1. Generations of district heating (DH)

<table>
<thead>
<tr>
<th>Timeline</th>
<th>1GDHS</th>
<th>2GDHS</th>
<th>3GDHS</th>
<th>4GDHS</th>
<th>5GDHS</th>
</tr>
</thead>
<tbody>
<tr>
<td>Year</td>
<td>1880</td>
<td>1970</td>
<td>2000</td>
<td>2010</td>
<td>2021</td>
</tr>
<tr>
<td>Key features</td>
<td>Steam as heat carrier</td>
<td>Pressurized hot water</td>
<td>Low temperature hot water</td>
<td>Ambient water systems</td>
<td>Borehole heat exchanger</td>
</tr>
<tr>
<td>Supply temperature</td>
<td>&gt; 200 °C</td>
<td>&gt; 100 °C</td>
<td>&lt; 30 °C</td>
<td>&lt; 30 °C</td>
<td>&lt; 30 °C</td>
</tr>
<tr>
<td>Energy efficiency</td>
<td>High</td>
<td>High</td>
<td>High</td>
<td>High</td>
<td>High</td>
</tr>
<tr>
<td>Typical layout</td>
<td>Solar thermal, CHP</td>
<td>Solar thermal, CHP</td>
<td>Solar thermal, CHP</td>
<td>Solar thermal, CHP</td>
<td>Multi-source, CHP</td>
</tr>
<tr>
<td>Gaps</td>
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</tbody>
</table>

2. Target questions in this review

Q1: What is the exact definition of 5GDHCS?
Q2: What are the distinct features of 5GDHCS compared with 4GDHCS?
Q3: What is the state-of-the-art progress in 5GDHCS?
Q4: What is the status of practical deployment of 5GDHCS?
Q5: What are the research gaps in existing studies?
Q6: What implications does the development of 5GDHCS bring to the decarbonization of both the district heating and electric power sectors?

Some fundamental questions concerning its definition, energy, exergy, and techno-economic competitiveness remain unclear.

Gaps

3. Research progress

- The 5GDHCS-related studies are growing fast, with over 30 works published each year since 2021 (See Fig. 2)
- Affiliations in 26 countries have contributed a share, where European countries are dominating the list (See Fig. 3)
- Most popular research topics include: network planning, optimal operation, digital simulation, and energy/exergy/environmental/techno-economic performance analysis

4. Real-life systems

- The number of newly-commissioned systems witnessed an increasing trend (See Fig. 4)
- European countries account for over 96% of all reported real-life systems, where Germany takes the lead (See Fig. 5)

5. Conclusion

- While 5GDHCS is a promising technology, it is still in its early stage of development, marked by substantial research gaps in technical, policy, regulatory, and market aspects
- Analysis on real-life cases indicates a long way ahead to achieve its widespread deployment

6. Reference