Energy efficiency of district networks compared with individual systems

Ashreeta Prasanna, Viktor Dorer
Energy supply for mixed-use districts

- New-build mixed districts
- Balance of social, economic and environmental needs
- Design considering both demand and supply
Mixed-use districts and heat pump systems

<table>
<thead>
<tr>
<th>Case no.</th>
<th>Residential Area</th>
<th>Office Area</th>
</tr>
</thead>
<tbody>
<tr>
<td>1</td>
<td>100%</td>
<td>0%</td>
</tr>
<tr>
<td>2</td>
<td>75%</td>
<td>25%</td>
</tr>
<tr>
<td>3</td>
<td>50%</td>
<td>50%</td>
</tr>
<tr>
<td>4</td>
<td>25%</td>
<td>75%</td>
</tr>
<tr>
<td>5</td>
<td>0%</td>
<td>100%</td>
</tr>
</tbody>
</table>

Low temperature district heating
Decentralised HP
(8°C - 22°C supply)

Low temperature district heating
Centralised ASHP/ GSHP
(55°C supply, 20°C return)

Individual Building
ASHP/GSHP
(35°C SH, 55°C DHW,
<18°C Free-cooling/Cooling)
Demand profiles of different building types

<table>
<thead>
<tr>
<th>Multi-family house (MFH)</th>
<th>Office building</th>
</tr>
</thead>
<tbody>
<tr>
<td>SH kW/m²/y</td>
<td>SH kW/m²/y</td>
</tr>
<tr>
<td>21.5</td>
<td>39.4</td>
</tr>
<tr>
<td>DHW kW/m²/y</td>
<td>DHW kW/m²/y</td>
</tr>
<tr>
<td>19.2</td>
<td>6.3</td>
</tr>
<tr>
<td>Cooling kW/m²/y</td>
<td>Cooling kW/m²/y</td>
</tr>
<tr>
<td>3.3</td>
<td>20.5</td>
</tr>
</tbody>
</table>

Data for profiles from PLUSQUA project, report accessible at:
Methodology:
District with LTN and decentralized HPs

Temperature of LTN (monitoring data) → COP of HP → Electricity consumption of HP for heating (35°C), (55°C) and cooling (25°C) +

2.5% of delivered energy for heating and cooling ← Electricity for pumping +

Profiles from monitoring ← Electricity consumption of households and offices ↓

Total electricity consumption
Methodology:
District heating (55°C) with centralized ASHP

Monthly average air temperature $\rightarrow$ COP of HP $\rightarrow$ Electricity consumption of HP for heating (55°C) +

Monthly average air temperature $\rightarrow$ Chiller efficiency $\rightarrow$ Electricity for cooling +

2% of delivered energy for heating $\leftarrow$ Electricity for pumping +

Profiles from monitoring $\leftarrow$ Electricity consumption of households and offices

$\downarrow$

Total electricity consumption
Methodology:
District heating (55°C) with GSHP

- Temperature at exit of borehole field → COP of HP → Electricity consumption of HP for heating (55°C)

- Monthly average air temperature → Chiller efficiency → Electricity for cooling

- 2% of delivered energy for heating → Electricity for pumping

- Profiles from monitoring → Electricity consumption of households and offices

↓
Total electricity consumption
Methodology:
Individual buildings with ASHPs

Monthly average air temperature → COP of HP → Electricity consumption of HP for heating (55°C and 35°C) +
Monthly average air temperature → Chiller efficiency → Electricity for cooling +
Profiles from monitoring ← Electricity consumption of households and offices ↓

Total electricity consumption
Methodology:
Individual buildings with GSHPs

- Borehole temperature (monitoring)
- Monthly average air temperature
- 1.5% of delivered energy for heating and cooling
- Profiles from monitoring

\[ \text{COP of HP} \rightarrow \text{Electricity consumption of HP for heating (55°C)} \]
\[ \text{COP of HP} \rightarrow \text{Electricity for cooling} \]
\[ \text{Electricity for pumping} \rightarrow \text{Electricity consumption of households and offices} \]
\[ \text{Total electricity consumption} \]
Comparison of COP
## Comparison of electricity demand

<table>
<thead>
<tr>
<th></th>
<th></th>
<th></th>
<th></th>
<th></th>
<th></th>
<th></th>
<th></th>
</tr>
</thead>
<tbody>
<tr>
<td>1</td>
<td>300</td>
<td>294</td>
<td>262</td>
<td>322</td>
<td>294</td>
<td>189</td>
<td>318</td>
</tr>
<tr>
<td>2</td>
<td>308</td>
<td>321</td>
<td>280</td>
<td>342</td>
<td>303</td>
<td>318</td>
<td>318</td>
</tr>
<tr>
<td>3</td>
<td>316</td>
<td>348</td>
<td>297</td>
<td>362</td>
<td>311</td>
<td>448</td>
<td>318</td>
</tr>
<tr>
<td>4</td>
<td>324</td>
<td>375</td>
<td>314</td>
<td>382</td>
<td>320</td>
<td>577</td>
<td>318</td>
</tr>
<tr>
<td>5</td>
<td>332</td>
<td>402</td>
<td>331</td>
<td>402</td>
<td>328</td>
<td>707</td>
<td>318</td>
</tr>
</tbody>
</table>

<table>
<thead>
<tr>
<th>Case No.</th>
<th>MFH Area [m²]</th>
<th>Office Area [m²]</th>
<th>PV Area [m²]</th>
</tr>
</thead>
<tbody>
<tr>
<td>1</td>
<td>20,000</td>
<td>0</td>
<td>2000</td>
</tr>
<tr>
<td>2</td>
<td>15,000</td>
<td>5,000</td>
<td>2000</td>
</tr>
<tr>
<td>3</td>
<td>10,000</td>
<td>10,000</td>
<td>2000</td>
</tr>
<tr>
<td>4</td>
<td>5,000</td>
<td>15,000</td>
<td>2000</td>
</tr>
<tr>
<td>5</td>
<td>0</td>
<td>20,000</td>
<td>2000</td>
</tr>
</tbody>
</table>
Comparison of electricity demand

Electricity required to supply heating and cooling
Total electricity required (including households and offices)
Electricity from rooftop PV (hourly balance)

- Case 5 has 76% self-consumption of electricity from rooftop PV (average)

<table>
<thead>
<tr>
<th>Case no.</th>
<th>Average self-consumption</th>
</tr>
</thead>
<tbody>
<tr>
<td>1</td>
<td>73%</td>
</tr>
<tr>
<td>2</td>
<td>61%</td>
</tr>
<tr>
<td>3</td>
<td>58%</td>
</tr>
<tr>
<td>4</td>
<td>66%</td>
</tr>
<tr>
<td>5</td>
<td>76%</td>
</tr>
</tbody>
</table>
Electricity balance with rooftop PV

Case 3: GSHP Bld

Case 5: GSHP DH
Discussion and future work

• Electricity demand similar regardless of heating system chosen due to high influence of user demand

• GSHP systems which can supply both heating and cooling are less sensitive to change in use (needs to be validated for other district types)

• Certain system choices require additional equipment (additional chillers for cooling, or solar thermal panels for re-generation of borehole fields)

• Balance with PV (production and demand) higher for certain district types

• Further analysis of sensitivity to demand profiles and electricity for pumping

• Further analysis considering districts with additional use-types (industry, restaurants, etc.)

• Include of cost analysis in tool
HUES Platform – Resources

An ecology of open source computational resources to support distributed energy systems (DES) design and control

Resources:
- Models & algorithms
- Modeling tools
- Data
- Code

Purpose:
1. To **accelerate DES research** by making models, data and code more accessible and understandable to researchers.
2. To **improve DES design & control** in practice by developing innovative, validated tools for practitioners.

Publicly accessible and open source:
[https://hues-platform.github.io](https://hues-platform.github.io)

Integrates ongoing research in:
Thank you for your time
Questions?
Ashreeta.Prasanna@empa.ch

This research has been financially supported by the Energy Funding Programme of CTI within the SCCER FEEB&D.

Further information at www.sccer-fee bd.ch
Low temperature bi-directional networks (LTN)

Direction of energy flow

<table>
<thead>
<tr>
<th>Direction of fluid flow</th>
<th>Directional</th>
<th>Bi-directional</th>
</tr>
</thead>
<tbody>
<tr>
<td>directed</td>
<td>Heat or cooling operation, central pump, forward and return flow clearly defined</td>
<td>Heat and cooling operation, central pump, mix of temperatures in return flow pipe</td>
</tr>
<tr>
<td>non directed</td>
<td>n.a.</td>
<td>Heat and cooling operation, decentralized pumps, no clearly defined forward or return flow pipe</td>
</tr>
</tbody>
</table>