Effects of energy efficiency measures in district-heated buildings of different district heat supply systems

Truong Nguyen
Linnaeus University
Introduction

• In Sweden, district heated buildings are common:
  – about 84% floor area of apartment buildings are heated by district heat
  – consumed a half of the country’s district heat in 2011
• District heating systems are of different scales with different operation units

Changes of heat demand due to energy efficiency measures can influence the operation of district heat production systems and their related energy systems

=> Effects can vary with contexts
Aims

• Evaluating effects of different energy efficiency measures in an existing district-heated building

• Considering different contexts: the building is located and connected to different district heating systems of different scales, and technical setup

 Evaluating how primary energy is being changed as a consequence of:

  ▪ energy efficiency measures, taking into account the hourly variation of final energy saving
  ▪ actual operation amongst different heat supply units of different district heat production systems.
Case study building

- A building in Växjö is used as a reference:
  - wood-framed
  - 4 stories
  - 16 apartments
  - 1190 m² floor area
## Types of energy efficiency measures

<table>
<thead>
<tr>
<th>Description</th>
<th>Effect of improvement</th>
</tr>
</thead>
<tbody>
<tr>
<td>• Improved water taps</td>
<td>Reduced hot water used by 40%</td>
</tr>
<tr>
<td>• 10 cm additional mineral wool insulation to the roof</td>
<td>U-value from 0.13 to 0.09 W/m² K</td>
</tr>
<tr>
<td>• Windows replaced by triple-glazed units</td>
<td>U-value from 1.9 to 0.90 W/m² K</td>
</tr>
<tr>
<td>• Doors replaced by triple-glazed units</td>
<td>U-value from 1.19 to 0.90 W/m² K</td>
</tr>
<tr>
<td>• 25 cm additional mineral wool insulation to external walls</td>
<td>U-value from 0.20 to 0.10 W/m² K</td>
</tr>
<tr>
<td>• Ventilation heat recovery unit with 80% efficiency</td>
<td>Reduced ventilation heat loss by 57%</td>
</tr>
<tr>
<td>• Electric efficient household appliances</td>
<td>Reduced household electricity by 44%</td>
</tr>
</tbody>
</table>
Groups of energy efficiency measures

Measures are grouped in 3 categories

1. Measures to reduce district heat demand: improvement of water tap and building envelope
2. Measure to reduce district heat demand but increase electricity use: ventilation heat recovery
3. Measure to reduce electricity use but increase district heat demand: efficient household appliances.
### Final energy savings

#### Effects of each EE measure group

<table>
<thead>
<tr>
<th>Measure group</th>
<th>Savings (MWh)</th>
<th></th>
<th></th>
<th></th>
</tr>
</thead>
<tbody>
<tr>
<td></td>
<td>Heat</td>
<td>Electricity</td>
<td>Total</td>
<td></td>
</tr>
<tr>
<td>- EE group 1</td>
<td>42.2</td>
<td>-</td>
<td>-</td>
<td>42.2</td>
</tr>
<tr>
<td>- EE group 2</td>
<td>30.5</td>
<td>-4.8</td>
<td>-</td>
<td>25.7</td>
</tr>
<tr>
<td>- EE group 3</td>
<td>-7.6</td>
<td>23.8</td>
<td>-</td>
<td>16.3</td>
</tr>
</tbody>
</table>

![Accumulated final energy savings](chart.png)

- **Measure to reduce district heat demand**
- **+ Measures to reduce district heat but increase electricity use**
- **+ Measures to reduce electricity but increase district heat use**
Final heat use of the case study building – arranging in a descending order

- Initial
- + EE measure group 1
- + EE measure group 2
- + EE measure group 3

114 MWh
48.5 MWh
Final heat use of the case study building

a) Before EE measures: 114 MWh

b) After EE measures: 48.5 MWh
Considered district heating systems

Helsingborg: ~ 330 MW$_{\text{peak}}$, 1100 GWh/year
Växjö: ~ 185 MW$_{\text{peak}}$, 630 GWh/year
Ronneby: ~ 33 MW$_{\text{peak}}$, 110 GWh/year
**District heat production in Helsingborg**

Production in 2013: 1100 GWh
District heat production in Växjö

Production in 2013: 630 GWh

District heat production in Växjö

Production in 2013: 630 GWh
District heat production in Ronneby

Production in 2013: 110 GWh
Assumptions of system operation

- At each instant, changes of heat demand marginally influence the operation of district heat production units.
- Change of cogenerated electricity in DHSs is balanced by coal-based standalone condensing power plants.
- Subtraction method is used to estimate the primary energy use of heat production.
Change of heat and electricity use

EE measure group 1: measures to reduce district heat demand

Helsingborg DHS
Change of electricity coproduction at the DHS

EE measure group 1:
measures to reduce district heat demand
Change of heat and electricity use

Change of demand (kW)

Day

Heat use
Electricity use

At DHS
At power plants

Changes of fuel use

Change of primary energy use (kW)

Day

Helsingborg DHS

EE measure group 1: measures to reduce district heat demand
EE measure group 1: measures to reduce district heat demand
EE measure group 1: measures to reduce district heat demand

Changes of fuel use

Changes of heat and electricity use
Final energy savings and primary energy savings

- Measures to reduce district heat demand
- + Measures to reduce district heat but increase electricity use
- + Measures to reduce electricity but increase district heat use
Ratio of primary and final energy savings

District heat production system

- Measures to reduce district heat demand
- Measures to reduce district heat but increase electricity use
- Measures to reduce electricity but increase district heat use
Conclusions

• Energy efficiency gives large final energy saving but the primary energy saving vary significantly, depends on:
  – the characteristics of the energy efficiency measure
  – the characteristics of the used distric heat production system

• Energy efficiency in buildings connected to a small-scale DHS using heat-only boilers is more primary energy efficient

Evaluation of energy efficiency measures in district-heated buildings requires a systems perspective where the final energy savings in buildings are matched to the actual operation of the connected DHS.
Thank you!
EE measure group 2: measures to reduce district heat but increase electricity use
EE measure group 2: measures to reduce district heat but increase electricity use.
Change of heat and electricity use

EE measure group 2: measures to reduce district heat but increase electricity use

Changes of fuel use
Change of heat and electricity use

EE measure group 3:
measures to reduce electricity but increase district heat use

Changes of fuel use
EE measure group 3: measures to reduce electricity but increase district heat use
Change of heat and electricity use

EE measure group 3: measures to reduce electricity but increase district heat use

Changes of fuel use