D5.1 MODERATE analytics for buildings V1.0

MODERATE

Marketable Open Data Solution for Optimized Building-related Energy Services

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Executive Summary

This report is the first out of three describing successive iterations and refinement in the development of MODERATE services. In particular, software requirements specification for the services leading to the first stage of development are given based on initial assumptions about the most relevant KPIs to target users, including energy/facility managers, utility companies, ESCOs, real estate companies, policy makers, and further users as designer, construction product manufacturer, digital service providers, aggregators. A first assumption was made supported by consortium industrial partners, representing all the target users. Revisions of the services specifications, integrating extensive feedback by industrial partners, early adopters and other stakeholders will be described in successive reports D5.2 (intermediate release) and D5.3 (final release).

The deliverable first introduces KPIs sets identified for each target users, how the data-driven services will compute them, which conditions and limitations exist to the application of services, and how to provide the selected KPIs to each target user.

Several analytics services i.e., related to building operation optimization, building renovation and renewable energy deployment, are then designed, developed, and combined to shape specific tools supporting the planning and management of building assets and portfolios of buildings including energy management, environmental performance, renovation optimisation and investment planning, and relying on buildings monitoring data, user preferences, and knowledge on the building stock. The analytics services, boosted by high-quality synthetic datasets i.e., building stock characteristics, energy consumption profiles and installed HVAC technologies, will be developed following an interoperable and open approach, to serve key information to support the user in targeting better energy and environmental performance, as well as improved comfort conditions and cost optimization for building components and systems.

Each tool is described in terms of scope and context, input and output, user experience and interoperability. The application to specific demo cases is also introduced. Finally, integration of services and tools within the MODERATE marketplace is introduced.

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1. Introduction

The decisions related to management and upgrade of new generations of buildings as well as the definition of new policies for the energy efficiency of buildings to reduce CO2 emissions should follow informed decision-making processes based on data.

To have a correct evaluation of a series of events, the data quality represents key aspect to avoid inaccurate decision processes. MODERATE bases all its developments on datasets that are diverse, consistent, reliable, complete and of high quality, that are transformed into knowledge. For example, the knowledge on the building stock is composed of synthesized and enriched datasets, artificially produced to have the same statistical properties of the original data but enabling anonymization and carrying information from different sources. This approach allows for the development of analytics whose results are very similar, and in many cases improved, if compared to those derived from using original datasets.

At this stage a clarification on terminology is needed to distinguish between services, analytics, and tools. In the context of MODERATE, a service is any software that can elaborate and provide an output on request. It is a term related to IT context. Analytics are services that operate on big data in order to get specific insights. It is a term related to data analysis and science. The interaction with the user is not foreseen in the analytics, then the combination of user interface, I/O mechanisms for data, and analytics, configures a tool. Tool is neither an IT term nor data science related, it is an instrument intended from the point of view of the user.

MODERATE develops ten different analytics that are able to provide comprehensive and effective KPIs set to the target users, covering the needs from five categories of the building sector stakeholders, such as energy and facility managers, utility companies, real estate, ESCOs and policy makers.

The analytics are developed following open-source principles, combined into interoperable tools, and demonstrated in real-life workflows by the industrial partners covering each category. The approach is iterative, where after the first phase of co-development and implementation, feedback from the partners is collected and processed, leading to further improvement of the tools that will be used for the engagement of early adopters, and fostering a large replication in the mid-term beyond the project timeframe.

Tools are the main interaction point for the users, which can get comprehensive insights supporting decisions not only limited to scope and quality of the user input but significantly based on knowledge already available on the platform. Tools rely on several underlying MODERATE functionalities and features, which enable the availability and rule the use of shared data.

Tools fall under three categories:

1. **MODERATE System management.** Analytics can be used on static (i.e. EPCs) and timeseries data from monitoring of the building (i.e. energy metering, IEQ monitoring), providing insights into energy consumption and solution of potential inefficiencies through fault detection and forecasting, optimisation of technical building systems, and guidance for planning improvements i.e., replacement, staged renovation and deep energy retrofit of buildings. The tools that fall within this category are:
    a. Fault detection and forecasting tool.
    b. Energy Systems Optimization tool.
    c. Energy Conservation Measure selection tool.

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2. **MODERATE Building optimisation and assessment.** Analytics exploit AI-based modelling to evaluate building energy performance and identify areas for improvement in terms of solar rooftop potential, cost savings, and overall building energy performance. The tools will support EPC arrangement for energy efficiency and renewable energy projects, as well as Measurement and Verification of energy upgrades implemented by ESCOs, the assessment of potential benefits from installing renewable energy sources, and establishing energy communities by utility companies, benchmarking energy and non-energy related key performance indicators (KPIs) by energy and facility managers. Within this category fall the following tools:
    a. Solar cadastre tool.
    b. Local energy communities' location assessment tool.
    c. Measurement & Verification (M&V) for building energy assessment tool.
    d. Benchmarking tool.
3. **MODERATE Analytics for decision making.** This category is focused on analysing data, i.e. EPCs, building characteristics, savings from application of ECMs, to support policy evaluation and decision making, helping building managers make informed choices about resource allocation and energy management. Tools support in evaluating effect and risks related to actions and policies on building, building portfolio, and building stock level. Within this category fall the following tools:
    a. De-risking tool for investment in energy efficiency.
    b. Energy Performance Certificate harmonization tool.
    c. Geo-clustering tool.

Solutions are co-developed and tested by consortium partners on their business workflow, first looking for effective and practical decision support tools.

As an additional feature, the platform will allow users to generate tailored workflow by connecting external data sources and service application programming interfaces (APIs) within a simple environment.

The open-source code and technical documentation related to each services is available on https://github.com/MODERATE-Project, along with example datasets and models. Further documentation and reports: https://zenodo.org/communities/moderate. Online services will be available for testing on MODERATE Platform.

1.1. Purpose of this document

The document aims at providing specifications on analytics and tools developed by MODERATE project. By following an iterative refinement approach based on target users' feedback and consequent better tailoring of services, information contained in this version of the document will be improved in further document versions.

Tools are the main interaction point for the users, which can get insights and support based on data available on the platform, user input data and analytics. On the other hand, such tools rely on several underlying MODERATE functionalities and features, which enable the connection and proper use of own and third party information.

As represented in the DIKW pyramid (Figure 1), the role of analytics is to leverage data and information, thus to create knowledge and wisdom for supporting the user, in particular by means of KPIs related to energy and non-energy related aspects of buildings. By strongly relying on innovative methodologies for data collection, standardization, synthetization, and enrichment of building and building stock data, each analytics and tools are designed and developed to match user expectations and needs, exploiting realistic data and models to fill gaps with reliable information.

Figure 1 Data Information Knowledge Wisdom (DIKW) pyramid.

1.2. Structure of the document

The first part of the document describes which are the key information that each target user is looking for, to solve a relevant typical issue in their business.

The second part of the document introduces specification for each tool, consisting of four sections:

- *Service description*: this section provides an overview of the tool and its purpose.
- *Input/output* description: this section reviews inputs required by the tool to operate correctly and provide reliable results. Parameters/settings are also described. Finally, outputs are described.
- *User experience*: each tool might target different users. Aiming to provide an overview on the workflow and user interaction, this section shows how the single user can access the tool and which steps they need to follow to run analysis. User friendliness is an important aspect outlined.
- *Application through MODERATE project*: this section shows in practical way how the tool will be used by different use cases.

Further aspects will be covered in successive reports, i.e., detail on use cases, data quality and security, interfaces.

2. Identification of KPIs set

The process of identification of the single KPIs started from a wide review of different European projects involved in the H2020 (i.e., Cultural-E, MakingCity, CityXChange), and recent papers on building engineering, energy efficiency, and performances measurement. Five macro-categories have been identified such as: Energy and Facility Managers, Utilities Companies, Territorial Governance - Policy Makers, Real Estate, ESCOs. Designers have been added as beneficiary of the "wisdom" on KPIs. As result, depending on the specific needs of each single identified user, a list of 52 possible KPIs was drafted, and then subdivided in different categories depending on the aspects and characteristics of single KPIs. The main categories such as: Energy & Grid interaction, building(s) energy use, IEQ (Indoor Environmental Quality), Environmental Impact, Economic Impact, and Social Impact were identified. Single KPIs may have relevance in more than one of the previous mentioned categories, as they cover multiple aspects for a building efficiency and performance evaluation. In addition to these KPIs, the categories will be complemented with other performances' indicators, such as the Smart Readiness Indicator to enlarge and adapt the analyses to the recent developments in the building sector, particularly to the capacity of responding and adapting to the needs of the grid and the users.

2.1. Energy and Facility managers

Energy and Facility managers need to monitor the performances and efficiency of their systems through the average consumption and the demand's peak of the main parts of the building(s) such as: heating and cooling systems, ventilation system, but also the effectiveness and production of installed (or potentially installed) RES. This information is fundamental both for managers of private building stocks and/or municipalities to monitor the performances of the buildings over time and with respect to benchmark values and/or among different stocks, as well as to manage and prevent possible faults of the system(s).

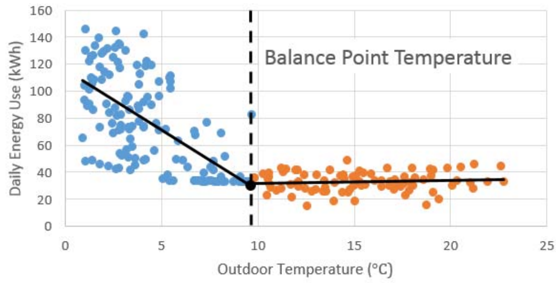
Specific needs:

- To estimate and monitor the demand and consumption of the main systems (e.g., heating, cooling, etc) of the building(s) and system(s).
- To monitor the efficiency of the systems through their performances and efficiency over the time with respect to benchmark period values, both in terms of buildings' dimension and/or habitats, and among different systems.
- To provide alerts or advice for O&M interventions in case of overcoming of certain value for the system(s).

Identified KPIs:

NAME	DESCRIPTION/CALCULATION METHOD	METRIC	SOURCE
Energy demand	Energy demand and consumption calculated over a certain period (i.e., month or year) for the whole system(s) with respect to the available area or volume of the system(s) itself	$kWh/m^2 \cdot year$	[1]
Energy savings	Percentage of savings in terms of energy demand with respect to a baseline value in a certain period	%	[2]
Cooling/Heating Peak Power	Maximum peak of power for heating or cooling demand of the system	W	[1]

Percentage of Peak Load reduction	Peak load is the maximum power consumption of a building or a group of buildings to provide certain comfort levels. Through the establishment of DPEBs and the correct application of ICT systems, the peak load can be reduced on a high extent and therefore the dimension of the supply system (EU SCIS Monitoring KPI Guide, 2018). The indicator is used to analyse the maximum power demand of a system in comparison with the average power.	%	[3]
Percentage of energy grid failures	This KPI shows the fail-safe operation of deployed systems. The move towards highly distributed RES and the subsequent declining contribution from large, controllable power plants can result in issues in demand-supply matching and concerns over future capacity adequacy. With the application of ICT measures, it is possible to correct potential misbehaviour of the system and avoid unexpected breaks in energy supply.	%	[3]
Heating/Cooling total consumption per net area/volume or people	Heat to be delivered to, or extracted from, a conditioned space to maintain the intended temperature conditions during a given period per net area/volume	$kWh/m^2 \cdot$ year or kWh/people	[1]
Annual electric demand per net area/volume or people	Total electric demand over a year normalized per useful area/volume or people	$kWh/m^2 \cdot$ year or kWh/people	
Heat Pump Seasonal Performance Factor	Ground, air, water heat pump performance indicator (SPF) is given by the following formula: $$SPF = 0{,}33 \times \frac{T_{e,i} + 273}{T_{e,i} - T_{s,i}}$$ Where, ground, air, water heat pumps performance indicator is defined through inlet and outlet temperature of the system. So, the inlet temperature of the source is defined as follows: $$T_s = T_{s,i} + Delta$$ Where temperature $T_{s,i}$ represents the average heating seasonal air or ground temperature. Outlet temperatures (emission) are directly determined by the heat emission system. The outlet temperature of the emission is defined as follow: $$T_e = T_c + Delta$$	-	[1]

	Where temperature T_c represents the building comfort temperature.		
Energy signature	Graph describing the correlation between the Heating/Cooling consumption and the External Temperature. Useful indicator to characterize a virtous behaviour of the system.  		[1]
Annual Heating and/or Cooling demand per net area or volume and Heating Degree Days or Cooling Degree Days	Thermal energy demand for available area or volume normalized with the HDD or CDD. $Q' = \frac{Q}{A\ (or\ V) * HDD\ (or\ CDD)}$ $Q' = Normalized\ thermal\ consumption$ $A\ (or\ V) = Area\ (or\ Volume)$ In case of reference location: $Q' = \frac{Q}{A\ (or\ V)} * \frac{HDD_R}{HDD_L} (or \frac{CDD_R}{CDD_L})$ where: $CDD_R = T_{SUN-AIR,\ UNI10349} - T_{SET}$ $CDD_L = T_{SUN-AIR,\ Measured} - T_{SET}$ $T_{SUN-AIR} = T + R_{se} * F_{sh,ob} * \alpha_{sun,\ c} * I_{sun,\ mn}$	kWh/m²· year	[1]
Index of CO_2 (Air quality)	Level of carbon dioxide (CO_2), commonly used as an overall proxy for contamination and lack of adequate ventilation depending on the national threshold levels. The index of air quality based on CO_2 evaluation is defined as: $I_{i,t}^{CO_2} = f(x) = \begin{cases} 1, & CO_2^{real} < CO_2^{threshold} \\ \frac{CO_2^{real}}{CO_2^{threshold}}, & otherwise \end{cases}$ is equal to 1 when its value is lower than the limit, otherwise it is calculated as the ratio between the real value and the threshold.		[1]
Number of overheating/overcooling hours during	Percentage of hours in which the temperature is higher than the set point during heating or cooling period with respect to the time period considered	%	[1]

cooling/heating season			
Number of hours inside the set thermal range	Percentage of hours inside the range with respect to the time period considered	%	[4]
Thermal resistance or transmittance (wall, slab, etc.)	Transmittance or Resistance of component	W/m^2 K	[1]
Airflow rate	Amount of air inflowed in the system (usually through a volume meter; it provides information on the electrical and quality performances of the whole ventilation system	m^3	
HAVC system type	Typology and inventory of the components of the HAVC system, and their COP	-	
Number of complaints	Number of complaints by the users/residents	-	
Employees per shop	Number of employees in a certain shop	Employees/ shop	
Percentage of m^2 roof	Percentage of available roofs' area with relevant PV potential production (in particular those roofs well oriented to South or East-West) - % of m2	%	
Energy price	Weighted energy price by period prices, hours of each period and taxes	€/kWh	[1]
Energy subsidy available	Economic incentives for the electricity use and/or RES production in a certain area	€	

2.2. Utility companies

Utility companies focus on understanding the consumption habits of their final users to increase the efficiency of their systems, and to develop specific demand side flexibility programs to better match the consumption and local generation of renewable energy, and to reduce peaks in energy demand. Moreover, they aim to identify areas for developing new Local Energy Communities (LEC) to support the decarbonisation of the energy sector and mitigate possible faults of the grid due to power peaks' demands.

Specific needs:

- To monitor and understand the consumption habits and pathway in terms of energy and heating/cooling peak power demands, and their reduction over a certain period, of their final users, also including efficiency parameters of the system and the building stock.
- To improve the efficiency of the service avoiding possible faults or interventions on the grid.
- To develop specific programs depending on the flexibility of the final users.
- To identify possible area for installing RES, depending on the available area, the penetration of the specific technology, and the awareness of the users.

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Identified KPIs:

NAME	DESCRIPTION/CALCULATION METHOD	METRIC	SOURCE
Energy demand	Energy demand and consumption calculated over a year for the whole system(s) with respect to the available area or volume of the system itself	$kWh/m^2 \cdot year$	[1]
Energy savings	Percentage of savings in terms of energy demand with respect to a baseline value in a certain period	%	[2]
Cooling/Heating Peak Power	Maximum peak of power for heating or cooling the system	W	[1]
Percentage of Peak Load reduction	Peak load is the maximum power consumption of a building or a group of buildings to provide certain comfort levels. Through the establishment of DPEBs and the correct application of ICT systems, the peak load can be reduced on a high extent and therefore the dimension of the supply system (EU SCIS Monitoring KPI Guide, 2018). The indicator is used to analyse the maximum power demand of a system in comparison with the average power.	%	[3]
Percentage of energy grid failures	This KPI shows the fail-safe operation of deployed systems. The move towards highly distributed RES and the subsequent declining contribution from large, controllable power plants can result in issues in demand-supply matching and concerns over future capacity adequacy. With the application of ICT measures, it is possible to correct potential misbehaviour of the system and avoid unexpected breaks in energy supply.	%	[3]
Annual electric energy per net area/volume or people	Total electric demand over a year normalized per useful area/volume or people	$kWh/m^2 \cdot year$	[1]
Annual electric energy normalized per appliances	Annual electric demand normalized for the appliances	$kWh/m^2 \cdot year$	[1]
Annual RES electric production	Total annual electric production by RES	kWh	[5]
RES installed capacity	Total RES installed capacity	kWp	[5]
RES installed capacity index rate	Percentage of RES installed capacity in a certain period	%	
RES self-consumption	Percentage of self-consumption due to the installed RES with respect to the total electric demand of the system	%	[5]
Building typology	Typology of the building	-	

Occupancy data	Number of users divided by the time of occupancy of the building or available area	Employees/h or m^2	
Employees per shop	Number of employees in a shop for managers and/or utility companies	Employees/shop	
Number of complaints	Number of complaints by the users/residents	-	
Ground floor usage	Percentage of ground floor surface of buildings that is used for commercial or public purposes as percentage of total ground floor surface - % of m^2	%	[1]
Percentage of m^2 roof	Percentage of available roofs' area with relevant PV potential production (in particular those roofs well oriented to South or East-West) - % of m^2	%	
Levelized cost of electricity LCOE	The LCOE [€cent/kWh] is calculated through dividing all the costs (i.e., initial investment, maintenance and substitutions) by all the electricity produced over 15 years	€cent/kWh	[5]
Levelized cost of electricity on self-consumption $LCOE_{self}$	The expected self-consumed LCOE [€ cent/kWh] refers to the LCOE for the electricity that is self-consumed, it is therefore obtained as the total costs of installation and maintenance divided by only the electricity self-consumed	€cent/kWh	[5]
Storage installed capacity	Total amount of installed storage capacity (i.e., battery systems, etc.)	kWh	[5]
Storage installed capacity index rate	Percentage of installed capacity over a certain period	%	
Energy cost, Operational cost	Energy demand for final energy from thermal simulation or energy balance according to national code. Local energy prices. Compiled with maintenance cost to the operational cost.	€/y or per specific period/unit	[4]
Energy Price	Weighted energy price by period prices, hours of each period and taxes	€/kWh	[1]
Income data per household	Average income per number of households	€/household	
Population density	Number of people per area	People/Area	

2.3. Territorial governance and policy makers

To properly design and introduce effective policies, local authorities and policy makers require information on the actual diffusion, penetration, and effectiveness of technologies or incentives' schemes, leading to a reliable energetic transition and innovation of both the residential sector and the commercial and office buildings. They also need data on the awareness and engagement on environmental policies of private citizens, SMEs, and local authorities. In fact, the economic aspects such as: investment/maintenance/operational costs, energy prices, available subsides, and payback period provide fundamental financial information to encourage and include financers and investors in the refurbishment process of the building sector. However, social aspects such as the environmental

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awesomeness, the income per household, or the energy poverty give insight into the acceptance or the effectiveness of the new policies.

Specific needs:

- To know and monitor the penetration of different technologies (i.e., PV, thermal, heat pump, isolating systems, etc.) both in terms of efficiency and effectiveness in the building stock.
- To know the environmental awareness and the consumers engagement of private citizens, SMEs, municipalities and/or local authorities with respect to implemented policies or used technologies to develop new polices.
- To monitor the energy efficiency renovation activities and their economic costs for identifying development pathways for investors and financers.
- To include investors and financers in the decision-making process to enlarge the diffusion of energy efficiency interventions on the building stock.

Identified KPIs:

NAME	DESCRIPTION/CALCULATION METHOD	METRIC	SOURCE
Annual RES electric production	Total annual electric production by RES	kWh	[5]
RES installed capacity	Total RES installed capacity	kWp	[5]
RES installed capacity rate index	Percentage of RES installed capacity in a certain period	%	
RES self-consumption	Percentage of self-consumption due to the installed RES with respect to the total electric demand of the system	%	[5]
CO_2 emission	Quantity of CO2 eq. emitted by the whole building system over its lifecycle -where CO2 eq is the ratio of the time-integrated radiative forcing from the instantaneous release of 1 kg of a trace substance relative to that of 1 kg of a reference gas	tCO_2eq	[4]
CO_2 emission rate index	Percentage of CO2 emisision reduction over a certain identified period	%	
Ground floor usage	Percentage of ground floor surface of buildings that is used for commercial or public purposes as percentage of total ground floor surface - % of m^2	%	[1]
Percentage m^2 roof	Percentage of available roofs' area with relevant PV potential production (in particular those roofs well oriented to South or East-West) - % of m^2	%	
Payback period/Return on Investment	The payback period is the time it takes to cover investment costs. It can be calculated from the number of years elapsed between the initial investment and the time at which cumulative savings offset the investment	Years	[6]

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Levelized cost of electricity LCOE	The LCOE [€cent/kWh] is calculated through dividing all the costs (i.e. initial investment, maintenance and substitutions) by all the electricity produced over 15 years	€cent/kWh	[5]
Levelized cost of electricity on self-consumption $LCOE_{self}$	The expected self-consumed LCOE [€ cent/kWh] refers to the LCOE for the electricity that is self-consumed, it is therefore obtained as the total costs of installation and maintenance divided by only the electricity self-consumed	€cent/kWh	[5]
Storage installed capacity	Total amount of installed storage capacity (i.e., battery systems, etc.)	kWh	[5]
Storage installed capacity rate index	Percentage of storage installed capacity in a certain period	%	
Energy Price	Weighted energy price by period prices, hours of each period and taxes	€/kWh	[1]
Penetration of technology	Percentage of installed technology with respect to the total (i.e., installed heat pump with respect to the total heating systems, etc.)	%	
Penetration of technology rate index	Percentage of installed technology in a certain period	%	
Energy subsidy available	Economic incentives for the electricity use and/or RES production in a certain area	€	
Consumers engagement	Measures the involvement of users in the control over the energy use in the building		[4]
Environmental awareness	Increasing environmental awareness and educating about sustainability and the environment		[1]
Ease of use for end users	The extent to which the solution is perceived as difficult to understand and use		
Satisfaction level/Employment indicator	Percentage of new job created in a certain area over a defined period	€/household	
Income data per household	Average income per number of households	People/Area	

2.4. Real Estate

In the real estate sector, information on the quality, efficiency, and economic aspects are fundamental, especially to compare the performances of different buildings in similar conditions. Moreover, economic information such as: investment costs, payback period and similar ones support the risk investment evaluation in different ECMs and energy efficiency actions reducing the consumption and saving money.

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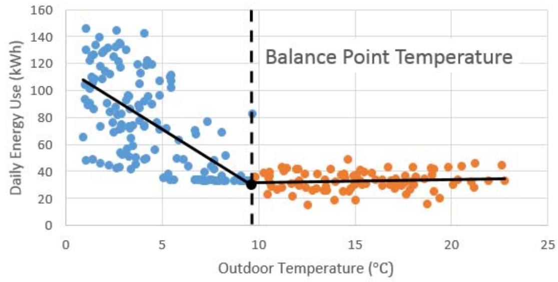
Specific needs:

- To evaluate performances on specific building(s) in terms of energy efficiency, comfort of internal environments, and economic parameters, comparing with similar stock(s) in comparable conditions.
- To identify interventions' pathways among the stock to reduce maintenance costs increasing the efficiency of the system and saving money.
- To evaluate the risks of investing in different interventions or technologies both in terms of initial costs and energy saving effectiveness.

Identified KPIs:

NAME	DESCRIPTION/CALCULATION METHOD	METRIC	SOURCE
Energy demand	Energy demand and consumption calculated over a year for the whole system(s) with respect to the available area or volume of the system itself	$kWh/m^{2,3} \cdot$ year	[1]
Energy savings	Percentage of savings in terms of energy demand with respect to a baseline value in a certain period	%	[2]
Heating/Cooling Peak Power	Max peak of Cooling and Heating system	W	[1]
Annual electric energy per net area/volume or people	Total electric demand over a year normalized per useful area/volume or people	$KWh/m^{2,3}$	[1]
Annual electric appliances demand per net area/volume or people	Annual electric appliances demand of a system normalized for the net area/volume or number of people	$kWh/m^{2,3}$ or kWh/people	
Heat Pump Seasonal Performance Factor	Ground, air, water heat pump performance indicator (SPF) is given by the following formula: $$SPF = 0{,}33 \times \frac{T_{e,i} + 273}{T_{e,i} - T_{s,i}}$$ Where, ground, air, water heat pumps performance indicator is defined through inlet and outlet temperature of the system. So, the inlet temperature of the source is defined as follows: $$T_s = T_{s,i} + Delta$$ Where temperature $T_{s,i}$ represents the average heating seasonal air or ground temperature. Outlet temperatures (emission) are directly determined by the heat emission system. The outlet temperature of the emission is defined as follow:	-	[1]

	$T_e = T_c + Delta$ Where temperature T_c represents the building comfort temperature.		
Energy Signature	Graph describing the correlation between the Heating/Cooling consumption and the External Temperture. Useful indicator to understand the "well" behaviour of the system. 		[1]
LENI (Light Energy Numeric Indicator)	The LENI (Lighting Energy Numeric Indicator) quantifies the annual electricity consumption for lighting per square meters	kWh/m^2 year	[7]
Building typology	Typology of the building	-	
Occupancy data	Number of users divided by the time of occupancy of the building or available area	Employees/h or Employees/m2	
Annual Heating and/or Cooling demand per net area or volume and Heating Degree Days or Cooling Degree Days	Thermal energy demand for available area Or volume normalized with the HDD or CDD. $Q' = \frac{Q}{A\ (or\ V) * HDD\ (or\ CDD)}$ $Q' = Normalized\ thermal\ consumption$ $A\ (or\ V) = Area\ (or\ Volume)$ In case of reference location: $Q' = \frac{Q}{A\ (or\ V)} * \frac{HDD_R}{HDD_L} (or \frac{CDD_R}{CDD_L})$ where: $CDD_R = T_{SUN-AIR,\ UNI10349} - T_{SET}$ $CDD_L = T_{SUN-AIR,\ Measured} - T_{SET}$ $T_{SUN-AIR} = T + R_{se} * F_{sh,ob} * \alpha_{sun,\ c} * I_{sun,\ mn}$	kWh/$m^{2,3}$	[1]
Index of CO_2 (Air quality)	Level of carbon dioxide (CO_2), commonly used as an overall proxy for contamination and lack of adequate ventilation depending on the national threshold		[1]

	levels. The index of air quality based on CO_2 evaluation is defined as: $$I_{i,t}^{CO_2} = f(x) = \begin{cases} 1, & {CO_2}^{real} < {CO_2}^{threshold} \\ \frac{{CO_2}^{real}}{{CO_2}^{threshold}}, & otherwise \end{cases}$$ is equal to 1 when its value is lower than the limit, otherwise it is calculated as the ratio between the real value and the threshold.		
Daylight Factor (DF)	The Daylight Factor (DF) is a commonly used indicator for assessing the effectiveness of natural daylights in a space. DF quantifies the amount of indoor daylight against the simultaneously available outdoor daylight		[4]
Number of overheating/overcooling hours during cooling/heating season	Percentage of hours in which the temperature is higher than the set point during heating or cooling period with respect to the time period considered	%	[1]
Number of hours inside the set thermal range	Percentage of hours inside the range with respect to the time period considered	%	[4]
Thermal resistance or transmittance	Thermal resistance or trasmittance of component (wall, slab, etc.) also considering refurbishment interventions for isolating the building	W/m^2 K	[1]
Number of complaints	Number of complaints by the users/residents	-	
Ground floor usage	Percentage of ground floor surface of buildings that is used for commercial or public purposes as percentage of total ground floor surface - % of m^2	%	[1]
Payback period/Return on Investment	The payback period is the time it takes to cover investment costs. It can be calculated from the number of years elapsed between the initial investment and the time at which cumulative savings offset the investment	Years	[6]
Levelized cost of electricity LCOE	The LCOE [€cent/kWh] is calculated through dividing all the costs (i.e. initial investment, maintenance and substitutions) by all the electricity produced over 15 years	€cent/kWh	[5]
Levelized cost of electricity on self-consumption $LCOE_{self}$	The expected self-consumed LCOE [€ cent/kWh] refers to the LCOE for the electricity that is self-consumed, it is therefore obtained as the total costs of installation and maintenance divided by only the electricity self-consumed	€cent/kWh	[5]
Investment cost	all costs that need to be covered until an energy efficiency measure is fully implemented	€, €/unit, €/m^2	[4]
Maintenance costs	yearly percentage of investment, included in Operational cost	€	[4]

Penetration of technology	Percentage of installed technology with respect to the total (i.e., installed heat pump with respect to the total heating systems, etc.)	%	
Penetration of technology rate index	Percentage of installed technology in a certain period	%	
Energy subsidy available	Economic incentives for the electricity use and/or RES production in a certain area	€	

2.5. ESCOs

Energy Service Companies require specific information on the energy demands and efficiency of the building stock to identify the best solutions for investments with the shortest payback period and greatest potential in terms of savings. In addition, data on the penetration of technologies and Renewable Energy Sources provide information for creating new Local energy Communities enlarging the revenues and accelerating the transition of the building sector.

Specific needs:

- To perform Measurement & Verification (M&V) procedures to improve the energy efficiency of the building stock and the collaboration with the building owners.
- To spread the energy efficiency interventions through a series of Energy Performance Contracts (EPC) depending on the building stock features.
- To identify areas for new PV installations.

Identified KPIs:

NAME	DESCRIPTION/CALCULATION METHOD	METRIC	SOURCE
Energy demand	Energy demand and consumption calculated over a year for the whole system(s) with respect to the available area or volume of the system itself	$kWh/m^{2,3} \cdot year$	[1]
Energy savings	Percentage of savings with respect to a baseline value in a certain period	%	[1]
Cooling/Heating Peak Power	Maximum peak of power for heating or cooling the system	W	[1]
Percentage of peak load reduction	Peak load is the maximum power consumption of a building or a group of buildings to provide certain comfort levels. Through the establishment of DPEBs and the correct application of ICT systems, the peak load can be reduced on a high extent and therefore the dimension of the supply system (EU SCIS Monitoring KPI Guide, 2018). The indicator is used to analyse the maximum power demand of a system in comparison with the average power.	%	[3]
Percentage of energy grid failures	This KPI shows the fail-safe operation of deployed systems. The move towards highly distributed RES and the subsequent declining contribution from large, controllable power plants can result in issues in demand-supply matching and concerns over future	%	[3]

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	capacity adequacy. With the application of ICT measures, it is possible to correct potential misbehaviour of the system and avoid unexpected breaks in energy supply.		
Annual electric appliances demand per net area/volume or people	Annual electric appliances demand of a system normalized for the net area/volume or number of people	$kWh/m^{2,3}$ or kWh/ people	
RES installed capacity	Total RES installed capacity	kWp	[5]
RES installed capacity index rate	Percentage of RES installed capacity in a certain period	%	
RES self-consumption	Percentage of self-consumption due to the installed RES with respect to the total electric demand of the system	%	[5]
Index of CO_2 (Air quality)	Level of carbon dioxide (CO_2), commonly used as an overall proxy for contamination and lack of adequate ventilation depending on the national threshold levels. The index of air quality based on CO_2 evaluation is defined as: $I_{i,t}^{CO_2} = f(x) = \begin{cases} 1, & CO_2^{real} < CO_2^{threshold} \\ \frac{CO_2^{real}}{CO_2^{threshold}}, & otherwise \end{cases}$ is equal to 1 when its value is lower than the limit, otherwise it is calculated as the ratio between the real value and the threshold.		[1]
Number of overheating hours during cooling/heating season	Percentage of hours in which the temperature is higher than the set point during heating or cooling period with respect to the time period considered	%	[1]
Number of hours inside the set thermal range	Percentage of hours inside the range with respect to the time period considered	%	[4]
Thermal resistance or transmittance	Thermal resistance or trasmittance of component (wall, slab, etc.) also considering refurbisment interventions for isolating the building	$W/m^2 K$	[1]
Ground floor usage	Percentage of ground floor surface of buildings that is used for commercial or public purposes as percentage of total ground floor surface - % of m^2	%	[1]
Percentage m^2 roof	Percentage of available roofs' area with relevant PV potential production (in particular those roofs well oriented to South or East-West) - % of m^2	%	
Renovation building rate	Percentage of building renovated over a certain period	%	

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Levelized cost of electricity LCOE	The LCOE [€cent/kWh] is calculated through dividing all the costs (i.e. initial investment, maintenance and substitutions) by all the electricity produced over 15 years	€cent/kWh	[5]
Levelized cost of electricity on self-consumption $LCOE_{self}$	The expected self-consumed LCOE [€ cent/kWh] refers to the LCOE for the electricity that is self-consumed, it is therefore obtained as the total costs of installation and maintenance divided by only the electricity self-consumed	€cent/kWh	[5]
Installed storage capacity	Total installed storage capacity	kWh	[5]
Storage installed capacity rate index	Percentage of installed capacity over a certain period	Storage installed capacity rate index	
Investment cost	all costs that need to be covered until an energy efficiency measure is fully implemented	€, €/unit, €/m^2	[4]
Payback period/Return on Investment	The payback period is the time it takes to cover investment costs. It can be calculated from the number of years elapsed between the initial investment and the time at which cumulative savings offset the investment	Years	[6]
Maintenance costs	yearly percentage of investment, included in Operational cost	€	[4]
Penetration of technology	Percentage of installed technology with respect to the total (i.e., installed heat pump with respect to the total heating systems, etc.)	%	
Penetration of technology rate index	Percentage of installed technology in a certain period	%	
Energy price	Weighted energy price by period prices, hours of each period and taxes	€/kWh	[1]
Energy subsidy available	Economic incentives for the electricity use and/or RES production in a certain area	€	

2.6. Designers and other potential users

Designers and other potential users require general and preliminary information for properly designing buildings. Information on total demand and consumption of existing buildings role as benchmark for scaling the new buildings. Moreover, designers can adapt their projects considering the IEQ data of similar buildings. Lastly, the economic costs, incentives and the penetration of innovative technologies in the building sector provide useful information for adapting new buildings in the residential and commercial contexts.

Specific needs:

- To properly design buildings on performances and data of the existing ones
- To evaluate the IEQ performances

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- To preliminary perform economic evaluations of buildings in a certain context

Identified KPIs:

NAME	DESCRIPTION/CALCULATION METHOD	METRIC	SOURCE
Building typology	Building typology (e.g., residential, commercial, etc.)	-	
Energy demand	Energy demand and consumption calculated over a year for the whole system(s) with respect to the available area or volume of the system itself	kWh/m^{2,3} · year	[1]
Cooling/Heating Peak Power	Maximum peak of power for heating or cooling the system	W	[1]
Annual Heating and/or Cooling demand per net area or volume and Heating Degree Days or Cooling Degree Deays	Thermal energy demand for available area Or volume normalized with the HDD or CDD. $Q' = \frac{Q}{A\ (or\ V) * HDD\ (or\ CDD)}$ $Q' = Normalized\ thermal\ consumption$ $A\ (or\ V) = Area\ (or\ Volume)$ In case of reference location: $Q' = \frac{Q}{A\ (or\ V)} * \frac{HDD_R}{HDD_L} (or \frac{CDD_R}{CDD_L})$ where: $CDD_R = T_{SUN-AIR,\ UNI10349} - T_{SET}$ $CDD_L = T_{SUN-AIR,\ Measured} - T_{SET}$ $T_{SUN-AIR} = T + R_{se} * F_{sh,ob} * \alpha_{sun,\ c} * I_{sun,\ mn}$	kWh/m^{2,3}	[1]
RES installed capacity index rate	Percentage of RES installed capacity in a certain period	%	
LENI (Light Energy Numeric Indicator)	The LENI (Lighting Energy Numeric Indicator) quantifies the annual electricity consumption for lighting per square meters	kWh/m^2 year	[7]
Daylight Factor (DF)	The Daylight Factor (DF) is a commonly used indicator for assessing the effectiveness of natural daylights in a space. DF quantifies the amount of indoor daylight against the simultaneously available outdoor daylight		[4]
Airflow rate	Amount of air inflowed in the system (usually through a volume meter; it provides information on the electrical and quality performances of the whole ventilation system	m^3	

Number of overheating hours during cooling/heating season	Percentage of hours in which the temperature is higher than the set point during heating or cooling period with respect to the time period considered	%	[1]
Number of hours inside the set thermal range	Percentage of hours inside the range with respect to the time period considered	%	[4]
Thermal resistance or transmittance	Thermal resistance or trasmittance of component (wall, slab, etc.) also considering refurbisment interventions for isolating the building	$W/m^2\,K$	[1]
Index of CO_2 (Air quality)	Level of carbon dioxide (CO_2), commonly used as an overall proxy for contamination and lack of adequate ventilation depending on the national threshold levels. The index of air quality based on CO_2 evaluation is defined as: $I_{i,t}^{CO_2} = f(x) = \begin{cases} 1, & CO_2^{real} < CO_2^{threshold} \\ \frac{CO_2^{real}}{CO_2^{threshold}}, & otherwise \end{cases}$ is equal to 1 when its value is lower than the limit, otherwise it is calculated as the ratio between the real value and the threshold.		[1]
Levelized cost of electricity LCOE	The LCOE [€cent/kWh] is calculated through dividing all the costs (i.e. initial investment, maintenance and substitutions) by all the electricity produced over the plant's lifetime	€cent/kWh	[5]
Levelized cost of electricity on self-consumption $LCOE_{self}$	The expected self-consumed LCOE [€ cent/kWh] refers to the LCOE for the electricity that is self-consumed, it is therefore obtained as the total costs of installation and maintenance divided by only the electricity self-consumed	€cent/kWh	[5]
Energy price	Weighted energy price by period prices, hours of each period and taxes	€/kWh	[1]
Energy subsidy available	Economic incentives for the electricity use and/or RES production in a certain area	€	
Investment cost	all costs that need to be covered until an energy efficiency measure is fully implemented	€, €/unit, €/m^2	[4]
Energy cost, Operational cost	Energy demand for final energy from thermal simulation or energy balance according to national code. Local energy prices. Compiled with maintenance cost to the operational cost.	€/y or per specific period/unit	[4]
Payback period/Return on Investment	The payback period is the time it takes to cover investment costs. It can be calculated from the number of years elapsed between the initial investment and the time at which cumulative savings offset the investment	Years	[6]

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Maintenance costs	yearly percentage of investment, included in Operational cost	€	[4]
Penetration of technology	Percentage of installed technology with respect to the total (i.e., installed heat pump with respect to the total heating systems, etc.)	%	
Penetration of technology rate index	Percentage of installed technology in a certain period	%	

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3. Tool development and application

In this chapter, MODERATE analytics and tools are described in their scope, data flow and exchanges, user experience and testing scenarios. The reported specification is based on initial assumptions of MODERATE consortium. The presented analytics services are at different development stages. While some of them are already fully developed and ready for a first testing cycle, others are still to be developed. User feedback will be integrated and further developments reported in D5.2 and D5.3.

3.1. MODERATE Fault detection and forecasting (A1.1)

An effective and efficient monitoring and control system is essential for service providers such as utility companies and ESCOs as well as facility managers. The goal of continuous service without failures is only achievable through a continuous evaluation and diagnosis of the data flow of the monitored system. Fault detection is based on mathematical models of signals and processes. Its application avoids the interruption of processes in buildings systems, and particularly effective when associating the detection with predictive maintenance.

This tool enables intelligent monitoring and supervision systems, where the fault is identified in near-real time, and positively contribute to building smartness and energy efficiency. The tool allows users, in particular energy managers and utility managers, to predict and explain system failures based on an improved knowledge of building characteristics and behaviour from MODERATE.

The tool relies on core functionalities and services available from the SYNAVISION platform (SYNAVISION.de), which offers a digital test bench for smart buildings based on digital twin models. All skills and described services can connect with the SYNAVISION platform via APIs and other data import and export services, which are already operational and validated.

3.1.1. Tool description

This tool is a software application that, exploiting synergies within MODERATE and SYNAVISION platform, offers a customizable environment for setting up time series data analytics for fault detection and forecasting for optimization of operations, thus enabling predictive maintenance on technical building systems.

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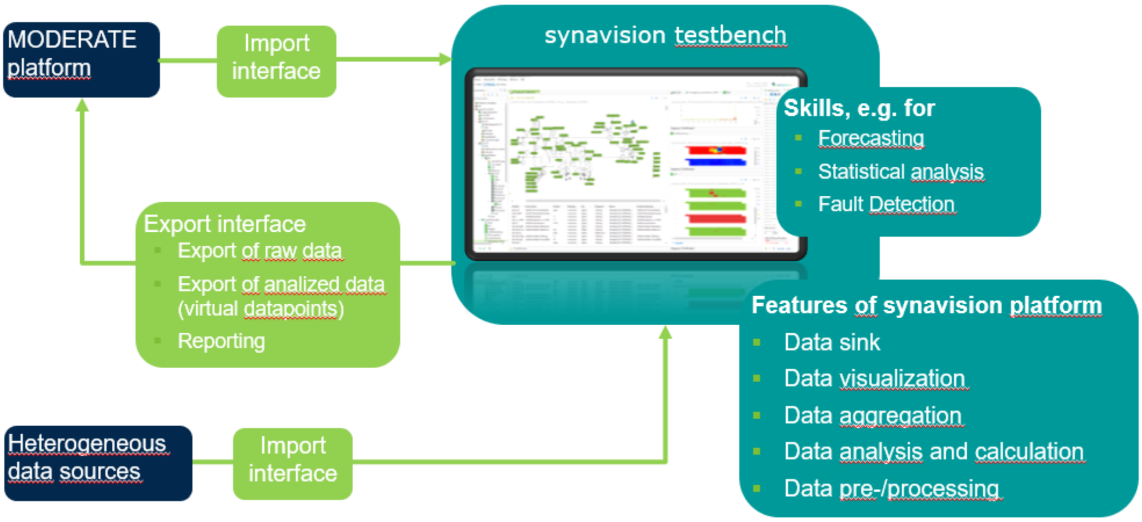

Figure 2 Interconnection between MODERATE platform and SYNAVISION platform.

The tool, within SYNAVISION platform, can connect with the MODERATE platform APIs, supporting interoperability with other tools and functionalities. It supports additional data I/O, as specific near real-time data handling. While import handles time series and metadata, exports can include various formats such as dashboards, files etc. for reporting KPIs to the users. SYNAVISION is an example of how the MODERATE platform can be extended also integrating potential services form non-open-source services.

A skill is defined as an application within the context of SYNAVISION platform, and in particular within SYNAVISION's test bench client-side software for digital twinning. It can import times series data and metadata, handle the data logically and arithmetically and export results. The skill is executed whenever new data is imported into corresponding workspace of the platform.

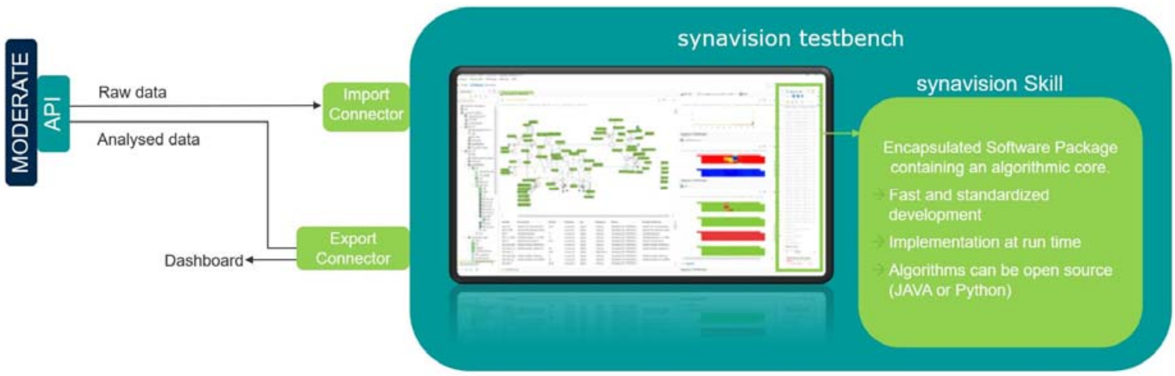

Figure 3 Skill-concept for analytics services of time series data.

The setup process is similar for any skills. It uses the same header and footer for general information as well as for input and output behaviour. The core process containing algorithms and results is unique depending on the functionality coded into the skill.

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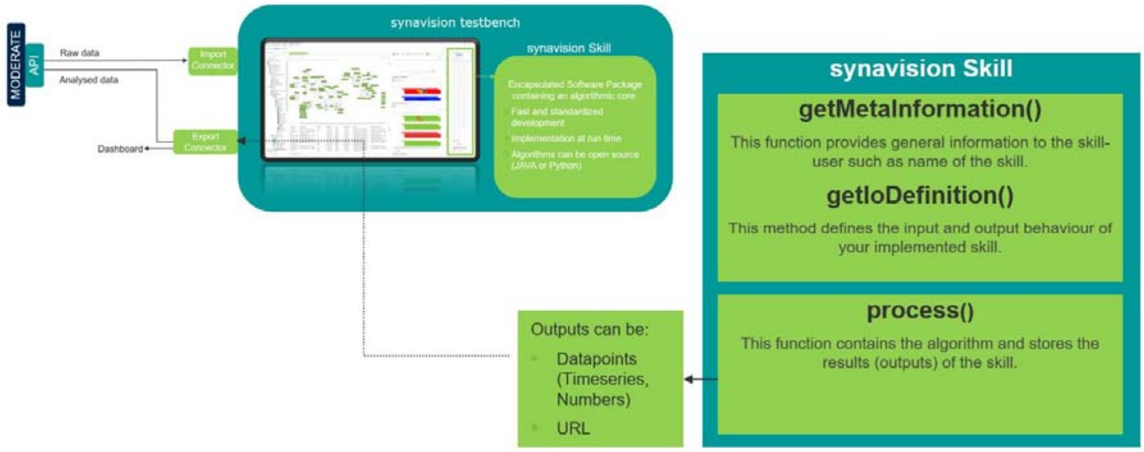


Figure 4 Internal structure of a skill.

Besides the skill engine, the SYNAVISION platform allows for a highly flexible domain-specific language (sand-box model) for additional, individual data handling.

The skill for anomaly detection identifies anomalies in time series. Various algorithms for anomaly detection can be selected by the user. In addition, meaningful metrics are generated, which provide an overview of the general state as well as the recent historical data points regarding occurring anomalies.

3.1.2. Input/output

The skill asks for the following input and parameters:

- Numerical time series of which a subrange is to be checked for anomalies, including user data as well as time series datasets passed by MODERATE APIs, i.e., from other MODERATE services. The skill can handle any kind of data, i.e., energy metering, mass flow rate, electric current, IEQ monitoring. The type of algorithm, time range and other variables need to be adapted for best performance.
- Size of the time window to be checked for anomalies (test interval). The specification is made in time steps according to the data point quantization. For example, to test the last day of the time series or the last 96 timesteps of the time series for anomalies at a quarter-hour resolution, a time window size of 96 must be specified).
- Size of the time window in number of time steps according to the data point quantization to be used for learning the normal process (training interval).
- Selection of the concrete algorithm to be used to detect the anomalies:
  - Auto Regression
  - Generalized ESD Test
  - Inter Quartile Range
  - Rolling Average
  - Principal Component Analysis.

  The algorithmic options provided here have been identified as useful and robust options for generic anomaly detection and shall be applied depending on the type and characteristics of the time series data. The selection of the algorithm needs to be done by an expert depending on individual types of data.

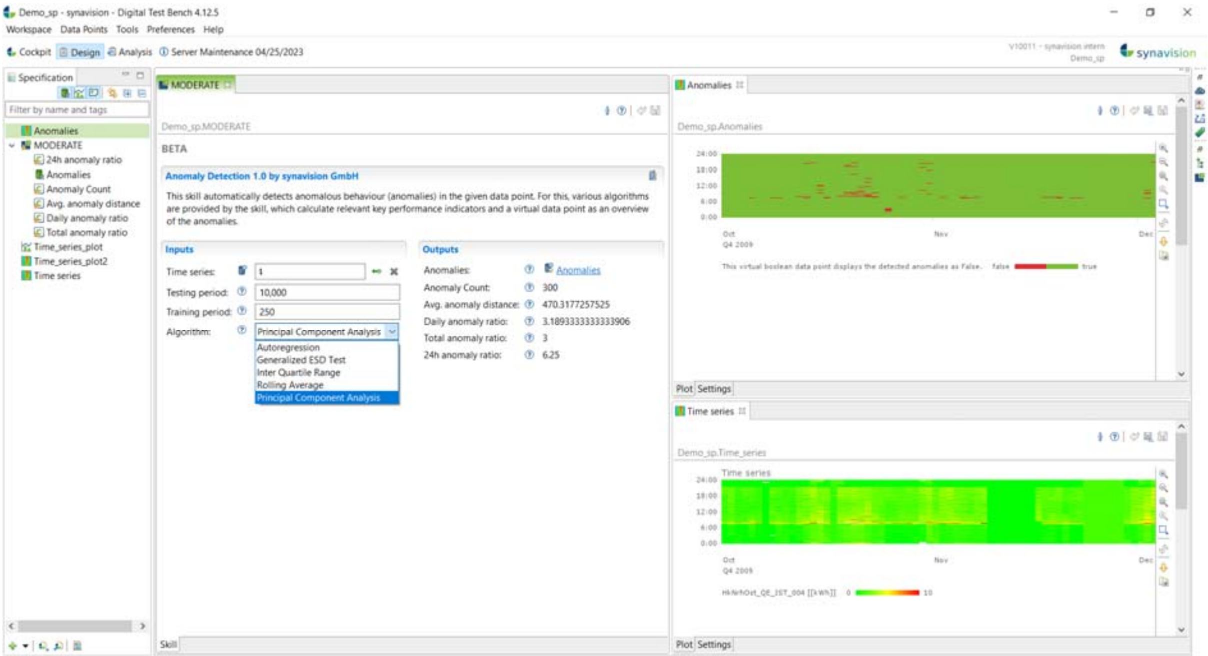


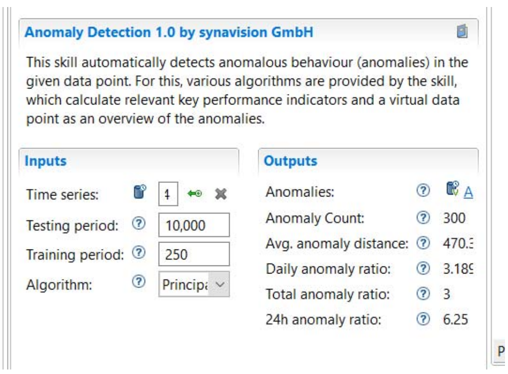
Figure 5 Setup menu for the configuration of the skill within the SYNAVISION platform.

The following Output data is provided by the skill and available to MODERATE APIs:

- Anomalies (time series [0;1])
- Anomaly count (number of anomalies within the testing period)
- Avg. anomaly distance (average number of time steps between anomalies)
- Daily anomaly ration (Average of anomalies per day)
- Total anomaly ration (Percentage of anomalies for all valid input values)
- 24h anomaly ration (Percentage of anomalies within the last 24 hours of the testing period).

3.1.3. User experience

In principle the skill is an application without an UI, that runs on SYNAVISION client-server application. In this case, the Digital Test Bench provides the UI functionalities, connects to SYNAVISION platform and to MODERATE APIs. The client, as shown in the screenshot, offers the easy application of the skill following these steps:



- Enter a workspace.
- Create an instance of the skill by double clicking, naming and saving the instance.
- Choose the times series you want to analyse by drag and drop.
- Enter the length of testing and training period (number of time steps)
- Choose the algorithm to be applied.
- Save the skill.

Figure 6 Configuration menu of the skill.

The following screenshot shows a time series (below) and the anomalies detected through a principal component analysis.

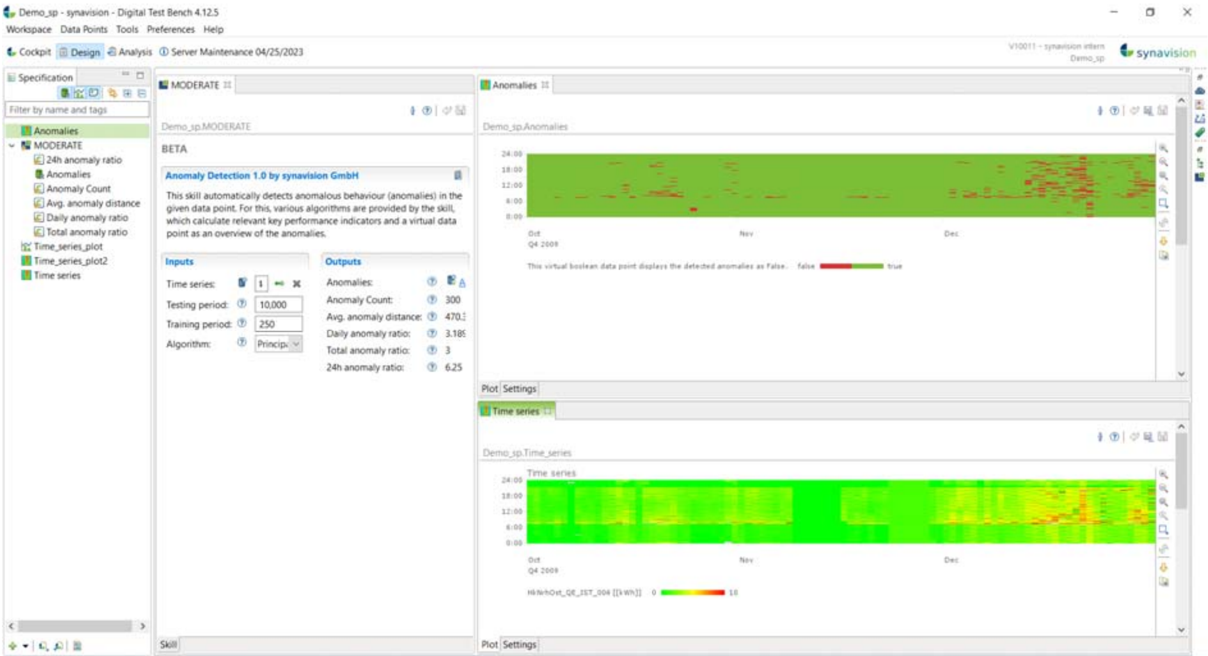


Figure 7 Visualization of the skill output (example, anomalies marked gradually in lower plot and in red in top plot).

The functionalities are also available through MODERATE APIs, to support interoperability.

3.1.4. Application on MODERATE pilot cases

Within MODERATE, this service can be used to identify anomalies in any time series, e.g., weather data, metering data etc. Extended with an auto-correction skill for data enhancement, e.g., for deleting and replacing values, the tool can be used as a powerful "behind-the-scenes"-tool to improve data quality and performance of other services within the MODERATE platform.

The tool will be tested by real users (pilots) from MODERATE target groups and more specifically ESCOs (VEOLIA), Facility manager (Würth Italia) as well as SYNAVISION. The tool is currently intended for application on time series data from building automation systems. Further testing will verify the applicability on grid management data in cooperation with Enercoop, aiming at improving the quality of the service by reducing possible faults or errors of the grid.

3.2. Energy system optimization (A1.2)

New building frontiers are taking hold and increasingly complex systems require greater controls. IoT is becoming an essential element to ensure that the potential of the building defined in the design phase is respected. Continuous commissioning is fundamental to optimize buildings in order to identify the right set-up that guarantees the best level of comfort at the lowest cost. The use of big data along with AI techniques enables optimization of building systems, facilitating the work of energy and facility managers.

This tool applies machine learning techniques on synthesized data to generate possible optimizations in the systems. The user can identify the possible optimizations in the technical building systems and evaluate their applicability.

3.2.1. Tool description

The Energy system optimization tool is another example of a SYNAVISION platform's skill defined in chapter 3.1, that is developed to and connected with the MODERATE platform as a service for prediction on timeseries data. In particular, this skill can generate a time series dataset for a selected period of time in the future based on at least three weeks of historical data (the minimum useful range to generate acceptable results, found empirically) and additional information from MODERATE knowledge. Various algorithms for prediction are available to the user. In addition, meaningful KPIs are generated providing additional information on the data used and the information generated.

3.2.2. Input/output

The skill asks for the following input:

- Numerical time series containing the historical data.
- Size of the time window for which the time series shall be predicted.
- Size of the time window used as training data.
- Selection of the concrete algorithm to be used to predict the future behaviour:
  - Holt Winters Additive Trend Additive Season
  - Holt Winters Additive Trend Multiplicative Season
  - Neural Basis expansion analysis
  - Trigonometric seasonality, Trend and Season
  - Trigonometric seasonality, Trend Box-Cox, Trend
  - Trigonometric seasonality, Trend Box-Cox, Trend and Season
  - Trigonometric seasonality, Trend Box-Cox, Trend and 2 Season

As output, the skill delivers:

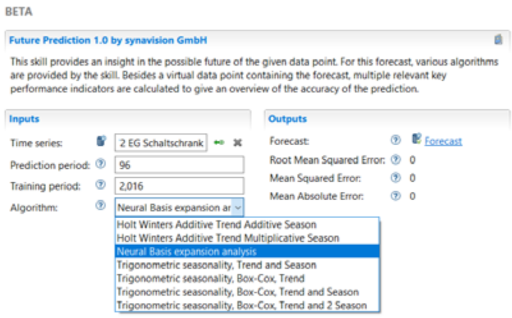
- a forecasted time series

and as indicators for the quality of the prediction

- the Root Mean Squared Error
- the Mean Squared Error
- the Mean Absolute Error.

3.2.3. User experience

SYNAVISION test bench application is used as a client-server application, providing the UI for the skill. The client, as shown in the screenshot, offers the easy application of the skill following these steps:



- Enter a workspace.
- Create an instance of the skill by double clicking, naming and saving the instance.
- Choose the times series you want to predict by drag and drop.
- Enter the length of prediction and training period (number of time steps)
- Choose the algorithm to be applied.
- Save the skill.

Figure 8 Configuration menu of the skill.

The following screenshot shows the time series (blue) and the predicted times series for the next day (green).

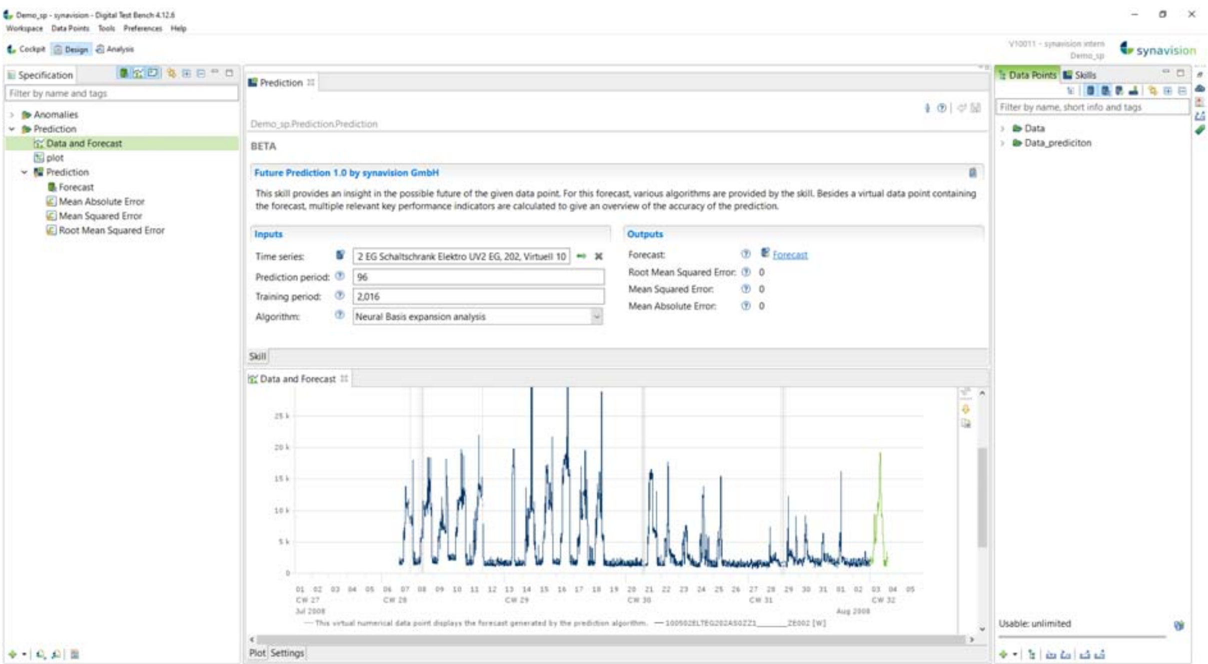


Figure 9 Visualization (example) of an initial time series (blue) and the prediction for the following day (green).

The functionalities are also available through MODERATE APIs, to support interoperability.

3.2.4. Application on MODERATE pilot cases

Time series prediction can be used to model the future behaviour of a system, e.g., the energy consumption of a building. Knowing the future energy consumption can help to manage energy demand by optimizing the management of storage capacities, e.g., through load shifting or peak shaving. By knowing when a load peak is likely, when energy prices are high (or low) or demand is going to be low (or high), the building management system can decide to increase or reduce the amount of stored energy in buffer tanks or construction and thus avoid reaching peaks or buying energy at high cost.

The tool will be tested by real users (pilots) from our target groups and more specifically project partners aiming to reduce the energy consumption of their buildings through better management of plant controls, as VEOLIA, Würth Italia and SYNAVISION, on test buildings through the development of Digital Building Twins.

3.3. ECM application (A1.3)

Increasing the energy efficiency of existing buildings is a priority from different points of view: the environmental performance, the security of energy supply and the quality of life of citizens. The renovation of existing buildings has a particularly high potential. It is therefore logical, from an economic and operational point of view, to implement appropriate energy saving measures when a building is renovated. The ECM tool improved in MODERATE is based on a wider study and development carried out by EURAC aimed at a simplified performance evaluation of the building with the purpose of defining the priority of energy upgrading interventions in a stock of buildings. The development of the tool started with the H2020 MATRYCS and INFINITE projects. In MODERATE more features are added, such as benchmarking building using synthetic data, improvement of the computing engine related to HVAC systems, and wider testing with datasets on EPCs.

3.3.1. Tool description

The tool structure is represented in Figure 12.

The aim of the tool is to identify the most cost-effective combination of ECMs and the expected benefits. The tool assesses and simulates the building implementing the hourly dynamic calculation of heating and cooling demand, as defined by the ISO 52016. This approach is aligned to the provisions in the EPBD recast:

“Numeric indicators of final energy use per unit of reference floor area per year, in kWh/m2y and of energy needs according to ISO 52000 in kWh/m2y shall be used. The methodology applied for the determination of the energy performance of a building shall be transparent and open to innovation and reflect the best practices, in particular from additional indicators.

Members States shall describe their national calculation methodology based on the Annex A of the Key European Standard on energy performance of buildings named EN ISO 52000-1, EN ISO 52003-1, EN ISO 52010-1, EN ISO 52016-1, EN ISO 52018-1, EN 16798-1, EN 52120-1 and EN 17423 or superseding documents”.

It also mentions that “The energy needs and energy use for space heating, space cooling, domestic hot water, ventilation, lighting and other technical building systems shall be calculated using hourly or sub-hourly time calculation intervals in order **to account for varying conditions that significantly affect the operation and performance of the system and the indoor conditions**, and **to optimise costs, health, indoor environmental quality and comfort levels** defined by Member States at national or regional level. The calculation shall include an **estimation of the thermal responsiveness** of the building and its capacity to **offer flexibility to the energy grid**.”

It is worth noting that specialized software already exists for supporting building professionals in energy performance calculation and certification of buildings based on national energy performance standards. In contrast, the ECM tool targets building owners to provide a comprehensive and reliable outlook on identified gaps on building energy performance to orient and support the decision of owners on the type of upgrade of the building. Additionally, the ECM tool follows the reported international standards fostering harmonization, and thus it leverages synthetic data to fill knowledge gap that the owner, might experience in gathering required inputs for running the tool.

The tool computes energy and non-energy related KPIs on buildings based on mentioned standards, i.e., energy demand and comfort indicators about the hourly operative temperature for the entire year which can be exploited for M&V tool.

After the calculation of the energy consumption of the building the user can have the possibility to proceed in two ways:

- Calibrate the model. It is possible to calibrate the model with real data at monthly frequency. The user can provide 12 values relating to the building's energy consumption. The tool optimizes the initial model by trying to reduce the gap between simulated and real values. This is done by working on the convective and radiative internal heat transfer coefficients. Of course, this procedure assumes that the building behaves in a "perfect" manner where the variation generated by user behaviour does not have an elevated effect on the consumption itself.
- Evaluate the ECM. Currently, 31 types of ECMs referring to achievable facade-side and plant-side improvements and their combination can be evaluated. Here we consider possible improvements related to vertical opaque components (walls) horizontal (roof) and vertical transparent elements (windows) for the facade side while plant side we consider achievable improvements on the generation and emission systems.

The tool allows comparison of simulated data with a database of real data for buildings having the same intended use and located in the same country, obtained by MODERATE knowledge. The database is in common with other tools (geo-clustering and benchmarking) where a process of data standardization and metadata has been used to describe different datasets, then retrieved by the tool.

Given the correlation between ECM and risk assessment of investment in energy efficiency systems, several useful Indicators and coefficients are integrated to provide useful indications for investment on ECM, in connection with the de-risking tool.

In collaboration with other European projects, additional analysis tools have been integrated and are being integrated such as:

Photovoltaic Simulation (ECM) and Optimization. Photovoltaics simulation allows the user to assess how much photovoltaics capacity is needed when the energy consumption for heating is covered entirely by an electric generator (heat pump), and additional data is required including i. e., an annual profile of electricity consumption from appliances. The optimization provides a guide for the design of a photovoltaic plus battery energy storage system coupled with a heat pump for different locations and thus different climates in Europe. Through a multi-objective optimization approach applied to the six European geoclusters and applying different solution selection criteria, it is possible to obtain the optimal photovoltaic capacity (kWp) normalized over the thermal consumption of a reference building and the optimal capacity of the battery per kWp of photovoltaic (kWh/kWp) installed. Due to the normalization process, results can be generalized and can be used for designing similar systems in all buildings around Europe. The results must be intended as a support for designers for the early-design phase of such systems or as an initial guess for an iterative process in more advanced evaluations.

Integration in an open BIM platform. Much building information in particular those referring to geometric aspects can be directly taken from a BIM model in particular using the IFC standard. In this case the tool will be able to link to a BIM and automatically obtain information that would otherwise have to be entered manually by the user.

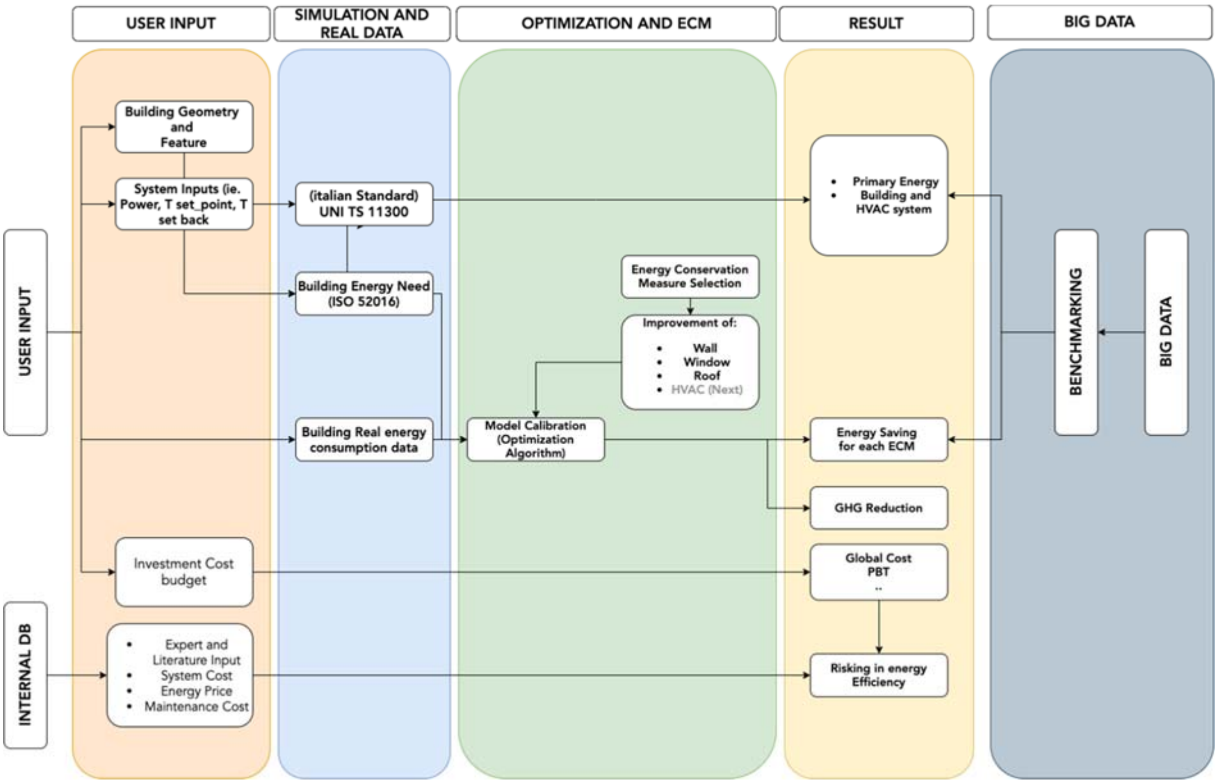


Figure 10 General schema of the ECM tool, including modular components localized for Italy, and interoperability with other MODERATE tools and models.

3.3.2. Input/output

The tool requires several pieces of information from the user related to the physical characteristics of the building and its technical building systems. While an energy audit would be very useful, most information can be inferred from EPCs or main user input, by relying on MODERATE knowledge. The ECM tool calculates building energy consumption using the UNI 52016 standard for the requirements part and linked to an HVAC sizing system to provide the information needed to define the building's energy behaviour. Data from energy monitoring systems are used to calibrate the models to be closer to reality.

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INTERFACE

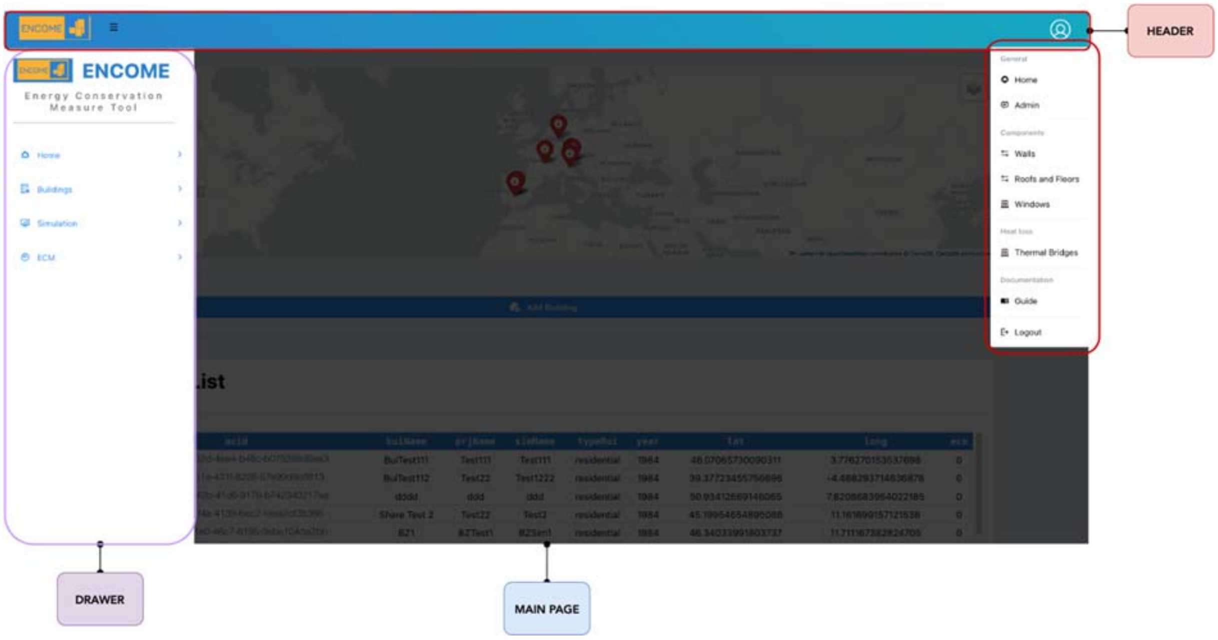

Figure 11 ECM tool interface.

The user can enter information at different level of details on building, its components (walls, roofs, floors, windows) and technical building systems, then select and apply ECMs to a building and run analysis, and finally visualize buildings on a map or as single card with KPIs and benchmarking.

The tool visualizes the following results:

1. The Heating and Cooling consumption of the building as final energy and primary energy, in different time scales: annual, monthly, and hourly.
2. yearly, monthly, and daily average of heating and cooling consumption.

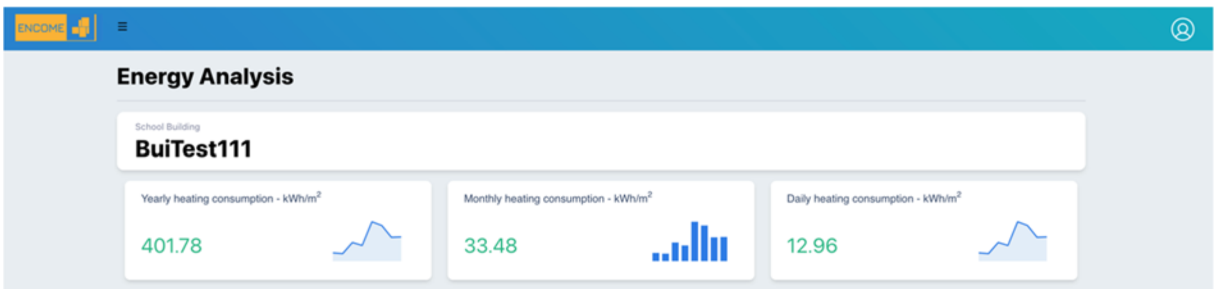

Figure 12 Example of summary results.

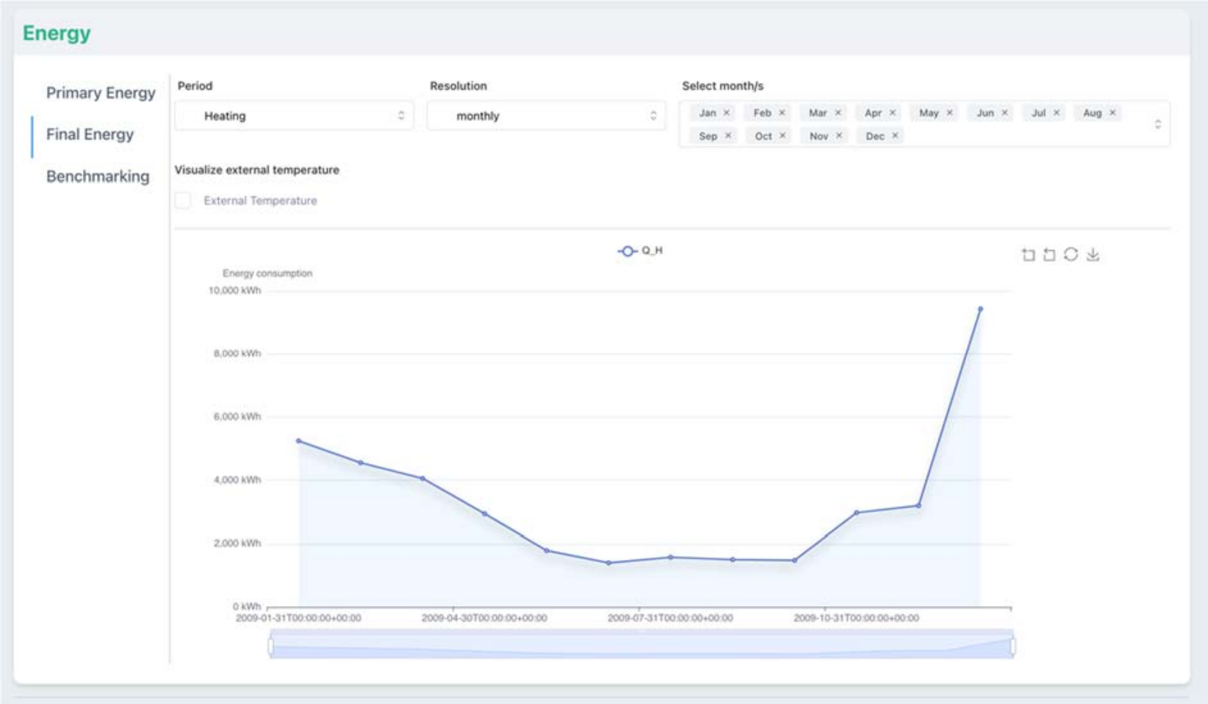

Figure 13 Example of Final Energy computation.

Figure 14 Example of Primary Energy computation.

The user could calibrate the model after running the building simulation. The aim of this functionality is to reduce the gap between the real data and the simulated one, heating consumption of the building on a monthly level is required. The ECM tool calibrates the value of the internal convective and radiative heat transfer coefficient of the walls using the PSO (Particle Swarm Optimization) algorithm.

In most cases, the calibrated model is expected to show better performance. On the other hand, such an approach introduces certain approximations. For example, by assumption the actual values of building energy consumption are mainly given by the building characteristics and not by user misbehavior. In addition, the calculation is single zone, this implies that complex multi-zone buildings and/or even buildings with different uses (e.g., residences and offices), are difficult to improve and represent.

Users can assess how to improve building energy performance by selecting ECMs from a list, derived from the combination of both envelope and technical building systems suitable upgrades. For example, selecting a wall and window improvement system results in three possible ECMs: wall only, window only, wall and window together.

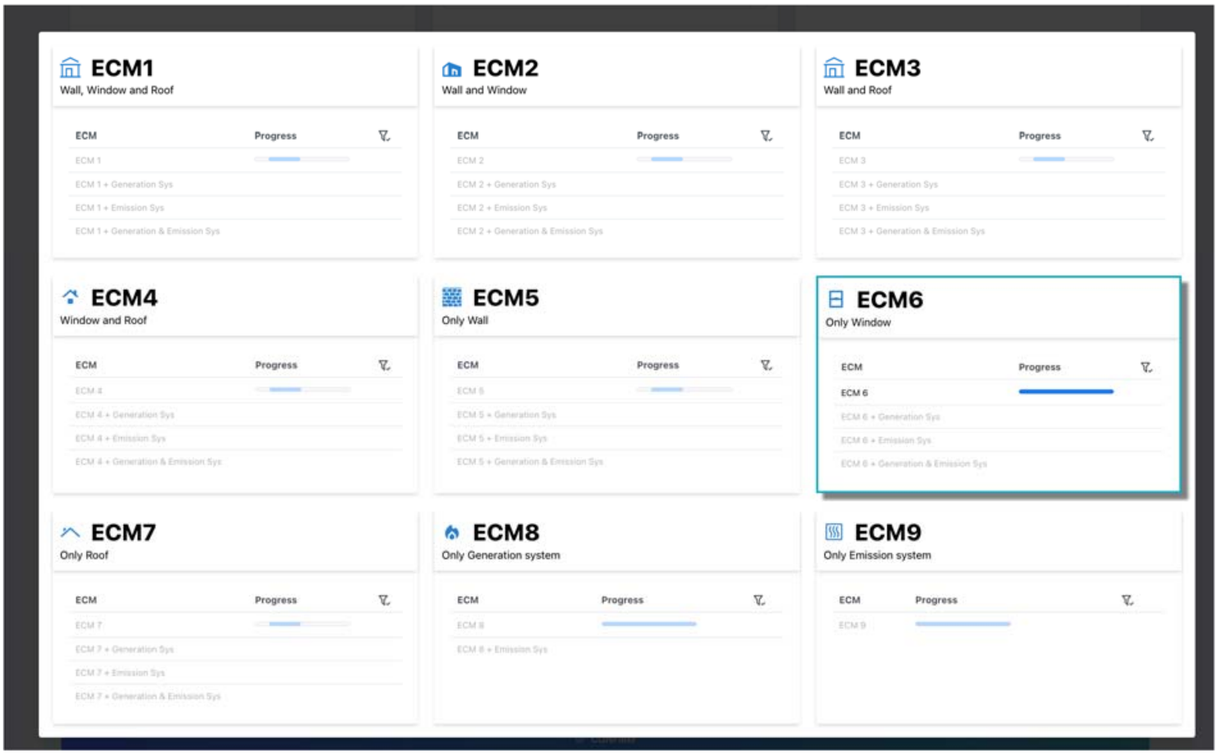

Figure 15 Example of alternative improvement scenarios from application of different ECMs sets to a building.

The user can also introduce information on the costs of each ECMs. This evaluation along with the pricing of energy and the type of energy savings allows for computing indicators related to the performance expected for the investment, and in particular how the investment is affected by risks as energy price volatility, ECMs underperformance and increased maintenance needs.

A specific section is developed in collaboration with the INFINITE and MATRYCS project, in this case adding the ability to simulate and optimize the photovoltaic system by providing additional information regarding the geometric capabilities of the roof and the photovoltaic system. More detailed information can be available within the paper "A simple Guide for designing a photovoltaic and battery system coupled with a Heat Pump across Europe"[3]

[3] A simple Guide for designing a photovoltaic and battery system coupled with a Heat Pump across Europe – M.Dallapiccola, J.Adami,D.Moser, 8th World Conference on Photovoltaic Conservation

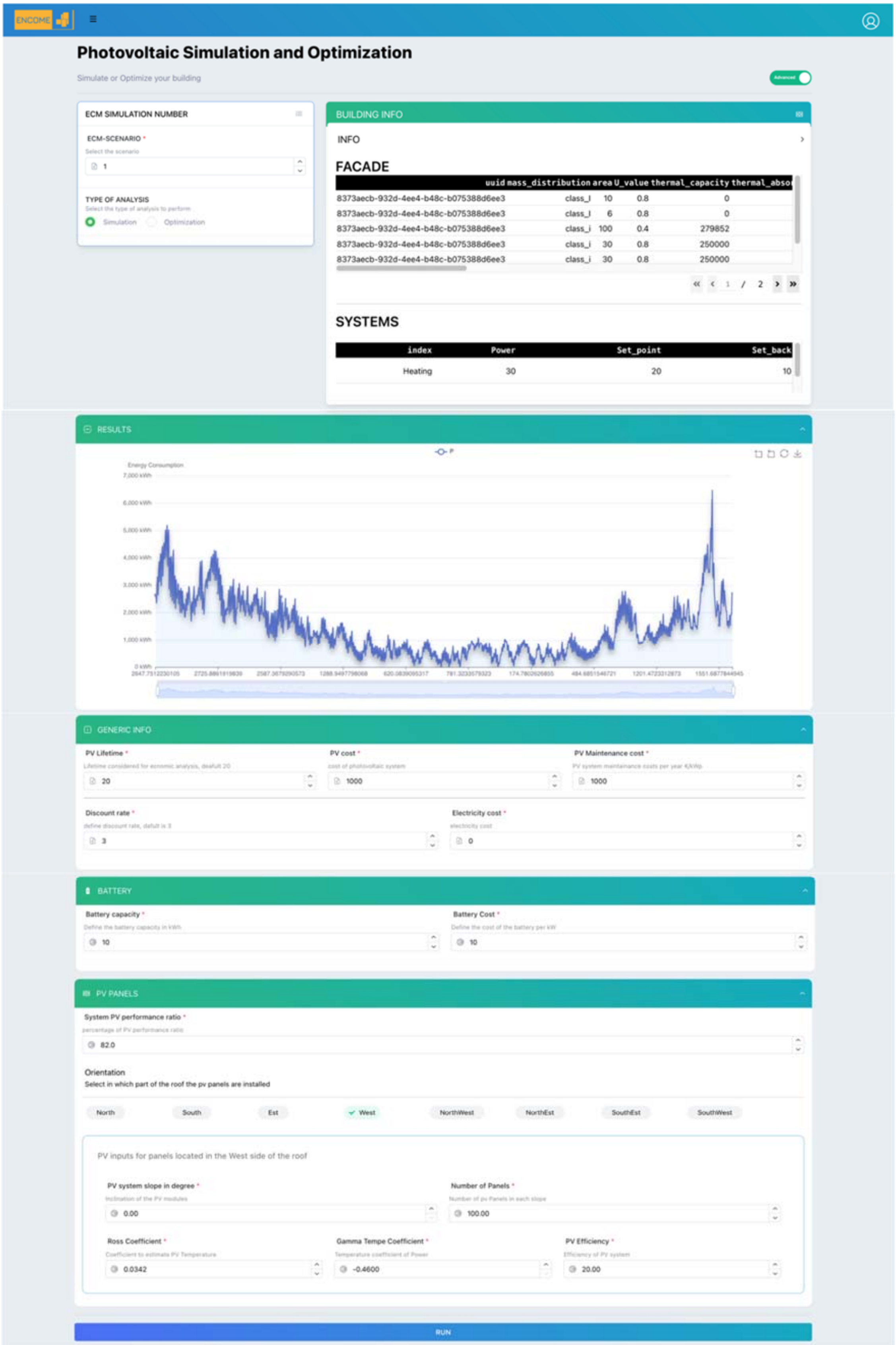

Figure 16 Example of photovoltaic computation and optimization.

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3.3.3. User experience

The tool provides several analyses and evaluations. As a first step, after entering the building data, the user obtains the values of hourly energy consumption through the calculation by ISO 52016. From there, the user can decide whether to calibrate the model with the actual data or to define possible ECMs by evaluating whether to improve the walls, windows, roof, generator, or emission system. All this is done using a sidebar that provides the different menus, and a specific section to evaluate the databases of the different components. The results are saved to specific databases and can only be viewed by the building owner.

3.3.4. Application on MODERATE pilot cases

The tool will be tested by real users (pilots) from MODERATE target groups and more specifically project partners aiming to improve planning of their building stock:

- IVE - Instituto Valenciano de la Edificación to identify through standard processes the effective energy renovation actions of a building stock (residential buildings in Valencia area)
- Würth Italia to identify the effective energy renovation actions of their building portfolio (retail shops and office buildings)

3.4. Solar Cadastre (A2.1)

The Solar Cadastre tool returns the solar potential of roofs and analyse the potential benefits of photovoltaic systems at the building level, with a focus on the energy and economic aspects. The following figure represents the workflow of the Solar Cadastre.

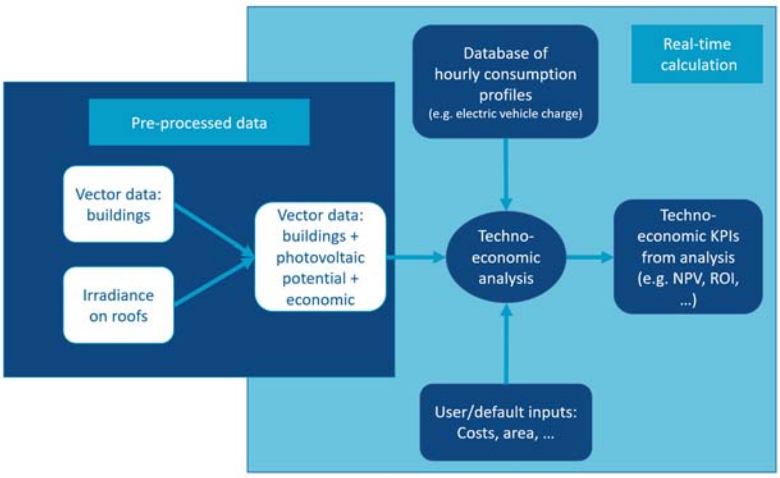

Figure 17 Workflow of the Solar Cadastre.

Additionally, the tool can compare real photovoltaic performances with expected ones for existing systems. In this case, the workflow is modified as follows.

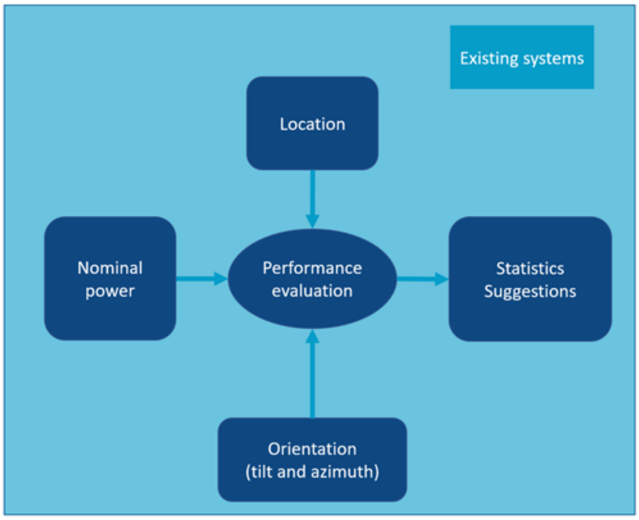

Figure 18 Workflow of the Solar Cadastre for existing systems.

3.4.1. Tool description

The Solar Cadastre tool is a web Geographic Information System (GIS) application that allows users to visualize the areas of roofs with the highest photovoltaic potential in a given area, considering both energy and economic aspects. This information can be used to make informed decisions about the feasibility and benefits of implementing solar energy policies in the area, and to encourage the adoption of photovoltaics.

Moreover, the tool offers the capability to insert building-specific and techno-economic data to perform a comprehensive techno-economic analysis of a photovoltaic system by estimating the self-consumed electricity. The results of this analysis are represented as energy and economic indicators, as well as plots, in a user-friendly interface.

The Solar Cadastre also offers the capability to analyse existing photovoltaic systems. The tool compares the expected energy generated by a similar system installed in the same area and the yearly energy produced by the system provided by the user. This allows the tool determining if the system is performing as expected and identifying potential issues with the system. For example, if the actual energy production is lower than the estimated energy production, this may indicate that the system is not performing optimally. Users can then use this information to identify potential issues with the system, such as shading or faults.

The Solar Cadastre can provide a wide range of benefits for policymakers, real estate, and citizens, including:

Benefits for Policy Makers

1. Informed decision-making: with data on the solar potential of roofs, policymakers can make informed decisions about the feasibility and benefits of implementing solar energy policies in the area.

2. Targeted incentives: the tool can identify areas with high solar potential, enabling policymakers to target incentives and subsidies to encourage property owners to install solar panels. This can help accelerate the adoption of photovoltaics in the area.

3. Planning for a sustainable future: understanding the solar potential of roofs can help policymakers plan and achieve climate goals, where solar energy can play a key role.

Benefits for Real Estate

1. Increased property value: knowledge of the solar potential of a roof can assist real estate agents in assessing the potential value of a property. Installing solar panels can increase the value of a property.

2. Marketing tool: the knowledge of solar potential can be used as a marketing tool to attract environmentally conscious buyers and tenants.

3. Energy savings: installing solar panels can lead to significant energy savings, which can increase the attraction of properties with high solar potential.

Benefits for Citizens

1. Lower energy costs: citizens can significantly reduce their energy costs by installing solar panels, particularly in areas with high solar potential. The Solar Cadastre can support the individual choice to invest in a photovoltaic system.

2. Environmental benefits: solar energy is a clean and renewable source of energy, which enables citizens to reduce their carbon footprint and contribute to a more sustainable future. The Solar Cadastre can increase the awareness of citizens with respect to the role they can play in the energy transition.

3. Energy independence: with the Solar Cadastre, citizens can understand how the photovoltaic system can reduce their dependence on the grid and energy market prices.

3.4.2. Input/output

To perform different types of analysis, the Solar Cadastre requires different inputs, ranging from simple location data for solar potential visualization to more detailed technical and economic data for techno-economic analysis and performance evaluation of existing systems. By providing these inputs, users can perform a comprehensive analysis of the solar potential of rooftops, estimate the energy cost savings of installing photovoltaics, and evaluate the performance of existing systems. The user can customize all inputs; however, defaults data will be included to improve usability such as references to online sources. The following Figure 19 represents a minimal mock-up of the user interface.

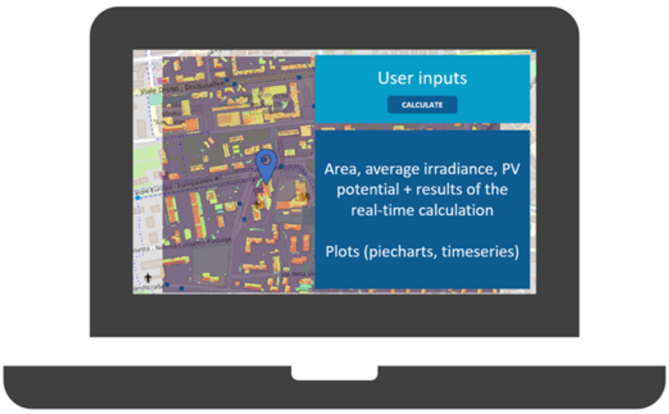

Figure 19 First mock-up of the user interface

For each tool functionalities, the Solar Cadastre requires the following inputs.

Solar Potential visualization

- Location: the Solar Cadastre requires the location of the area of interest to visualize a detailed map of the solar potential of rooftops in that area. The location can be entered by the user or selected through an interactive map interface.

- Pre-processed irradiance on roofs and vector data representing the selection of surfaces based on a raw economic analysis included in the pre-processing phase. These data are a requirement to ensure the proper functioning of the tool.

Techno-economic Analysis

- Cost of electricity: this input represents the cost of the electricity that would be saved by installing a photovoltaic system. It is usually entered in units of currency per kilowatt-hour (kWh) and can be obtained from local utility companies or energy market data.

- Cost of the photovoltaic system: this input represents the cost of purchasing and installing a photovoltaic system. It includes the cost of modules, inverters, mounting systems, and mounting. It is usually entered in units of currency per kilowatt-peak (kWp) and can vary depending on the market and the quality of the system.

- Technical properties: the Solar Cadastre requires technical properties such as the module efficiency, which represents the percentage of sunlight that can be converted into electricity by the photovoltaic modules. These properties can be obtained from the manufacturer's datasheets. The Solar Cadastre provides default values to facilitate the user experience.

- Description of the electric consumption load: this input is used to obtain the electricity consumption of the building or household where the photovoltaic system would be installed. It includes the presence of electric vehicles charging stations, and other high-power appliances.

Performance Evaluation of Existing Systems

- Yearly generated electricity: this input represents the actual amount of electricity generated by an existing photovoltaic system over a year. It can be obtained from monitoring systems or from electricity bills.

- Photovoltaic system nominal power: this input represents the rated power output of the existing photovoltaic system, usually measured in kWp. It is usually known from the photovoltaic owner.

- Orientation (tilt and azimuth) of the photovoltaic system: this input represents the angle at which the photovoltaic modules are installed on the roof. It includes the tilt angle, which represents the angle between the modules and the horizontal plane, and the azimuth angle, which represents the angle between the modules and the south direction. These angles can affect the amount of sunlight that the modules receive and can impact the performance of the system.

Overall, the Solar Cadastre requires different inputs for different types of analysis, ranging from simple location data for solar potential visualization to more detailed technical and economic data for techno-economic analysis. By providing these inputs, users can perform a comprehensive analysis of the solar potential of rooftops, estimate the energy cost savings of installing photovoltaics, and evaluate the performance of existing systems.

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3.4.3. User experience

The user experience of the Solar Cadastre can be divided in four examples, depending on the type of user. In the following sections, the expected main examples are reported.

Workflow for a Policy Maker

Step 1: the policy maker access into the Solar Cadastre web application and selects the area they are interested in.

Step 2: the Solar Cadastre shows a map of the solar potential of rooftops in the selected area, based on pre-processed data.

Step 3: The policy maker can use the map to identify areas with high solar potential and prioritize solar energy development efforts in the area. They can also use the data to make informed decisions about the feasibility and benefits of implementing solar energy policies.

Workflow for Citizens

Step 1: The citizens access the Solar Cadastre web application and inputs their address.

Step 2: The Solar Cadastre shows a report on the solar potential of the citizen's roof based on the pre-processed data.

Step 3: The citizens can use the shown data to understand the solar potential of their roof and estimate the energy cost savings of installing a photovoltaic system. They can also input building-specific and techno-economic data to perform a comprehensive techno-economic analysis of the system and determine if it is economically sustainable.

Workflow for an Existing Photovoltaic System Owner

Step 1: the photovoltaic system owner logs into the Solar Cadastre web application and inputs data on their existing system, such as the yearly energy produced.

Step 2: The Solar Cadastre compares the actual energy production of the system with the estimated energy production for its area, based on the solar potential of the roof and other factors.

Step 3: The system owner can use the comparison to understand if their system is performing as expected and identify any potential issues with the system, such as shading or orientation problems. They can then take steps to improve the system's performance.

Workflow for a Real Estate Company

Step 1: The real estate agent accesses to the Solar Cadastre web application and selects the property they are interested on the interactive map.

Step 2: for the selected building, the Solar Cadastre visualizes a summary of the pre-processed data including the solar potential of the property's roof and the percentage of the roof which is economically more interesting for the installation of a photovoltaic system.

Step 3: the real estate agent can use the summary to understand the solar potential of the property and estimate the potential increase in property value from installing a photovoltaic system. They can also use the information as a marketing tool to attract environmentally conscious buyers and tenants.

Step 4: if the property already has a photovoltaic system, the real estate agent can input data on the system's performance to compare it to the estimated energy production for its area. This allows the real estate agent to determine if the system is performing well and use the information to market the property as an energy-efficient and sustainable option.

3.4.4. Application on MODERATE pilot cases

The Solar Cadastre application will be tested in the municipality of Crevillént, to provide information on the solar potential in the urban area. The availability and resolution of data for the municipality, i.e., the vector data, will be evaluated before proceeding with the testing. If necessary, other locations will be evaluated in case of lack of data. Once collected, data will be processed to generate the input for the Solar Cadastre application, including the calculation of a new dataset for the solar radiation data, if not available.

The Solar Cadastre application will be used to assess the solar potential of different locations within the municipality and to provide information on the city solar potential. Finally, the real-time calculation will be tested for different building typologies and users.

The results will be analysed to understand the solar potential of different areas and identify areas that have high or low solar potential. Maps, plots, and visualizations will be extrapolated to make the information more accessible to policymakers, urban planners, and individuals interested in solar energy and feedback will be collected from potential users.

The tool will be tested by real users (pilots) from our target groups and more specifically project partners aiming to develop energy communities and test the tool for possible future replicability in different locations.

IVE – Instituto Valenciano de la Edificación and Enercoop – Cooperativa Eléctrica benéfica San Francisco de Asís, operating on the same geographical area, will define suitable areas for communities in the Valencia region.

3.5. Local energy community location assessment (A2.2)

Local energy communities are a key development towards the decarbonisation of buildings, social interaction, and the increasing penetration of renewables sources. LECs represent a legal entity in which different actors meet their energy needs by cooperating in energy production, transmission, and consumption. One of the most important problems to be solved and which currently represents the first step towards the definition of an LEC is the identification of the actual areas where such communities can thrive. Different types of data and knowledge are needed to ensure a proper definition of an LEC area such as: Energy consumption data of a building stock, cadastral data with related geometric information, intended use, free areas on roofs, types of plumbing and electrical systems, etc. These data must be processed and modelled using machine learning techniques to generate a result that is actually usable in the real application. The tool will also consider thermal aspects by defining the optimal area for LEC using e.g., a district heating network.

3.5.1. Tool description

Local energy communities (LECs) play a significant role in the decarbonization of buildings and social interaction, as well as in the integration of renewable energy sources. LECs are legal entities where various actors come together to meet their energy needs through cooperation. Accordingly, most of the LECs are typically starting their journey with the development of renewable energy production installations. However, a key issue for the new promoters of LECs is understanding the feasibility of their area of interest to become an energy community with renewable energy production.

To support LECs promoters and interested parties, such as citizens, this tool aims at assessing the feasibility of locations (municipalities) to develop LECs considering a wide range of data and knowledge, including energy consumption data, cadastral data with geometric information, intended use, available space on roofs, electrical system types, and more. Advanced data analytic techniques are applied to process and model this data to generate a feasibility report usable for supporting decisions towards the development of new LECs-. The analysis also considers synergies with different type of networks existing in the area, such as district heating and cooling network and E-charging.

With the increased interest on energy communities across Europe, this tool will be of high value, providing a very useful insight and an initial feasibility assessment for the development of a LEC in an area of interest.

3.5.2. Input/output

The first step to proceed with the analysis is to identify an area of interest by the user that will be used as the main input to the tool. Once an area is defined the following data sources of the input location will be required by the tool to perform the analysis:

- Energy consumption of the area: How much energy is consumed in the area will define the size of the generation needed for the LEC. This can be extracted from public databases by post code or municipality when available (for example Datadis[4] in Spain), although these might have low resolution. If the user has more precise energy consumption data of their entire community, this could be used as input to the tool. Otherwise, this parameter could be estimated.
- PV potential: this information will be extracted from the solar cadastre tool, in which the PV potential of the different roofs of the area is analysed. Additionally, this tool will help to identify the best roofs in the area to implement a collective PV self-consumption installation based on the potential of the roofs and the energy consumption.
- Social aspects: The location of poor areas within the area of study could help to identify areas in which this investment could be more appropriate to tackle energy poverty by municipalities or policy makers. The density of population can also be used to decide on the type of generation installation to be deployed in the LEC, self-consumption or PV plant selling to the market.
- Regulation: Description of what could be developed in each area according to the actual regulation will be needed. For example, in Spain a LEC with PV production can be developed in 2 ways, 1) self-consumption that is limited to consumers in a radius of 2000m, 2) PV plant, which might be limited to the capacity of the network where the connection is intended and subject to much larger implementation times (2-5 years). These data can be found in official regulatory documentation for each country, scientific papers or other EU projects related to energy communities, but the database will probably need to be created.

With the objective of the tool being the identification of the potential of an area or municipality to develop an energy community with PV generation based on technical, economic, social, and regulatory aspects, this tool will produce as an output a short report on the capabilities of the area to

[4] https://datadis.es/queries

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become a LEC. This report could be automatically generated based on the analysis of the characteristics.

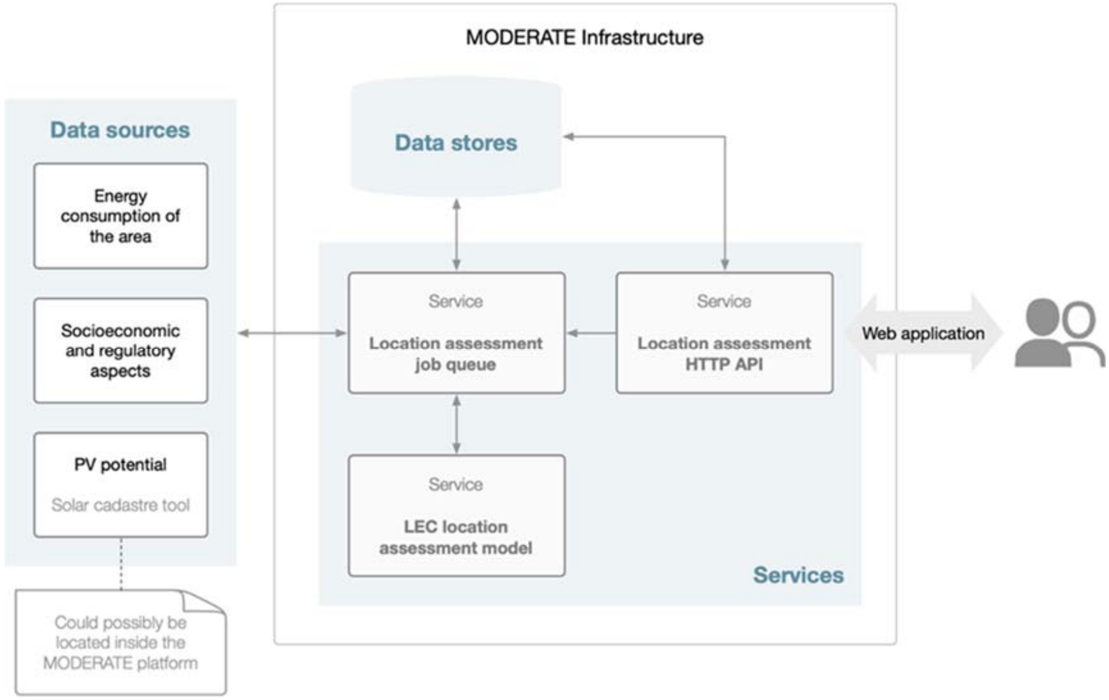

Figure 20 LEC assessment tool workflow.

3.5.3. User experience

This tool will present the same user experience for all types of stakeholders, through a web application where they will introduce a very simple input and will get the output via email and with the possibility to interact with a map in the process. Authentication of the user and selection of the tool will be required, then the user will indicate the municipality of interest from a selection box so that the analysis can start. Depending on the data sources available and the size of the municipality, the analysis can be performed online or offline, with the results of the analysis being sent to the user after the analysis is complete. Furthermore, a map with information on the solar radiation (solar cadastre) could be shown to provide a more visual and interactive experience.

3.5.4. Application on MODERATE pilot cases

This tool will be applied similarly for the different stakeholders which are most likely to adopt it, specifically this tool could be used by the following actors:

- ESCOs: adoption of the tool could lead to a more proactive and effective manner of offering services related to the development of energy communities.
- Municipalities: use of the tool will allow municipalities to decide on whether they want to promote an energy community in their area as they are typically very interested in its environmental and social impact.
- Local associations: Local associations that want to become energy communities but are unsure about where to start will be able to get an initial feasibility analysis in a very simple manner by using the tool.

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- Citizens: Individual citizens with interest in participating or promoting energy communities could use the tool as a starting point to convince other citizens, associations, or the municipality to start the development of an energy community.

The tool will be tested by real users from our target groups and more specifically project partners IVE – Instituto Valenciano de la Edificación and Enercoop - Cooperativa Eléctrica benéfica San Francisco de Asís.

3.6. M&V for building energy assessment (A2.3)

According to IPMVP Efficiency Valuation Organization, M&V is fundamental to energy efficiency financing, energy performance contracting, energy performance management, GHG accounting efforts, and many government and utility programs. Based on IPMVP protocol, M&V is broadly adopted by energy services companies and increasingly used by utilities and government agencies for their demand-side management incentive programs and by building managers to assess and improve their facilities' performances. Increasingly, financial institutions understand the advantages of using standardized and objective M&V as a risk reduction framework for their investments.

3.6.1. Tool description

The tool allows target users as ESCOs, real estate companies, asset managers and energy managers from local authorities, to demonstrate or verify that upgrades (ECMs) applied to an existing building could effectively translate into the expected performance improvement, i.e., energy savings guarantees compelled in EPC contracting, without penalizing performance in non-energy domains. Thus, beyond energy savings, the service provides a comprehensive assessment of how energy and non-energy related KPIs have performed because of the upgrade delivered to the building. The aim is to demonstrate and quantify the impact of implemented actions on energy savings, while assessing performance in non-energy domains, including economic and environmental performance, as well as costs, indoor environmental quality, comfort and well-being, to verify the performance of buildings across the board and learn lessons and confidence for driving further investments.

The tool could be exploited by ESCOs to offer more comprehensive targets in EPC contracting or Public-Private partnerships. The tool can extend to analysis of buildings' portfolios.

The tool relies on IPMVP protocol as a reference methodology. The service leverages synthetic data and machine learning for creating a model for generating the baseline for building energy performance. In this way, the tool will lead to an objective computation of baseline scenario for the specific building type and use, also relying on knowledge from synthetic data on how similar buildings perform in similar circumstances, instead of generating the baseline solely by relying on the previous auditing and building specific sources i.e., by linear regression or assessors' considerations.

3.6.2. Input/output

The tool requires inputs as:

- general description of the building as location and use.
- Which type/when ECMs are applied.
- data on energy consumption by energy carrier before and after implementation of ECMs.
- Weather data, occupancy.

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- information on conditioned areas and temperature setpoints, before and after implementation of ECMs.
- Energy pricing.
- Emission factors.

The tool will output:

- Report with comparison of before and after energy consumption or demand must be made on a consistent basis.
- KPIs concerning energy savings, cost savings, emissions reduction, comfort, IEQ among others.

A minimum amount of data will be gathered from user input, while most information will be collected by MODERATE knowledge, other services, and external data sources.

3.6.3. User experience

In the basic workflow, the user will access the tool UI and input general data on the building and related to the implemented upgrades. The service will fetch remaining data autonomously, whenever possible. The project can be saved, and new analysis can be run over time. The service will be interoperable with other services i.e., ECM tool, de-risking, benchmarking, and clustering to enable complementary evaluations at building and building portfolio levels.

3.6.4. Application on MODERATE pilot cases

The tool will be tested by real users (pilots) from our target groups and more specifically project partners IVE, VEOLIA and Würth Italia.

3.7. Benchmarking (A2.4)

This tool allows user to compare building performance across different domains (i.e., energy, environment, costs, comfort) and at different levels (building vs similar buildings, building vs the same building in the past), in an objective way. The tool targets municipalities, policy makers, energy/facility managers, real estate companies, asset managers and planners for actions at building and building's portfolio levels.

3.7.1. Tool description

This tool allows the user to compare KPIs with a realistic meaningful benchmark. A realistic benchmark could be prepared by leveraging on synthetic data, and/or based clustering over owned portfolio.

Different types of KPIs can be compared, i.e., energy and environmental performance, costs, energy saved over investment in building upgrades, and further indices can be derived i.e., potentials, trends, risks, GWP.

The tool is well aligned to the EPBD recast, where 'energy building benchmark' means an information platform to publicly disclose energy performance and yearly consumptions of single and multi-unit buildings over time, compared to similar buildings or to modelled simulations of a reference building built to a specific standard, such as minimum energy performance standards, and using the range of energy performance classes.

The service can be integrated in other services, i.e., fault detection to check if an underperformance condition tracked is real or not, to limit false-positive information to the facility manager, or in the M&V to compare against the baseline, or in ECM tool for comparing alternatives.

The service could be used by policy maker to evaluate the effectiveness of applied technologies on building stock.

3.7.2. Input/output

The tool requires different input depending on the purpose. In a basic workflow, to compare energy and environmental performance of a building on a yearly basis, the tool would require information on the location, type and use of the building, its characteristics, energy consumption, weather, and occupancy especially if they changed significantly.

As an additional example, in which the user wanted to compare a building with other similar buildings in the same portfolio, also the information on other buildings should be input.

3.7.3. User experience

The user can access a UI, select the needed benchmarking functionality and input needed data. A card reports about comparison of pre-defined KPIs. Similar workflows will be supported by other interoperable services, with a context-specific user interface.

3.7.4. Application on MODERATE pilot cases

The tool will be tested by real users (pilots) from our target groups and more specifically project partners as Würth Italia, IVE – Instituto Valenciano de la Edificación, VITO.

3.8. De-risking investment in building energy efficiency (A3.1)

This tool allows user to quantify how likely a planned project (new construction or renovation not yet realized) can lead to lower economic results than expected, providing such information at the time of the investment decision (preliminary design). In other words, how the investment in the planned solutions is robust or could eventually deviate due to conditions that may change in the future, within the time horizon of the investor. The aim of the tool is then to support the investors in dealing with technical-economic aspects and in particular, in quantifying the uncertainty on results of investments related to building energy performance, in the context of tightening of global energy supply and decarbonization trends:

- security of supply, price volatility, supply chain disruptions.
- short term energy savings vs long term energy efficiency measures.
- strict regulatory obligations to meet energy consumption and emission targets.
- initiatives that link carbon accounting and sustainability.
- growing interest in demonstrated savings (M&V) when splitting risks and responsibilities by contract.

3.8.1. Tool description

The tool that allows the user (real estate, ESCO, asset/energy manager) to check how much the planned solution for an energy efficiency project is robust in terms of exposition to future changes to the context considering i.e., energy prices volatility and climate change.

Given a set of solutions that are foreseen in the energy efficiency project and a definition of the baseline scenario (the type of building, the location, the as-built conditions in case of renovation), the tool combines the information and models on energy pricing and climate change with knowledge about ECMs, then it computes the reference scenario and the probability that the running costs deviate from the original estimation. The result of the computation contributes to support decisions on the investment, to reduce perceived risk and to favour resilience.

3.8.2. Input/output

The tool requires inputs as:

- General information on the building and its assets, as location, type/use, characteristics, installed renewables capacity.
- Information on the planned ECMs, and other relevant changes foreseen by the project.
- Energy prices
- Operating costs

The tool outputs the sensitivity of the solution to changes in input variables, and the probability of changes in energy cost and in other operating costs.

3.8.3. User experience

The user can access a UI, and input needed data on the building and the project. The tool supports new construction and renovation of different building type (the available options may vary). A card reports about KPIs. Similar workflows will be supported by other interoperable services, with a context-specific user interface, as ECM tool.

3.8.4. Application on MODERATE pilot cases

The tool will be tested by real users (pilots) from our target groups and more specifically project partner Köhler&Mainzer.

3.9. Energy Performance Certificate harmonization (A3.2)

3.9.1. Tool description

EPC harmonization is one of the targets added to the latest EPBD recast. In this regard, other EU research funded projects, such as QualDeEPC, CrossCERT or the EPC4EU data model, are guiding efforts towards achieving the goal set by the EU. According to this objective, all Energy Performance Certificates (EPCs) must be based on a harmonized scale of energy performance classes by 2025.

While the development of a harmonized calculation methodology is underway, it is crucial to ensure the interoperability of EPC databases throughout the European Union. This objective is considered a key aspect of the tool being developed. By normalizing the main energy performance indicators obtained from national EPB Assessments, it will be possible to compare parameters between countries and eliminate the influence of national choices.

On a broader level, this tool aims to retrieve EPC data from official regional/national repositories to be used for various analytical purposes. In addition to EPC harmonization, there are three other analytics incorporated into the tool:

- **Quality check**: this feature enables the identification of input data errors by comparing EPC indicators with a predefined model source. There are several options for the comparison model, including:
  - Official EPC repository with over 250.000 issued certificates: the level of detail may vary based on access privileges to the database, ranging from basic information which would include the main EP indicators and cadastral reference to full xml files, which will impact the subsequent analysis.
  - Actual data from energy meters.
  - Simplified model like renovEU or similar tools.
  - Cadastral data obtained from the INSPIRE service which includes comprehensive information such as the age of the building, number of floors, and building usage.
  - The specific model used for comparison will vary based on different metrics, such as climatic zone/location, year of construction, type of building, and thermal insulation.
- **Clustering**: this functionality groups EPCs at various territorial scopes (e.g., local, regional, and national) and compares such mean values with specific EPCs. This allows for a comparative analysis and identification of trends within different geographical areas.
- **Dynamic calibration**: this analytic tool enables the calibration of input parameters with high uncertainty by using actual energy measurements. It provides accurate recommendations for improvement, approaching more realistic scenarios.

EPC harmonization analytic intended to be connected to the Benchmarking tool and the Energy Conservation Measure Tool.

To sum up, the main focus of this tool is to retrieve and systematise full EPC data to:

- Perform the quality check.
- Link with other analytics, such as the ECM, the Geoclustering or the Benchmarking Tools.

3.9.2. Input/output

The tool prompts the user to provide the following inputs:

- EPC xml: via file upload
- EPC report data: the user can manually input EPC report data through the tool's dashboard. This data may include various details and parameters related to the energy performance of the building.
- Energy use data: Users can also manually input energy use data through the tool's dashboard.
- Analytics requested: Users can specify the desired analytics or functionalities they want the tool to perform on the provided data.

Based on the inputs and selected functionalities, the tool generates different reports. The “Quality check report” displays warning messages according to different indicators. If any indicator falls outside the range defined by the model, it is flagged as an error. The report helps identify discrepancies or inconsistencies in the provided data.

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The "Normalised EPC indicator" report displays adjusted values of EPC indicators based on the harmonization of Energy Performance Certificates as mandated by the EPBD recast. It ensures that the EPC indicators are aligned with the standardized scale of energy performance classes.

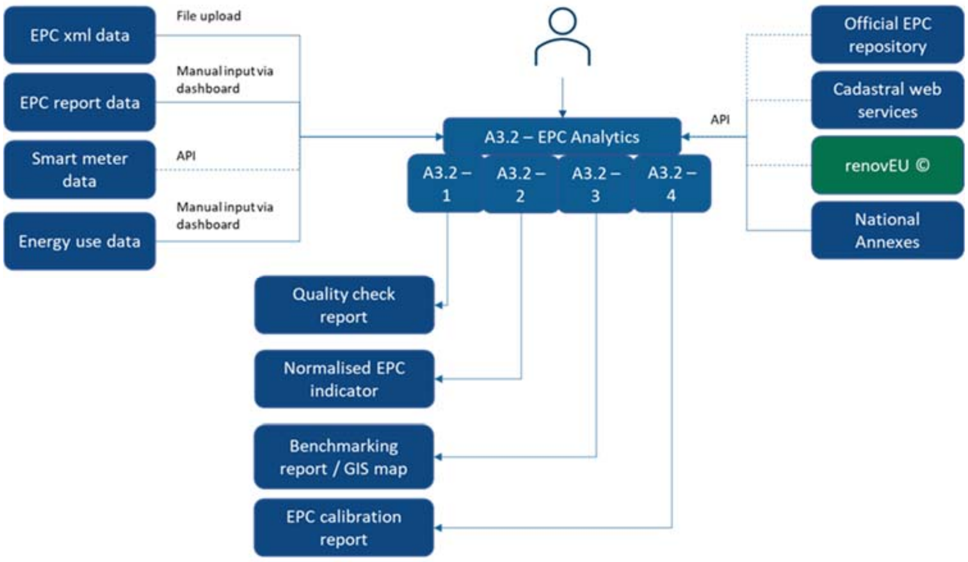

Figure 21 EPC harmonization tool workflow.

By generating these reports, the tool assists users in evaluating the quality of EPC data, identifying potential errors, and obtaining normalized and standardized indicators for effective energy performance assessments.

3.9.3. User experience

At this point, the user experience is still to be designed and may vary depending on the specific report generated and target user addressed:

- Quality check report: this report is primarily intended for public bodies responsible for control and inspection of EPCs, as intended by the EPBD. These bodies can utilize it to identify any incorrect indicator and ensure compliance. Additionally, EPB assessors can also use the report to review the accuracy of the EPC before submission.

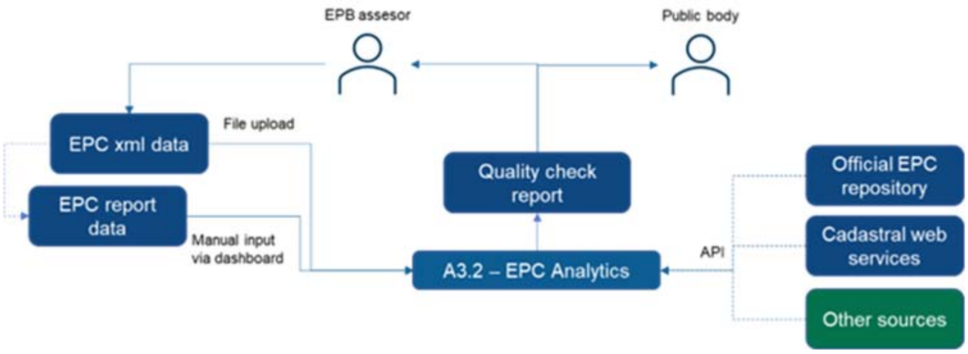

Figure 22 Example workflow for EPC quality checking.

- Normalized EPC indicator: Policymakers at the European level and international investors can make use of this report. It allows them to compare the energy efficiency of buildings across

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different countries on a standardized basis. This information helps policymakers make informed decisions and investors determine suitable investment opportunities.
- Benchmarking report (clustering): This analysis is designed to be utilized by stakeholders throughout the value chain. Building owners can use it to benchmark the performance of their buildings against relevant standards and industry peers. Public bodies can analyse the findings to identify trends and patterns, aiding in the development of effective policies and strategies.
- EPC calibration report: EPB assessors, who are responsible for providing energy efficiency recommendations to building owners, can benefit from this summary. It assists them in calibrating input parameters with high uncertainty by utilizing actual energy measurements. It will enable assessors to provide more realistic and effective guidance.

In summary, the outputs generated from the tool cater to different stakeholders within the realm of energy performance assessment and policymaking.

3.9.4. Application on MODERATE pilot cases

The EPC analytics will be tested by real users (pilots) from our target groups and more specifically industrial partners aiming to assess its value.

EPC data is foreseen to be collected in two pilot cases: one in the Valencia region and another in Italy. Non-disclose agreements will be signed in order to articulate these collaborations.

In terms of the quality check report, IVE– Instituto Valenciano de la Edificación (acting as industrial partner) intends to work in collaboration with IVACE (Official EPC Register in the Valencia Region) and EPC assessors in order to codesign and test this service, applying it to the IVACE's EPC database of Valencian Community.

Regarding EPC cross-country harmonised comparison, the data coming from the EPC samples mentioned will be used to carry out calculations with the ECM application (based on EU calculation methodology) in order to compare results obtained with the national calculations (official EPCs).

Finally, other industrial partners in MODERATE, such as Würth Italia, Enercoop and Köhler&Meinzer are interested in the analytic to be used internally to manage their own portfolio (Enercoop and Würth) and both internally and externally, to manage their own portfolio and to be offered to clients respectively (Köhler) and will support both the design and testing of it.

3.10. Geo-clustering (A3.3)

3.10.1. Tool description

The main objective of the tool is to allow the comparison, analysis, and evaluation of building stock performance using clustering techniques. Clustering is the process that groups buildings in a set of meaningful classes, called clusters. A cluster is a collection of data objects that show similarities and that can be treated collectively and represented as one group.

The tool can be tailored depending on the user's need and specific interest, i.e. the energy manager can compare the performance of buildings located in a same or different area as well as know what could be a possible saving in the refurbishment of a building applying specific action; building designer can figure out the performance of technologies for a certain specific use and climate; researchers can analyse the impact of specific building features on energy consumption or to assess the relation between building envelop, technical building systems and comfort across different geographical contexts.

Furthermore, Geo-clustered data are valuable to highlight cross-national similarities and provide useful information to policy makers and legislative bodies for more tailored policy decisions.

The tool enables users to:

- visualise the energy and comfort information of buildings.
- compare buildings' performance through the use of Key Performance Indicators (KPIs).
- benchmark a building against others in the same category, one characterized by similar functionalities, or against another specific building of own portfolio.
- cluster buildings according to the selected KPIs and get the resulting clusters on a map.

The definition of the KPIs is a fundamental step for the analysis of the dataset and to identify meaningful output. The KPIs are used both for comparing buildings, by benchmarking tool connected to this tool, and for clustering.

Leveraging the previous developments within H2020 MATRYCS project, two unsupervised machine learning algorithms will be used for clustering: K-Means algorithm and HDBSCAN.

3.10.2. Input/output

The geo-clustering tool needs both data and metadata to perform the analysis. The metadata is static information of the datasets that does not change over the time. The metadata file is generated following the MODERATE data model based on the Brick ontology as semantic elements definition.

In the basic workflow, user will input data on the buildings, and describe precisely and unambiguously the different elements that characterize each building and its systems.

The output is the segmentation of the dataset into group of buildings.

3.10.3. User experience

In the tool, the buildings are clustered in groups by similar features. In addition to selecting the building type, the user, depending on his needs, chooses the relevant KPI among those identified during the project. The resulting clusters are represented with different colours and range of values in the map.

3.10.4. Application on MODERATE pilot cases

The tools will exploit the open synthetic datasets originated from partners as Würth Italia and Köhler&Meinzer. The dataset provides a list of values related to buildings feature, energy consumption, weather, and economic data. The tool will be enhanced and validated by real users (pilots) from our target groups and more specifically project partners IVE– Instituto Valenciano de la Edificación, Köhler&Meinzer and VITO.

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4. MODERATE – Services integration

This section introduces how the services or applications will integrate within the platform architecture. A draft version of the MODERATE platform architecture is presented in the following figure, which can help illustrate the interactions that will be described in the subsequent list.

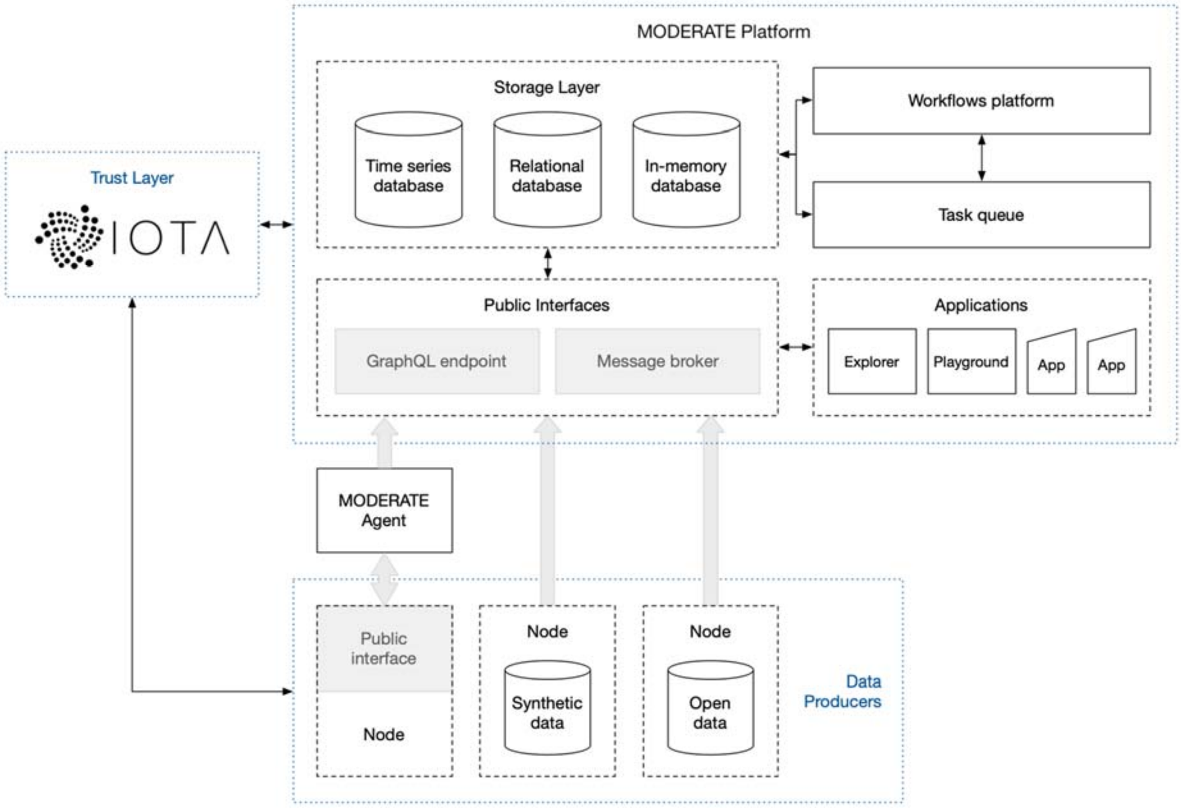

Figure 23 - Draft architecture of MODERATE.

The platform's **basic building blocks** consist of **storage and processing layers**. Storage services consist of data stores and databases that allow services to read and write their datasets, regardless of the data's structure. Processing services are a collection of software tools that permit the execution of distributed data pipelines. The specifics of how services interact with the storage and processing layers depend on the software's low-level details and where the service is deployed. For instance, a service located within the MODERATE platform's cloud infrastructure can connect directly to a PostgreSQL database using the native driver and private URL. However, a service deployed on a MODERATE partner's premises will need to use a secure and encrypted HTTP API to upload a dataset.

The MODERATE platform offers **public interfaces**, which are the communication endpoints that it exposes to the Internet. There are two interfaces planned for deployment: an API transported over HTTP and a message broker that will enable the publish-subscribe pattern, based on MQTT. These public interfaces primarily serve as gateways to the storage and processing layers, as previously mentioned. MODERATE services must implement the appropriate HTTP or MQTT interface to integrate with the platform. For instance, if a service needs to run an inference request for a machine learning model that is deployed on the platform, it may have to send an HTTP POST request.

Interactions between services will require a case-by-case analysis since each service has its own unique requirements and scope. However, as a rule, services utilize the same technologies as the MODERATE platform's public interfaces, which include HTTP APIs and message brokers. To minimize coupling and integration errors, as well as improve maintainability, it is critical for services to adhere to well-known specifications like OpenAPI and AsyncAPI when formally and comprehensively defining their interfaces. It is essential to note that not all services need to expose their functionalities in a machine-readable manner for other services to consume, as this depends on the specific details of each service.

Since the trust layer of the MODERATE platform relies on IOTA Technologies, any interactions with the **trust layer** must adhere to IOTA specifications. The IOTA foundation provides a collection of client libraries and tools to simplify development and testing in this regard. There are two feasible approaches to this. The first involves integrating the low-level details of the interaction with the IOTA Tangle within the MODERATE platform, which would entail exposing the requisite functionalities through the public interfaces. The second approach is for services to integrate with the IOTA stack directly, which is more flexible but necessitates more resources from service developers. In the latter approach, service developers must be familiar with the intricacies of the IOTA ecosystem and should learn the best practices.

Any **monetization services** associated with the MODERATE platform will also rely on IOTA technologies. As a result, the same principles that apply to interaction with the trust layer apply to interaction with the monetization services as well.

Services can interact with **data producers** either by accessing their datasets in the storage layer directly or by using the public interfaces. Directly accessing the storage layer provides greater flexibility and functionality, but it also increases coupling. Unless the scenario necessitates strict or specific requirements, it is advisable to utilize the public interfaces instead.

4.1. MODERATE service dashboard

Users can access a range of services (apps) through the MODERATE service dashboard, also referred to as the **Explorer**. This web application features a comprehensive catalog of services developed under the MODERATE project, allowing users to instantly view key details of each service. The Explorer serves as the gateway to MODERATE's main research findings. Each service card includes a brief description and relevant links, such as Docker images for local testing and deployment, GitHub repositories, and quick access to the MODERATE Playground.

Just like the services, the Explorer also showcases a range of datasets produced and curated within MODERATE and offers metadata catalogue functionalities. It is worth mentioning that synthetic datasets will have a prominent presence in the catalog since MODERATE focuses on the application of synthesis techniques as a contribution to the state of the art. Users can either download the datasets or reach out to the owner to purchase access, if necessary. The trust layer ensures increased trust guarantees and traceability and can potentially serve as a platform for monetary transactions. However, the development of payment services is not currently within the scope of MODERATE.

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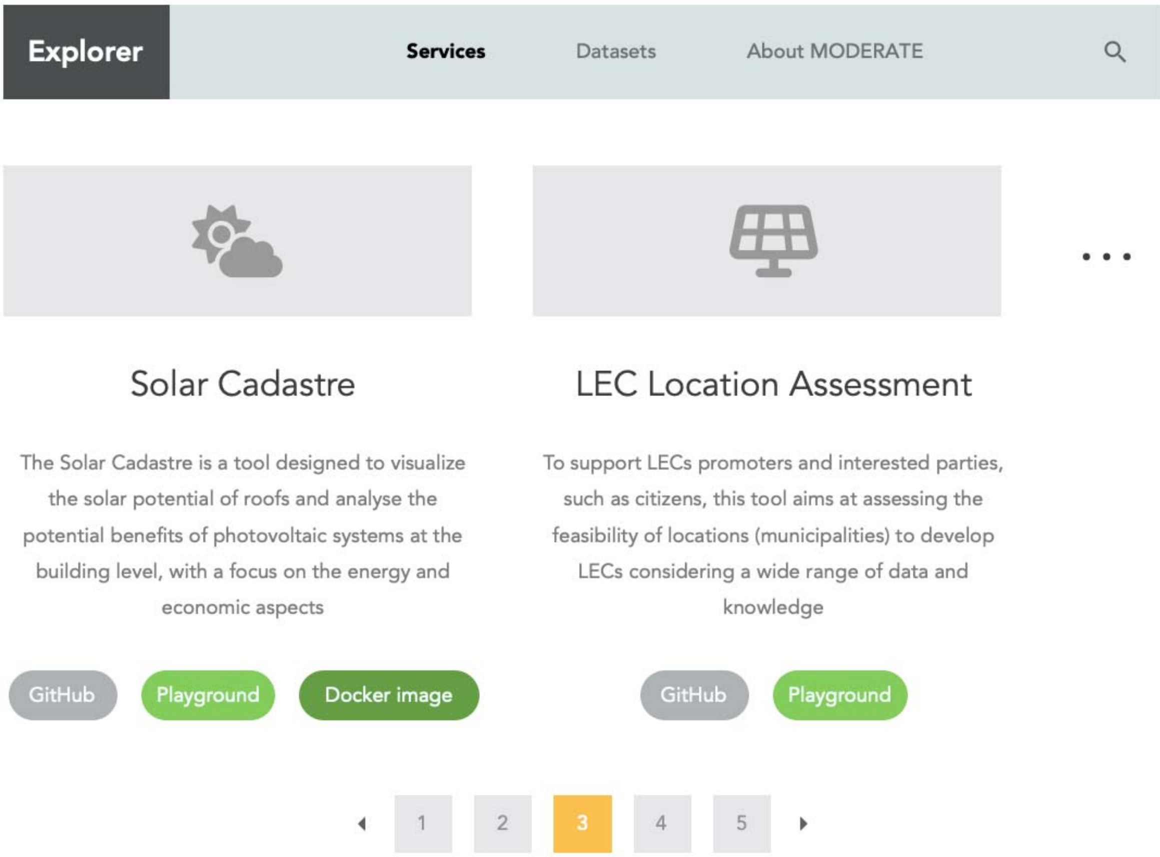

Figure 24 - Mock-up of the MODERATE Explorer web application

The MODERATE **Playground** complements the Explorer by offering users a web-based environment to evaluate services without downloading, configuring, or deploying them locally. While the specific features of the Playground may vary depending on the service design and implementation, the initial plan is to provide an updated instance of all services. Each service will be available anonymously and hosted on the main MODERATE platform cluster.

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5. Conclusion

This document reported on the first development round of MODERATE services. Software requirements specification and development were based on well-verified initial assumptions concerning the scope, I/O, user experience and integration of each service with other services, MODERATE platform functionalities, knowledge from enriched datasets and AI.

According to the availability of a pre-existing implementation for some services at the beginning of the project, and because of different services foresee different complexity, the first development round ended with the presentation of services eventually using graphical mockups and working prototypes, to industrial partners and other relevant target users, aiming for feedback.

The document reported the specific sets of KPIs identified as useful, complementary, and comprehensive in addressing relevant challenges for MODERATE target users. The definition of suitable KPIs, and their grouping in comprehensive informative sets, relied on literature research and meetings with industrial partners. The selection of KPIs will continue in the next development round, and services will be tailored for their computation.

Next development step will rely on increased interaction with target users, for feedback. On this basis, specification will be updated after ingesting feedback from the industrial partners and needs from the Use Case Activation Plans developed by the project for the demonstration.

The focus of the second development round will be on boosting interoperability between services, data standardization and enriched synthetic datasets from MODERATE.

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