Development of heat saving platform in the system dynamics model for transition to 4th generation district heating

M.sc.ing., researcher Jelena Ziemele,
B.sc. Armands Gravelsins,
Dr.sc.ing. Andra Blumberga
Dr.hab.sc.ing., Professor Dagnija Blumberga
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To evaluate by use of system dynamics model the impact of energy conservation measures for reaching 4th generation DH system
Current Situation in the Latvian District heating (heat sources)

Share of fuels in Latvian DH

Heat energy share produced in CHP and boiler house

- Fossil fuel
- Renewable fuel

Heat energy share produced in boiler house, %
Heat energy share produced in CHP, %

Current Situation in the Latvian District heating (heat networks and end users)

Specific heat energy consumption for space heating, kWh/m²

Heat losses in DH networks, %

Average heat energy losses in DH systems for several Latvian region

<table>
<thead>
<tr>
<th>Year</th>
<th>Riga region</th>
<th>Pieriga region</th>
<th>Vidzeme region</th>
<th>Kurzeme region</th>
<th>Zemgale region</th>
<th>Latgale region</th>
<th>Average at Latvia</th>
</tr>
</thead>
<tbody>
<tr>
<td>2011</td>
<td>14.3</td>
<td>13.8</td>
<td>13.1</td>
<td>13.8</td>
<td>13.1</td>
<td>13.1</td>
<td></td>
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<tr>
<td>2013</td>
<td>13.8</td>
<td>13.8</td>
<td>13.1</td>
<td>13.8</td>
<td>13.1</td>
<td>13.1</td>
<td></td>
</tr>
</tbody>
</table>

Creation of dynamic hypotheses

The diffusion of 4GDH concept within traditional DH:

- Efficiency measure in heat source, renewable energy technology;
- Low temperature heat network;
- Efficiency measure by consumers, Low energy consumers

Causal loop diagram representing the relationships between the total capacity of installations and investment and depreciation flows *

**“System Dynamics” edited by A.Blumberga, RTU, 2011**
Causal loop

Heat tariff of fossil fuel

Heat consumption decrease

Heat losses decrease

Low temperature network

Energy conservation measures in buildings

New technology inconvenience cost

Access to finance

Energy efficiency requirements in legislation

Standards and normative

Investment in renewable energy technologies

Investment in fossil fuel technologies

The share of fossil fuel technology

The share of renewable energy sources

Heat tariff of renewable energy sources decrease

Heat consumption decrease

Heat losses decrease

Low temperature network

Energy conservation measures in buildings

New technology inconvenience cost

Access to finance

Energy efficiency requirements in legislation

Standards and normative
System dynamics model structure

Heat sources part

Heat consumers

Heat transmission part

Efficiency platform

Heat network regime: Low-temperature 60/30

Three policy instruments:
1. Subsidies
2. Risk reduction
3. Efficient improvement
1. Technology Database
2. Statistical Database
3. Data of heat sources
4. Data of heat network
5. Data of heat consumers
6. Assumption
7. Definition of independent variables
8. Regression function determination for independent variables
9. Efficiency Platform
10. Creating a dynamic hypothesis
11. Model formulation and simulation
12. Model testing
13. Historical data validation and evaluation
14. Scenarios simulation
15. Refine the model
16. Expert evaluation of simulation results
17. Expert workshop and system improvement
18. Additional economic indicators assessment for scenarios
19. DH companies development strategies

Conceptual scheme of methodology
## Description of Scenarios

<table>
<thead>
<tr>
<th>Scenario</th>
<th>Resulting U-value (W/(m·K))</th>
<th>Technology life time (years)</th>
<th>Policy instruments</th>
</tr>
</thead>
<tbody>
<tr>
<td></td>
<td>Wall, Floor, Roof</td>
<td></td>
<td>Subsidies</td>
</tr>
<tr>
<td></td>
<td>Window, Ventilation</td>
<td></td>
<td></td>
</tr>
<tr>
<td></td>
<td>Industrial area*</td>
<td></td>
<td></td>
</tr>
<tr>
<td>Base scenario (BSc)</td>
<td>1.07; 0.82; 0.42</td>
<td>NG-25; S-20; B-25; HP-20</td>
<td>0</td>
</tr>
<tr>
<td>Scenario 1(Sc1)</td>
<td>0.19; 0.22; 0.15</td>
<td>NG-20; S-20; B-20; HP-20</td>
<td>0</td>
</tr>
<tr>
<td>Scenario 2(Sc2)</td>
<td>0.15; 0.22; 0.11</td>
<td>NG-15; S-20; B-15; HP-20</td>
<td>0</td>
</tr>
<tr>
<td>Scenario 2P(Sc2P)</td>
<td>0.15; 0.22; 0.11</td>
<td>NG-15; S-20; B-15; HP-20</td>
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<tr>
<td>Scenario 3(Sc3)</td>
<td>0.08; 0.22; 0.09</td>
<td>NG-10; S-20; B-10; HP-20</td>
<td>0</td>
</tr>
<tr>
<td>Scenario 3P(Sc3P)</td>
<td>0.08; 0.22; 0.09</td>
<td>NG-10; S-20; B-10; HP-20</td>
<td>1</td>
</tr>
</tbody>
</table>

NG – natural gas HOB; B – biomass HOB; S- solar collector; HP – heat pump; 1- activ; 0- non activ ; HOB – heat only boiler
Energy consumption analysis.
Low temperature benchmarking

Specific heat energy consumption, kWh/m² per year

- Apartment buildings
- Industrial area

<table>
<thead>
<tr>
<th>Scenario</th>
<th>Specific heat energy consumption</th>
</tr>
</thead>
<tbody>
<tr>
<td>BSc</td>
<td>187.00</td>
</tr>
<tr>
<td>Sc 1</td>
<td>139.07</td>
</tr>
<tr>
<td>Sc 2</td>
<td>95.40</td>
</tr>
<tr>
<td>Sc 3</td>
<td>60.50</td>
</tr>
</tbody>
</table>

Specific heat energy consumption of apartment buildings

Specific heat energy consumption of industrial area

- Low temperature level benchmark

2nd International Conference on Smart Energy Systems and

AALBORG UNIVERSITY
DENMARK
Impact of energy efficiency measures for reaching 4th generation DH system

Heat energy production share, %

Short term perspective

Long term perspective

- Base sc. NG
- Sc. 2 NG

Base sc. Solar
Sc. 2 Solar

-Base sc. Biomass
Sc. 2 Biomass

2015 2020 2025 2030 2035 2040 2045 2050

2nd International Conference on Smart Energy Systems and
Economic feasibility of energy conservation measures by heat sources and consumers

Investment for project, Euro

Specific heat consumption for apartment building area, kWh/m²

Investment by heat source side, EUR
Investment by consumers side, EUR
Conclusions

1. Implementation of energy conservation measures influence transition of DH system to 4\textsuperscript{th} generation. For the analysed case the low temperature benchmark was at 0.63 from produced energy at the base scenario.

2. The modeled scenarios show that the pace of 4GDH implementation depends on the policies used by each country. Subsidies are the most effective mechanisms for transition toward 4GDH.

3. The developed system dynamic model with efficiency platform could be applied to other heating systems if corresponding initial data are added.

4. The optimal development scenario depends on efficiency measures which are implemented at consumers and/or producers, and the integrated effect of these measures. This optimum can be identified through economic feasibility assessment.
Additional information:

M.sc.ing.Jelena Ziemele
jelena.ziemele@rtu.lv
Economic feasibility of energy efficiency measures by heat sources and consumers

Internal rate of return (IRR), %

Sc 1

Sc 2

Sc 3

-5 0 5 10 15 20 25 30

Project by heat source (r=10%)

Project by heat source (r=7%)

Project by heat source (r=3.5)

Project by heat consumers (r=10%)

Project by heat consumers (r=7%)

Project by heat consumers (r=3.5)
## Choice of model indicators

<table>
<thead>
<tr>
<th>Heat sources</th>
<th>Heat network</th>
<th>Heat consumers</th>
</tr>
</thead>
<tbody>
<tr>
<td>Efficiency factor, %</td>
<td>Heat losses, MWh per year</td>
<td>Specific heat energy consumption, kWh/m² per year</td>
</tr>
<tr>
<td>Heat production, MWh</td>
<td>Electricity consumption, MWh per year</td>
<td></td>
</tr>
<tr>
<td>Fuel and electricity price, EUR/MWh</td>
<td>Insulation size and quality, W/(mK)</td>
<td>Heating area, m²</td>
</tr>
<tr>
<td>Operation &amp; Maintenance cost, EUR/MWh</td>
<td>Thermal length, m</td>
<td></td>
</tr>
<tr>
<td>Installed capacity, MW</td>
<td>Pipes surface, m²</td>
<td></td>
</tr>
<tr>
<td>Investment cost, EUR/MWh</td>
<td></td>
<td></td>
</tr>
<tr>
<td>CO₂ emission, tCO₂/MWh</td>
<td></td>
<td></td>
</tr>
<tr>
<td>Sollar collector area, m²</td>
<td></td>
<td></td>
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<tr>
<td>accumulation volume, m³</td>
<td></td>
<td></td>
</tr>
<tr>
<td>Coefficient of performance, MWh_th/MWh_el</td>
<td></td>
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</table>
Policy

• Subsidies:
  – 25% of investment costs
  – Reduced service life for gas boilers

• Risk reduction:
  – Initial risk – 10 EUR / MWh for renewable energy technologies

• Efficiency improvement:
Supply (T1) and return (T2) water temperature regime

Outdoor temperature, °C

DH water temperature, °C

-20 -18 -16 -14 -12 -10 -8 -6 -4 -2  0  2  4  6  8  10

2nd GDH T1 120/70 — 2nd GDH T2 120/70 — 3rd GDH T1 90/60
3rd GDH T2 90/60 — 4th GDH T1 60/30 — 4th GDH T2 60/30