USING INDUSTRIAL EXCESS HEAT IN DISTRICT HEATING NETWORKS:
A SIMULATION ASSESSMENT OF POTENTIALS AND COST-EFFECTIVENESS FOR A REFINERY IN PORTUGAL

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Using excess heat from refineries seems viable.

Selected refineries providing excess heat to nearby district heating:

<table>
<thead>
<tr>
<th>Refinery</th>
<th>Location</th>
<th>Installed capacity [MW]</th>
<th>Total delivered heat [GWh]</th>
<th>Share of DH heat [%]</th>
</tr>
</thead>
<tbody>
<tr>
<td>MiRO</td>
<td>Karlsruhe, Germany</td>
<td>90</td>
<td>520</td>
<td>50%</td>
</tr>
<tr>
<td>OMV Schwechat</td>
<td>Vienna, Austria</td>
<td>170</td>
<td>500-600</td>
<td>10%</td>
</tr>
<tr>
<td>Preem and Shell</td>
<td>Gothenburg, Sweden</td>
<td>85 + 60</td>
<td>1100</td>
<td>30%</td>
</tr>
<tr>
<td>Shell</td>
<td>Fredericia, Denmark</td>
<td>55</td>
<td>510</td>
<td>26%</td>
</tr>
</tbody>
</table>

Refinery Karlsruhe
- Largest refinery in Germany: ~15 million tonnes of mineral oil products
- 5 km pipe to connect to existing DH
- Construction in 2010 and 2015
- Investment: 54 million, of which 5 million Euros support by Government
Research question

- Assess economic and technical feasibility to decarbonize H&C supply in the focus area comparing alternative options
  - Using solar thermal, heat pumps, photovoltaics and/or biomass?
  - Using excess heat from nearby oil refinery via a DHC network?

Methodology

- Techno-Economic energy systems modeling with hourly time resolution for demand and supply
- Using tool Energy Pro
- Two perspectives distinguished:
  1. (Simple) socio economic perspective (1.5% discount rate, no excess heat price)
  2. and private economic perspective (7% discount rate, excess heat price)
- Inclusion of local stakeholders was planned and partly achieved (work together with local energy consulting company INEGI)
Matosinhos
- North of Portugal at the coast near Porto
- ~175,000 inhabitants
- No DHC infrastructure in the city and surroundings

Focus area
- Shopping mall and large stores
  - Individual gas boilers + compression chillers
  - Demand for cooling three times higher than heating
- Residential area under construction
- Refinery as potential excess heat source

Energy demand in focus area
- Cooling: 28 GWh/a
- Heating: 15 GWh/a
- Both included on hourly basis
Assumptions
## Scenario set-up: supply options

### H&C supply scenarios defined

<table>
<thead>
<tr>
<th>Scenario</th>
<th>Heating source</th>
<th>Cooling source</th>
<th>Electricity source</th>
<th>District H&amp;C network?</th>
</tr>
</thead>
<tbody>
<tr>
<td>1. Status Quo</td>
<td>Natural gas boiler</td>
<td>Compression chiller</td>
<td>Grid</td>
<td>-</td>
</tr>
<tr>
<td>2. Status Quo (incl. Capital Costs)</td>
<td>Natural gas boiler</td>
<td>Compression chiller</td>
<td>Grid</td>
<td>-</td>
</tr>
<tr>
<td>3. Status Quo with solar thermal</td>
<td>Natural gas boiler</td>
<td>Compression chiller</td>
<td>Grid</td>
<td>-</td>
</tr>
<tr>
<td>4. Heat pump</td>
<td>Heat pump (air-source)</td>
<td>Compression chiller</td>
<td>Grid</td>
<td>-</td>
</tr>
<tr>
<td>5. Heat pump with PV</td>
<td>Heat pump (air-source)</td>
<td>Compression chiller</td>
<td>Photovoltaic +</td>
<td>-</td>
</tr>
<tr>
<td>6. Heat pump with solar thermal</td>
<td>Heat pump (air-source) and solar thermal</td>
<td>Compression chiller</td>
<td>Grid</td>
<td>-</td>
</tr>
<tr>
<td>7. Heat pump + solar thermal and PV</td>
<td>Heat pump (air-source) and solar thermal</td>
<td>Compression chiller</td>
<td>Photovoltaic</td>
<td>-</td>
</tr>
<tr>
<td>8. Refinery waste heat</td>
<td>Waste heat</td>
<td>Absorption chiller</td>
<td>Grid</td>
<td>yes</td>
</tr>
<tr>
<td>9. Biomass trigeneration</td>
<td>Biomass CHP</td>
<td>Absorption chiller</td>
<td>Own</td>
<td>yes</td>
</tr>
</tbody>
</table>
• **Estimated excess heat potential**
  – *Estimated based on refinery publications, literature and comparison to other refineries*
  – Refinery energy consumption for heating estimated: ~ 2,500 GWh/a
  – Excess heat used from several sources:
    – Flue gas: ~30 GWh/a)
    – Heat exchanger
    – Hot water from coolers: ~40 GWh/a
      – Absorption chiller with 90°C at generator and 20°C at condenser (sea water)
    – Total: 70 TWh (+3%) -> Much more heat is available...

• **Costs DHC network**
  – Heating network: 600 EUR/m (diameter 120 mm)
  – Cooling network: 1500 EUR/m (diameter 500 mm)
  – Trench Length: ~5 km
  – Lifetime: 30 years
### Techno-economic technology data

<table>
<thead>
<tr>
<th>Technology Type</th>
<th>Natural gas boiler</th>
<th>Compression chiller</th>
<th>Flat plate solar collector</th>
<th>Air source heat pump</th>
</tr>
</thead>
</table>

<table>
<thead>
<tr>
<th>Technology Type</th>
<th>Photovoltaic</th>
<th>Shell and tube heat exchanger</th>
<th>Absorption Chiller</th>
<th>Biomass CHP</th>
</tr>
</thead>
<tbody>
<tr>
<td>Fixed O&amp;M</td>
<td>0.5 - 1% of Inv.[13]</td>
<td>**1.5% of Inv.[14]</td>
<td>***4% of Inv. [3]</td>
<td>4.5% of Inv.[19]</td>
</tr>
</tbody>
</table>

*Project Costs Factor for additional equipment = 3.5 [15]*
** Assumptions based on [3,14]*
*** Project Costs Factor for additional equipment = 2.5 [15]*
****Performance ratio = 0.84 [13]*
Results for

1. (simple) socio economic perspective
   (1.5% discount rate, no price for excess heat)
2. private economic perspective
   (7% discount rate, 15 euros/MWh price for excess heat)
Results for socio-economic perspective
(1.5% interest rate, excess heat price 0 euros/MWh)

CO2 savings and Levelised cost for heating and cooling by supply option

- Status quo
- Status quo (incl. capital cost)
- Status quo + solar thermal
- Heat pump
- Heat pump + PV
- Heat pump + solar thermal
- Refinery waste heat

- CO2 emissions [t CO2/a]
- LCOH Heating [eur/MWh]
- LCOH Cooling [eur/MWh]
Results: Private economic perspective
(7% interest rate, excess heat price 15 euro/MWh)

Heat supply and achieved CO2 reduction
Results: Private economic perspective
(7% interest rate, excess heat price 15 euro/MWh)

Levelised cost for heating and cooling by supply option

![Chart showing levelized costs for different supply options.](chart-image)
Conclusions

• **Excess heat cost-effectiveness**
  • Potential is sufficient to supply all buildings within the scope
  • From socio-economic perspective the LCOH for excess heat use are cheapest, even cheaper than status-quo only running cost
  • From private economic perspective, the excess heat use is cheaper than HP+PV and status-quo (incl. capital cost), but more expensive than status-quo without capital costs
  • Considering the depreciated capital costs of the existing system might result in comparable costs as the use of excess heat

• **Policy recommendations**
  • Policies are needed to make the use of excess heat also profitable from a private economic perspective to reflect the benefits seen at the socio-economic perspective
  • Using excess heat from the refinery as door-opener for building a DHC grid that can in the future be extended by other RES
Thank you for your attention!

Next: Webinar on estimating and mapping excess heat potentials (September 29, 10am)

http://www.progressheat.eu/

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<table>
<thead>
<tr>
<th>Energy carrier</th>
<th>Price for 2015 (incl. tax, no VAT)</th>
<th>Price for 2030 (incl. tax, no VAT)</th>
<th>Price for 2050 (incl. tax, no VAT)</th>
</tr>
</thead>
<tbody>
<tr>
<td>Natural gas</td>
<td>60</td>
<td>72</td>
<td>77</td>
</tr>
<tr>
<td>Electricity</td>
<td>115</td>
<td>128</td>
<td>101</td>
</tr>
<tr>
<td>Decentral PV LCOE</td>
<td>126</td>
<td>98</td>
<td>78</td>
</tr>
<tr>
<td>Excess heat</td>
<td>0/15</td>
<td>0/15</td>
<td>0/15</td>
</tr>
</tbody>
</table>