

JOINT FINAL CONFERENCE

Next Generation Energy Performance Assessment,
Rating and Certification

Towards a Smart and Decarbonised Future for European Buildings

Part 3: Specific results of the 3 projects
ePANACEA: The Smart Energy Performance
Assessment Platform (SEPAP)

24 May 2023
Brussels and online





ePANACEA methodology- M1&M2

SEPAP

Mohsen Sharifi, Vito

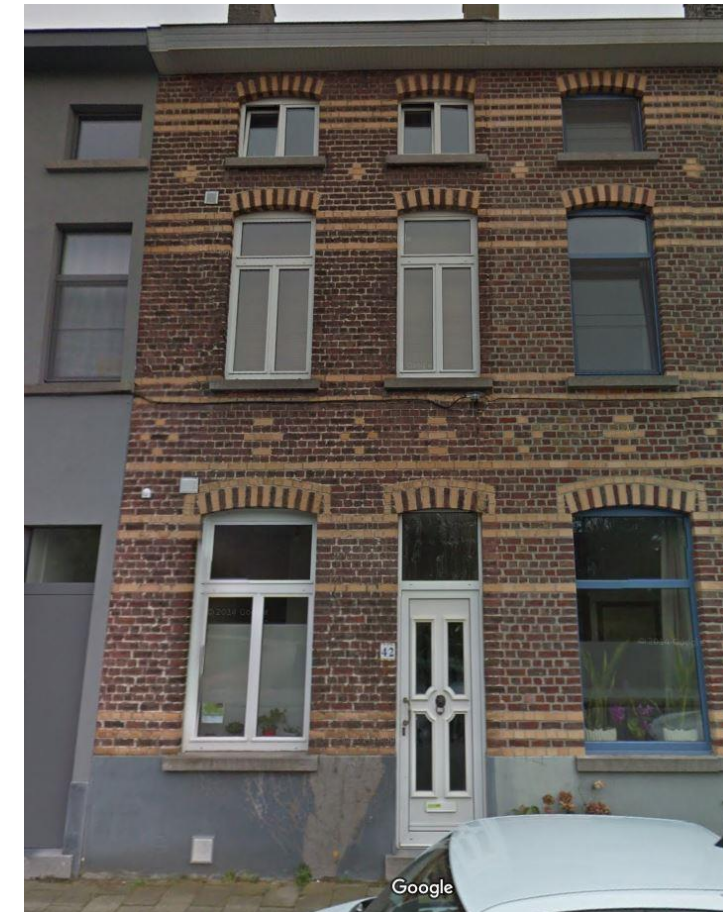


This project has received funding from the European Union's HORIZON 2020 research and innovation programme under grant agreement No 892421

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Belgium – BE-03

Name of building (e.g. Private Single Family Home...)	Single family house (Private house)
Building address (Zip code and city)	9040 Gent, Belgium
Year of construction	1904 (envelope renovated in 2017)
EPC rating for primary energy demand	B; 156 kWh/(m ² .a)
Building typology	Single family terraced city house
Available data from past periods	Energy and indoor environmental parameters hourly data (or higher frequency) 1/12/2017-31/1/2018
Main data source (e.g. smart meters, utility servers...)	Smart meters
Number of users/occupants (estimation)	2 adults + baby
Construction type	Heavy construction
Size of building (gross floor area) in m²	146,91
Conditioned gross volume in m³	496,9
Construction type	Heavy construction
U-value Average U-value [W/(m².K)] of the building	0,69
Information about windows	Average U-value of windows [W/(m ² .K)]=1,95
Information about shading	No shading
Infiltration rate	0,3705 1/h blower door



SEPAP



- 1 Project data
- 2 Schedules
- 3 Facility
- 4 Lighting systems
- 5 Other equipment
- 6 Energy bills
- 7 SRI
- 8 M1
- 9 M2

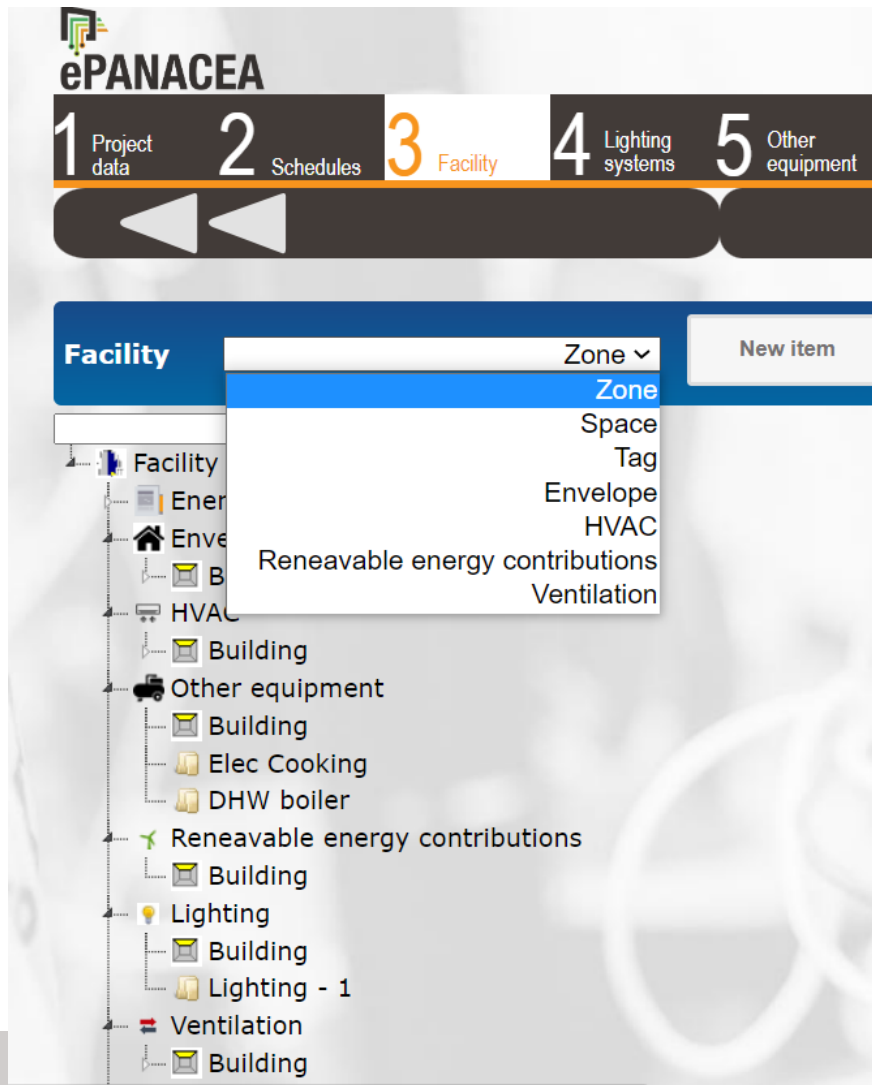


- Project
- Location and other data
- Meeting and visits
- Documentation

Building location

Company name:	<input type="text" value="RenoseeC"/>
VAT number:	<input type="text" value="--"/>
State/Province:	<input type="text" value="East Flanders"/>
Town/City:	<input type="text" value="Gent"/>
Address line 1:	<input type="text" value="Renosee C"/>
Address line 2:	<input type="text"/>
Postal code:	<input type="text"/>

Building envelope, HVAC and bills



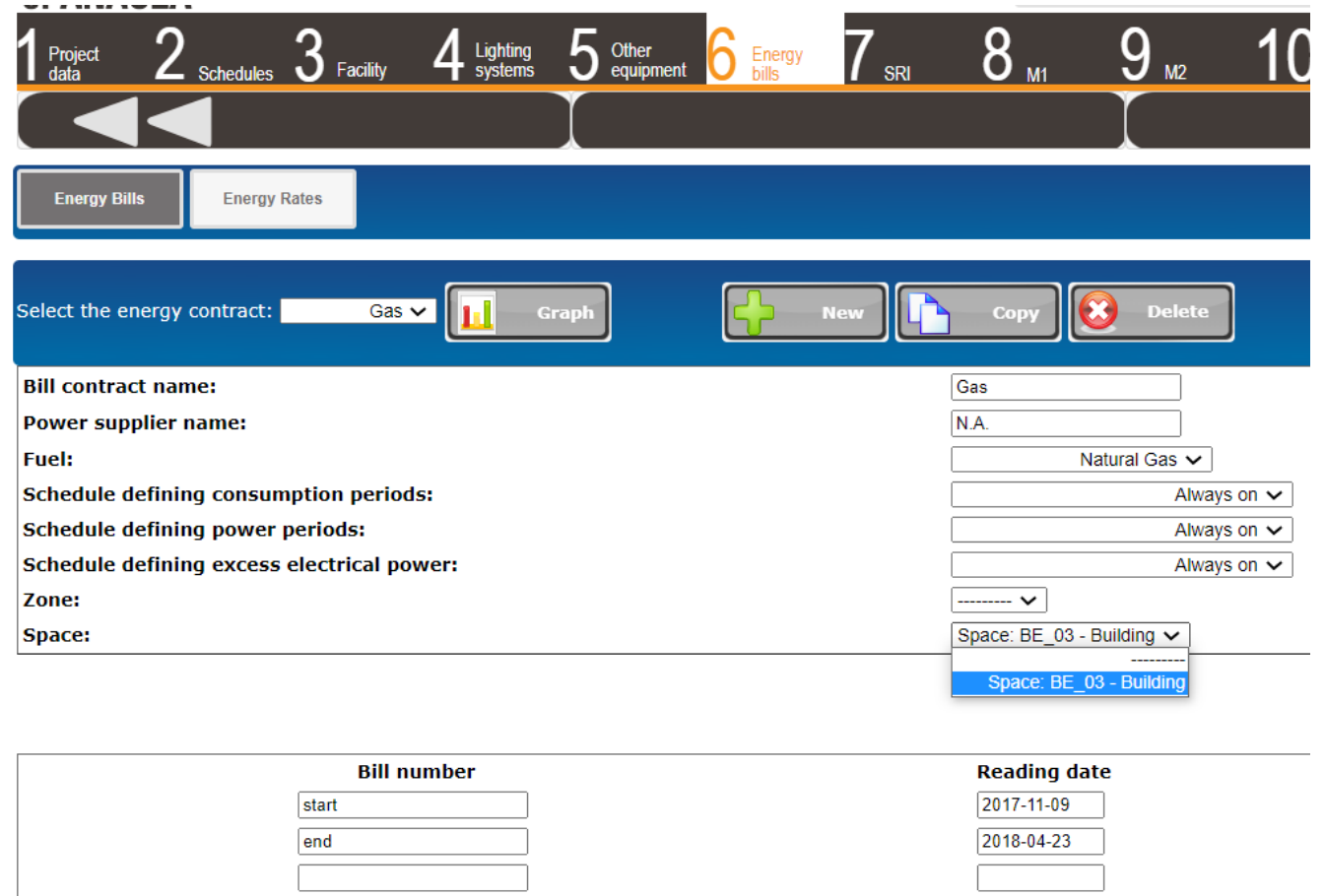
ePANACEA

1 Project data 2 Schedules 3 **Facility** 4 Lighting systems 5 Other equipment

Facility Zone ▾ New item

- Zone
- Space
- Tag
- Envelope
- HVAC
- Renewable energy contributions
- Ventilation

- Facility
 - Energy
 - Envelope
 - Renewable energy contributions
 - HVAC
 - Building
 - Other equipment
 - Building
 - Elec Cooking
 - DHW boiler
 - Renewable energy contributions
 - Building
 - Lighting
 - Building
 - Lighting - 1
 - Ventilation
 - Building



1 Project data 2 Schedules 3 Facility 4 Lighting systems 5 Other equipment 6 **Energy bills** 7 SRI 8 M1 9 M2 10

Energy Bills Energy Rates

Select the energy contract: Gas ▾ Graph + New Copy Delete

Bill contract name: Gas

Power supplier name: N.A.

Fuel: Natural Gas ▾

Schedule defining consumption periods: Always on ▾

Schedule defining power periods: Always on ▾

Schedule defining excess electrical power: Always on ▾

Zone: ----- ▾

Space: Space: BE_03 - Building ▾
Space: BE_03 - Building

Bill number		Reading date
start		2017-11-09
end		2018-04-23

Results

1 Project data 2 Schedules 3 Facility 4 Lighting systems 5 Other equipment 6 Energy bills 7 SRI 8 M1

Energy Needs Fuel Availability Measured Fuel Measured Energy by Service Energy Decomposition Normalized Energy Use

Energy Needs

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

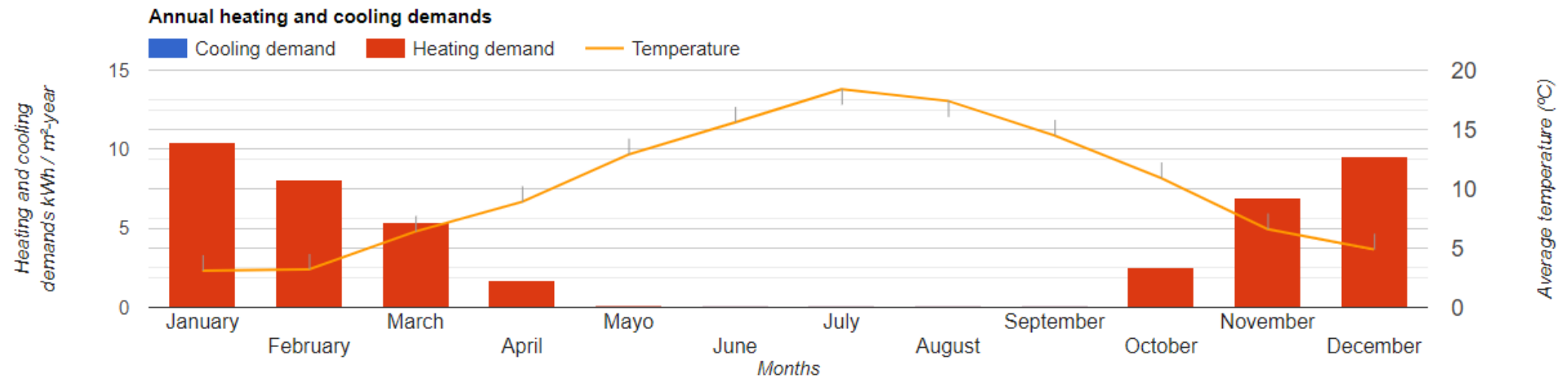
Calculated Total Heating (kWh):	<input type="text" value="8070.6"/>
Calculated Cooling (kWh):	<input type="text" value="0"/>
Calculated Domestic Hot Water (kWh):	<input type="text" value="1881.0"/>
Calculated Lighting (kWh):	<input type="text" value="2547.4"/>
Calculated Ventilation (kWh):	<input type="text" value="0.0"/>
Calculated Pump (kWh):	<input type="text" value="0.0"/>
Calculated Cooking (kWh):	<input type="text" value="469.5"/>
Calculated Appliance (kWh):	<input type="text" value="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

...



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ePANACEA methodology- M3

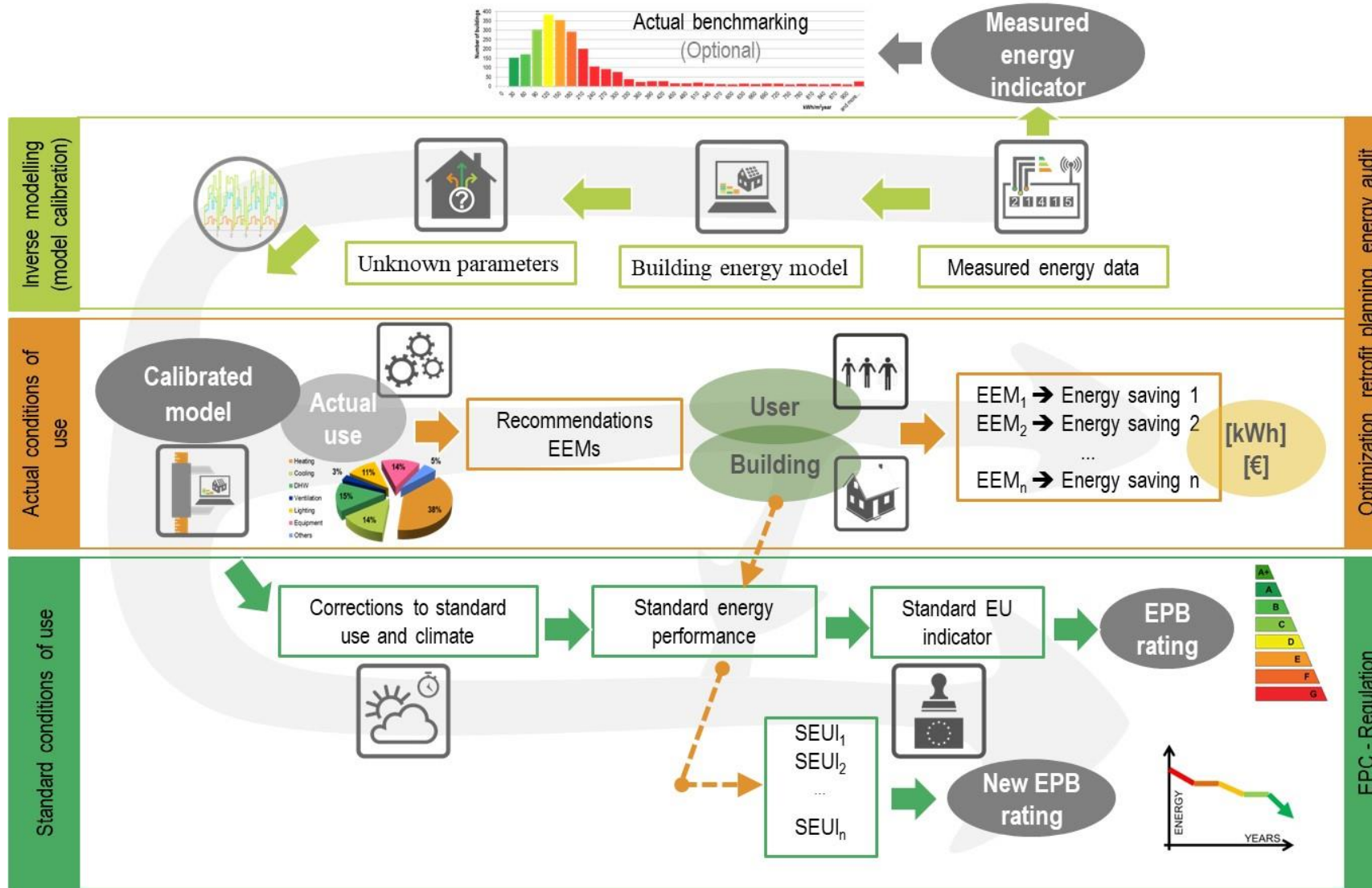
Auto-calibration of white-box BEMs for EPCs

María Fernández Boneta, National Renewable Energy Centre - CENER

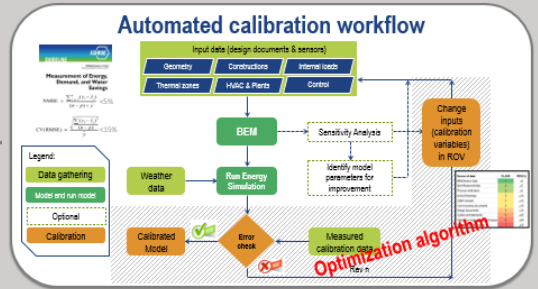
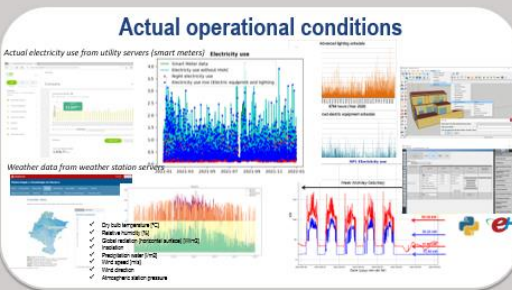
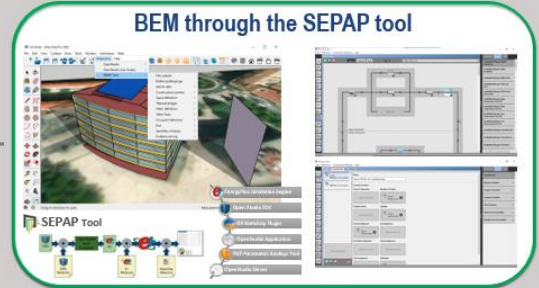
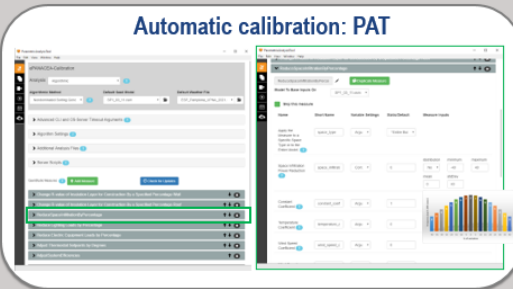
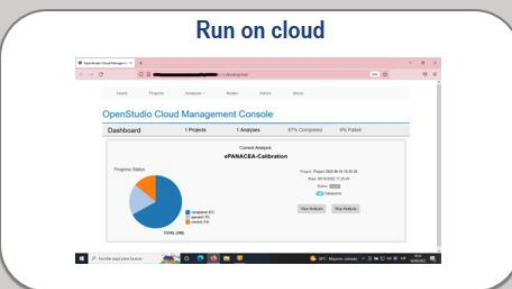
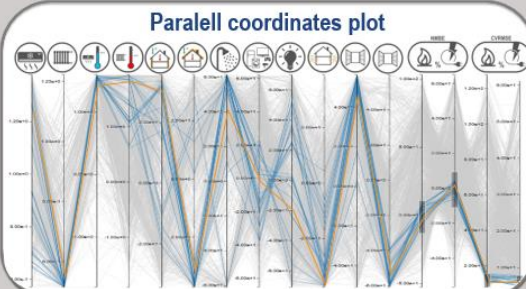
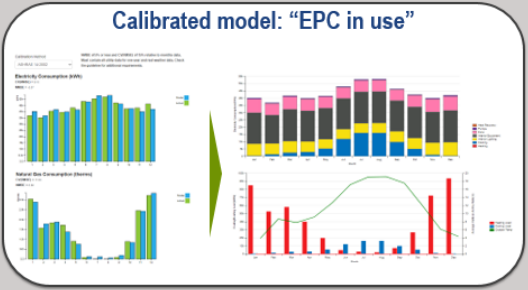
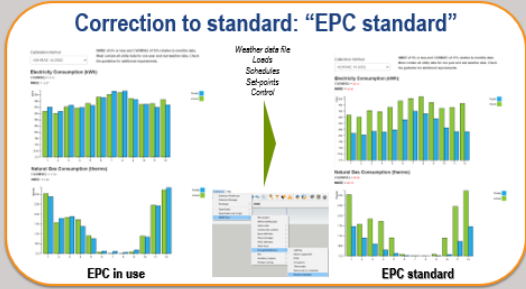
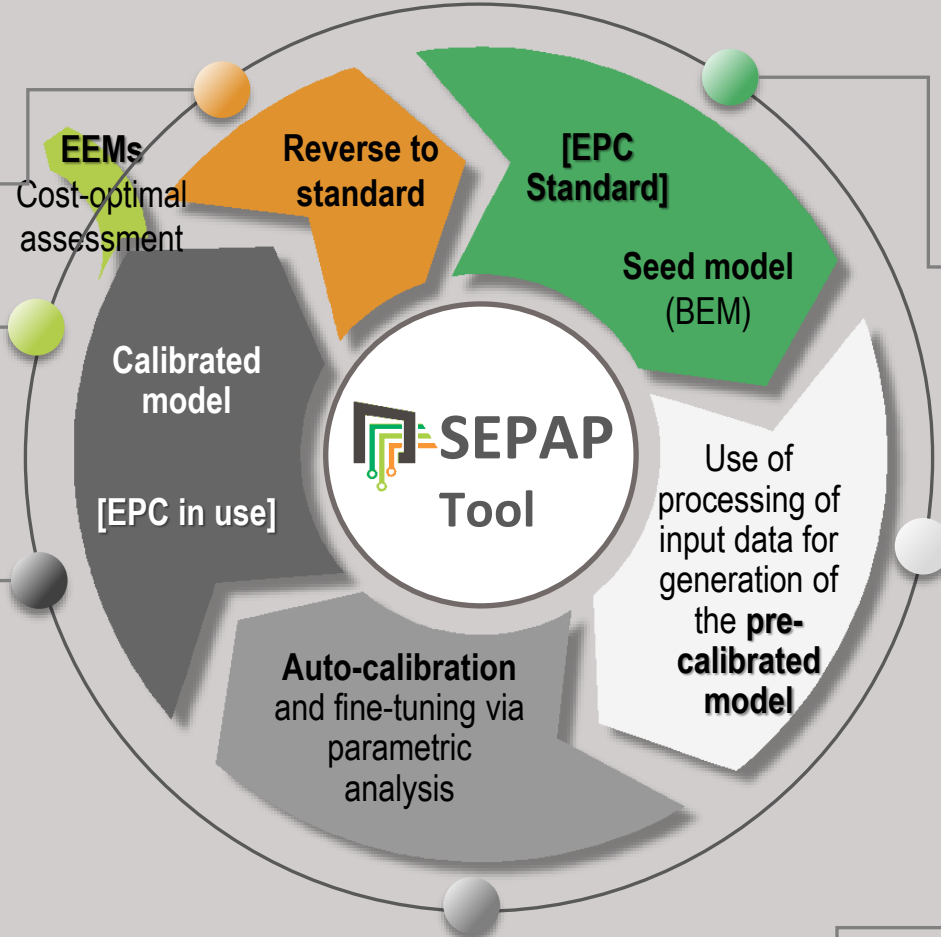


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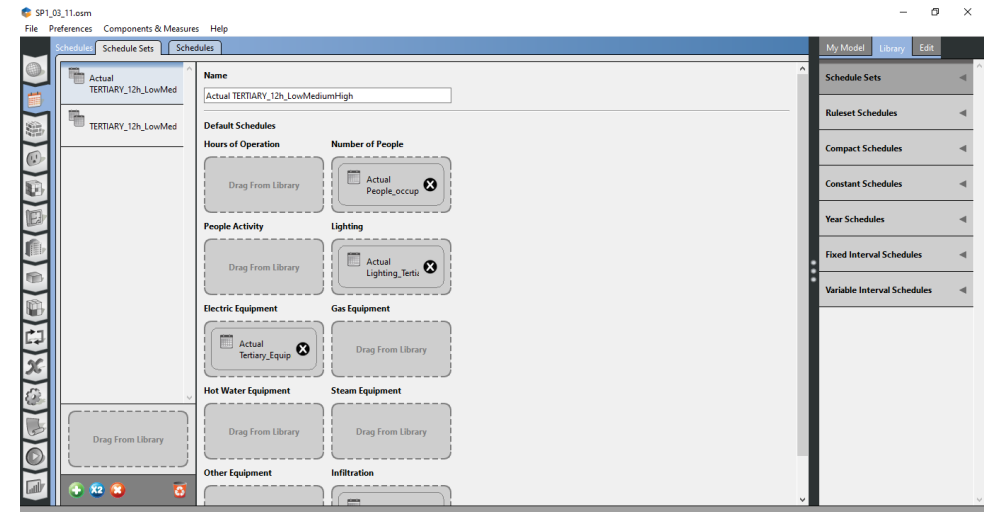
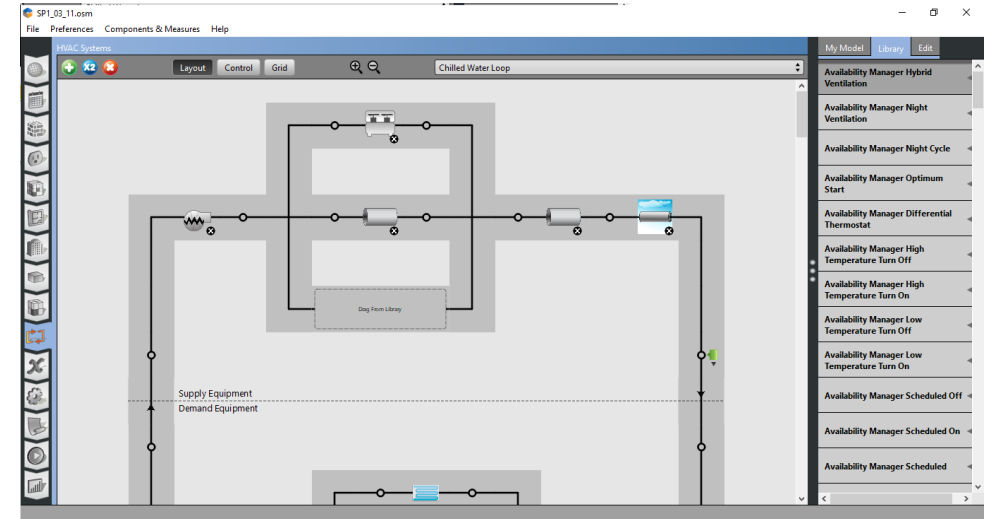
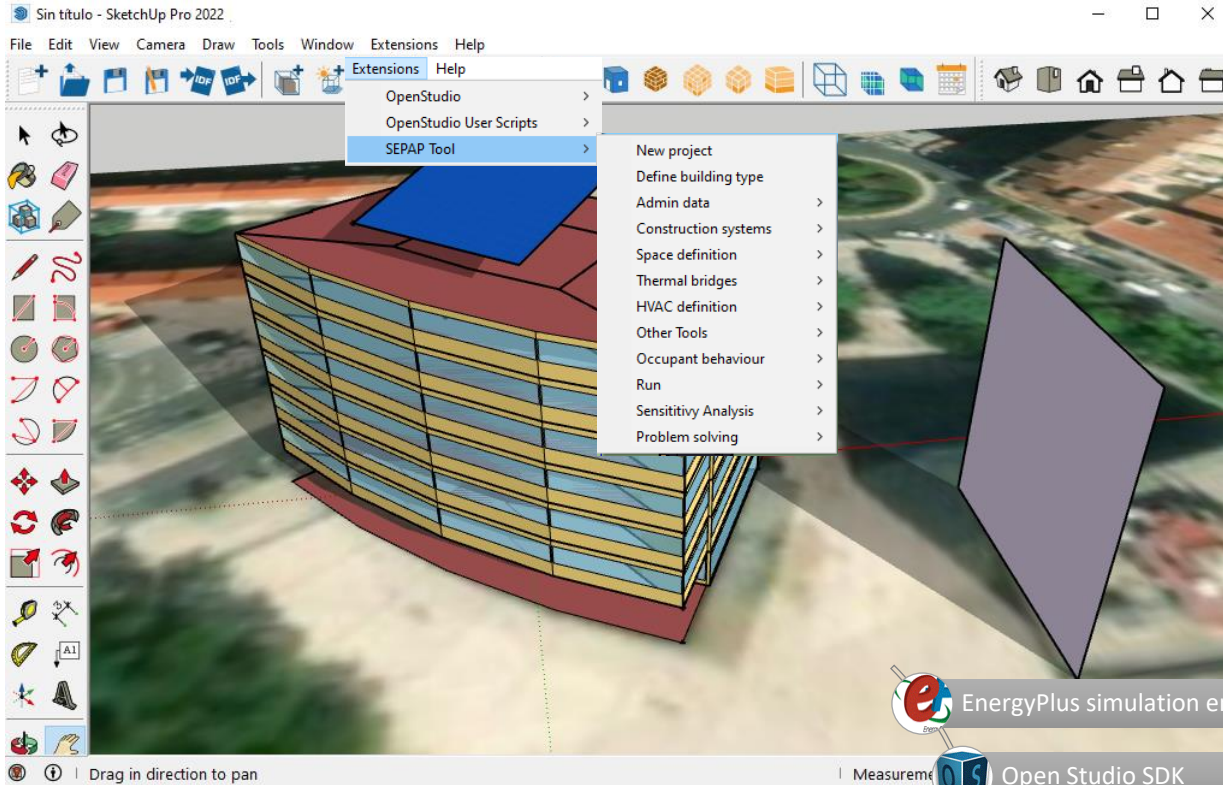
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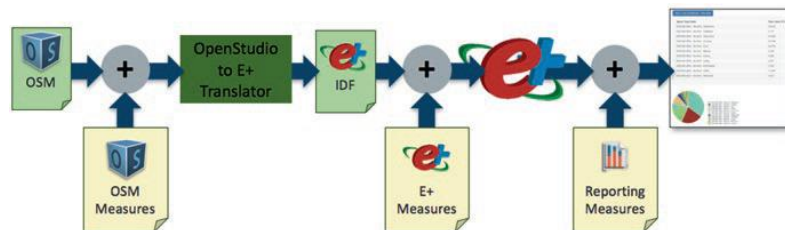
The EPC cycle





BEM through the SEPAP tool



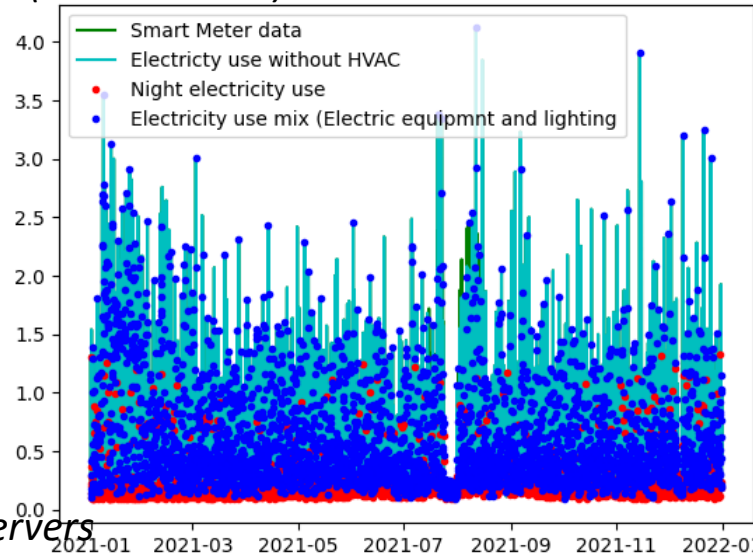
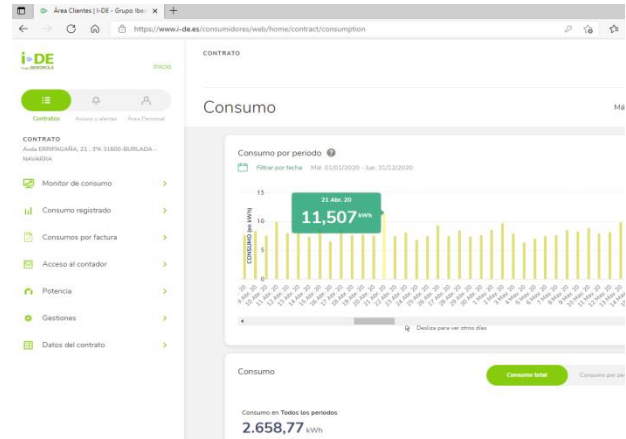
SEPAP Tool



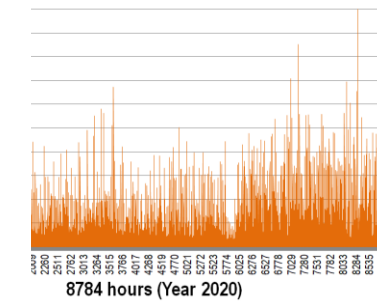
-  EnergyPlus simulation engine
-  Open Studio SDK
-  OS SketchUp Plugin
-  OpenStudio Application
-  PAT-Parametric Analysis Tool
-  OpenStudio Server

Actual operational conditions

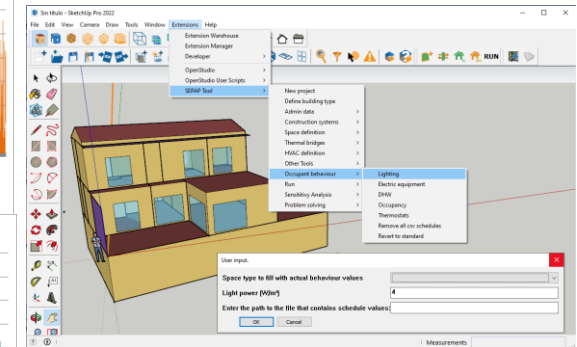
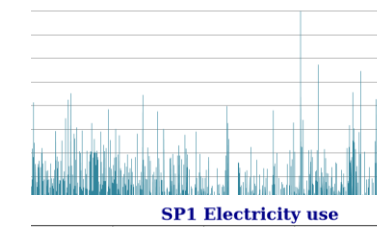
Actual electricity use from utility servers (smart meters) Electricity use



Advanced lighting schedule

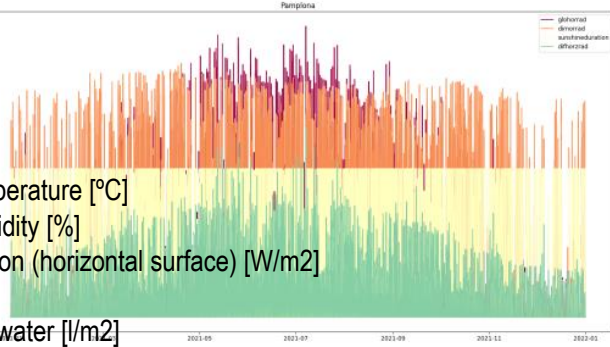
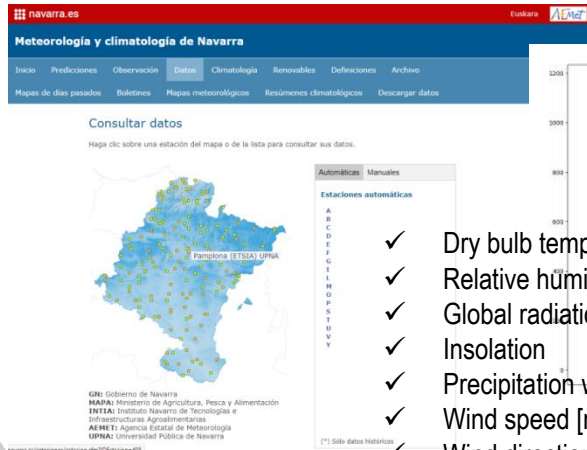


ced electric equipment schedule

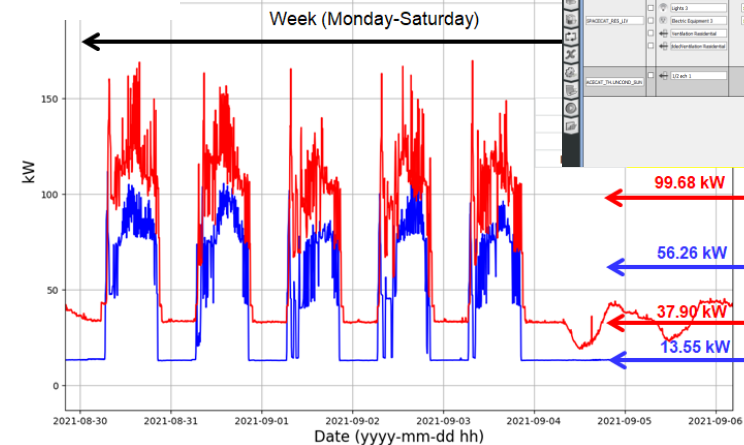


Load Name	Power	Definition	Schedule	Active periods (From-To)
Internal Power 1	1,000.00	Variable control	Day to Day	Day to Day
Light 1	1,000.00	Occupancy	Occupancy	Occupancy
Electric Equipment 1	1,000.00	Occupancy	Occupancy	Occupancy

Weather data from weather station servers



- ✓ 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



Automated calibration workflow



ASHRAE Guideline 14-2014
(Supersedes ASHRAE Guideline 14-2002)

Measurement of Energy,
Demand, and Water
Savings

$$NMBE = \frac{\sum_{i=1}^n (y_i - \hat{y}_i)}{(n-p) \times \bar{y}} < 5\%$$

$$CV(RMSE) = \frac{\sqrt{\frac{\sum (y_i - \hat{y}_i)^2}{(n-p)}}}{\bar{y}} < 15\%$$

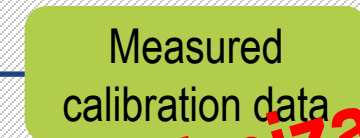
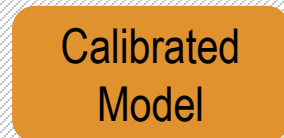
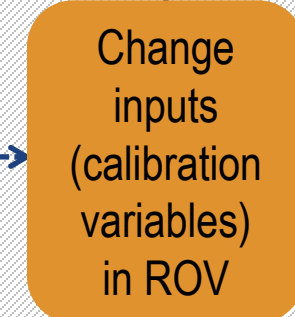
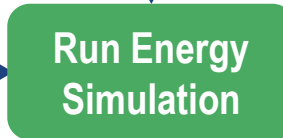
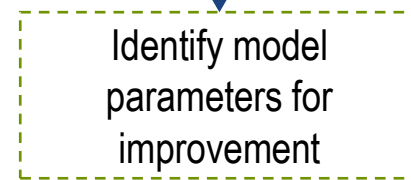
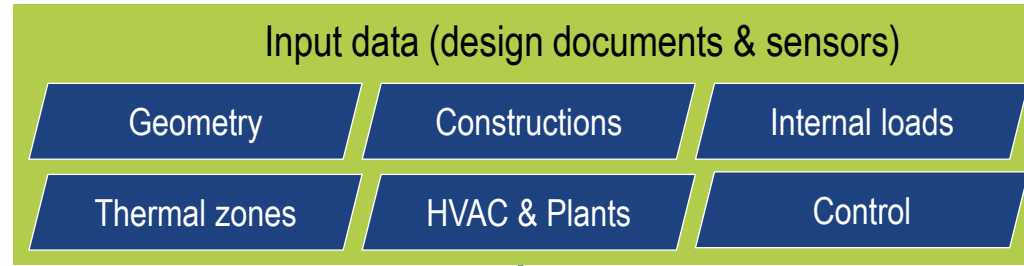
Legend:

Data gathering

Model and run model

Optional

Calibration



Optimization algorithm
Rev n

Source of data	CLASS	ROV(%)
BMS/Sensor Data	1	±2
Spot Measured data	2	±5
Physical verification	2	±5
As-built drawings	3	±10
O&M manuals	3	±10
Commissioning documents	3	±10
Design documents	4	±15
Guides and standards	5	±30
Reference manual default values	6	±40
Manufacturer information	7	±50

Automatic calibration: PAT

ParametricAnalysisTool

File Edit View Window Help

ePANACEA-Calibration

Analysis Algorithmic ?

Algorithmic Method Default Seed Model Default Weather File

Nondominated Sorting Gene ? SP1_03_11.osm ESP_Pamplona_UPNA_2021.

Advanced CLI and OS-Server Timeout Arguments ?

Algorithm Settings ?

Additional Analysis Files ?

Server Scripts ?

OpenStudio Measures ? + Add Measure Check for Updates

- Change R-value of Insulation Layer for Construction By a Specified Percentage Wall
- Change R-value of Insulation Layer for Construction By a Specified Percentage Roof
- ReduceSpaceInfiltrationByPercentage**
- Reduce Lighting Loads by Percentage
- Reduce Electric Equipment Loads by Percentage
- Adjust Thermostat Setpoints by Degrees
- AdjustSystemEfficiencies

ParametricAnalysisTool

File Edit View Window Help

ReduceSpaceInfiltrationByPercentage

ReduceSpaceInfiltrationByPerceer Duplicate Measure

Model To Base Inputs On SP1_03_11.osm

Skip this measure

Name	Short Name	Variable Settings	Static/Default	Measure Inputs
Apply the Measure to a Specific Space Type or to the Entire Model. ?	space_type	Argu	*Entire Bui	
Space Infiltration Power Reduction ?	space_infiltrati	Cont	0	distribution: No, minimum: -40, maximum: 40, mean: 0, stdDev: 40
Constant Coefficient ?	constant_coef	Argu	1	
Temperature Coefficient ?	temperature_c	Argu	0	
Wind Speed Coefficient ?	wind_speed_c	Argu	0	

% of variation	Frequency
-40	3
-35	3
-30	4
-25	5
-20	5
-15	6
-10	6
-5	7
0	7
5	7
10	6
15	6
20	5
25	5
30	4
35	3
40	3

Run on cloud

The screenshot displays the OpenStudio Cloud Management Console interface. At the top, a navigation bar includes links for Home, Projects, Analyses, Nodes, Admin, and About. Below this, the main heading reads "OpenStudio Cloud Management Console". A summary bar indicates "1 Projects", "1 Analyses", "67% Completed", and "9% Failed".

The central focus is the "Current Analysis: ePANACEA-Calibration" section. It features a "Progress Status" pie chart and a summary of analysis details. The pie chart shows the following distribution:

Status	Count
completed	67
queued	19
started	14

TOTAL (100)

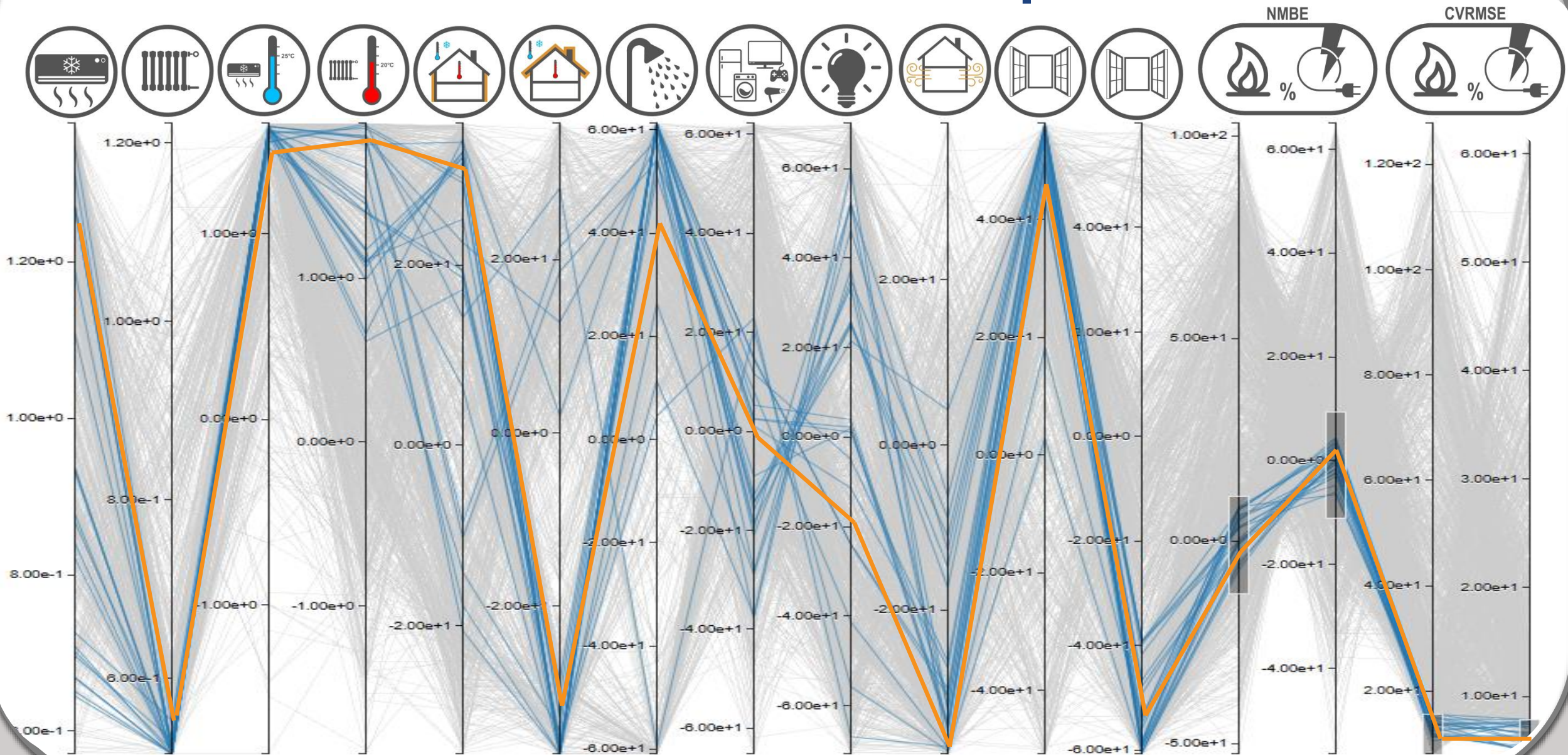
Analysis details include:

- Project: Project 2022-06-16 19:20:38
- Start: 06/16/2022 17:20:49
- Status: started
- 100 Datapoints

Interactive buttons for "View Analysis" and "Stop Analysis" are provided at the bottom of the analysis summary.

The Windows taskbar at the bottom shows the search bar with the text "Escribe aquí para buscar", system tray icons for temperature (38°C), location (Mayorm, soleado), and date/time (19:35, 16/06/2022).

Paralell coordinates plot



Calibrated model: "EPC in use"

Calibration Method

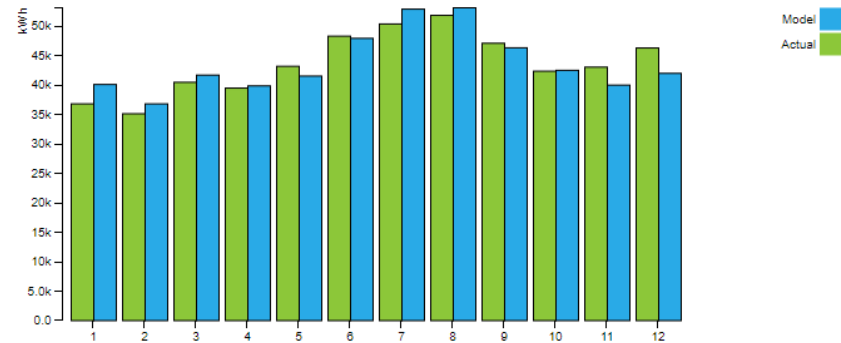
ASHRAE 14-2002

NMBE of 5% or less and CV(RMSE) of 15% relative to monthly data.
Must contain all utility data for one year and real weather data. Check the guideline for additional requirements.

Electricity Consumption (kWh)

CV(RMSE) = 5.10

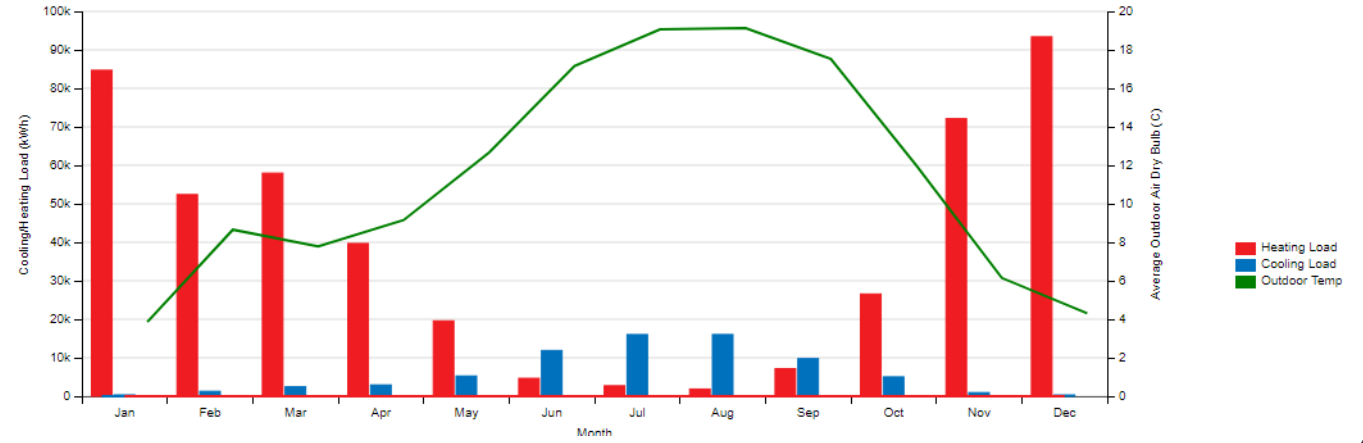
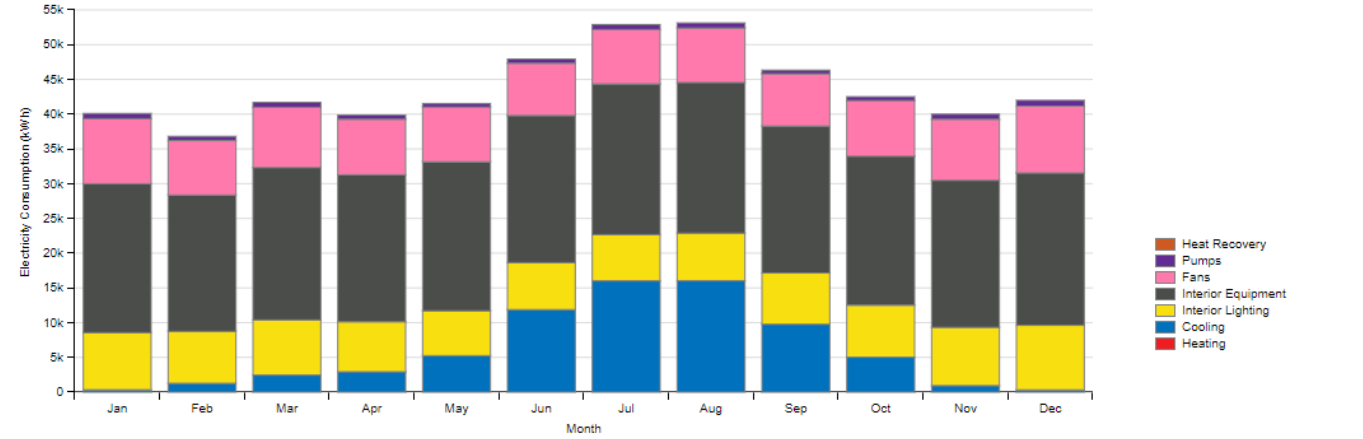
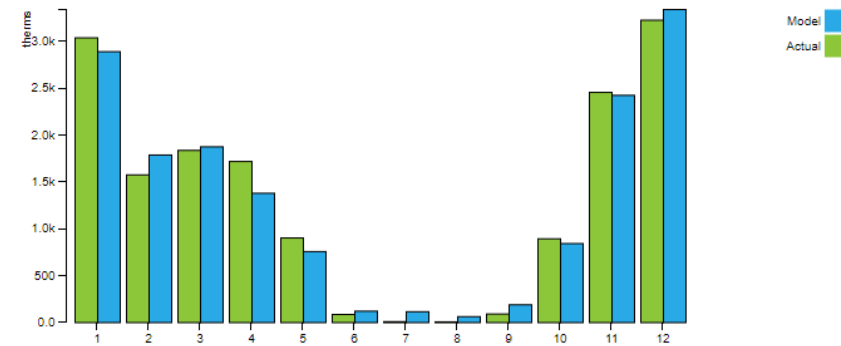
NMBE = -0.07



Natural Gas Consumption (therms)

CV(RMSE) = 11.33

NMBE = 0.38



Correction to standard: "EPC standard"

Calibration Method

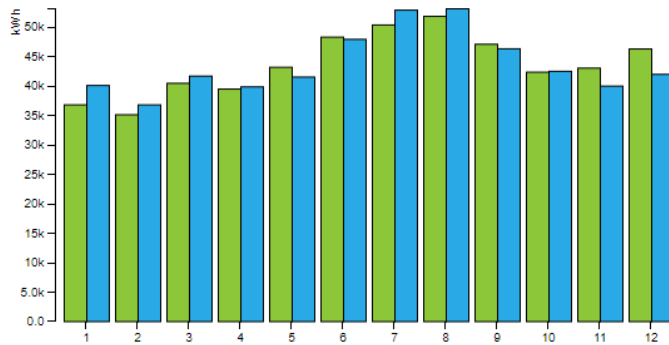
ASHRAE 14-2002

NMBE of 5% or less and CV(RMSE) of 15% relative to monthly data.
Must contain all utility data for one year and real weather data. Check the guideline for additional requirements.

Electricity Consumption (kWh)

CV(RMSE) = 5.10

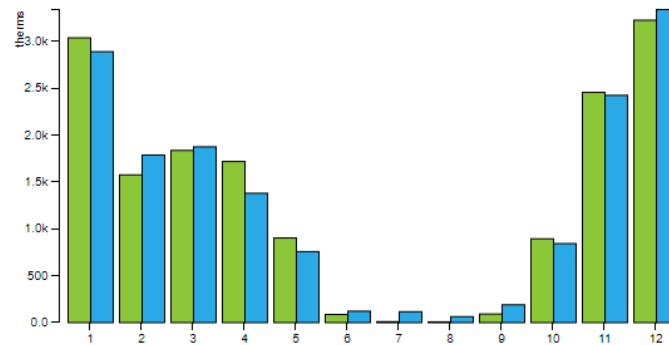
NMBE = -0.07



Natural Gas Consumption (therms)

CV(RMSE) = 11.33

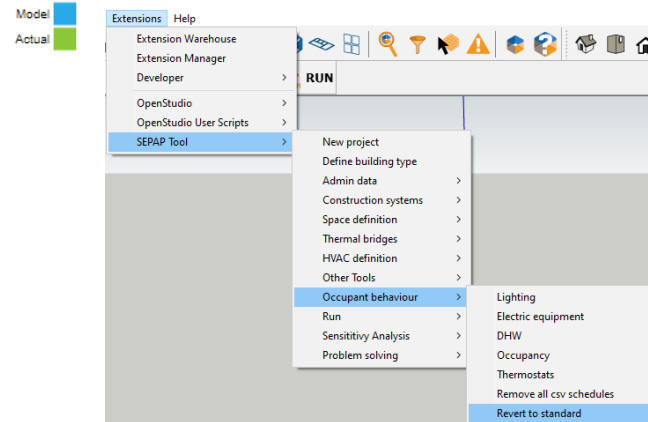
NMBE = 0.38



EPC in use

Weather data file

Loads
Schedules
Set-points
Control



Calibration Method

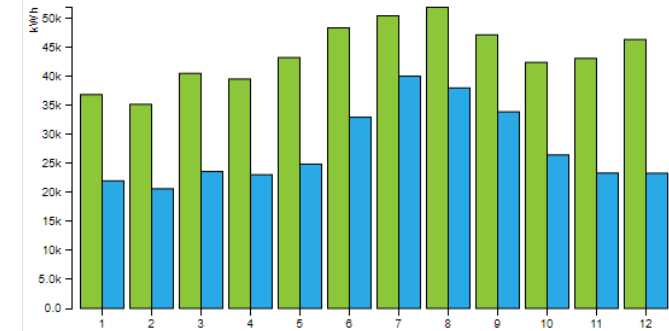
ASHRAE 14-2002

NMBE of 5% or less and CV(RMSE) of 15% relative to monthly data.
Must contain all utility data for one year and real weather data. Check the guideline for additional requirements.

Electricity Consumption (kWh)

CV(RMSE) = 39.10

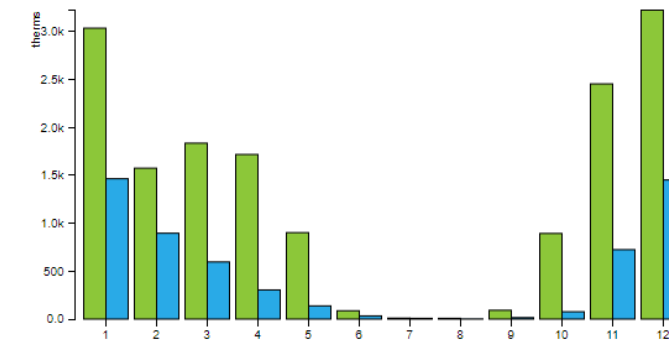
NMBE = 40.09



Natural Gas Consumption (therms)

CV(RMSE) = 85.06

NMBE = 69.75



EPC standard

Cost optimal via PAT

ParametricAnalysisTool

File Edit View Window Help

ePANACEA - Cost-optimal

Analysis: Algorithmic

Algorithmic Method: Design Of Experiments (DOE)

Default Seed Model: calibratedSP1_office.osm

- Advanced CLI and OS-Server Timeout Arguments
- Algorithm Settings
- Additional Analysis Files
- Server Scripts

ParametricAnalysisTool

File Edit View Window Help

Outputs

OpenStudio Results 3.4

Display Name	Output Selection			Objective Function Settings			
	Short Name	Variable Type	Visualize	Objective Function	Target Value	Units	Weighting Factor
total_lifecycle_cost	total_lifecycle_cost	Double	true	true	0		1
total_source_energy	total_source_energy	Double	true	true	0		1

OpenStudio Cloud Management Console

Analysis Results — Optimal cost SP1 office 2

Update Chart

Select x and y variables to update the chart

X: openstudio_results_34_total_source_energy

Y: openstudio_results_34_total_lifecycle_cost

Pareto Front

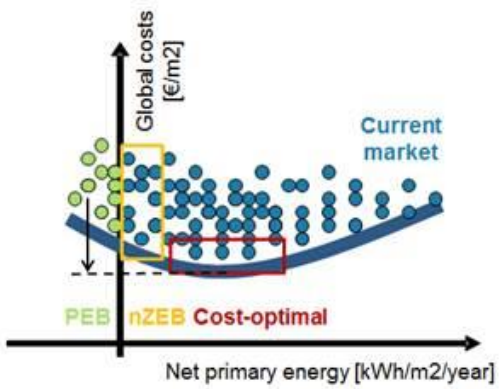
Save this pareto front for later use

X: openstudio_results_34_total_source_energy

Y: openstudio_results_34_total_lifecycle_cost

Name:

- OpenStudio Measures
- SetLifecycleCostParameters
 - Add Insulation Layer for Walls
 - Add Insulation Layer for Roofs
 - Replace with high efficiency glasses
 - Reduce Lighting Loads by Percentage Optimal Cost
 - OptimizationHighEfficiencyBoiler
 - OptimizationHighEfficiencyChiller

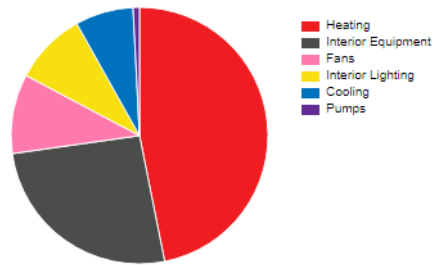


Comparison

Calibrated model with 'actual use'

End Use	Consumption (kWh)
Heating	462,786
Cooling	72,258
Interior Lighting	90,058
Exterior Lighting	0
Interior Equipment	255,803
Exterior Equipment	0
Fans	98,831
Pumps	7,897

PEC_{nren} = 286.7 kWh/m²año
Emissions = 53.0 kgCO₂/m²año



Weather data files
Loads
Schedules
Set-points
Control

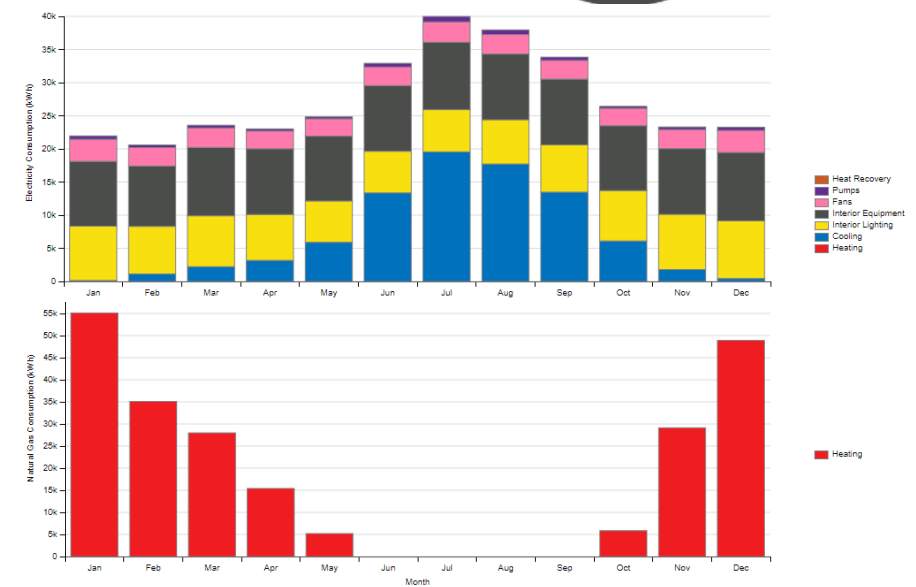
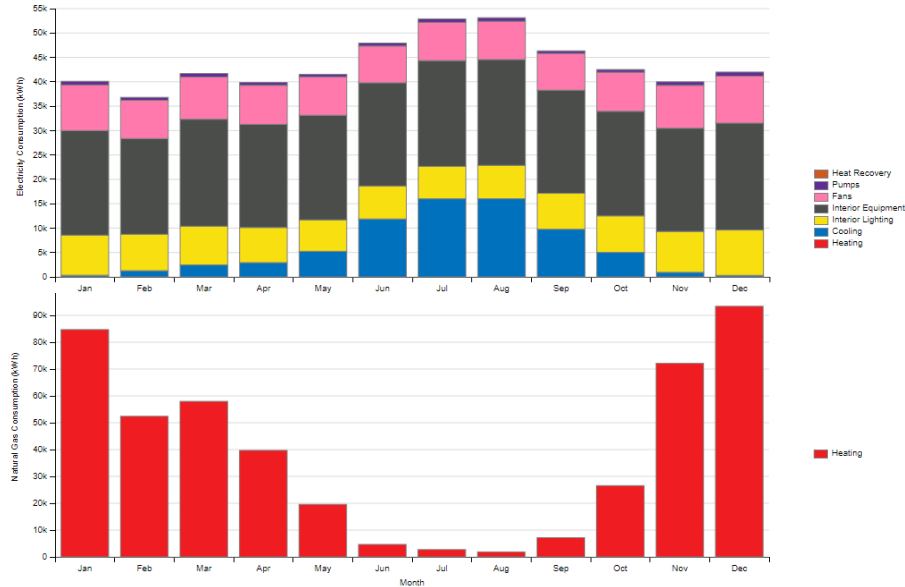
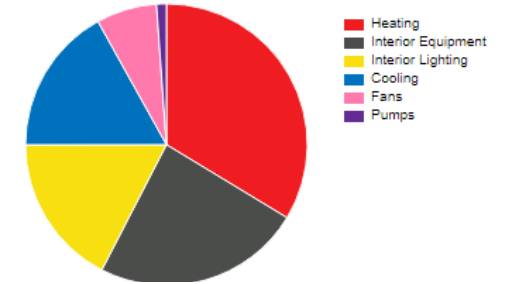


Corrected model to 'standard use'

End Use	Consumption (kWh)
Heating	167,456
Cooling	84,242
Interior Lighting	86,575
Exterior Lighting	0
Interior Equipment	118,847
Exterior Equipment	0
Fans	34,500
Pumps	5,625

-64% Heating
+17% Cooling
-4% Interior Lighting
-54% Interior Equipment
-65% Fans
-29% Pumps

PEC_{nren} = 147.3 kWh/m²año
Emissions = 26.6 kgCO₂/m²año



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](#)



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