Part 3: Specific results of the 3 projects
ePANACEA: The Smart Energy Performance Assessment Platform (SEPAP)
ePANACEA methodology - M1&M2
SEPAP
Mohsen Sharifi, Vito
<table>
<thead>
<tr>
<th>Name of building (e.g. Private Single Family Home…)</th>
<th>Single family house (Private house)</th>
</tr>
</thead>
<tbody>
<tr>
<td>Building address (Zip code and city)</td>
<td>9040 Gent, Belgium</td>
</tr>
<tr>
<td>Year of construction</td>
<td>1904 (envelope renovated in 2017)</td>
</tr>
<tr>
<td>EPC rating for primary energy demand</td>
<td>B; 156 kWh/(m².a)</td>
</tr>
<tr>
<td>Building typology</td>
<td>Single family terraced city house</td>
</tr>
<tr>
<td>Available data from past periods</td>
<td>Energy and indoor environmental parameters hourly data (or higher frequency) 1/12/2017-31/1/2018</td>
</tr>
<tr>
<td>Main data source (e.g. smart meters, utility servers…)</td>
<td>Smart meters</td>
</tr>
<tr>
<td>Number of users/occupants (estimation)</td>
<td>2 adults + baby</td>
</tr>
<tr>
<td>Construction type</td>
<td>Heavy construction</td>
</tr>
<tr>
<td>Size of building (gross floor area) in m²</td>
<td>146,91</td>
</tr>
<tr>
<td>Conditioned gross volume in m³</td>
<td>496,9</td>
</tr>
<tr>
<td>Construction type</td>
<td>Heavy construction</td>
</tr>
<tr>
<td>U-value Average U-value [W/(m².K)] of the building</td>
<td>0,69</td>
</tr>
<tr>
<td>Information about windows</td>
<td>Average U-value of windows [W/(m².K)]=1,95</td>
</tr>
<tr>
<td>Information about shading</td>
<td>No shading</td>
</tr>
<tr>
<td>Infiltration rate</td>
<td>0,3705 1/h blower door</td>
</tr>
</tbody>
</table>
Building envelope, HVAC and bills
Results

This information is calculated from the theoretical model as described in the Facility, Lighting and Other Cooking, DHW, Pump, Ventilation and Appliances to classify the equipment consumption to its category.

- Calculated Total Heating (kWh): 8070.6
- Calculated Cooling (kWh): 0
- Calculated Domestic Hot Water (kWh): 1881.0
- Calculated Lighting (kWh): 2547.4
- Calculated Ventilation (kWh): 0.0
- Calculated Pump (kWh): 0.0
- Calculated Cooking (kWh): 469.5
- Calculated Appliance (kWh): 0.0

Next
Outcomes

Annual heating demand: 6521.18 kWh/año (44.67 kWh/m²-año)
Annual demand for refrigeration: 0.00 kWh/año (0.00 kWh/m²-año)
Thank you for your attention

For further information, please contact via contact@epanacea.eu
ePANACEA methodology - M3

Auto-calibration of white-box BEMs for EPCs

María Fernández Boneta, National Renewable Energy Centre - CENER
Report on the use of innovative certification schemes and its implementation | Zenodo
The EPC cycle

- **EPC in use**
- **EPC Standard**
- **Seed model (BEM)**
- **Calibrated model**
- **Auto-calibration and fine-tuning via parametric analysis**
- **Reverse to standard**
- **Use of processing of input data for generation of the pre-calibrated model**

**Cost-optimal via PAT**

**Correction to standard: “EPC standard”**

**Calibrated model: “EPC in use”**

**Parallel coordinates plot**

**Run on cloud**

**Automatic calibration: PAT**

**BEM through the SEPAP tool**

**Actual operational conditions**

**Automated calibration workflow**

**SEPAP Tool**

- **EEMs**
- **Cost-optimal assessment**

**SEPAP**

- **Tool**
- **EPC in use**
- **EPC Standard**
- **Reverse to standard**
- **Seated model (BEM)**
- **Calibrated model**
- **Auto-calibration and fine-tuning via parametric analysis**
BEM through the SEPAP tool
Actual operational conditions

Actual electricity use from utility servers (smart meters)

- Dry bulb temperature [°C]
- Relative humidity [%]
- Global radiation (horizontal surface) [W/m²]
- Insolation
- Precipitation water [l/m²]
- Wind speed [m/s]
- Wind direction
- Atmospheric station pressure

Electricity use

Weather data from weather station servers

- 8784 hours (Year 2020)
- Advanced lighting schedule
- SP1 Electricity use
- Precipitation data

Week (Monday-Saturday)
Automated calibration workflow

Legend:
- Data gathering
- Model and run model
- Optional
- Calibration

Input data (design documents & sensors)
- Geometry
- Constructions
- Internal loads
- Thermal zones
- HVAC & Plants
- Control

BEM

Weather data

Run Energy Simulation

Sensitivity Analysis

Identify model parameters for improvement

Calibrated Model

Error check

Measured calibration data

Change inputs (calibration variables) in ROV

Legend:
- Sensitivity Analysis
- Identify model parameters for improvement
- Change inputs (calibration variables) in ROV

Legend:
- Data gathering
- Model and run model
- Optional
- Calibration

Optimization algorithm

Mathematical equations:
- $\text{NMBE} = \sum_{i=1}^{n} \frac{(y_i - \hat{y}_i)}{(\bar{y} - \bar{y})} \times 100 < 5$
- $\text{CV(RMSE)} = \sqrt{\frac{\sum (y_i - \hat{y}_i)^2}{(n-1) \cdot \bar{y}}} < 15$

Table:

<table>
<thead>
<tr>
<th>Source of data</th>
<th>Class</th>
<th>ROV%</th>
</tr>
</thead>
<tbody>
<tr>
<td>Site measured data</td>
<td>1</td>
<td>&lt;5</td>
</tr>
<tr>
<td>Physical verification</td>
<td>2</td>
<td>&lt;5</td>
</tr>
<tr>
<td>Aircraft drawings</td>
<td>3</td>
<td>&lt;10</td>
</tr>
<tr>
<td>CVM manuals</td>
<td>3</td>
<td>&lt;10</td>
</tr>
<tr>
<td>Commissioning documents</td>
<td>3</td>
<td>&lt;10</td>
</tr>
<tr>
<td>Design documents</td>
<td>4</td>
<td>&lt;50</td>
</tr>
<tr>
<td>Guides and standards</td>
<td>6</td>
<td>&lt;40</td>
</tr>
<tr>
<td>Building commissioning</td>
<td>7</td>
<td>&lt;50</td>
</tr>
</tbody>
</table>
Automatic calibration: PAT
Run on cloud
Paralell coordinates plot
Calibrated model: “EPC in use”
Correction to standard: “EPC standard”
Cost optimal via PAT
Comparison

**Calibrated model with ‘actual use’**

<table>
<thead>
<tr>
<th>End Use</th>
<th>Consumption (kWh)</th>
</tr>
</thead>
<tbody>
<tr>
<td>Heating</td>
<td>462,786</td>
</tr>
<tr>
<td>Cooling</td>
<td>72,256</td>
</tr>
<tr>
<td>Interior Lighting</td>
<td>90,056</td>
</tr>
<tr>
<td>Exterior Lighting</td>
<td>0</td>
</tr>
<tr>
<td>Interior Equipment</td>
<td>255,803</td>
</tr>
<tr>
<td>Exterior Equipment</td>
<td>0</td>
</tr>
<tr>
<td>Fans</td>
<td>96,631</td>
</tr>
<tr>
<td>Pumps</td>
<td>7,897</td>
</tr>
</tbody>
</table>

PEC\textsubscript{ren} = 286.7 kWh/m\textsuperscript{2}año
Emissions = 53.0 kgCO\textsubscript{2}/m\textsuperscript{2}año

**Corrected model to ‘standard use’**

<table>
<thead>
<tr>
<th>End Use</th>
<th>Consumption (kWh)</th>
</tr>
</thead>
<tbody>
<tr>
<td>Heating</td>
<td>167,456</td>
</tr>
<tr>
<td>Cooling</td>
<td>84,242</td>
</tr>
<tr>
<td>Interior Lighting</td>
<td>86,075</td>
</tr>
<tr>
<td>Exterior Lighting</td>
<td>0</td>
</tr>
<tr>
<td>Interior Equipment</td>
<td>118,847</td>
</tr>
<tr>
<td>Exterior Equipment</td>
<td>0</td>
</tr>
<tr>
<td>Fans</td>
<td>34,000</td>
</tr>
<tr>
<td>Pumps</td>
<td>5,625</td>
</tr>
</tbody>
</table>

PEC\textsubscript{ren} = 147.3 kWh/m\textsuperscript{2}año
Emissions = 26.6 kgCO\textsubscript{2}/m\textsuperscript{2}año

Weather data files
Loads
Schedules
Set-points
Control
Conclusions and next steps

**Conclusions**

- The development of accurate models that reduce the current performance gap between theoretical and actual consumption is possible with cost-effective procedures (e.g. 2-3 working days for complex buildings).
- With the appropriate tools, it is possible and feasible to extrapolate the methodology based on auto-calibrated white-box models, from the scientific to the commercial environments.
- Multi-objective optimization based on genetic algorithms plus parametric analysis in the cloud allows to reduce the computational cost of the calibration process.
- The automation of the workflow based on available computational tools will reduce the need for professional training in terms of cost and time.
- If the estimation of energy savings resulting from the implementation of energy efficiency measures is not based on the actual energy use of the building (i.e. calibrated model), we cannot guarantee the accuracy.
- The use of calibrated models within EPC schemes would reduce the uncertainty of some parameters, also used for the "EPC standard", such as envelope thermal transmittance or outdoor air renovation (ach)
- End-users show a higher level of engagement with energy efficiency when the EPC information is based on their occupant behaviour patterns (i.e. actual energy use) and they perceive this information as helpful in making decisions about investments.

**Next steps and future research lines**

- Test and validation phase through 15 case studies in 5 countries to confirm initial findings (still ongoing)
- Automated cost-optimal assessment through a multi-objective optimisation (via PAT) to achieve nZEB (still ongoing)
- Integration of the methodology into national simplified procedures (future developments)
Thank you for your attention

For further information, please contact via contact@epanacea.eu

Video tutorial on YouTube channel: (171) ePANACEA Method 3 of Assessment - Tutorial - YouTube