Tri-generation concepts
31.01.2020, Workshop

Tri-generation concepts: A lab-facility for combined heat, power and cooling generation

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Outline

- Introduction/Overview on Demand
- Combined cooling heating power systems
- Lab-facility at HS-Koblenz
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CHP-Plants > 50 MW
in Germany in 2019
(quantity of existing CHP-plants in different size categories Germany 2015 - 2017)

Installed power: 4 GW
**Comparison of efficiencies depending on power range**

<table>
<thead>
<tr>
<th></th>
<th>elektrische Nutzenergie</th>
<th>Nutzwärme aus Motorkühlung</th>
<th>Nutzwärme aus Abgas</th>
<th>Verluste</th>
</tr>
</thead>
<tbody>
<tr>
<td>Gasmotor 140 kW</td>
<td>36</td>
<td>33</td>
<td>22</td>
<td>9</td>
</tr>
<tr>
<td>Gasmotor 3.4 MW</td>
<td>44</td>
<td>22</td>
<td>21</td>
<td>13</td>
</tr>
<tr>
<td>Gasturbine 200 kW</td>
<td>19</td>
<td>56</td>
<td>25</td>
<td></td>
</tr>
<tr>
<td>Gasturbine 5.5 MW</td>
<td>31</td>
<td>49</td>
<td>20</td>
<td></td>
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<tr>
<td>Kohlekraftwerk</td>
<td>36</td>
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</tbody>
</table>

Energieanteile in %

[www.asue.de]
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Share of power generation by CHP in Germany 2003 to 2018
Power generation by CHP in Germany 2003 to 2018

Nettostromerzeugung mit Kraft-Wärme-Kopplung (KWK)
Vergleich der Entwicklung der KWK-Nettostromerzeugung mit den Zielen der Bundesregierung*

[Statistisches Bundesamt; Ökoinstitut, Umweltbundesamt 11/2017]
Total final energy in 2015 (EU28)

H&C final energy by end-use in 2015 (EU28)
Zoom into the *industrial* sector

- **Process cooling (0-15°C)**: 2%
- **Process cooling (<-30°C)**: 1%
- **Process cooling (<-30°C)**: 1%
- **Space cooling**: 1%
- **Space heating**: 14%
- **Process heating (100-200°C)**: 21%
- **Process heating (>500°C)**: 42%
- **Process heating (200-500°C)**: 9%

**54% of industrial H&C demand**
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Consumption for cooling by countries in EUROPE

Electricity consumption for cooling by country

- **Process cooling**
- **Space cooling**
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Non natural gas usage / germany

![Electric energy output from biogas in Germany from 2000 to 2018](image)

landfill, sewage and mine gas: => 394,2 MW (0,182 % of installed power in Germany)

but biogas production is different:

production in 2018 represents 5,9 % of the overall production of electricity or 30,5 % of the share of CHP-Power Plants

[AGEE-Stat, Statista 2019]
Main Applications of natural Gas Engines:
- base load, medium load and peak load power plants
- green house
- emergency power systems

Standard Design Criteria:

- full load working hours > 4500 h resulting from a duration curve
- Power range of engines 50% up to full load
- Launching requirements
- Suitable for low voltage 400 V up to 10 kV or 30 kV
- Exhaust gas limitation depending on application

[AGEE-Stat, Statista 2019]
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Combined Cooling Heating Power Systems/Plants

low temperature waste heat from mixture cooling
High temperature heat pumps – possible applications

- heat recovery from exhaust gas and mixture cooling
- increase district heating, district boost
- primary control power, PtH

[Prospekt – Industriewärmepumpen; Ochsner Energietechnik, 2020]
High temperature heat pumps – integration in CHP

Additional $P_{th}$ from waste heat:
- Exhaust gas: 6%
- Mixture cooler: 3-4%
Load simulation with a HT-heatpump
List of components of all project partners

- 2x heat pumps (one reversible)
- 3x adsorption chiller
- 3x CHP (e.g. stirling engine)
- 1x solar heating system
- serveral heat and cold storages and more ...
Lab-facility at HS-Koblenz

- pipes to dry cooler (outside)
- cold water storage (1 m³)
- adsorption chiller (10 kWth)
- stirling engine (CHP, 0.8 kWel, 7 kWth)
- hot water storage (1 m³)
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Lab-facility at HS-Koblenz

Vereinfachtes Fließschema des Labors

- Cold storage
- Adsorption chiller
- Heat storage
- Electrical flow heater
- Stirling engine
- Dry cooler
- Fuel
- Electricity
Examination aims

- optimal design of storage size
- part load behaviour and control of pumps, temperature levels of heat exchangers

Optimization of

- cost,
- primary energy,
- or emissions
Thank you for your attention!