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Danfoss

District Energy – the resilient energy infrastructure

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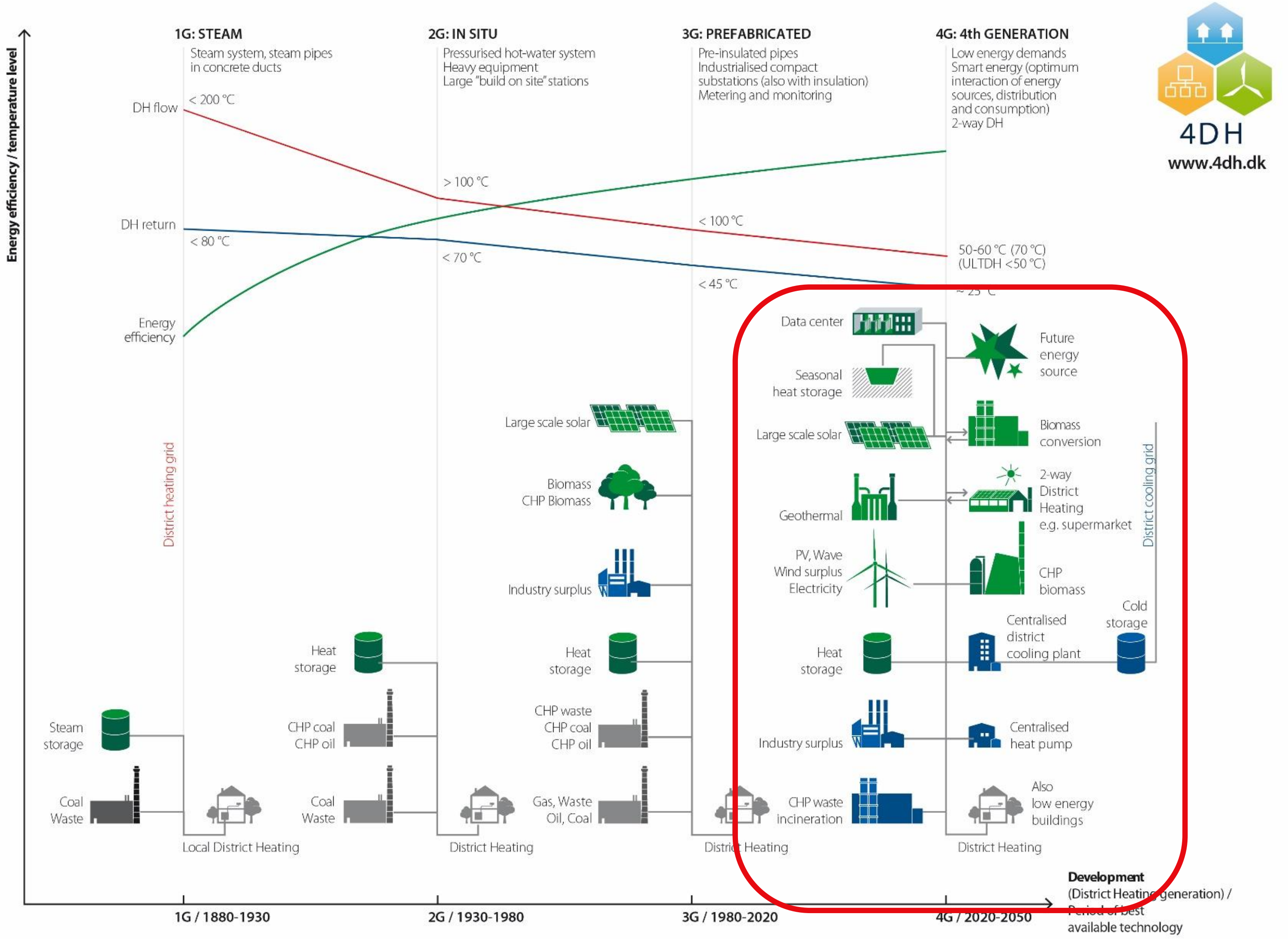
District heating is a continuously evolving infrastructure

- Through the evolution of district heating various resilience favorable factors have been built in

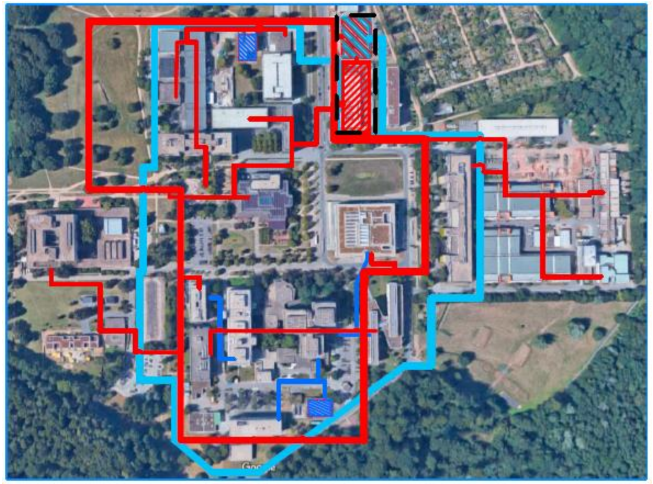
- The key parameters that make district energy resilient are
  - Multiple heat sources
  - Fuel flexibility
  - Meshed distribution layouts
  - Simple design and operation
  - Local and closed solution
  - Pressurized water
  - Low temperature levels



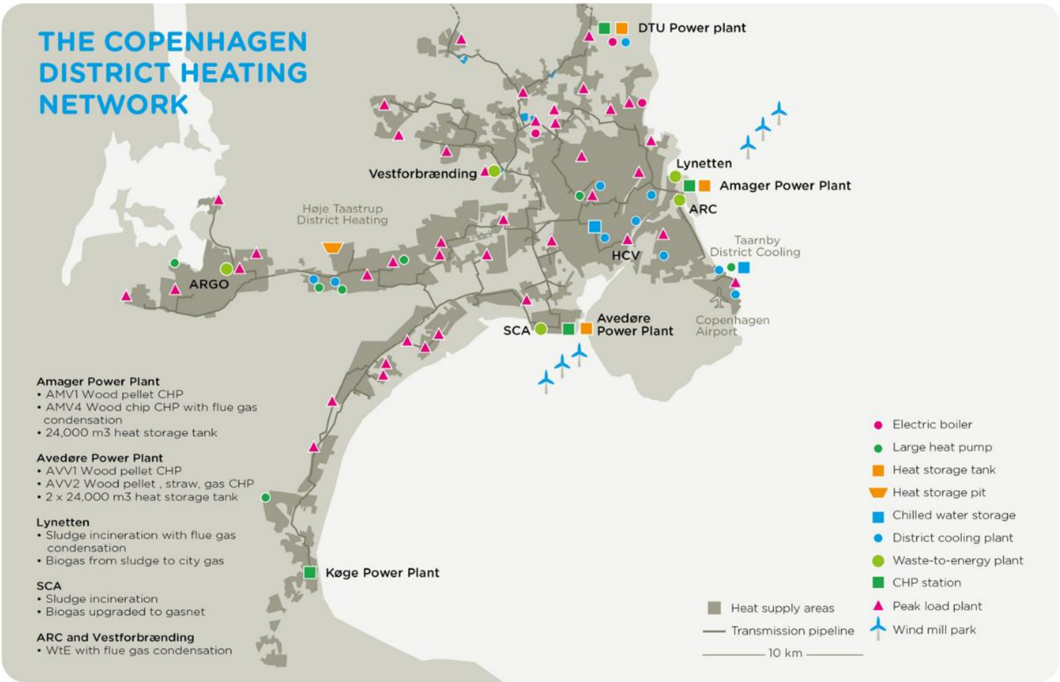
System design and operation
- Play to the strengths

- District heating systems are local solutions
  - Covering from relatively small campuses to large cities

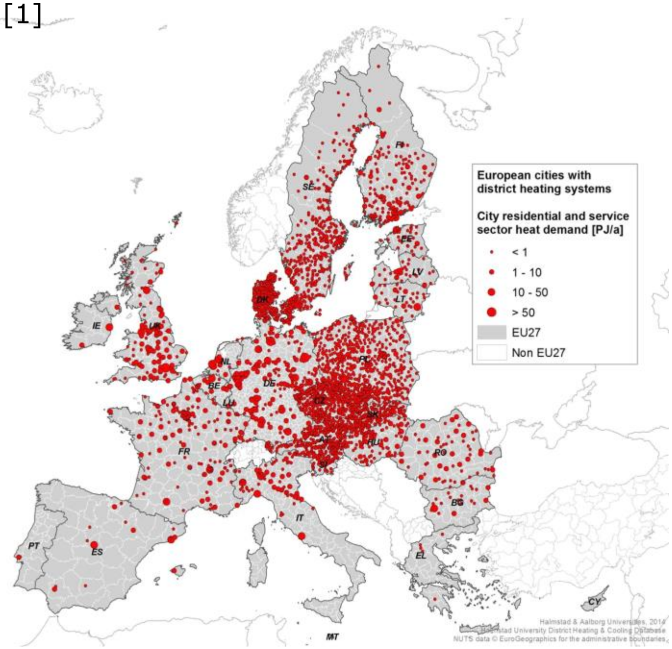
- Fulfilling building heating demands does not need high quality energy
  - It is the energy that no one cares about



Campus Lichtwiese at Technical University of Darmstadt.
Source: [1]



Copenhagen district heating systems.
Source: [2]



Over 3800 district heating systems in Europe.
Source [3]

System design and operation
- Play to the strengths

- Urban areas tend to have abundances of low-quality energy
  - Waste heat from power generation, industrial and commercial processes
  - Geothermal, solar, water reservoirs
- Depending on the location various renewable thermal sources may be available, solar heat, water reservoirs, ambient heat and etc.

- Storing low temperature heat is simple and efficient
  - The larger the thermal storage the more efficient it is
  - It can have multiple roles:
    - Energy storage, peak load units, emergency supply units or to decouple the heat demand and heat generation

Thermal storage at a CHP plant.
Source: Ramboll A/S

Main heat sources for Copenhagen district heating systems.
Source [2]

System design and operation
- Play to the strengths

- **Water born systems**

  - Water is abundantly available and is not an explosive medium

  - Water based systems have high inertia, a heat plant failure is not immediately, if at all, felt by the customer

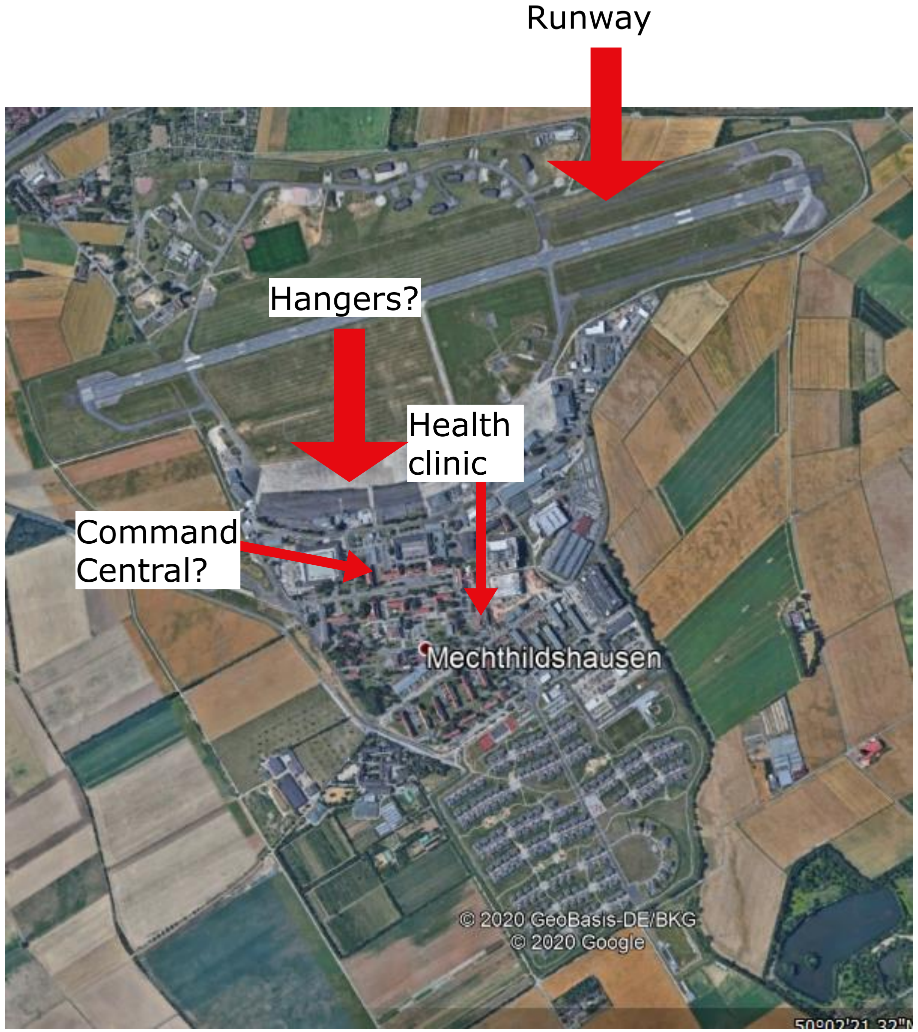
  - Pipelines water leakages normally occur gradually and can be detected well in advance of total failure

  - Due to high level of robustness of the system maintenance can be scheduled for periods of minimal impact to heat consumers and city residence

Installation of a pipe in central Copenhagen.
Source: Danish Board of District Heating

System design and operation
- Play to the strengths

- **Heat planning is a necessity**
  - ***Thermal users***
    - Where are the critical users located?
      - Hospital, command centrals, mission critical installations
    - What are their requirements?
      - For how long can they be without supply?
      - Is there a redundancy requirement?
      - What temperature level do they need to maintain full operation?
  - ***Thermal sources***
    - Are there thermal sources available in the vicinity of the demand area?
    - What fuels are available?
      - Gas grid, power grid, …
    - Are there any limitations on the location of peak/emergency plants?
    - Pipeline constraints
      - Crossing bridges, big roads, rail roads, airfields can be a major operation



Clay Kaserne, Wiesbaden.
Source: Google

System design and operation
- Play to the strengths

- For mapping possible heat sources we need to consider the local area
- Clay Kaserne happens to be closely located to Wiesbaden and Frankfurt
  - Both have well established district heating systems
  - Multiple existing heat plants operating with wide array of fuels
- Taking advantage of the nearby district heating systems and supplementing it with local peak/reserve boilers would lead to a very reliable thermal infrastructure

Area around Clay Kaserne, Wiesbaden.
Source: Google

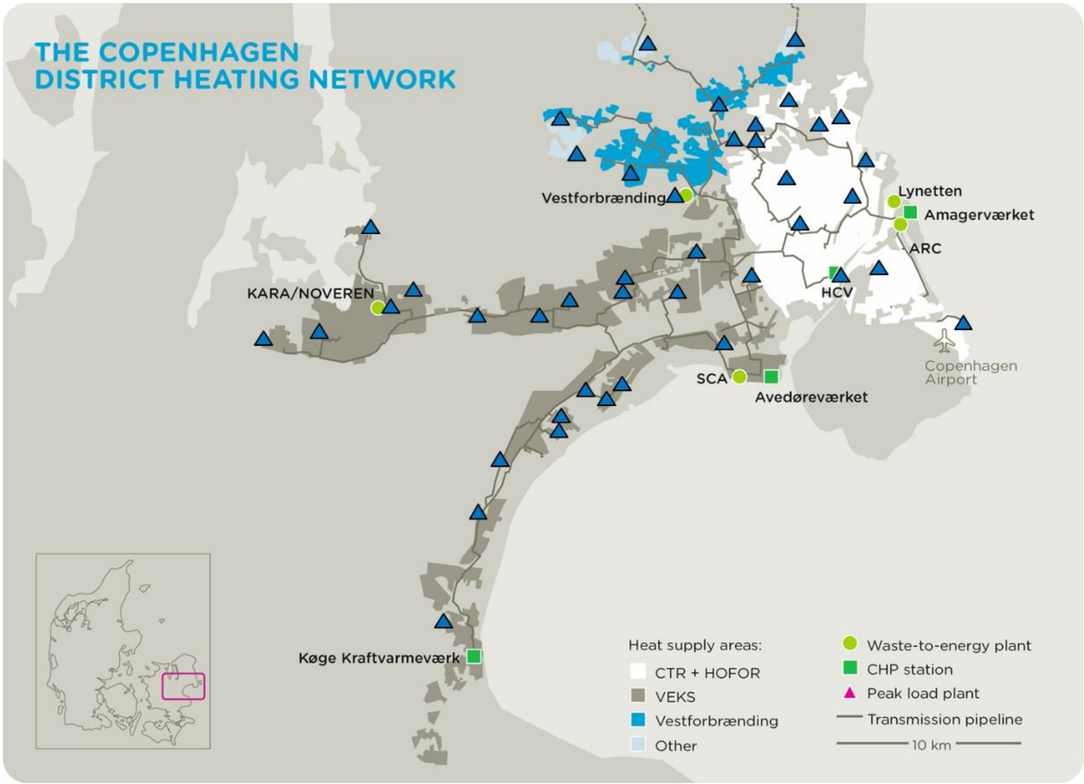
Thermal sources

Multi thermal source systems
- The enabler of thermal resilience

- **Base load source:** distributed around the supply network
- **Peak load boilers**
  - Strategically located considering
    - Pipeline capacity limitations
    - Geographical complications
    - Critical consumers
- **Portable emergency/reserve boilers**
- **Thermal storages**
  - Theoretically thermal storages can be located anywhere
  - Practically they tend to be located at the heat sources
    - To decouple the thermal storage capacity from the system supply temperature
- **Emergency power generators**
  - For operating the distribution pumps in case of grid failures

Portable district heating boiler.

Thermal storage tanks.
Source: Ramboll A/S



Copenhagen District Heating.
Source: Ramboll A/S

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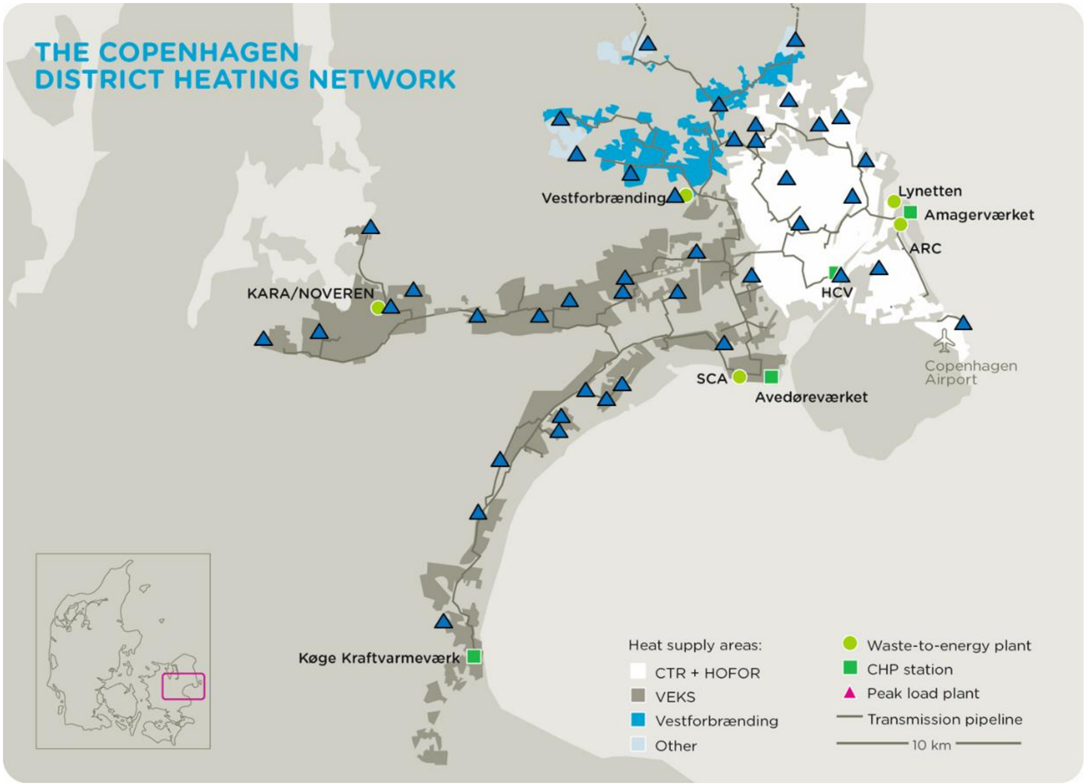


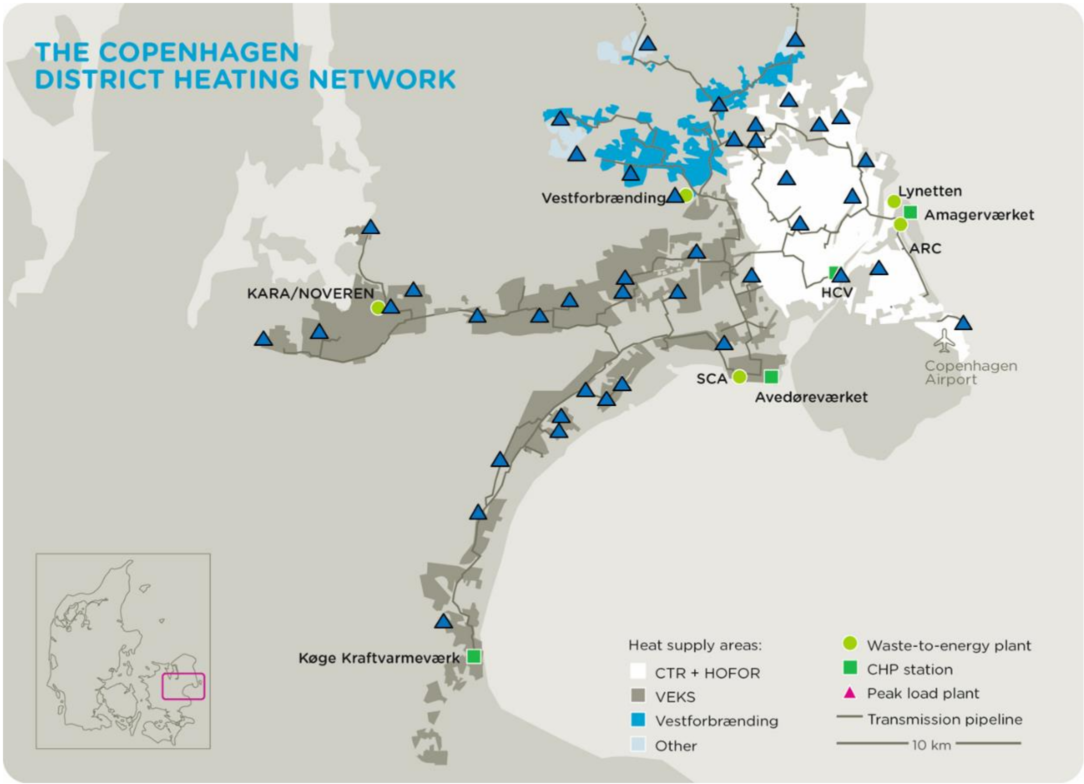
Copenhagen District Heating.
Source: Ramboll A/S

Multi thermal source systems
- Measures to take in case of disruptions?

- Disruptions at the thermal sources can in principle be due to various reasons
  - Malfunctioning plant
    - Redistribute the load to other plants in the system
  - Fuel shortage
    - Change fuels in multi fuel capable boilers
    - Operate a different thermal plant
  - Human related aspects (strikes, infections, sabotage and etc.)
    - Redistribute the load to other plants in the system
  - Climate related (storms, floods, earthquakes and etc.)
    - Redistribute the load to other plants in the system
  - Cascading plant failures
    - **Unlike power systems district energy systems do not experience cascading plant failures**


Portable district heating boiler.


Thermal storage tanks.
Source: Ramboll A/S



Copenhagen District Heating.
Source: Ramboll A/S

Distribution network

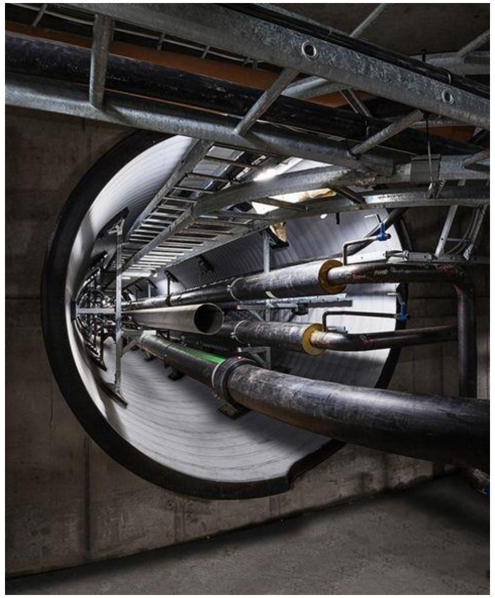
Distribution network
- Pipelines

- Depending on the conditions the distribution pipeline can be:
  - Direct buried
  - Placed in ducts or tunnels
  - Above ground

- Underground infrastructure reduces the risk of:
  - Damage from natural causes (storms, floods, severe colds, fires, falling trees, earthquakes, animals and etc.)
  - Human causes like vehicle collisions and intentional damage

Pipeline in Thule, Greenland.
Source: Ramboll A/S

Direct buried pipe installation.



Utility tunnel.
Source: Uponor

Source: Danfoss A/S

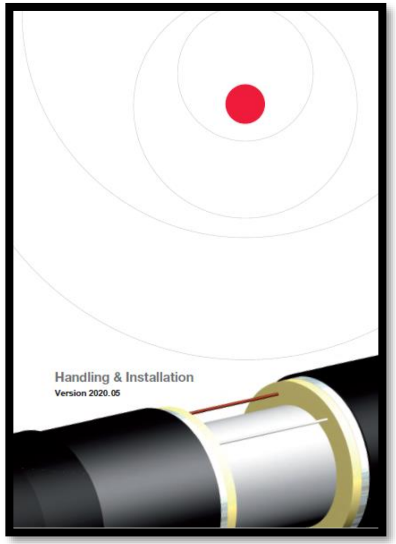
Distribution network
- Resilient designs

- There are number of factors that improve the resilience of the distribution network

  1. Damage resistant design and installation of the pipe network

     - Assemble long pipe stretches above ground and simultaneously lower the pipeline to the trenches
     - Design for eventual stress due to elongation once in operation
       - Bends, compensators and preheating prior to backfilling trenches
     - Use pipe material that can handle both temperature and pressure of the system
     - Apply strict water quality procedures

- **Do what the pipe manufacturer recommends!**



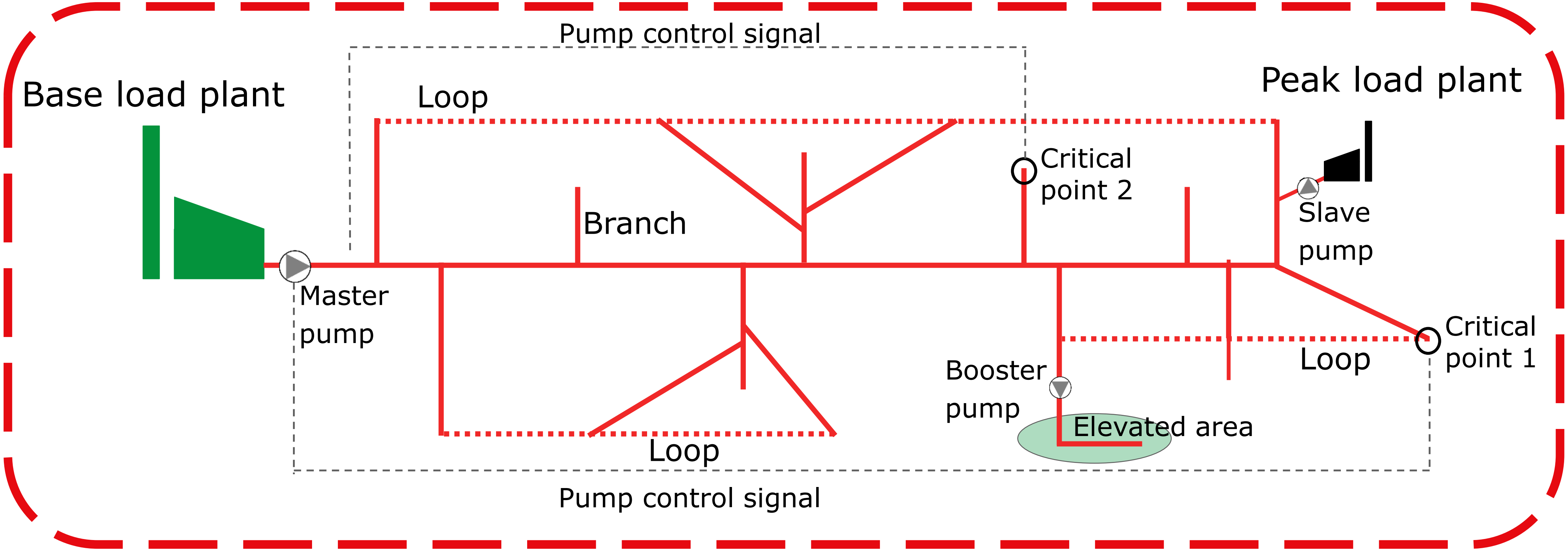
Handling & Installation guidelines.
Source: Logstor A/S

Installation of a pipeline.
Source: Ramboll A/S

Distribution network
- Resilient designs

- There are number of factors that improve the resilience of the distribution network

2. Meshed pipe network layout, multi source and pump strategy



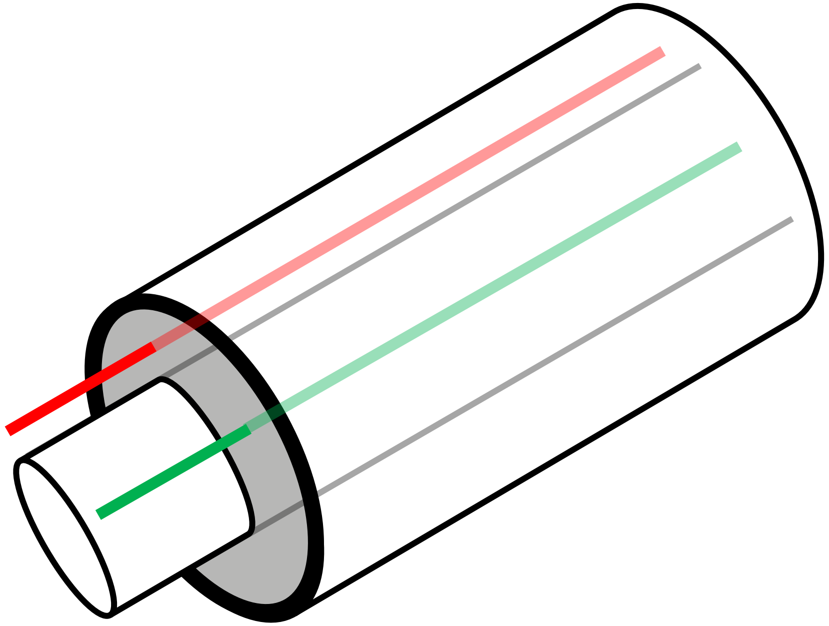
Distribution network
- Resilient designs

- There are number of factors that improve the resilience of the distribution network

  3. Utilization of fault detection equipment and preventive maintenance

     - Early detection of imminent failures will help keep the system robust, reliable and reduce chances of cascading failures in case of disruptions

       - Pipeline leakage detection wires



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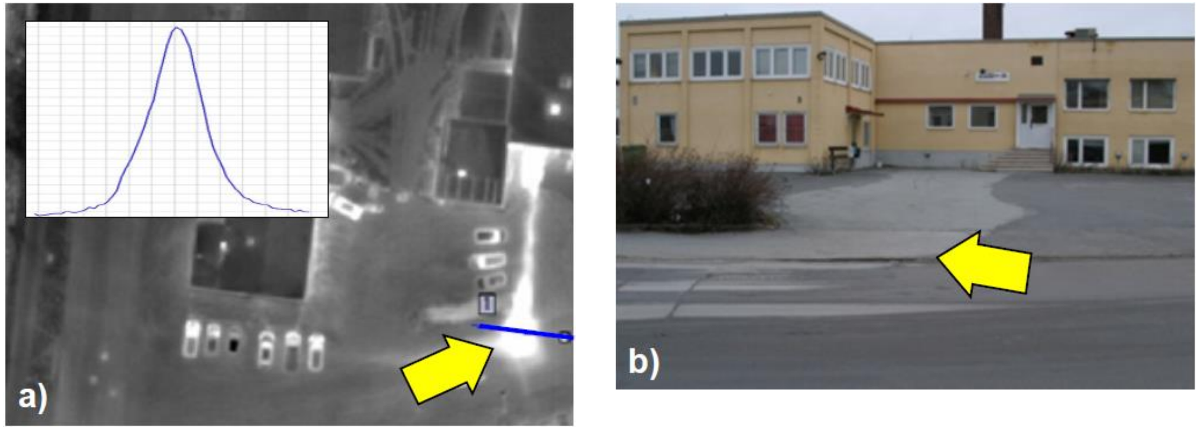
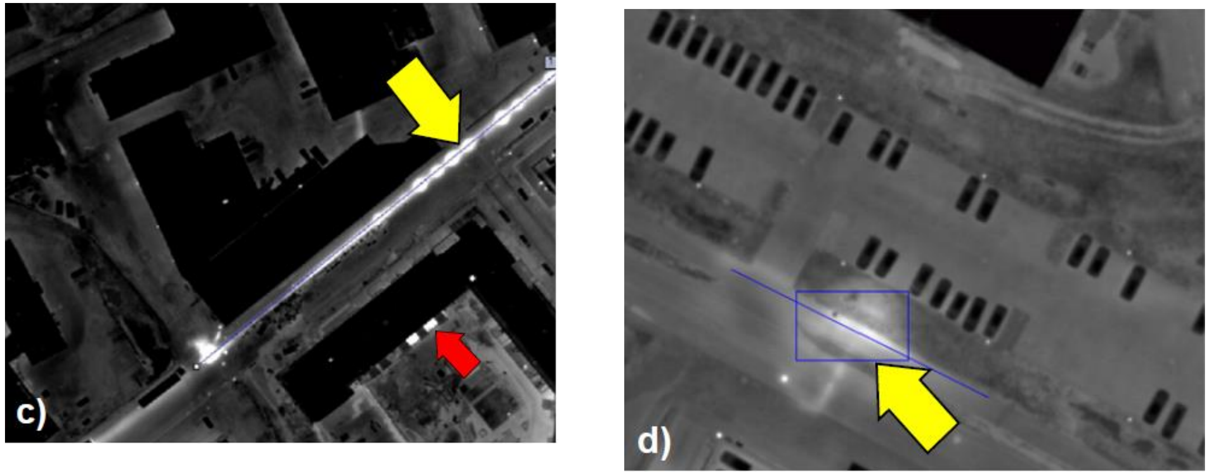
     - Thermographic imaging of the pipeline from air – [4]



a) Thermographic imaging of a leak and b) same place during daytime.
Source: Termisk Systemteknik



c) and b) Thermographic imaging of a leakages
Source: Termisk Systemteknik

Distribution network
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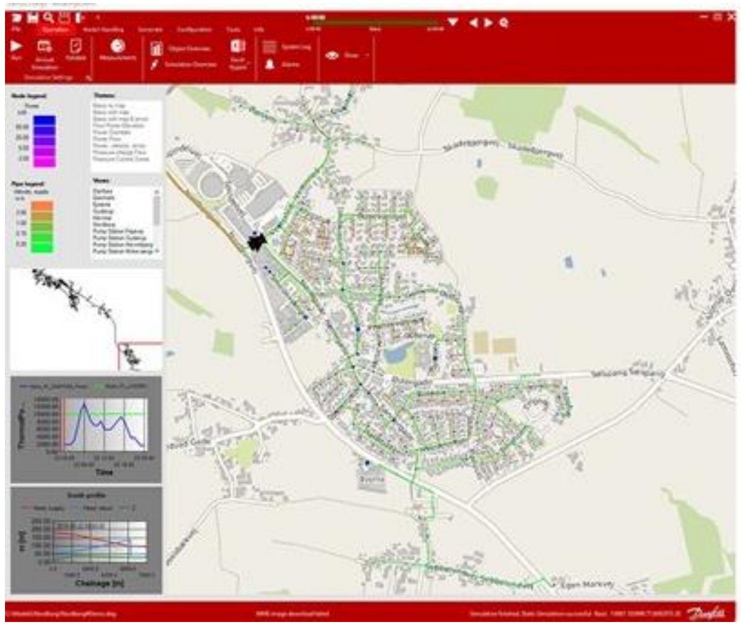
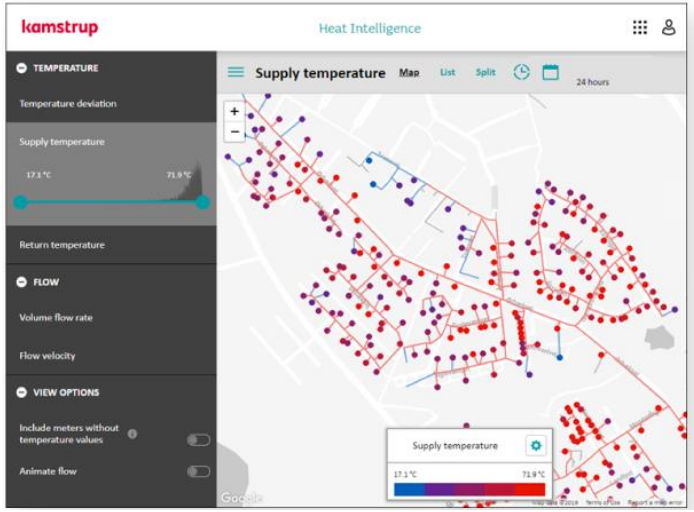
    - Early detection of imminent failures will help keep the system robust, reliable and reduce chances of cascading failures in case of disruptions
        - Pipeline leakage detection wires
        - Thermographic imaging of the pipeline from air
            - Source: [4]
        - Application of digital clones or big data can further help to find potential faults



Source: Danfoss A/S

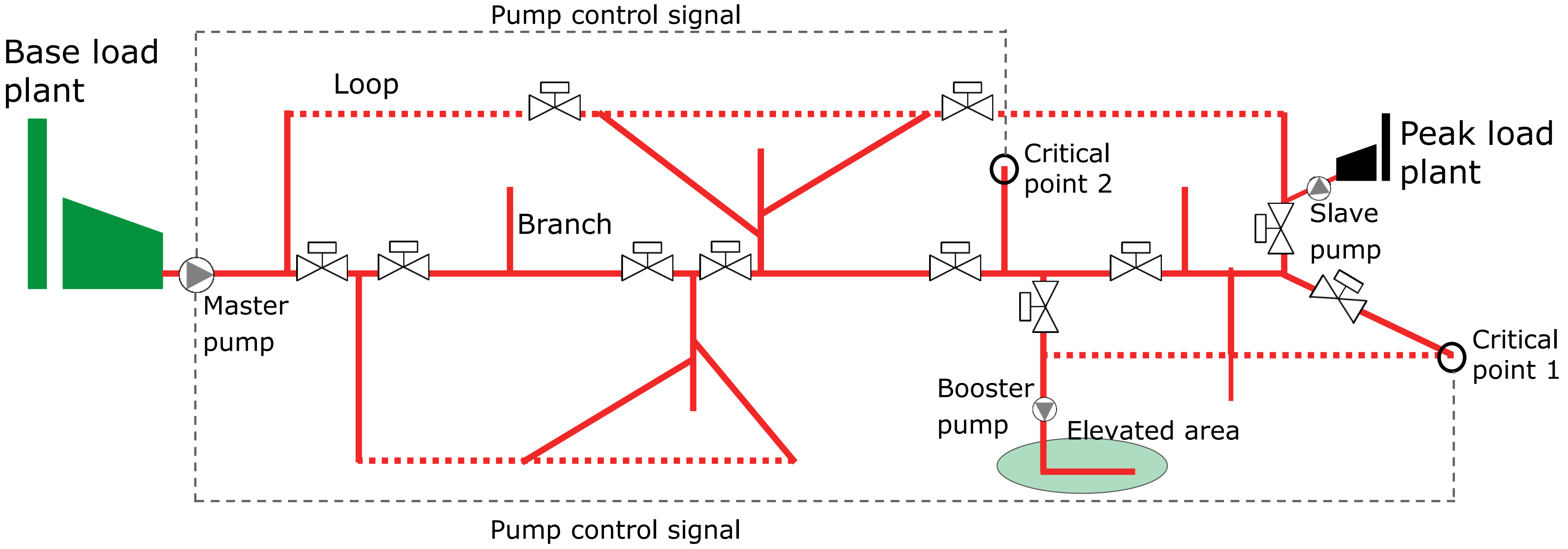


Source: Kamstrup A/S

Distribution network
- Resilient designs

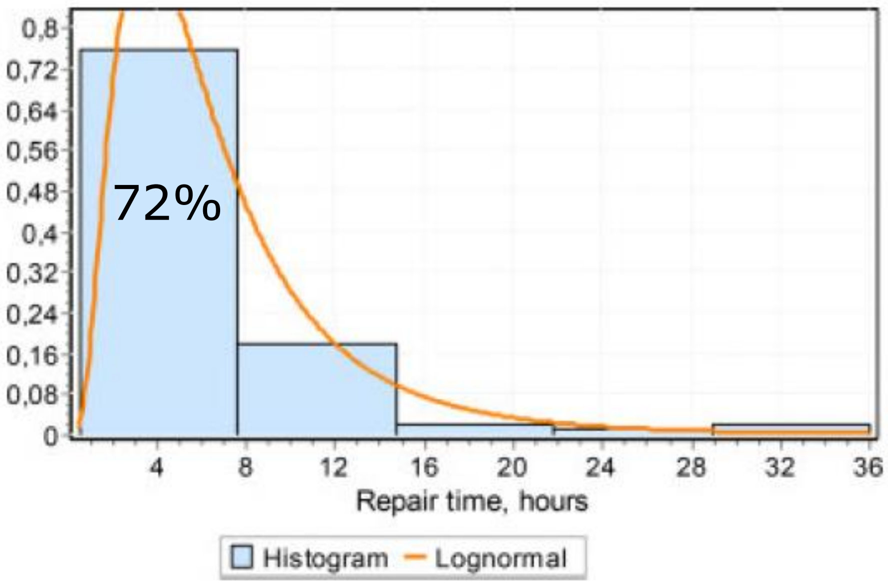
- There are number of factors that improve the resilience of the distribution network

4. Strategic location of shut off valves



Pipeline failures
- Experience from Kaunas, Lithuania, and Warsaw, Poland

- **Pipeline repairs**
  - **Warsaw district heating, Poland largest network [5]**
    - System from the 1950's, at periods insufficiently maintained
    - Corrosion accounted for 88% of failures, piercing of pipe 1% and other reasons 11%
      - Only 5% of failures occurred in **modern pre-insulated pipes**, which have been applied since modernization started in 1992
      - Pre-insulated pipes account for 41% of the installed pipes (691 km)
    - 64% of failures occurred in service pipes
  - **Kaunas, Lithuania [6]**
    - System from the 1960's, at periods insufficiently maintained
    - 72% of repairs are made within 8 hours
    - 2% of repairs take more than 24 hours
- **Note:** Water pipes do not explode, usually they start to leak gradually
  - Gradual leakage does not prevent heat delivery



The figure shows time to repair pipeline.
Source: [5]

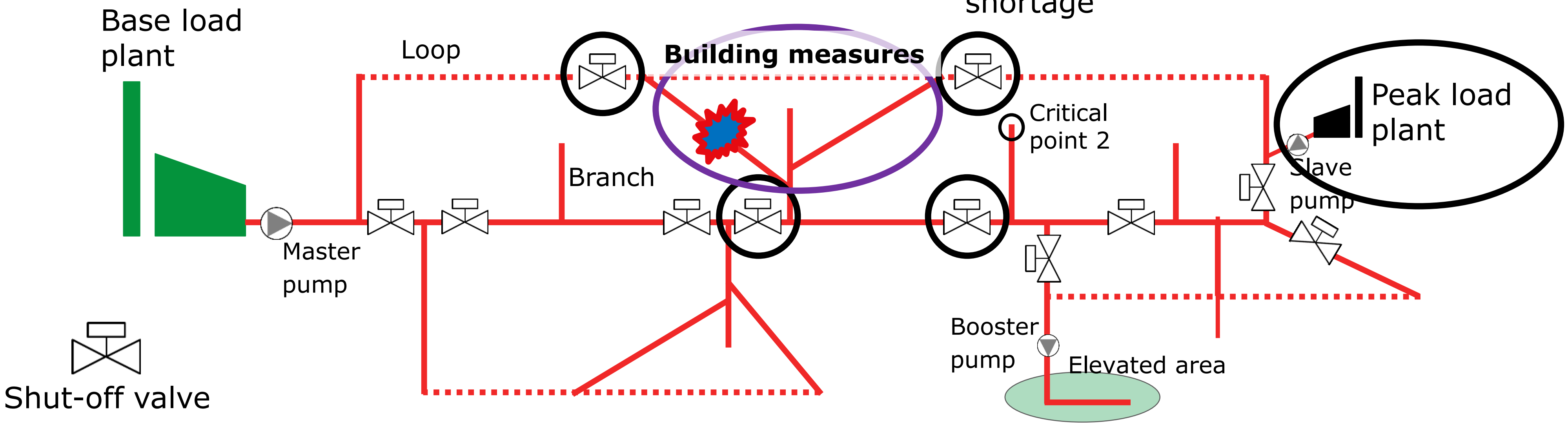
Pipeline failures

- Measures to take in case of disruptions?

- Isolate the impact of the failure by closing shut-off valves around the failure

- **Inside the impacted area**
  - Ensure optimized building operation (minimize heat losses by strict operating procedures of doors and windows)
  - Connect portable building boilers to the building heat interface unit
  - ***Repair pipeline***

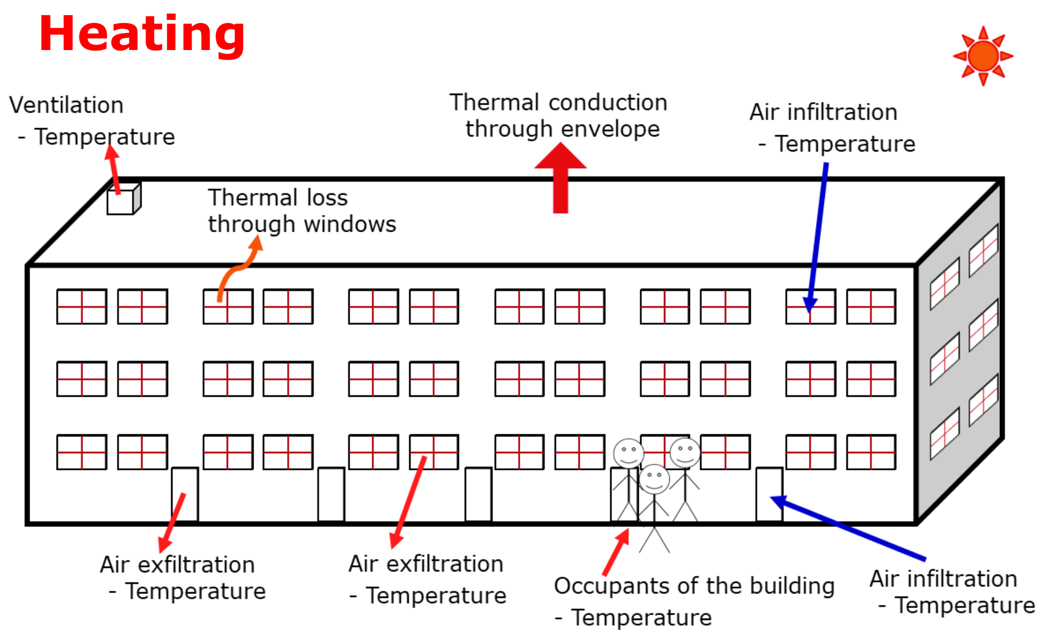
- **Outside the impacted area:**
  - Start peak/reserve boilers if available / portable boiler
  - In case of insufficient emergency capacity
    - Limit the heat draw off by buildings
      - Reduce capacity allowance **and** reduced internal building system supply temperature
    - Prioritize buildings in case of extended supply shortage

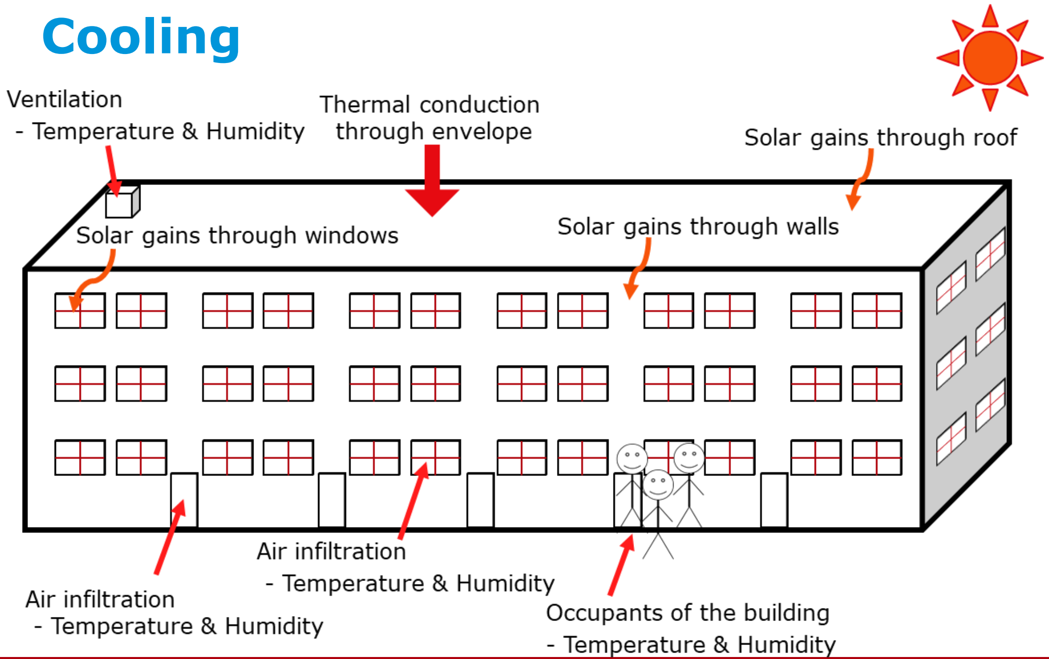


Buildings: Thermal consumers

Buildings
- The make it or break it parameter

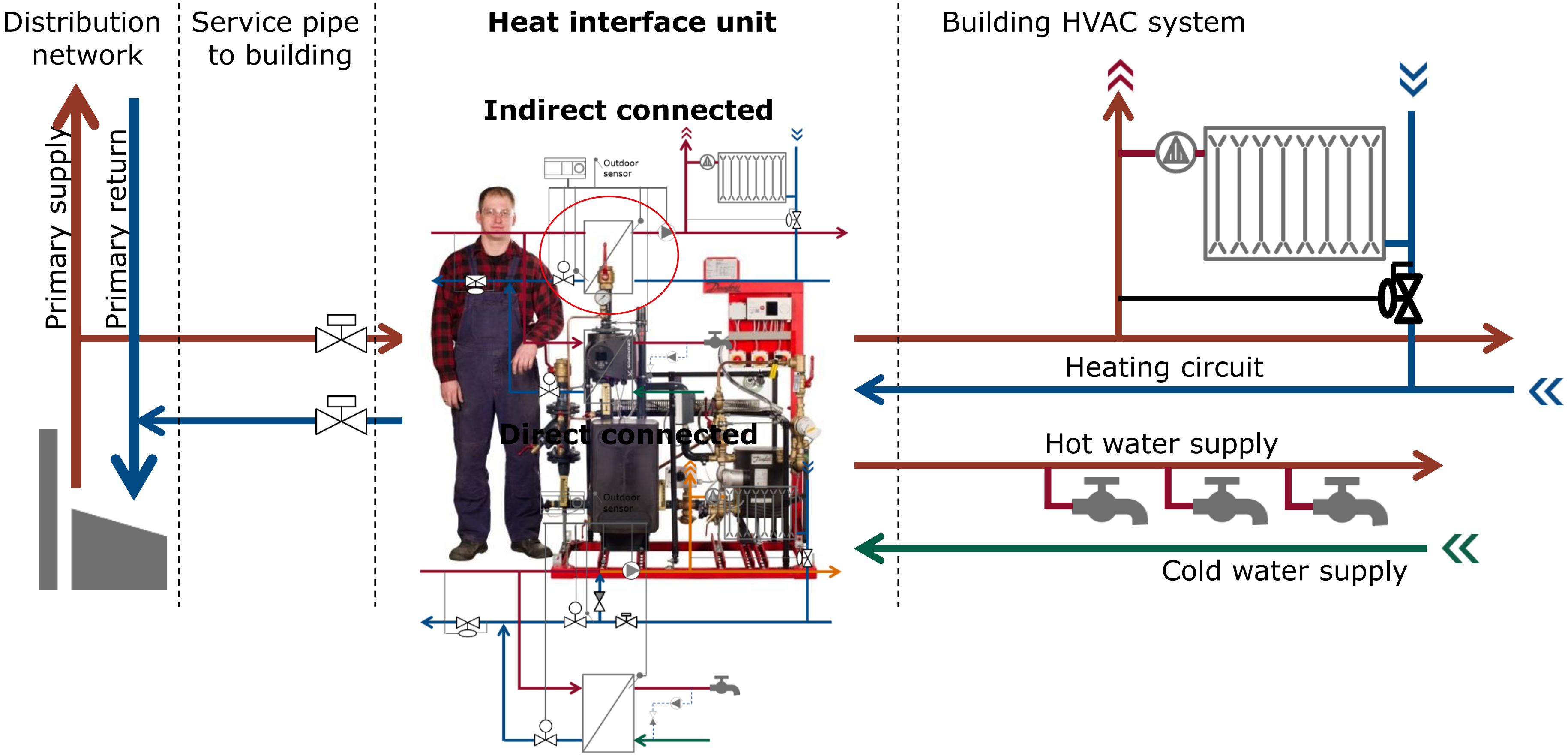
- Buildings and the end users need to play their part
  - The more energy efficient the more relaxed is the energy system
- Energy efficiency in this context is the ability of the building to:
  - Retain the status quo
    - Minimal heat loss and gains to/from ambient
  - Efficiently utilize the thermal supply
    - Maximum temperature difference between supply and return
- The benefits of increased energy efficiency are
  - Increased time constant of the thermal mass
  - Minimal primary energy demand
  - Reduced peak energy demand





Buildings
- Heat transfer units

- Building heat interface is simple and robust
- It is factory assembled and tested
- Can be designed for portable emergency boiler connections
- Can be replaced partly or fully in matter of hours
- Low pressure hot water → Simple to operate



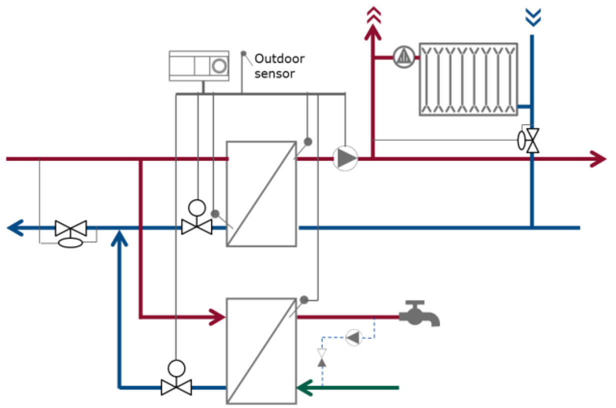
Heat interface disruptions
- Measures to take in case of disruptions?

- Disruptions of the heat interface units can be:
  - Component malfunctioning
  - Loss of power

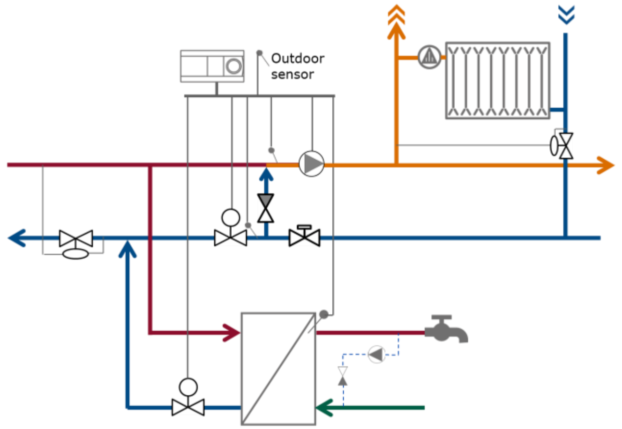
- In case of malfunctioning components, f.ex. valves it is normally possible to operate them manually to guarantee stable heat supply
  - If stuck in close position replacement is simple, fast and easy indoor work

- Depending on the heat interface unit, direct or indirect, a loss of power will lead to failure of electronic equipment, actuators, pumps and electronic controllers
  - In these cases the critical components are the pumps
    - Until power is restored the building heat supply is limited to the natural circulation within the building
      - Depending on the building installation natural circulation has been shown to account for 40%-80% of the heat supply prior to pumps being stopped

Indirect connected



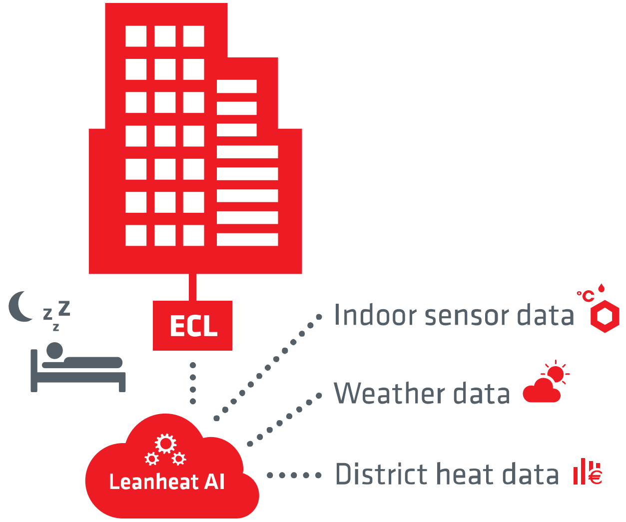
Direct connected



Building heat transfer units
- Digital solutions

- SCADA systems can provide remote monitoring and control of heat interface units
  - Ability to prioritize buildings

- Artificial intelligent can be applied to:
  - Estimate the building thermal mass
  - Predict the time until building reaches a critical condition
  - Optimize the building heating installation



Leanheat AI learns on the building thermal mass
- Optimizes the supply temperature
- Reduces peak demands
- Gives knowledge on building thermal constant

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Case examples

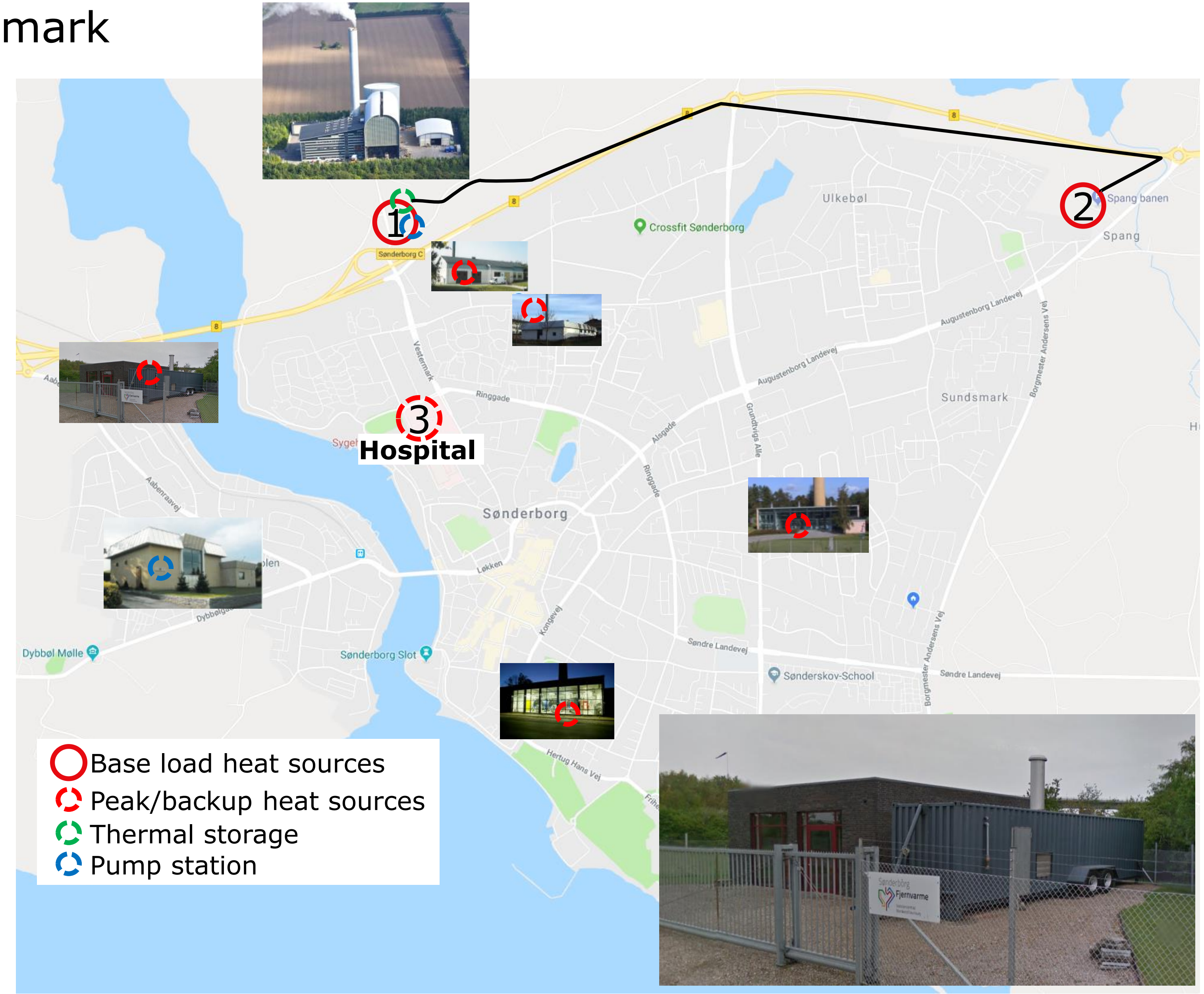
Case: Sønderborg, Southern Denmark

- Population: ~28.000 persons
- Households: ~10.000
- District heating coverage: ~99%

- **Main heat sources:**
  - Base load: Waste incineration
  - Mid load: Biomass heat plant, geothermal plant and absorption heat pumps
  - Peak load: Biooil / gas boilers

- **Portable emergency boiler**

- **Critical building**, Hospital, has its own emergency boiler
  - Which also serves as a reserve boiler for the district heating network



Case: Sønderborg, Southern Denmark

- Population: ~38.000 persons
- Households: ~10.000
- District heating coverage: ~99%

- **Distribution system** has meshed distribution design

Conclusions

- District heating and cooling systems have a proven reliance track record
- The key points when realizing a resilient district energy systems are:
  - Adhere to the requirements from the component manufacturers
    - Installation techniques, water quality, …
  - Apply multiple heat sources, strategically located around the system and supplement them with heat storages
  - Design meshed systems, multiple delivery routes
  - Apply pipe leakage detection vires and fault detection software's **and** perform periodic visual and operational inspection of components
  - Energy efficient buildings add to supply flexibility, reduce peak demand, increase the critical time to act
  - **Schedule maintenance at times that have minimum impact on heat consumers**

Thank you for your attention

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