Cost optimal analysis of PEBs/PEDs

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Overview

- EXCESS project overview
  - General overview of the project
  - Overview of four demo cases (Spain, Austria, Finnland, Belgium)

- Cost optimal analysis - overview of method

- Results of Cost optimal analysis of EXCESS demos
  - Overview of all demo results
  - Detailed analysis of Spanish pilot case
  - Conclusion
The EXCESS project

- EXCESS - FleXible user-CEntric Energy poSitive houseS
- EU Horizon2020 project with 21 partners from 8 countries, 2019-2024
- Main aim is to show how nZEBs can be transformed into PEBs
- Four demo sites in four different climate zones
- Focus on innovative technical solutions (deep boreholes for seasonal storage, PVT, multifunctional facade element, …)
EXCESS demo case Spain/Valladolid

- Historical palace from 16th century
- Located in the historical center of Valladolid
- Mediterranean climate
- Insulation without change of facade
- Change from gas to aerothermal heat pump (40kW) and floor heating
- PV (51.4kWP) with battery (30kWh)
- PVT for DHW (2.8kW)
- Building will achieve PEB-level after renovation
- Construction works will be finished by end of this year
EXCESS demo case Austria/Graz

- Former feed production silo in former industrial area of Graz
- Continental climate
- Renovation to an area with mixed uses including offices, sport facilities and restaurants
- Renovation with highly insulated prefabricated multifunctional façade elements (component activation, insulation, BiPV)
  - 88kWp building integrated PV
- Cascadic heat pump system for heating and cooling
- Building energy management system
- PEB level will achieved after renovation
EXCESS demo case Belgium/Hasselt

- Social housing complex in Hasselt
- Demo building includes four apartment with 20 dwellings
- Oceanic/Coastal climate
- Change to multisource geothermal heat pump
- 44kWp PV for renewable electricity
- 44kWp PVT panels for electricity, heatpump and recharge of bedrock
- Small wind turbine on the roof (5kWe)
- Building energy management system
- PEB level can be achieved after renovation
EXCESS demo case Helsinki/Finnland

- New building in Kalasatama district, city of Helsinki
- 8 floors, mixed-use building including residential apartments, commercial spaces and a restaurant
- Nordic climate
- Hybrid geothermal energy system
- ~600m deep boreholes
- 67 kW multisource heat pump with high COP
- 87 kWp building integrated PV
- 79 kWp PVT for the heat pump and recharging the bedrock
- PEB level cannot be achieved
Cost-optimal analysis of PEBs

- **Target:** Define cost-optimal technologies and technology packages for PEBs

- **Development of cost-optimal calculation framework**
  - Based on cost-optimal framework acc. (EU) No 244/2012 – supplementing guideline to EPBD
  - Guideline defines a comparative methodology framework for calculating cost-optimal levels of minimum energy performance requirements for buildings and building elements
  - Comparison of global costs and net primary energy demand

- **Cost-optimal analysis of pilot cases in EXCESS project**
  - Definition of technology packages
  - Cost/Energy curves for several technology packages of each pilot case
  - Identification of cost-optimal technical solutions and technology packages for pilot cases
Cost-optimal analysis method

- **Global costs include**
  - Investment costs
  - Replacement cost (if expected technology lifetime is lower than the calculation period)
  - Residual value (if expected technology lifetime is higher than the calculation period)
  - Maintenance and operation cost for complete calculation period
  - Energy cost and revenues from RES feed-in for complete calculation period
  - All values as NPV (discount factor 3%)

- **Net primary energy demand includes**
  - Annual energy demand for heating, cooling, air-conditioning, DHW and lighting
  - Annual electricity production from RES
  - Energy demand/production in terms of primary energy

- **Calculation parameter**
  - Calculation period: 30 years (according cost-optimal framework EU No 244/2012)
  - Discount factor: 3%
Cost-optimal analysis of EXCESS demos

Spain

Finnland

Belgium

Austria

FleXible user-CEntric Energy poSitive houseS
Scenarios for building elements (envelope, thermal system, PV, BEMS) defined
Scenarios are combined to 42 technology packages and cost-optimal framework applied

<table>
<thead>
<tr>
<th>Building envelope</th>
<th>Description</th>
<th>Investment costs [k€]</th>
<th>Investment costs per unit [k€/m² or kW]</th>
<th>Expected technology lifetime [k]</th>
</tr>
</thead>
<tbody>
<tr>
<td>D0</td>
<td>Baseline (smooth regulation envelope, U-value of envelope 0.44, floor 0.15, windows 1.6)</td>
<td>145 700</td>
<td>315 €/m²</td>
<td>50</td>
</tr>
<tr>
<td>D1</td>
<td>High efficiency envelope, U-value of envelope 0.12, floor 0.1, floor 0.27, windows 0.87</td>
<td>209 100</td>
<td>217 €/m²</td>
<td>50</td>
</tr>
<tr>
<td>D2</td>
<td>High efficiency envelope GS plus heat recovery unit (EXCESS scenario)</td>
<td>338 600</td>
<td>293 €/m²</td>
<td>50</td>
</tr>
</tbody>
</table>

<table>
<thead>
<tr>
<th>Thermal system</th>
<th>Description</th>
<th>Investment costs [k€]</th>
<th>Investment costs per unit [k€/m² or kW]</th>
<th>Expected technology lifetime [k]</th>
</tr>
</thead>
<tbody>
<tr>
<td>TS0</td>
<td>Gas heating with boiler and solar thermal for DHW heating</td>
<td>78 360</td>
<td>348 €/GW</td>
<td>15</td>
</tr>
<tr>
<td>TS1</td>
<td>Aerothermal heat pump (40 kW) with floor heating</td>
<td>156 100</td>
<td>1665 €/kW</td>
<td>20</td>
</tr>
<tr>
<td>TS2</td>
<td>Aerothermal heat pump (4kWp) with PV (2.3kWp) for DHW (EXCESS scenario)</td>
<td>156 000</td>
<td>3505 €/kWp</td>
<td>20</td>
</tr>
</tbody>
</table>

<table>
<thead>
<tr>
<th>PV facility</th>
<th>Description</th>
<th>Investment costs [k€]</th>
<th>Investment costs per unit [k€/kWp]</th>
<th>Expected technology lifetime [k]</th>
</tr>
</thead>
<tbody>
<tr>
<td>PV0</td>
<td>no PV</td>
<td>0</td>
<td>0 €/kWp</td>
<td>n.a.</td>
</tr>
<tr>
<td>PV1</td>
<td>22.75 kWp (70 panels each 325Wp), no storage</td>
<td>48 000</td>
<td>2110 €/kWp</td>
<td>25</td>
</tr>
<tr>
<td>PV2</td>
<td>11.10 kWp (50 panels each 335Wp), no storage</td>
<td>55 300</td>
<td>1695 €/kWp</td>
<td>25</td>
</tr>
<tr>
<td>PV3</td>
<td>11.10 kWp (50 panels each 375Wp), 3.3kWh battery, energy storage (EXCESS scenario)</td>
<td>140 900</td>
<td>1856 €/kWp</td>
<td>25</td>
</tr>
</tbody>
</table>

<table>
<thead>
<tr>
<th>Building management system</th>
<th>Description</th>
<th>Investment costs [k€]</th>
<th>Investment costs per unit [k€]</th>
<th>Expected technology lifetime [k]</th>
</tr>
</thead>
<tbody>
<tr>
<td>C30</td>
<td>Baseline monitoring - control for heaters</td>
<td>4 120</td>
<td>n.a.</td>
<td>30</td>
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<tr>
<td>C51</td>
<td>Standard monitoring - control for space heating/venting system</td>
<td>15 000</td>
<td>n.a.</td>
<td>30</td>
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<tr>
<td>C52</td>
<td>Advanced Building Energy Management System (EXCESS scenario)</td>
<td>56 500</td>
<td>n.a.</td>
<td>30</td>
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</table>
EXCESS demo Valladolid – results of cost optimal analysis

- Analysis of heating system

- TS0: Business as usual (gas heating system)
- TS1: Aerothermal heatpump
- TS2: Aerothermal heatpump + PVT (DHW)

- Change from TS0 to TS1
  - reduces net primary energy and global costs (for envelop D0 and D1)
  - Reduces net primary energy but increases global costs (for envelop D2)
  - => Cost effectiveness depends on quality of envelope

- Change from TS1 to TS2
  - Increases global costs => PVT not cost effective
  - TS1 cost-optimal heating system scenario
Analysis of envelope

- D0: Baseline Spanish regulation envelope
- D1: Envelope high efficiency
- D2: Envelope high efficiency + heat recovery
- Change from D0 to D1 to D2
  - reduces net primary energy but increases global costs
  - => D0 is cost efficient technology in Spanish pilot case
EXCESS demo Valladolid – results of cost optimal analysis

- Analysis of PV system

- PV0: no PV system
- PV1: 22.75 kWp PV, no storage
- PV2a: 51.38 kWp PV, no storage
- PV2b: 51.38 kWp PV, 30kWh battery storage

- Change from PV0 to PV1 to PV2a
  - Reduces net primary energy without increase of global costs => cost efficient

- Change from PV2a to PV2b
  - No influence on net primary energy but increase of global costs => not cost efficient

- PV2a is cost efficient scenario
Sensitivity analysis

- High influence of electricity cost
- Slope of linear trendline decreases for electricity prices of 0.3€ and feed-in tariffs of 0.2€
- Electricity prices of 0.4€ turns almost all analysed PEB technologies into cost-efficient technologies that reduce global costs
Main Conclusions

- Not all PEB technologies reduce global costs with current energy prices and a 30 years calculation period => subsidies, grants, other support needed to upscale PEBs
- Results very sensitive to calculation parameters such as electricity prices, discount rate, calculation period, PEF
- PV and change of heating system (from gas to heatpump) are mostly cost-efficient (reduction of net primary energy and global costs)
- PVT, BiPV, Co-generation unit and envelop improvement are often not cost efficient if only energy demand/generation is considered
- Shape of building is a crucial parameter as PEB can be only achieved cost-efficient if there is enough area for PV
- **Current PEB definition exhibits shortcomings => PEB possible just with PV if enough area is available**
Main Conclusions

- Even if technologies may not be cost effective, they can be enabling technologies or provide additional benefits that were not considered in the analysis.
  - PVT can be used in combination with geothermal heat pump to:
    - Increases COP of heat pump
    - Regenerate the bedrock => amount and depth of boreholes can be smaller
    - Long-term reliability of thermal system (ground source) increased
  - Multifunctional façade element:
    - Flexibility of building thermal mass increases self-sufficiency rate of the district
    - Non-intrusiveness
    - Higher comfort
Thank you for your attention

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