Are generally designed with low temperature heating installation
    - Floor heating
    - Low temperature radiators
  - **D**omestic **H**ot **W**ater installation is designed to minimize energy consumption
    - Instantaneous DHW preparation
    - Minimum DHW pipe distances
    - No DHW circulation
- Those points fit exactly with 4GDH!

Low-temperature DH for existing buildings

? also ?

Low-energy buildings

- Low-temperature heating systems
- Low heat demand

...✓

Existing buildings

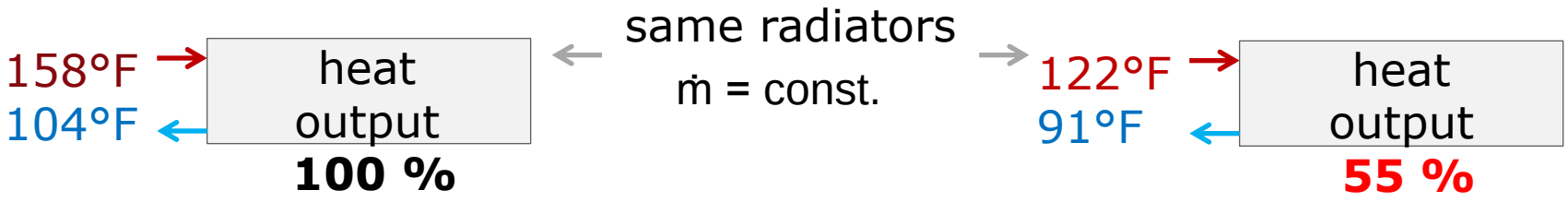
- 85% of building stock
- High temperature systems
- High heat demand

...?

Low-temperature DH for existing buildings

- Supported by the Danish government
- 8 single-family houses from 1970
- With traditional **radiators**: 158/104/68°F

- How much could be T_{sup} reduced without violating comfort?



Numerical simulations

- Many possibilities
  - Various refurbishment stages
  - Low-temperature radiators

Real measurements

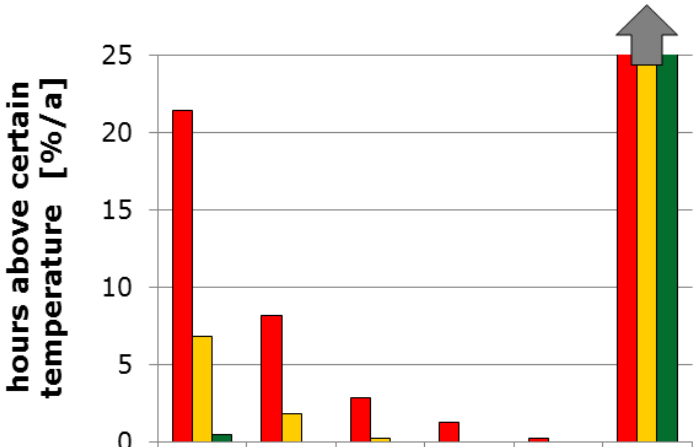
- Should follow real conditions
- Results are coming soon…

Low-temperature experience I

- Single-family-house from 1970 – results from simulation

- The results showed:
  - Even for non-renovated buildings 122°F supply temperature is sufficiently high for 78,6% of the year
  - With moderate renovations, new windows, low-temperature supply can be used for 93,2% of the time
- This implies that already today low-temperature district heating could be achieved with a temperature boosting during the coldest periods

Duration of T_{supply} over certain temperature



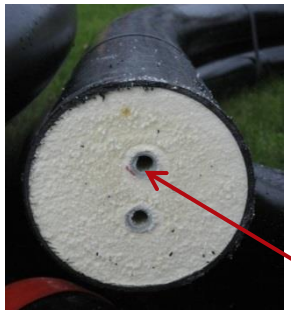
	>122°F	>131°F	>140°F	>149°F	>158°F	122°F
non-renovated 68°F	21,4	8,1	2,9	1,3	0,2	78,6
new windows 68°F	6,8	1,8	0,2	0,0	0,0	93,2
extensive renovation 68°F	0,4	0,0	0,0	0,0	0,0	99,6

T_{supply} [° C]

Source: Brand. M, Svendsen. S, *Renewable-based low-temperature district heating for existing buildings in various stages of refurbishment.* Energy, 2013.

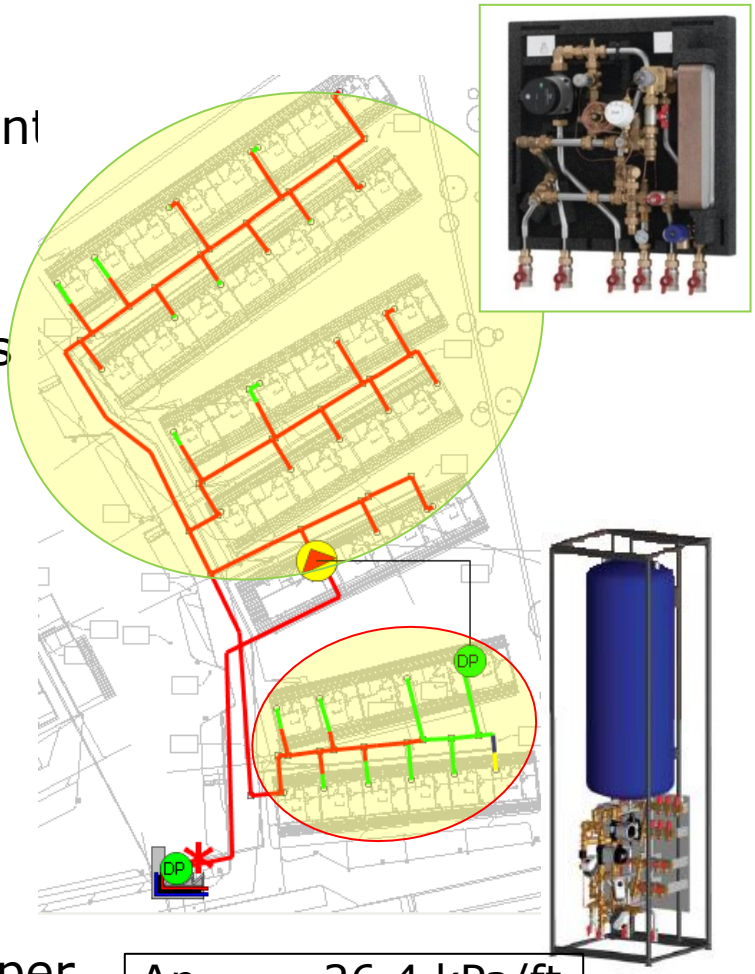
Low-temperature experience II
- Lystrup, Denmark

- Project supported by the Danish government
- 40 low-energy single-family houses
- Higher DH water speed, higher press. drop
- Testing of developed low-temp. substations
- Only 14% heat loss from DHN vs. 41% for traditional designed 176/104°F
- Additional pumping energy is only 4% of primary energy saved from the heat loss



- Good cost-efficiency
- No complaints
- Instantaneous substation lower total heat loss & cheaper

Inner diameter 0,55 in!



Δp_{max} = 26,4 kPa/ft
w_{max} = 6,56 ft/s
$Ød_{min}$ = 0,55 in

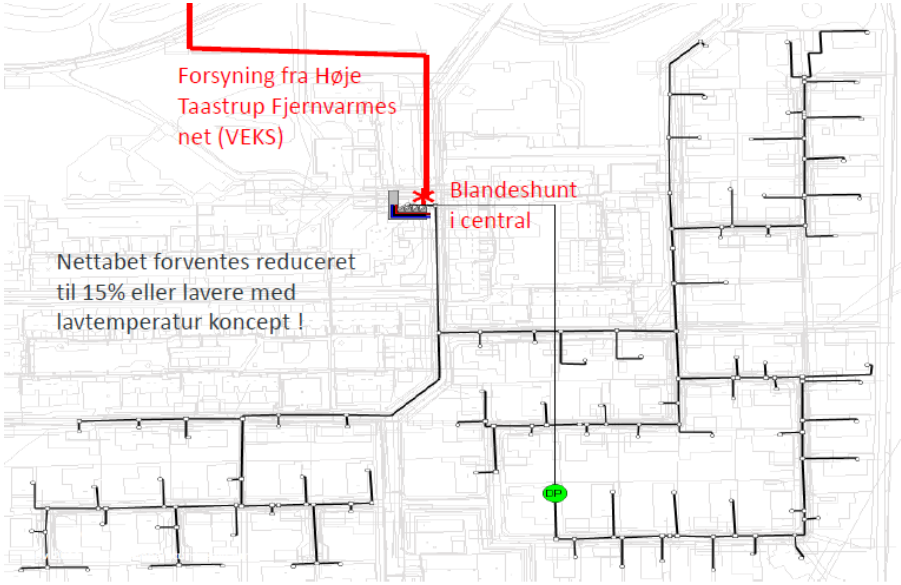
Low-temperature experience III
- Sønderby, Denmark

Low-temperature DH for existing buildings

- Project supported by the Danish government
- 75 single-family buildings from 1997
- **Floor heating**

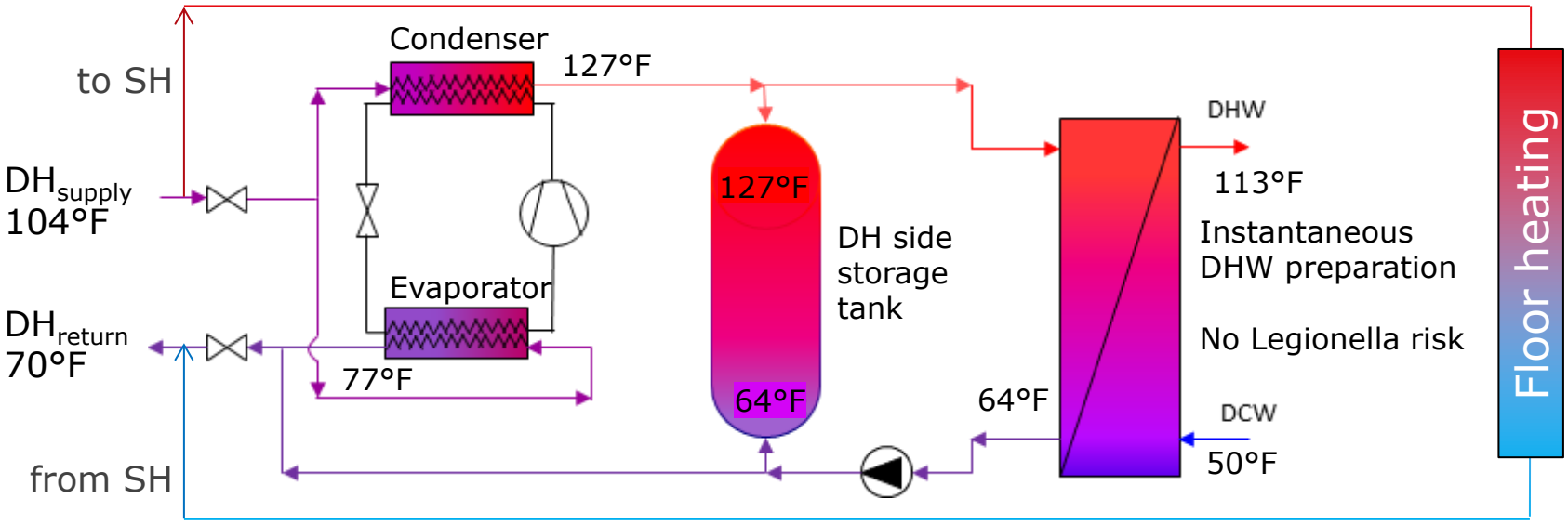
Realisation

- New low-temperature DH in-house substation
- New DH network
  - Heat loss reduced from 41% -> 14%
- 80% of heat demand supplied from main DH return line
- Average T_{sup} = 131°F
- No complaints



Experience IV - Heat pump supplied by Ultra-LTDH - **Copenhagen, Denmark**

- DH supply temperature is 104°F
- Space heating part is not "boosted" => floor heating
- DH supply flow part for DHW is split up in two parts:
  - Heat source (evaporator) / Heat sink (condenser) → supply for DHW preparation
- Constant heat source → high and stable COP (4.5)



Experience V – Electrical heat to boost domestic hot water **- Odder, Denmark**

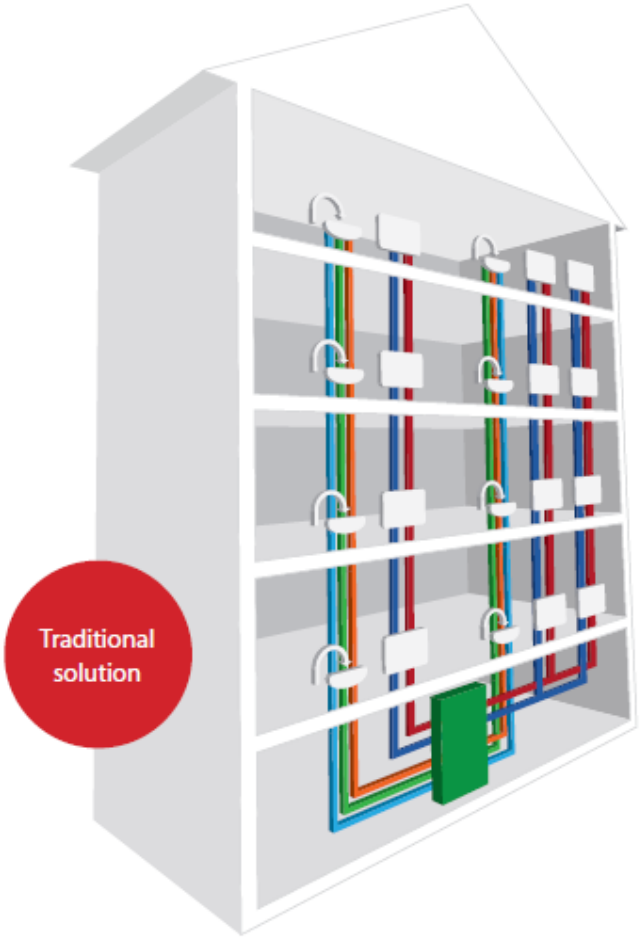
- **DH designed for 104/77°F**
  - Electric heater added on outlet of DHW
    - DHW instantaneously heated to 99°F by DH
    - Electrical heater boosts the temperature up to 140°F by electric heater
  - Expected heat loss reduction is:
    - 17% compared to 122/77°F
    - 40-55% compared to 176/104°F
  - Prototypes installed in 5 houses
    - First results are promising

Surplus heat from supermarket cooling system
- SuperBrugsen in Høruphav, Denmark

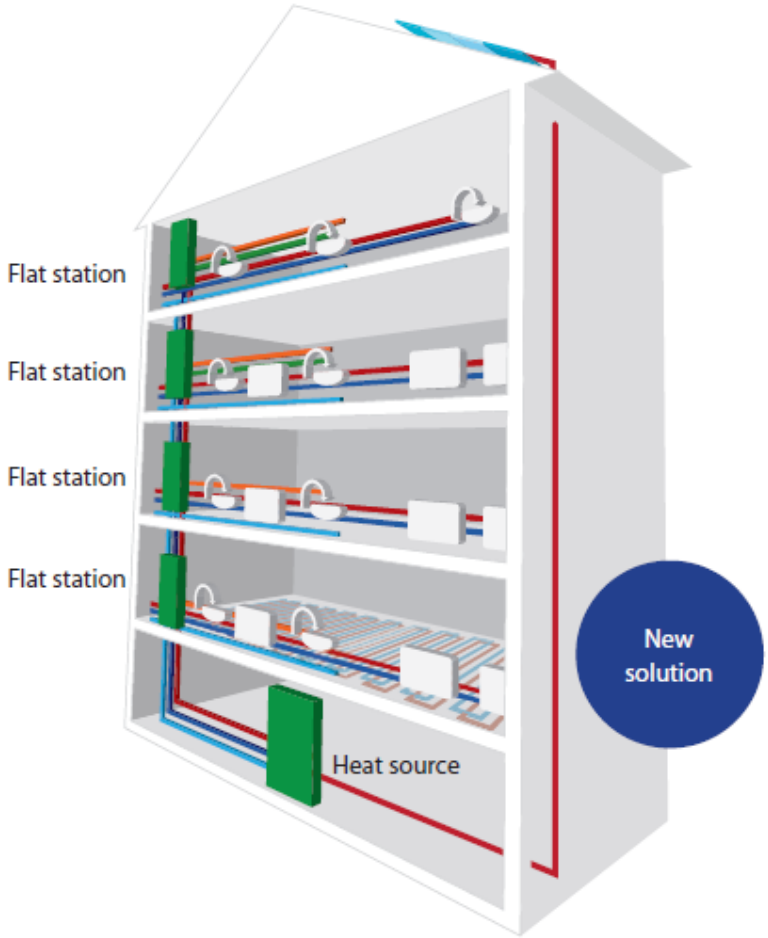
- Area: 1000 m^2 from 2010
- Cooling Capacity: 160 kW
  - Waste heat: 140-212°F
- Partnership model:
  - SuperBrugsen – paid for waste heat
  - Danfoss – investigation of potential DH application economical feasibility
  - DH utility – more of "green energy"

Can LTDH also be applied in apartment buildings?

2nd and 3rd generation DH

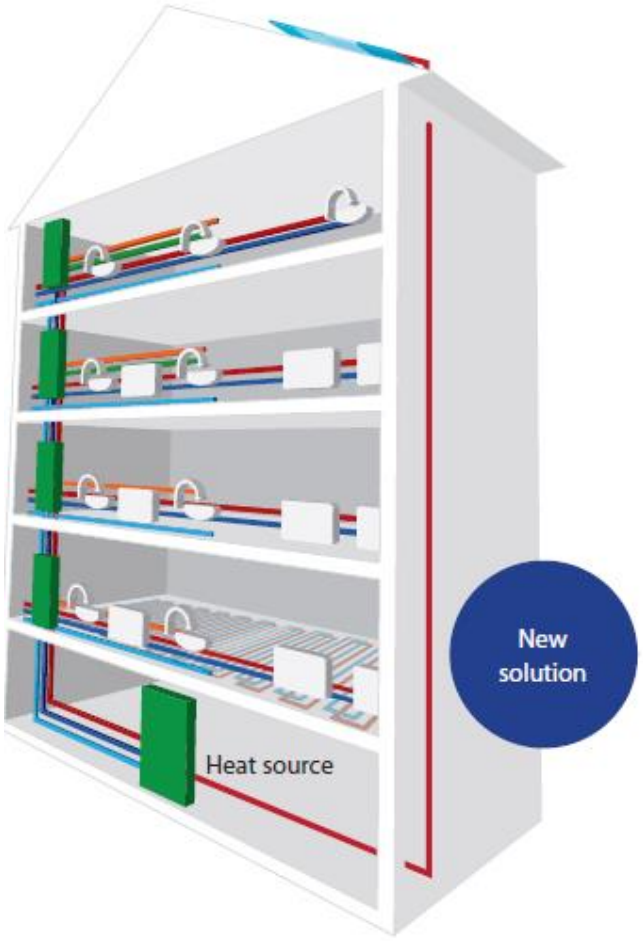


4th generation DH



4GDH and multifamily buildings?

- **Flat stations**
  - Suitable for low-temperature DH
  - Flat station in each flat
  - Overall DHW system volume <3 L
    - ☺ No risk of Legionella
  - Individual control over space heating
  - Simple energy metering
    - ☺ One heat meter for all heat consumption
  - No DHW circulation
    - ☺ Reduced heat loss
  - No vertical risers in flats
    - ☺ Reduced noise
    - ☺ Reduced heat loss



Concluding Remarks

- The concept of LTDH has been demonstrated and shown to work
- Benefits of bringing down the district heating supply temperatures are
  - Significant reduction of distribution heat losses
  - Increased potential to access local low temperature renewable heat sources
- The industry is ready for the 4th generation district heating
  - All the necessary technologies are already available
- **No matter the applied DH generation the principles set forth in the 4GDH should be applied!**
- If there are few buildings that are preventing the network temperature to be decreased temperature boosting at the critical buildings should be considered
- District energy, heating and cooling, is the technology of the future green energy system!

Thank you for your attention

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