Energy benefit assessment of a Water Loop Heat Pump system integrated with a CO$_2$ commercial refrigeration unit

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Global Warming

• High GWP refrigerants being banned

• Need for reduction of energy consumption (CO$_2$ emission)
Refrigeration

• Low GWP refrigerants
  – Natural (Propane, CO₂, Ammonia)
  – Synthetic (HFC blends, HFO)
CO$_2$ as refrigerant

😊 Low cost, widespread, non-flammable, non-toxic, well known......

😊 Effective heat recovery

😊 Poor efficiency at warm climate conditions → more complex systems → higher investment and maintenance costs
HVAC

• Interest for heat pumps with heat reclaim from renewable sources or heat recovery at low temperature

• Thermal insulation of buildings → need for both heating and cooling at winter time in the presence of even small internal loads

• WLHP: Water Loop Heat Pumps
Heat recovery at low temperature: whole amount (WLB)
just desuperheating (WLD)
• Transient state simulation of
  – building with internal loads
  – display cabinets and cold rooms
  – refrigeration system
  – HVAC system

• TRNSYS

interaction

heat recovery

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• The reference system

– R404A for the commercial refrigeration unit
– R410A for the heat pumps for HVAC
– R134a for the heat pump for DHW
• The building
  – 6352 m² food store
  – 5411 m² warehouse, service and hallways
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  – 6352 m² food store
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<table>
<thead>
<tr>
<th>Climate conditions</th>
<th>Climate 1</th>
<th>Climate 2</th>
<th>Climate 3</th>
</tr>
</thead>
<tbody>
<tr>
<td>Annual average temperature [° C]</td>
<td>18.6</td>
<td>16.4</td>
<td>11.6</td>
</tr>
<tr>
<td>Average annual temperature fluctuation [K]</td>
<td>13.4</td>
<td>15.8</td>
<td>22.2</td>
</tr>
<tr>
<td>Maximum daily temperature fluctuation [K]</td>
<td>10.6</td>
<td>10.4</td>
<td>23.7</td>
</tr>
<tr>
<td>Heating degree days [HDD/year]</td>
<td>751</td>
<td>1435</td>
<td>2404</td>
</tr>
</tbody>
</table>
Climate 2

Heating (-) and cooling (+) demands [MWh]

January  | February  | March  | April  | May  | June  | July  | August  | September  | October  | November  | December  
--- | --- | --- | --- | --- | --- | --- | --- | --- | --- | --- | ---
food store | service 1 | service 2 | warehouse 1 | warehouse 2 | hallways 1 | hallways 2 | hallways 3 | hallways 4 | hallways 5 | hallways 6 | hallways 7
• Refrigeration
  – CO$_2$ as refrigerant
  – 140 kW MT
  – 28 kW LT
• Refrigeration

![Operation mode diagram]

- Climate 1
- Climate 2
- Climate 3

- Subcritical
- Transition
- Transcritical
• Water loop temperature

- dry cooling
- $t_{DC}$
- neutral
- $t_{HR}$
- heat recovery
- $t_{AH}$
- aux. heater

![Graph showing annual energy consumption vs. temperature](image)
- Water loop temperature

![Graph showing daily average temperature for different climates and water loop conditions (WLB, WLD). The graph displays temperature in °C for each month from January to December, with lines representing climate 1, climate 2, and climate 3 for both WLB and WLD conditions.](image-url)
• Energy consumption

![Bar chart showing energy consumption in different climates and scenarios. The chart compares HVAC, DHW, Refrigeration, and Auxiliary devices.](chart)

- Climate 1:
  - AHD: Ref. -2.9%
  - WLD: +10.5%
  - WLB: Ref. -4.6%

- Climate 2:
  - AHD: Ref. +4.7%
  - WLD: Ref. -5.2%
  - WLB: -9.2%

- Climate 3:
  - AHD: WLD -5.2%
  - WLB: WLD -9.2%
Conclusions

• Efficient low GWP solutions with natural refrigerants are available also at warm climate conditions
• Heat recovery plays a key role in a view of global energy consumption of the shopping mall
• WLHP shows to be a viable solution even if thermal loads do not allow its best exploitation
• Solution sets can be identified through modelling
Thank you
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