Experiences with Micro-Cogeneration in Residential Buildings in Germany

Workshop
"Building Integration of Micro-Generation Technologies"

NIST, October 27th 2010, Gaithersburg USA

Peter Tzscheutschler
Institute for Energy Economy and Application Technology
Technische Universität München
Outline

• Studied Systems

• Lab tests at TUM
  • System Integration
  • Results
  • Energy, CO₂ savings

• Field tests in southern Bavaria
  • System Integration
  • Results
Hydraulic Scheme
- Example Senertec Dachs

Thermal energy
Fuel energy
CoGen unit, peak boiler outlet
CoGen unit, peak boiler return
Heating circuit and hot water system outlet
Heating circuit and hot water system return
Natural gas supply
B1-B5 Balance Areas
Installed Systems

Senertec Dachs
5,5 kWh_{el},
14,0 kWh_{th}

Solo Stirling Mod. 161
7,5 kWh_{el},
22,0 kWh_{th}

Vaillant ecoPower
4,7 kWh_{el},
12,5 kWh_{th}
+ aux. burner

Remeha eVita
1,0 kWh_{el},
5,0 kWh_{th}

OTAG Lion PB
2,2 kWh_{el},
18,0 kWh_{th}
Test Bench at TUM

- Close to reality experiments
- Reproducible conditions
- Acquisition of all relevant parameters
- Application of type-days
  - summer
  - transition
  - winter
Results of Type Day Measurements

**ecoPower**

- [kWh/d]
- Winter clear
- Winter cloudy
- Transition cloudy
- Transition clear
- Summer

**Solo Stirling**

- [kWh/d]
- Winter clear
- Winter cloudy
- Transition cloudy
- Transition clear
- Summer

**Dachs**

- [kWh/d]
- Winter clear
- Winter cloudy
- Transition cloudy
- Transition clear
- Summer

- Losses peak boiler
- Losses CHP unit
- Electricity generation CHP unit
- Heat production peak boiler
- Heat production CHP unit
- Heating Circuit
- Hot water system

Corrected from influence of test stand
Duration Curve of Demand and Generation

- Heat demand (77,0 MWh)
- Gas consumption (111,2 MWh)
- Losses (8,5 MWh)
- CHP thermal (62,7 MWh)
- CHP electrical (25,6 MWh)
- Peak boiler (14,3 MWh)

Outdoor temperature
[kWh/d] - [°C]
CO₂-Emissions

![Bar chart showing CO₂ emissions for different heating systems.](chart)

- Heating boiler MFH 10: -25.3%
- ICE 1 MFH 10: -31.3%
- ICE 2 MFH 10: -21.8%
- FC Prototype MFH 10: -24.0%

**Spec. CO₂-emissions [kg/(m²a)]**

- Heating boiler MFH 10: 620 g₂₃₀/kWh₂₃₀
- ICE 1 MFH 10: 230 g₂₃₀/kWh₂₃₀

Institute für Energy Economy and Application Technology
Prof. Dr.-Ing. U. Wagner, Prof. Dr. rer. nat. Th. Hamacher

Technische Universität München
Field Testing Campaign

Remeha eVita

1,0 kWh_{el}, 5,0 kWh_{th} + aux. burner
Some words on the Set up

• Cooperation with local gas utility

• Field trial was announced in newspapers
  -> 1,200 applications
  -> 800 met the parameters

• 4 were chosen
  • Systems were given for free
  • except a contribution of 1,500 € for the installation

• TUM integrated measuring equipment
  • all relevant parameters
  • remote access via internet
System Integration

A: Combined Storage

B: DHW Storage
µCHP Operation during a Winter Day

Consumption/Output [kW]

Gas Consumption
CHP th. output
CHP el. output

Output [kW]

Heating
Hot water
Circulation

Time
µCHP Usage on a Winter Day

µCHP unit
- 81% thermal efficiency
- 10% electrical efficiency
- 91% total efficiency

Total System
- 71% thermal efficiency
- 10% electrical efficiency
- 81% total efficiency

Diagram:
- µCHP unit: 109 kWh
- µCHP losses: 9.8 kWh
- Thermal storage: 5.9 kWh
- Circulation losses: 5.3 kWh
- Gas: 88.6 kWh
- Heating: 61.2 kWh
- DHW: 16.2 kWh
- Electrical: 10.6 kWh
- DHW: 5.3 kWh
- Heating: 16.2 kWh
- Electrical: 10.6 kWh
## Results of Field Tests

<table>
<thead>
<tr>
<th></th>
<th>System 1*</th>
<th>System 2</th>
<th>System 3</th>
<th>System 4</th>
</tr>
</thead>
<tbody>
<tr>
<td>Time period [h]</td>
<td>2,124</td>
<td>4,342</td>
<td>4,388</td>
<td>4,363</td>
</tr>
<tr>
<td>Gas Consumption [kWh]</td>
<td>3,920</td>
<td>21,938</td>
<td>17,335</td>
<td>17,582</td>
</tr>
<tr>
<td>El. Generation [kWh]</td>
<td>282</td>
<td>2,288</td>
<td>1,726</td>
<td>1,944</td>
</tr>
<tr>
<td>Heat output [kWh]</td>
<td>3,215</td>
<td>18,576</td>
<td>14,041</td>
<td>14,001</td>
</tr>
<tr>
<td>Electrical efficiency**</td>
<td>-</td>
<td>7%</td>
<td>10%</td>
<td>10%</td>
</tr>
<tr>
<td>Thermal efficiency</td>
<td>-</td>
<td>82%</td>
<td>85%</td>
<td>81%</td>
</tr>
<tr>
<td>Total efficiency</td>
<td>-</td>
<td>89%</td>
<td>95%</td>
<td>91%</td>
</tr>
<tr>
<td>On-Site use</td>
<td>-</td>
<td>71%</td>
<td>61%</td>
<td>34%</td>
</tr>
</tbody>
</table>

* short runtime due to technical problems
** related to total gas consumption, incl. aux. burner

- Systems working very reliable
- Operation can be optimized
Short Summary

• People are very interested in producing their own electricity

• µCHP systems are highly efficient

• Systems are (so far) very reliable

• Potential for optimization of control strategies
Thank you for your Attention