Demonstration project ‘De Schipjes’: a zero-fossil-fuel energy concept in the historic city center of Bruges

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Key Innovations
- Use of dynamic simulations to design a 100% renewable energy sources (RES)-based district heating (DH) network in an historic city center;
- Use of dynamic simulations to optimize the control strategy during design and commissioning of the completed project in real operation.

Research Implications
A reality check of dynamic simulations is not just a nice-to-have but brings valuable insights, such as system parameter values for systems in operation (often differing from nominal values), better estimates for stochastic user behavior and the feasibility of (theoretical) control strategies.

Introduction
Almshouses ‘De Schipjes’ (Figure 1) is a social housing neighborhood located in the historic city center of Bruges. In 2014, VLAIO (Flemish Agency for Innovation and Entrepreneurship) granted a demonstration project to renovate ‘De Schipjes’ extensively with focus on the energetic and ecological aspects of the houses while taking into account the neighborhood’s classification as heritage. The project consortium consists of two universities (KU Leuven, Ghent University), three companies (Boydens engineering, Viessmann-Belgium, Microtherm) and two social organizations (OCMW Bruges, De Schakelaar).

![Figure 1: Almshouses 'De Schipjes' (Google, n.d.).](image)

The buildings were extensively retrofitted to decrease the heat demand (Van Kenhove et al., 2015) and a DH network was aimed for. Which heat production units, heat emission systems and network temperatures to use was an open question. An experience-based long list of concepts was narrowed down to four different scenarios whose main characteristics are summarized in Table 1. To assess the energetic and ecological performance of the different scenarios, a simulation-based study was performed by Aertgeerts (2016).

Table 1: 4 scenarios for the DH network. CHP refers to combined heat and power, STC to solar thermal collector, ASHP to air source heat pump, GSHP to ground source heat pump, BHP to booster heat pump and TSR to supply/return network temperature.

<table>
<thead>
<tr>
<th>Scenario 1 (S1)</th>
<th>Scenario 2 (S2)</th>
<th>Scenario 3 (S3)</th>
<th>Scenario 4 (S4)</th>
</tr>
</thead>
<tbody>
<tr>
<td>Boiler</td>
<td>ASHP</td>
<td>Boiler</td>
<td>GSHP</td>
</tr>
<tr>
<td>CHP STC</td>
<td>Boiler</td>
<td>GSHP STC</td>
<td>STC BHPs</td>
</tr>
<tr>
<td>T_s=80°C</td>
<td>T_s=50/70°C</td>
<td>T_s=50/70°C</td>
<td>T_s=50°C</td>
</tr>
<tr>
<td>T_a=63°C</td>
<td>T_r=30/50°C</td>
<td>T_r=30/50°C</td>
<td>T_r=30°C</td>
</tr>
</tbody>
</table>

The scenario analysis was performed for 11 houses, but during real-life implementation of the DH network, an extra house was added to the DH network which led to a possibly undersized heat production, potentially jeopardizing the thermal comfort in the buildings. This was an incentive to look deeper into the rule-based control (RBC) proposed by the designer thereby trying to enhance the control rules to overcome the installation of an extra boiler. Feyaerts (2018) used dynamic simulations to study the influence of an improved RBC on the operation of the DH network according to Scenario 4.

The methodology and results of both simulation studies (performance assessment and RBC improvement) are briefly discussed in the two following sections and finally a conclusion is drawn.

Scenario analysis
The four different energy concepts were modeled using the equation-based modeling language Modelica. The various components needed to model the building envelopes and energy systems were provided by the IDEAS (Jorissen et al., 2018) and Buildings library (Wetter et al., 2014). The different scenarios were assessed by comparing different performance indicators (PIs) of a full-year simulation, among them: primary energy use (referred to as PI1 in Figure 2), renewable energy (PI2), boiler fuel consumption (PI3), heat pump electricity consumption (PI4) and heat distribution losses (PI5). The simulation results of these PIs are shown in Figure 2 for the total neighborhood.

Based on these results and the priority set to sustainability, scenario 4 was chosen to be the desired energy concept. A simplified hydraulic scheme of the final energy system is shown in Figure 3.
This is the content from the document. It appears to be a scientific paper discussing energy system scenarios and control strategies in residential buildings. The text includes technical details, figures, tables, and references. Due to the complexity of the content, a detailed summary is provided below.

**Control strategy**

The main rules of the reference RBC are:

- On/off GSHP control using a hysteresis curve around 50°C;
- Heating curve to determine the supply temperature in the building’s heating system;
- Domestic hot water (DHW) production is given priority over space heating (SH).

Building simulations were used to assess the impact of several adapted control strategies by evaluating performance indicators like thermal discomfort, COP (coefficient of performance) of the GSHP and primary energy use. The most promising adapted RBCs were:

1. Preheating of DHW;
2. Simultaneous space heating and DHW production;
3. FH active during night (night setback);
4. Heating curve for the DH network.

An overview of the yearly simulation results of these four adapted RBCs and the reference RBC is provided in Table 2. More information concerning modeling assumptions, simulations and results can be found in the work of Feyraets, Aertgeerts, et al.

**Table 2: Results of the reference and adapted RBCs for a one-year simulation of the total neighborhood.**

<table>
<thead>
<tr>
<th></th>
<th>Primary energy use [GJ]</th>
<th>RES share [%]</th>
<th>COP GSHP [-]</th>
<th>COP BHP [-]</th>
<th>Thermal discomfort [Kh]</th>
</tr>
</thead>
<tbody>
<tr>
<td>Ref</td>
<td>432.4</td>
<td>66.3</td>
<td>3.13</td>
<td>3.78</td>
<td>17084</td>
</tr>
<tr>
<td>1</td>
<td>433.9</td>
<td>65.9</td>
<td>3.13</td>
<td>3.44</td>
<td>15426</td>
</tr>
<tr>
<td>2</td>
<td>433.8</td>
<td>66.6</td>
<td>3.14</td>
<td>3.78</td>
<td>14142</td>
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<tr>
<td>3</td>
<td>433.7</td>
<td>66.0</td>
<td>3.11</td>
<td>3.78</td>
<td>16079</td>
</tr>
<tr>
<td>4</td>
<td>414.3</td>
<td>73.7</td>
<td>4.37</td>
<td>3.54</td>
<td>16900</td>
</tr>
</tbody>
</table>

**Conclusion**

The importance of dynamic building simulations in the design and operation of a zero-fossil-fuel energy concept in the historic city center of Bruges is illustrated. In a first stage of the project, simulations allowed an extensive comparison of different energy system scenarios which led to the design of a low-temperature fully RES-based DH network supplied by a GSHP and STCs. In a later stage, detailed simulations were performed to assess different RBC algorithms impacting the energy performance of the energy system and thermal comfort. Future work will consist in applying and evaluating the proposed enhanced control rules in the real-life system, validating the simulation models using measurement data and further investigating the operational control of the system, e.g. by using a model predictive controller (MPC).

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**References**


