3rd International Conference on Smart Energy Systems and 4th Generation District Heating

Copenhagen, 12–13 September 2017

Aalborg University
Denmark
Assessment of primary energy savings through implementation of solar and heat pump hybrid in Warsaw district heating system

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Department of Distributed Energy
Institute of Heat Engineering, Warsaw University of Technology

COPENHAGEN, 13 SEPTEMBER 2017
Project SUPREME

SUPREME – Twinning for a sustainable, proactive research partnership in distributed Energy systems planning, modeling and management

UNIVERSITY OF TWENTE.

IMP PAN

AALBORG UNIVERSITY DENMARK

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www.4dh.eu  www.reinvestproject.eu  www.heatroadmap.eu
Agenda

1. Problems to be solved
2. Proposed solutions
3. Warsaw DHS
4. Laboratory installation
5. Measurement
6. TRNSYS Model
7. Results & Discussion
8. Conclusions
Problems

1. Too high primary energy usage

2. Smog

3. ... and many others
Energy production in Poland

Electricity generation in Poland by source

Location of newly-created energy blocks

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www.4dh.eu  www.reinvestproject.eu  www.heatroadmap.eu
Smog

http://media.philstar.com  www.crazynauka.pl
Solution

Hybrid system – combination of PV/T & HP
Solution

Hybrid system – combination of PV/T & HP

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www.4dh.eu    www.reinvestproject.eu    www.heatroadmap.eu
Prosumer opportunities
Warsaw district heating system

www.warszawskiecieplo.pl
WUT – Energy system
Energy system – Energy sources

Heat Pump SWC 230 – B0W35 22,1 kW COP 4,5
Heat Pump LWA 120 – A7W35 12,5 kW COP 3,9
DHS Compact C.H. 150 kW

Soil U-tube 3 units, double U-tube 1 unit, coaxial pipe 1 unit, 100m deep each; one spiral HE in foundations

Plate Collectors Watt 3000S 523 kWh/a 5 units
Evacuated Collectors Watt CPC 9 524 kWh/a 4 units
Hybrid PV Modules Sanyo HIT 240 HDE-4 240 Wp 5 units
Policrystaline PV Modules IBC PolySol 200VG 200 Wp 5 units
Amorphous PV Modules Sulfurcell SCG 60 HV F 60 Wp 5 units
PV/T Module Sensol EPVT 2.0 300 Wp 1 unit

www.4dh.eu  www.reinvestproject.eu  www.heatroadmap.eu
Measurements - PV/T module characteristics

Electric power vs temperature of the module

\[ P = 296,644.76 - 0.0033 \times T \]
\[ \Delta T = 43.76 \, \text{K} \]

14.8% decrease

12.6% decrease
Measurements - PV/T module characteristics

PV/T as a solar collector

<table>
<thead>
<tr>
<th>Thermal Power [W]</th>
<th>(Tav-Ta)/G</th>
<th>A [m²]</th>
<th>a₁ [W/m²]</th>
<th>a₂ [W/m²K²]</th>
</tr>
</thead>
<tbody>
<tr>
<td>982.66</td>
<td>0.0000</td>
<td>2.02</td>
<td>9,547</td>
<td>1,389</td>
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<tr>
<td>822.48</td>
<td>0.0005</td>
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<tr>
<td>672.05</td>
<td>0.0100</td>
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<tr>
<td>561.70</td>
<td>0.0150</td>
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<td></td>
<td></td>
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<tr>
<td>26,29%</td>
<td>0.0200</td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>367.06</td>
<td>0.0250</td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>5,93%</td>
<td>0.0300</td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>124.86</td>
<td>0.0350</td>
<td></td>
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</tr>
<tr>
<td>46,64%</td>
<td>0.0400</td>
<td></td>
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</table>
Solar regeneration parameters
Solar regeneration parameters
Cases

Domestic Hot Water purposes
1. PVT+DHW+REG+HP
2. DHW+REG+HP
3. PVT+DHW+HP
4. DHW+HP
5. PVT+REG+HP
6. REG+HP
7. PVT+HP
8. HP

Heating purposes
1. PVT+DHW+REG+HP+DHS
2. DHS
Primary Energy

\[ E_p = w_i \times E_n \]

\[ w_{i-HP} = 3 \]
\[ w_{i-DHS} = 0,68 \]

SPF > 4,41
Results – DHW purposes

Primary energy [kWh]

<table>
<thead>
<tr>
<th>Purpose</th>
<th>SPF</th>
</tr>
</thead>
<tbody>
<tr>
<td>1. PVT+DHW+REG+HP</td>
<td>4.21</td>
</tr>
<tr>
<td>2. DHW+REG+HP</td>
<td>4.17</td>
</tr>
<tr>
<td>3. PVT+DHW+HP</td>
<td>4.27</td>
</tr>
<tr>
<td>4. DHW+HP</td>
<td></td>
</tr>
<tr>
<td>5. PVT+REG+HP</td>
<td></td>
</tr>
<tr>
<td>6. REG+HP</td>
<td></td>
</tr>
<tr>
<td>7. PVT+HP</td>
<td></td>
</tr>
<tr>
<td>8. HP</td>
<td></td>
</tr>
</tbody>
</table>

Domestic Hot Water purposes
1. PVT+DHW+REG+HP
2. DHW+REG+HP
3. PVT+DHW+HP
4. DHW+HP
5. PVT+REG+HP
6. REG+HP
7. PVT+HP
8. HP
Results

Primary energy consumption without assumption of the el. en. from PV/T [kWh]

<p>| | | | | | |</p>
<table>
<thead>
<tr>
<th></th>
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<th></th>
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<th></th>
<th></th>
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</thead>
<tbody>
<tr>
<td>1</td>
<td>1616.24</td>
<td>2. DHW+REG+HP</td>
<td>5</td>
<td>1814.09</td>
<td>7</td>
</tr>
<tr>
<td>3</td>
<td>1433.81</td>
<td>6. PVT+REG+HP</td>
<td>7</td>
<td>1712.55</td>
<td></td>
</tr>
<tr>
<td>5</td>
<td>1814.09</td>
<td>7. PVT+HP</td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>7</td>
<td>2073.44</td>
<td>8. HP</td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>DHS</td>
<td>1712.55</td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
</tbody>
</table>

Domestic Hot Water purposes
1. PVT+DHW+REG+HP
2. DHW+REG+HP
3. PVT+DHW+HP
4. DHW+HP
5. PVT+REG+HP
6. REG+HP
7. PVT+HP
8. HP
Results

Gain from better PV cooling – 3.87%

Domestic Hot Water purposes
1. PVT+DHW+REG+HP
2. DHW+REG+HP
3. PVT+DHW+HP
4. DHW+HP
5. PVT+REG+HP
6. REG+HP
7. PVT+HP
8. HP
Results

HP electric energy load [kWh]

SPF

Domestic Hot Water purposes
1. PVT+DHW+REG+HP
2. DHW+REG+HP
3. PVT+DHW+HP
4. DHW+HP
5. PVT+REG+HP
6. REG+HP
7. PVT+HP
8. HP

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Parallel system

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Parallel system

Primary energy for heating purposes [kWh]

<table>
<thead>
<tr>
<th>Heating purposes</th>
<th>HP+DHS</th>
<th>DHS</th>
</tr>
</thead>
<tbody>
<tr>
<td>1. PVT+DHW+REG+HP+DHS</td>
<td>15195.94</td>
<td>17695.37</td>
</tr>
<tr>
<td>2. DHS</td>
<td></td>
<td></td>
</tr>
</tbody>
</table>

SPF = 5.05

$\Delta E_p = 2499.44 \text{ kWh}$

$e_{CO_2} = 854.8 \text{ kg CO}_2$
Conclusions

• Solar PV/T regeneration of the HP lower source improvement the SPF
• but without the Solar DHW mode it is not sufficient for decreasing the Ep consumption for DHW needs
• Hybrid based on the PV/T & HP can be competitive to DHS for DHW purposes with and without green el. en.
• Solar DHS mode gives greater reduction in primary energy use than Regeneration mode
• Cooling the PV/T by Regeneration system didn’t increase the electric efficiency significantly
• For longer periods of constant operation HP achieve SPF sufficient to be competitive to DHS without the el. en. from PV/T taken into consideration.
Further works

- Long time complex measurements
- Improvements in house heating simulations
- Validation of the model
- Optimization of the modeled system
- System proposal for the average single – family house from the suburbs
- Comparison with biomass boilers
Thank you for your attention!

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