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2. It will feature mid-day keynote addresses to bring together a global audience in a common time zone.

3. It will address the ideal climate and energy policy regime that should simultaneously respond to potentially conflicting objectives, especially in the era of COVID, ensuring energy security, promoting universal access to affordable energy services, and fostering greener and more sustainable energy systems while taking into account geopolitical and economic dimensions.

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News

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Capacity remuneration mechanisms in ... in this paper, we discuss the implementation...

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POTENTIAL OF EFFICIENT HEATING AND COOLING IN THE LIGHT OF DECARBONISATION TARGETS: THE CASE OF AUSTRIA

Lukas Kranzl, Richard Büchele, Mostafa Fallahnejad, Bernhard Felber, Jeton Hasani, TU Wien

Marcus Hummel, David Schmidinger, e-think

IAEE 8 June 2021
Motivation and research question

- Energy Efficiency Directive – Art 14: Promotion of efficiency in the supply of heating and cooling
- "Comprehensive assessment of the potential for an efficient heating and cooling supply" is to be carried out by Member States every 5 years (starting in 2015)
- Project on behalf of the Austrian Federal Ministry of Climate Action to fulfill the reporting obligation of Art. 14 & Annex VIII of the EED

Research questions

- What are economic potentials of efficient district heating (DH) supply in Austria by 2030 and 2050?
  - Which types of areas can/should be supplied by district heating?
  - What is an economically viable district heating supply mix in different types of district heating systems and in Austria in general?
  - What are drivers for the uptake of future district heating potentials?
Scope and system boundaries

- Focus on space heating and hot water preparation (industrial process heating only for consideration of industrial waste heat supply)

- „Efficient district heating“: according to the EED currently under revision => considered under the light of achieving climate targets

- The study assumes full climate neutrality of the Austrian energy system until 2040 in line with the current government programme and the European Green Deal.
Method

Step 1
• Survey of the status quo (heat demand and distribution, existing supply infrastructure, technologies and energy sources used)

Step 2
• Analysis of the potential of industrial waste heat for feeding into district heating networks

Step 3
• Identification of regions that could potentially be suitable for district heating (based on heat distribution costs).

Step 4
• Clustering of regions with similar characteristics (size, resource availability, and existing infrastructure).

Step 5
• Calculation of costs for heat supply (district heating supply and object-related supply).

Step 6
• Identification of the economic potential for efficient heat supply (comparison of costs for district heating and decentral supply).
Methodology for identifying economic potential of DH

**Approach**

**Step 1**

\[ K_{FW} = \Sigma (\ldots) \]

- CAPEX
- OPEX
- Energy
- CO\(_2\)

**Step 2**

- Within the region types
  - Similar supply option potentials
  - Similar size (DH potential)

**Step 3**

- For various scenarios
  - 2030/2050
  - Demand scenarios (saving scenarios)
  - DH connection rates
  - Energy and CO2 prices
  - Private and public points of views

**Step 4**

Comparison...

\[ K_{OE} = \Sigma (\ldots) \]

- CAPEX
- OPEX
- Energy
- CO\(_2\)
Step 1:
Identification of regions that could potentially be suitable for district heating
(based on heat distribution costs)
Step 1: Identification of regions that could potentially be suitable for district heating

**Scenarios of heat demand**

- **WEM** – With existing measures (includes already implemented measures, May 2016)
- **Transition Scenario** – a 80% reduction of CO2-Emissions till 2050 compared to 1990

Further assumptions for full decarbonisation of the gas supply to meet the objective of climate neutrality.
Step 1: Identification of regions that could potentially be suitable for district heating

Resulting regions

- Identified regions in the maximum scenario:

- Impact of different scenarios on the size of district heating areas:
Step 2:
Clustering of regions with similar characteristics (size, resource availability and existing infrastructure).
Clustering of potential district heating regions

- Individual consideration of the 4 major DH regions.
  - Types 1-4: Vienna, Graz, Linz, Salzburg

- Clustering of all other regions into 6 remaining district heating region types.
  - according to heat supply potentials (gas availability, geothermal potential, waste heat potential, river size)
  - and existing heat networks
Clustering of potential district heating regions

- Dendogram (right hand graph) shows the "distance" of regional clusters in terms of supply potentials and availability of a district heating grid.

- Horizontal line chosen for the choice of six regional clusters.

- Gas availability
- District heating grid
- Surface water
- Geothermal
- Waste heat (1)
- Waste heat (2)
Step 3:
Calculation of costs for heat supply
(District heat supply and individual, decentral supply)
The Objective function: \( \min(c_{total} - rev_{total}) \)

- Components of \( c_{total} \)
  - capital expenditures
    \[ \text{CAPEX} = \sum_j \text{Cap}_j \cdot i_j \cdot a_j + \sum_h \text{xCap}_{h,\text{fix}} \cdot \alpha_{h,\text{fix}} \]
    \[ a_{j,\text{fix}} = \frac{1 + x_i^{\alpha_{j,\text{fix}}}}{1 + x_i^{\beta_{j,\text{fix}}}} \]
  - Operational Fix Costs
    \[ O\text{PEX}_{\text{fix}} = \sum_j \text{Cap}_j \cdot \text{opex}_{\text{FIX}_j} + \sum_h \text{xCap}_{h,\text{fix}} \cdot \text{opex}_{\text{FIX}_{h,\text{fix}}} \]
  - Operational Costs
    \[ \text{OPEX} = \sum_{j,t} \text{xth}_{j,t} \cdot \left( \text{opex}_{\text{var}_j} + \frac{p_{\text{e},j,t}}{\eta_{h,j}} + \frac{f_{\text{em}_{\text{e},j,t}} \cdot p_{\text{e},j}}{\eta_{h,j}} \right) \]
    - ramp costs of CHP and waste incineration plants
    \[ \sum_{j,t} \left( x_{\text{th}_{j,t}} - x_{\text{th}_{j,t-1}} \right) \cdot 100 \cdot \frac{\text{€}}{\text{MW}_h} \left( x_{\text{th}_{j,t}} - x_{\text{th}_{j,t-1}} \right) > 0 \]
    \[ \forall j = \{ \text{CHP, waste treatment} \} \]
    \[ \forall t = [1,8760] \]
  - Components of \( rev_{total} \)
  - sale of electricity
    \[ \sum_{j,t} \text{xel}_{j,t} \cdot p_{\text{e},j,t} \]
Main Inputs
• Heat demand of the grid (selected region)
• Installed capacities of heat generators
• Energy carrier prices, €
• Load Profiles,
• Radiation Profiles
• Temperature Profiles
• Electricity Price Profiles

Main Outputs
• Heat generation costs
• Investment, operation and fuel costs
• Heat generation mix per heat generator
• CO2 Emissions.
• Full Load Hours, etc.
# Scenarios for district heating supply

<table>
<thead>
<tr>
<th>Scenario Type</th>
<th>No.</th>
<th>Description</th>
</tr>
</thead>
<tbody>
<tr>
<td><strong>Region types</strong></td>
<td>10</td>
<td>4 specific regions (Vienna, Graz, Linz, Salzburg)\n6 typical regions (demand / supply potential)\nFor each type of region::\n  • Temperatures (air, system, heat sources)\n  • Irradiation\n  • Load profile\n  • Resource availability</td>
</tr>
<tr>
<td>Year</td>
<td>2</td>
<td>2030 / 2050</td>
</tr>
<tr>
<td>Assessment method</td>
<td>2</td>
<td>Financial (BW) / economic(VW)</td>
</tr>
<tr>
<td>Heat demand</td>
<td>2-4</td>
<td>Two to four demands</td>
</tr>
<tr>
<td>Energy carrier and CO2 prices</td>
<td>2</td>
<td>Low vs. high prices</td>
</tr>
<tr>
<td>Technology Portfolios</td>
<td>3</td>
<td>A. predominately gas\nB. Gas with renewables and excess heat\nC. Predominantly renewables and excess heat, almost no gas</td>
</tr>
<tr>
<td><strong>Total</strong></td>
<td>480</td>
<td></td>
</tr>
</tbody>
</table>
## Characteristics of district heating generation portfolios
(with different characteristics in different types of regions and depending on the need to meet the needs)

<table>
<thead>
<tr>
<th>Installed capacities</th>
<th>Portfolio 1</th>
<th>Portfolio 2</th>
<th>Portfolio 3</th>
</tr>
</thead>
<tbody>
<tr>
<td><strong>Local resources</strong></td>
<td>Moderate-High</td>
<td>Moderate-High</td>
<td>High</td>
</tr>
<tr>
<td>(Geothermal, sewage HP, excess heat, Waste incineration plant, Solar-thermal)</td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td><strong>Biomass</strong></td>
<td>Moderate</td>
<td>Moderate</td>
<td>Moderate</td>
</tr>
<tr>
<td>(Boiler and CHP)</td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td><strong>Gas</strong></td>
<td>High</td>
<td>Moderate</td>
<td>Low</td>
</tr>
<tr>
<td>(Boiler and CHP)</td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td><strong>Air heat pump</strong></td>
<td>Low</td>
<td>Moderate</td>
<td>High</td>
</tr>
</tbody>
</table>
Share of green gas (synthetic gas & biogas) in the natural gas grid in 2030 at 6%, in 2050 at 100%.

2030 primarily biomethane in green gas,

2050 mainly H2 and PtG.

Assumptions on the mix and supply costs of green gas in 2030 and 2050.

<table>
<thead>
<tr>
<th>year</th>
<th>Assessment method</th>
<th>CO2 Price [EUR/tCO2]</th>
<th>Interest Rate [%]</th>
<th>Energy carrier prices include</th>
</tr>
</thead>
<tbody>
<tr>
<td>2030/2050</td>
<td>financial</td>
<td>81/183</td>
<td>7</td>
<td>✓</td>
</tr>
<tr>
<td></td>
<td>economic</td>
<td>300</td>
<td>3</td>
<td>×</td>
</tr>
</tbody>
</table>

Share Costs Share Costs
[EUR/MWh) [%] [EUR/MWh) [%]

Economic 300 3
Financial 81/183 7

VAT [\%]

Energy carrier prices include

Interest Rate [%] CO2 Price [EUR/tCO2]

Assessment method

2030/2050

Low Price

2030 2050
Share Costs Share Costs
[%] [EUR/MWh] [%] [EUR/MWh]
PtG 5% 150,0 40% 110,0
H2 15% 80,0 40% 70,0
Biomethane 80% 60,0 20% 80,0
Total 67,5 88,0

High Price

2030 2050
Share Costs Share Costs
[%] [EUR/MWh] [%] [EUR/MWh]
PtG 5% 210,0 40% 170,0
H2 15% 120,0 40% 100,0
Biomethane 80% 80,0 20% 100,0
Total 92,5 128,0
Results

Exemplary result of DH supply:

Cluster 7 (Regions with existing DH grids, gas infrastructure and high potential for river water source heat pump)

[Diagram showing the share in DH supply across different scenarios and portfolios for different years and demand scenarios.]
Step 4:
Identification of the economic potential for efficient heat supply.

(Comparison of costs for district heating and object-related supply).
Step 4: Identification of the economic potential for efficient heat supply

Methodology

Comparison ...

**KFW ... Cost of supply from district heating**
EUR/MWh]

**KDE ... Cost of decentralized supply**
EUR/MWh]

... for each district heating potential area

\[ K_{FW} < K_{DE} \] ... District heating is economical

\[ K_{FW} > K_{DE} \] ... District heating is not economical

... for each individual scenario

Total district heating potential [GWh/yr] in all areas where district heating is economic = Economic potential.

Sum of heat supply from the different technologies [GWh/yr] in all areas where district heating is economical = Economic potential per technology.
Comparison of the costs (LCOH) of decentral heat supply (red line) and the costs (LCOH) of district heating supply (boxplot) for different scenario variants in 2030, economic perspective.
Comparison of the costs (LCOH) of decentral heat supply (red line) and the costs (LCOH) of district heating supply (boxplot) for different scenario variants in 2050, economic perspective.

2050 - VW

<table>
<thead>
<tr>
<th>Transition</th>
<th>WEM</th>
</tr>
</thead>
<tbody>
<tr>
<td>LCOH District heating</td>
<td>LCOH individual heating</td>
</tr>
</tbody>
</table>

Max distribution costs [EUR/MWh]

Connection rate [%]

Prices

High prices

Low prices

High prices

Low prices
Results

Share of economic DH supply from total heat supply

2050, socio economic point of view

<table>
<thead>
<tr>
<th>Transition</th>
<th>WEM</th>
</tr>
</thead>
<tbody>
<tr>
<td>Useful energy demand, all buildings</td>
<td>Max distribution costs [EUR/MWh]</td>
</tr>
<tr>
<td>Useful energy demand, district heating potential</td>
<td>Connection rate [%]</td>
</tr>
</tbody>
</table>

High prices

Low prices
Result of heat supply 2050, socio economic point of view

- Biomass: still significant share; without high efficiency gains, increasing pressure on biomass resources
- Heat pumps: strongly increasing contribution also in district heating
- Geothermal energy is very relevant when available locally
- Large solar thermal systems: depending on size and remaining generation portfolio
Conclusion

- Assuming full decarbonization (gas from 100% green gas), gas is not a cost-effective option in the space heating sector (neither for district heating nor decentral).

- Based on our assumptions, gas-fired power plants will only have limited full-load hours by 2050. Thus, the role of CHPs for district heat supply will decrease. (However, the role of CHPs in the electricity system was not in our focus.)

- Thermal storage systems are becoming increasingly important (uncertainty regarding costs).

- Achievable connection rates have a major impact on the economic potential of district heating.

- The heat demand scenarios have less of an impact on the district heating potential than the achievable connection rates.
Limitations and uncertainties

- Possible cost development (including the locally existing site-specific conditions, which can lead to deviations in terms of costs), especially regarding large-scale thermal storage, solar thermal energy, costs for required land as well as deep geothermal (and the associated risks in the development).

- Technological developments and the efficiencies and corresponding technology characteristics to be expected in the future.

- Expected heat demand in district heating grids strongly depends on building renovation measures as well as on the achievable connection rates.

- Since these factors cannot be predicted in the long term, a continuously adapting planning process is required, both on the part of the heating network operators and on the part of policymakers.
Thank you!

lukas.kranzl@tuwien.ac.at