Hochschule Karlsruhe
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Fakultät für
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Modelling 5th Generation District Heating and Cooling Networks
Challenges, Problems and a Simulation Study

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What are 5th Generation District Heating and Cooling Networks?

5th Generation District Heating and Cooling (5GDHC) Networks[1] are the latest development of district heating networks. There is (yet) no general definition. However, all heating networks covered by this or similar descriptions are characterized by the following features[2]:

- Water or brine as a carrier medium,
- Network temperature close to the ground or ambient temperature,
- Decentralized substations required on the consumer side (e.g. heat pumps),
- Simultaneous coverage of both, heating and cooling demands with the same pipes,
- Sector coupling possibilities.

[1] Other used terms: (bidirectional) low temperature networks, cold heating networks, anergy networks, ...

[2] Buffa et al., 5th generation district heating and cooling systems: A review of existing cases in Europe, 2019.

What are 5th Generation District Heating and Cooling Networks?

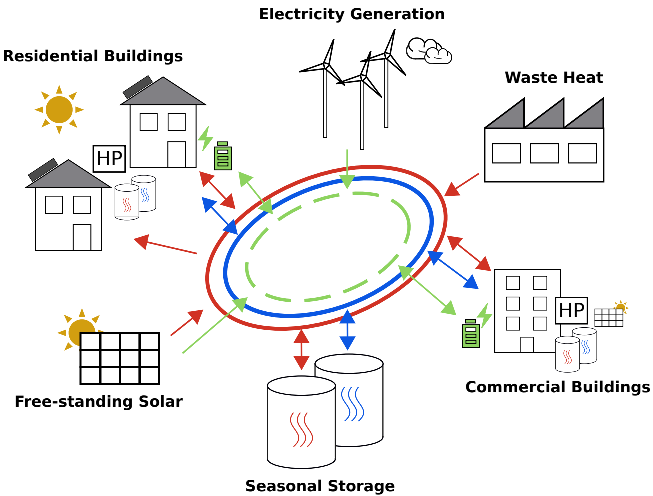

Figure: Schematic representation of a 5GDHC network.

Advantages and disadvantages of 5GDHC networks

- Low heat losses to surrounding soil (free storage),
- Low network investment costs,
- Sector coupling due to use of heat pumps and battery energy storage in combination with PV,
- Easy integration of (unlimited) renewable heat,
- Cost and operationally efficient control of the network temperature possible through the use of heat pumps.

- Potentially higher investment costs for end-users,
- Comparably higher pump work,
- **Sophisticated** system **control** required.

Modelling 5GDHC networks - Soil surrounding pipes

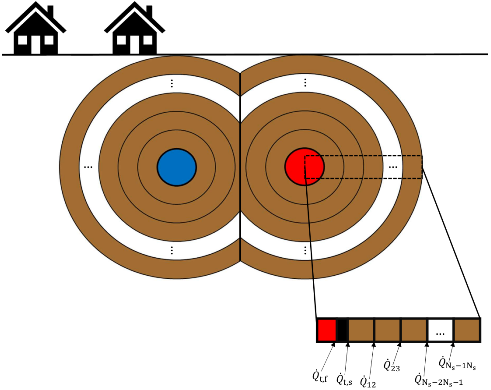

Figure: Profile of the considered soil around pipes.

$$\frac{\mathrm{d}T_{\mathrm{f}}(t)}{\mathrm{d}t} = \frac{1}{m_{\mathrm{f}} c_{\mathrm{f}}} \Big(\dot{m}(t) c_{\mathrm{f}} \big(T_{\mathrm{in}}(t) - T_{\mathrm{f}}(t)\big) - \dot{Q}_{\mathrm{f,t}}(t) \Big), \tag{1}$$

$$\dots \tag{2}$$

$$\dot{Q}_{\mathrm{f,t}}(t) = \alpha_{\mathrm{t}} \mathrm{A}_{\mathrm{t}} \big(T_{\mathrm{f}}(t) - T_{\mathrm{t}}(t)\big), \tag{3}$$

$$\dot{Q}_{\mathrm{t,s_1}}(t) = \lambda k_1 \big(T_{\mathrm{t}}(t) - T_{\mathrm{s_1}}(t)\big), \tag{4}$$

$$\dot{Q}_{\mathrm{s_i,s_{i+1}}}(t) = \lambda k_i \big(T_{\mathrm{s_i}}(t) - T_{\mathrm{s_{i+1}}}(t)\big), \tag{5}$$

$$i = 1, \dots, N_s, \tag{6}$$

$$\dot{Q}_{\mathrm{s_{N_s},s_{bd}}}(t) = \lambda k_i \big(T_{\mathrm{s_{N_s}}}(t) - T_{\mathrm{s_{bd}}}(t)\big). \tag{7}$$

$$k_i = \frac{2\pi l}{\log(r_{i,2}) - \log(r_{i,1})}$$

Modelling 5GDHC networks - Seasonal thermal storage

Figure: Pictures of the construction process of an ice storage[3].

[3]Stadtwerke Bühl GmbH, Bidirektionales kaltes Wärmenetz in Gutach i.Br., 2017.

Modelling 5GDHC networks - Seasonal thermal storage

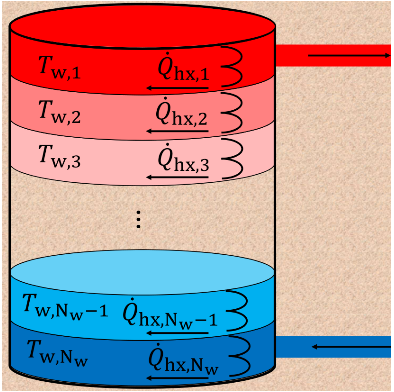

Figure: Graphical representation of an ice storage model.

$$
\begin{aligned}
\frac{\mathrm{d}T_{\mathrm{hx}}(t)}{\mathrm{d}t} =& \frac{1}{m_{\mathrm{hx}} c_{\mathrm{f}}} \Big(\dot{m}(t) c_{\mathrm{f}} \\
& \big(T_{\mathrm{in}}(t) - T_{\mathrm{hx}}(t) \big) - \dot{Q}_{\mathrm{hx}}(t) \Big), && (8)\\
\frac{\mathrm{d}T_{\mathrm{w}}(t)}{\mathrm{d}t} =& \frac{\dot{Q}_{\mathrm{hx}}(t)}{m_{\mathrm{w}} c_{\mathrm{w}}(T_{\mathrm{w}}(t))}, && (9)\\
\dot{Q}_{\mathrm{hx}}(t) =& \alpha_{\mathrm{hx}} \mathrm{A}_{\mathrm{hx}} \big(T_{\mathrm{hx}}(t) - T_{\mathrm{w}}(t) \big). && (10)
\end{aligned}
$$

$$
c_{\mathrm{w}}(T_{\mathrm{w}}) = \begin{cases} 4.18e3 \quad \frac{\mathrm{J}}{\mathrm{kg.K}} & \text{if } T_{\mathrm{w}} \geq 0, \\ 333.5e3 \quad \frac{\mathrm{J}}{\mathrm{kg.K}} & \text{if } -1 < T_{\mathrm{w}} < 0, \\ 1.88e3 \quad \frac{\mathrm{J}}{\mathrm{kg.K}} & \text{else.} \end{cases} \qquad (11)
$$

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Thank you very much for your attention!

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