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D7.2 1st Version of the Optimised Energy Performance Management Suite

This project has received funding from the European Union's Horizon 2020 Research and Innovation programme under Grant Agreement No 872734.

SYNERGY

Big Energy Data Value Creation within SYNergetic enERGY-as-a-service Applications through trusted multi party data sharing over an AI big data analytics marketplace

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Author:	**VTT,** ETRA, CIRCE, VERD, CAV

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Version	Date of issue	Content and changes	Edited by
0.1	23/06/2021	ToC	VTT
0.2	14/07/2021	Updated TOC with guidance	VTT
0.3	1/09/2021	The structure is updated after the methodology is agreed between WP5-WP7	WPLs (WP5-WP7)
0.4	15/09/2021	1st contributions on APPs features are filled	VTT, ETRA, CIRCE, VERD
0.5	30/09/2021	1st complete draft for all APPS is produced	VTT, ETRA, CIRCE, VERD, CAV
0.6	16/10/2021	Enhanced descriptions for APPs are provided by partners	VTT, ETRA, CIRCE, VERD, CAV
0.6	23/10/2021	Integrated draft is submitted for the internal review	VTT
0.7	29/10/2021	Final report ready, comments addressed	VTT, ETRA, CIRCE, VERD

Peer reviewed by:

Partner	Reviewer
FVH	Timo Ruohomäki
UBITECH	Dimitris Miltiadou, Konstantinos Perakis

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Abbreviations and Acronyms

Acronym	Description
AI	Artificial Intelligence
AI-RDSS	AI- Renovation Decision Supporting Service
BSC	Balancing and Settlement Code
BACS	Building Automation and Control System
BST	British Summer Time
CA	Consortium Agreement
DD	Degree Days
DoA	Description of Action (annex I of the Grant Agreement)
EC	European Commission
eDEC	Enhanced Display Energy Certificate
EPBD	Energy Performance of Buildings Directive
EV	Electric Vehicles
FMME	Facility Management Monitoring Engine
GA	Grant Agreement
GMB	Group Model Building
GML	Geography Markup Language
GMT	Greenwich Mean Time
HH	Half-hourly
HVAC	Heating, ventilation, and air conditioning
HVAC-PMS	HVAC Predictive Maintenance Service
IDA-ICE-RAS	and IDA-ICE based Renovation Analysis Service

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Acronym	Description
JSON	JavaScript Object Notation
KPI	Key Performance Indicator
LF	Load Factor
LSTM	Long Short Term Memory
MD	Maximum Demand
MQTT	Message Queuing Telemetry Transport
NRCMV	Near Real-time City Monitoring and Visualization service
oBIX	Open Building Information Xchange
PC	Project Coordinator
PMB	Project Management Board
PO	Project Officer
QM	Quality Management
SD	System Dynamics
SRI	Smart Readiness Index
SSO	Single sign-on
SUPS	Strategic Urban Planning Supporter
TC	Technical Coordinator
TL	Task Leader
ToC	Table of Contents
GUI	Graphical User Interface
UML	Unified Modelling Language
WP	Work Package

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Acronym	Description
WPL	Work Package Leader

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Executive summary

The current deliverable D7.2 "1st Version of the Optimized Energy Performance Management Suite" reports the first development results of Tasks 7.1, 7.2, 7.3 and 7.4, each one in charge of the design and development of the applications composing the energy applications suite which will be delivered by WP7. The purpose of this deliverable is to detail the status of the 1st release of the developed functionalities. Developments are built on the use cases and requirements analysis, and the specifications defined in erarlier WP7 deliverable D7.1. The energy applications emerging from WP7 are:

- Advanced Renovation Support App, which aims at supporting users (Facility managers, Building owners, ESCOs) in the design and selection of most appropriate building renovation actions.
- Urban Energy Monitoring and Planning Support App, which aims at supporting users (Urban planners, Municipalities' decision makers) to monitor near real-time energy performance of buildings and to identify any potential weaknesses in the performance. Combined with the simulation environment, this application will allow to design effective alternative urban transformation strategies towards urban sustainability defined in SECAP plans.
- Self-Consumption Optimization & Predictive Maintenance App, which aims at supporting users (Facility managers) to optimize the operation and energy management of large facilities and building complexes.
- Real-time Building Energy Performance and Smart Readiness Certification App, which aims at supporting users (Aggregators, Retailers, Facility owners) with tools to assist in the continuous assessment and certification of real-time dynamic assessment of energy performance of buildings.

The detailed development report, presented in this document, defines the development status of functional features, user interfaces and deployment technology stack of each application and their respective APIs and necessary licences related information, in great details. Furthermore, the integration of WP7 energy management applications with the SYNERGY platform developed in WP3 and WP4 is addressed.

The current report is the first of two development deliverables to be delivered by WP7, and it specifies the implementation status of all four applications. Follow-up deliverable, D7.3 (due on M42), will report the details of final implementation of all four WP7 applications, though the intermediate releases of all applications are planned in the meantime, e.g. on M24.

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1 Introduction

1.1 Purpose of the document

This deliverable reports in details the development work performed and the 1st release of the SYNERGY Building/ District-level Analytics for Optimized Energy Performance Management suite. The suite includes components for Advanced Renovation support, Urban Energy Monitoring and Planning Support, Facility Management Energy Analytics, Self-Consumption Optimization & Predictive Maintenance, and Real-time Building Energy Performance and Smart Readiness Certification applications, which have resulted from the specification work of tasks T7.1, T7.2, T7.3 and T7.4, respectively.

The objectives of the energy applications are as follows:

- To deliver highly innovative renovation decision support tools to building facilities managers, building owners and ESCOs for safeguarding the payback of Energy Performance Contracts applied during renovation projects;
- To support urban monitoring and planning operations of city authorities through real-time urban energy performance monitoring & assessment and planning of targeted interventions that can evidently satisfy energy efficiency objectives set in the SECAP plans;
- To equip facility managers and ESCOs, with real-time energy performance analytics towards optimizing energy management, maximizing self-consumption and optimizing predictive maintenance of building assets;
- To reinforce the business offering of ESCOs through a first-of-a-kind application for real-time energy performance and smart readiness certification of buildings.

This report sets the ground for the upcoming development activities of WP7 towards iterative implementation of Optimized Energy Performance Management Suite as well as the interaction with the SYNERGY platform (which is developed in the context of WP3 and WP4), which will be validated during the project demonstration phase carried out in WP8.

1.2 Scope of the document

This deliverable provides the detailed report on the first developments of Energy Performance Management applications and their respective components, accomplished till (M22) within the scope of WP7 tasks T7.1 -T7.4. Apart from the features provided by applications, the report includes information on APIs, technology stack and software libraries and also plans for the next releases of all applications.

1.3 Structure of the document

This document is structured as follows.

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- Chapters 2-5 provide the details of the development of all energy applications in WP7. The development details of each energy application are described by reporting the technical features that have been implemented (supported by respective screenshots), the technology stack and libraries which are used to develop and deploy respective applications in the concrete business contexts, the APIs, the installation instructions as well as the plans for future software releases and integration with the SYNERGY platform.
- Chapter 6 concludes this document by highlighting main discussion points of the report as well as outlining the aspects of future work.

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2 The advanced Renovation Support application

2.1 Overview

The advanced Renovation Support application aims at supporting users (Facility managers, Building owners, ESCOs) in the design and selection of most appropriate building renovation actions. This will be achieved by leveraging the real-time data coming from the actual operation of the building combined with occupants' behavior- and comfort profiles into iterative analytics and simulation loops to propose alternative renovation scenarios of selected buildings. This will help respective users to enhance generic routines currently used in similar commercial products, which are based on predicted energy performance of a building. The Advanced Renovation Support App includes the following components.

- AI boosted Renovation Decision Supporting Service (AI-RDSS)
- IDA-ICE based Renovation Analysis Service (IDA-ICE-RAS)

2.2 Implemented functionalities

The status of implemented features is shown in the following table.

Table 1.The status of implemented features for Advance Renovation Support application.

Feature	Status	Notes
AI-RDSS_1	Partially implemented	The very first standalone version of the GUI has been implemented (allows to input the renovation targets, building related information, renovation actions to be studied).
AI-RDSS_2	Partially implemented	The very first standalone version of the machine learning based building energy consumption model (digital twin) has been implemented, but it cannot be fully tested without the SYNERGY platform data (basic information of the building, building energy consumption data, local weather data).
AI-RDSS_3	Implemented	Implementation of the calculation feature is ready but related APIs are not fully tested with data.
AI-RDSS_4	Partially implemented	Implementation of the pre-selection of the most potential renovation action such as envelope insulation and air condition systems, has been started.
AI-RDSS_5	Partially implemented	The data storage & ML algorithms are implemented. The AI-RDSS module leverages background information of the pilot buildings and related energy consumption. At this point, some demo/test data (stored in local database) has been used for testing.

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Feature	Status	Notes
AI-RDSS_6 (optional)	Partially implemented	This is an optional feature which will be implemented if related data (country specific information such as investment costs, installation and energy costs and related carbon footprints) will be available e.g. provided by partners.
IDA-ICE-RAS_1	Partially implemented	Detailed level modelling can be started when AI-RDSS related analyses are done.
IDA-ICE-RAS_2	Partially implemented	Detailed level calculating of pre-selected renovation actions can be started when AI-RDSS related analyses are done.
IDA-ICE-RAS_3	Partially implemented	Prioritisation of calculated renovation actions can be started when IDA-ICE-RAS_2 has been done.

Hardcopies of standalone version of application related GUI are shown in Figure 1 - Figure 6. This standalone Windows application based GUI will be replaced in the next release with web browser based GUI.

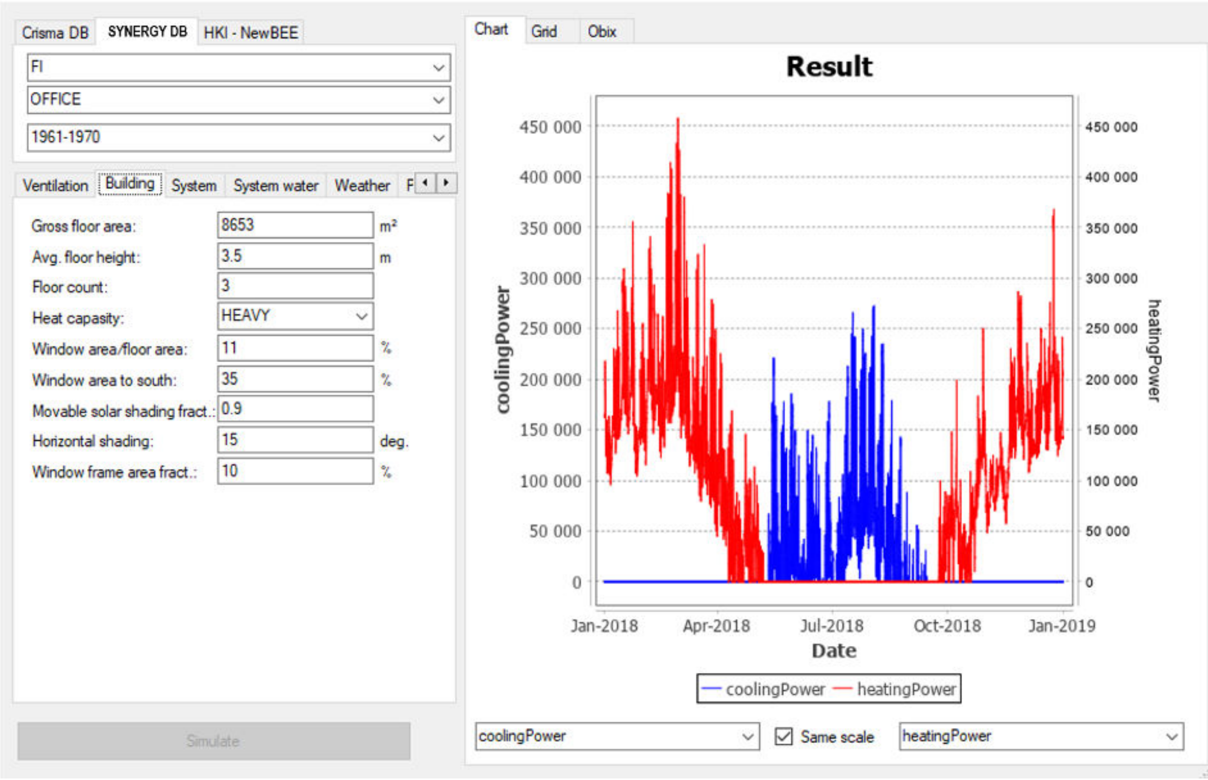

Figure 1: The main menu.

The objective is to read building specific values from SYNRGY platform (related JSON file) and check/change related values using next dialogs if needed.

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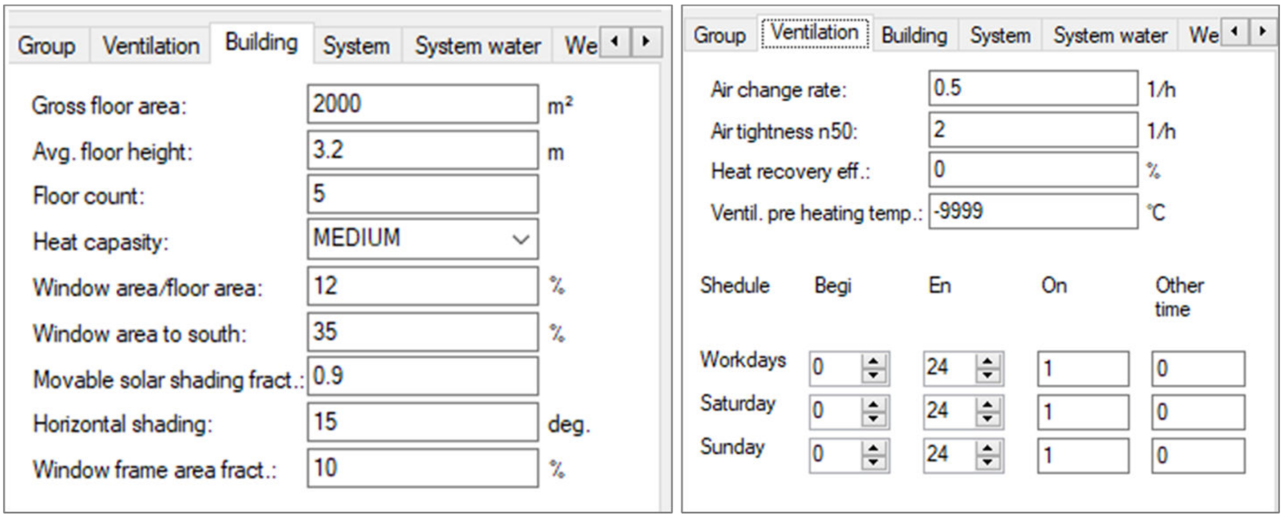

Figure 2: Selecting the existing building parameters – building and ventilation parameters.

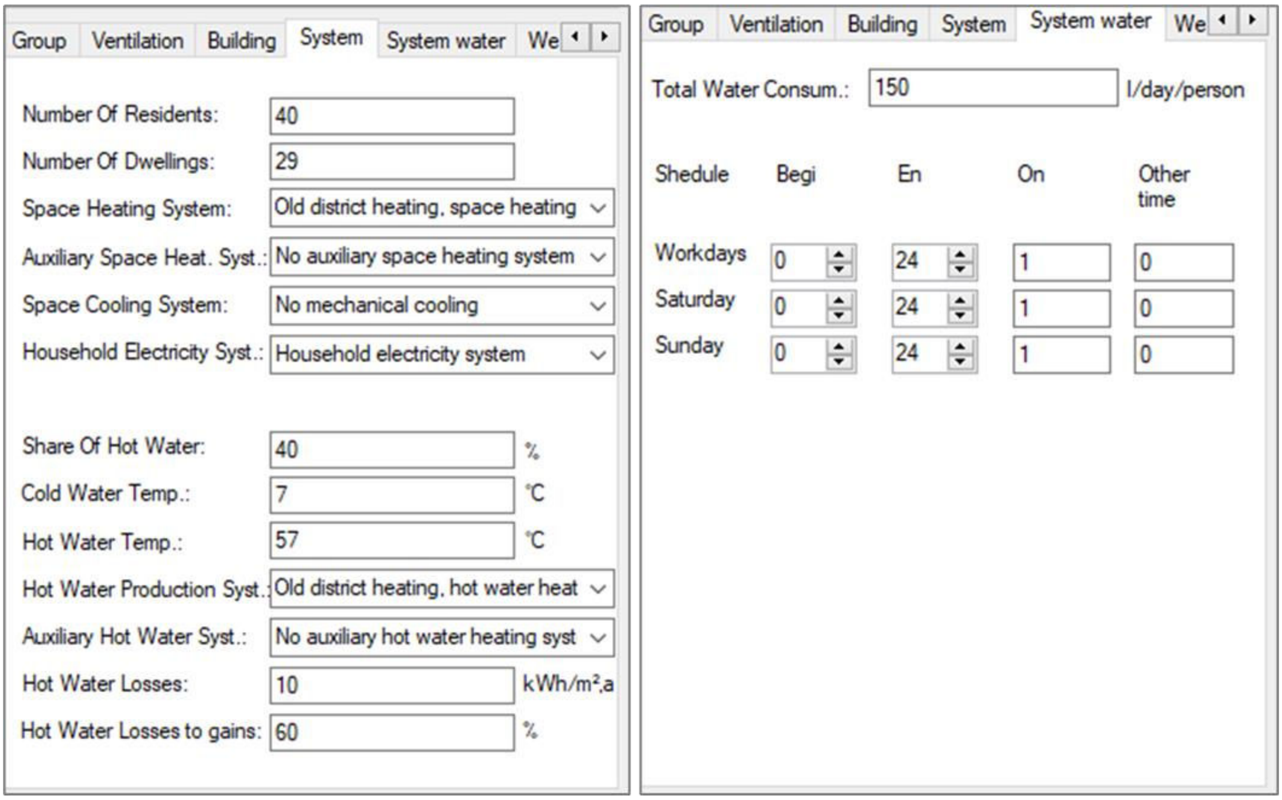

Figure 3: Selecting the existing building parameters – heating, cooling and water system parameters.

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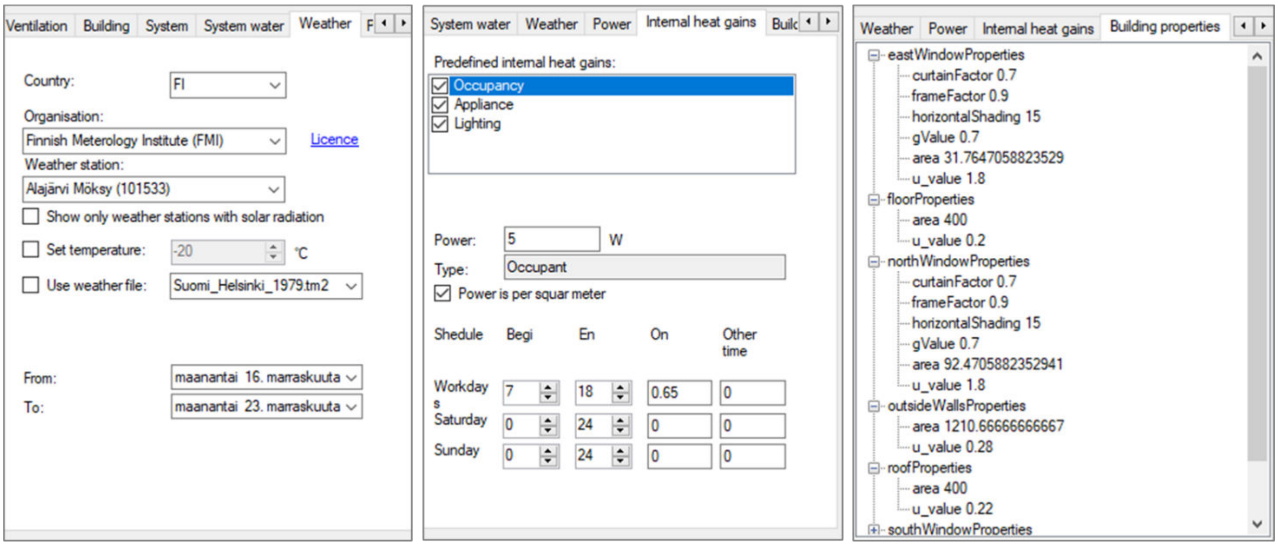

Figure 4: Selecting the existing building parameters – internal heat gains and weather data.

An example of some AI-RDSS simulation engine related outputs is shown in figure below.

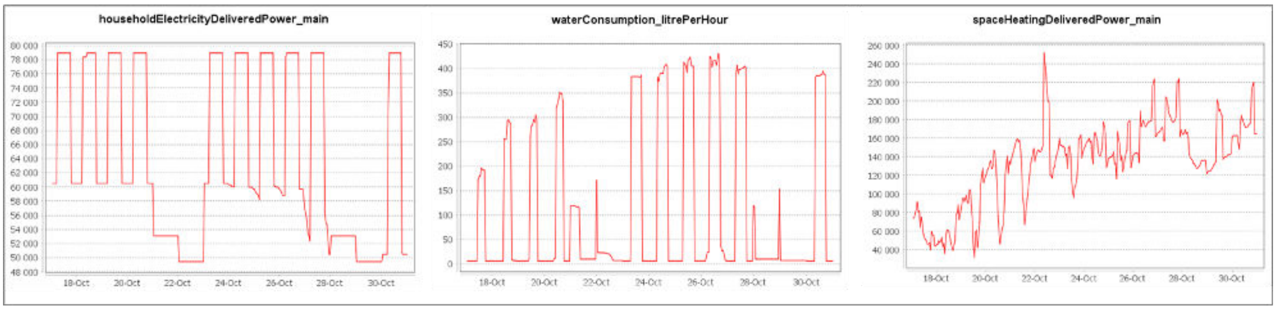

Figure 5: Example of simulation engine outputs.

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	Space heating and hot water		Appliance electricity		Space cooling		Carbon footprint		Energy cost	Investment	Payback time
CASE 1	kWh/a	kWh/m2,a	kWh/a	kWh/m2,a	kWh/a	kWh/m2,a	tCO2/a	kgCO2/m2,a	€/a	€	a(year)
Before	99894	50	89575	45	14329	7	70	0.04	23355	-	-
After	88912	44	89575	45	16692	8	67	0.03	22853	212784	423.9
Savings	10982	6	0	0	-2363	-1	3	0	502	-	-

	Space heating and hot water		Appliance electricity		Space cooling		Carbon footprint		Energy cost	Investment	Payback time
CASE 2	kWh/a	kWh/m2,a	kWh/a	kWh/m2,a	kWh/a	kWh/m2,a	tCO2/a	kgCO2/m2,a	€/a	€	a(year)
Before	99894	50	89575	45	14329	7	70	0.04	23355	-	-
After	88912	44	89575	45	16692	8	67	0.03	22853	212784	423.9
Savings	10982	6	0	0	-2363	-1	3	0	502	-	-

…

	Space heating and hot water		Appliance electricity		Space cooling		Carbon footprint		Energy cost	Investment	Payback time
CASE N	kWh/a	kWh/m2,a	kWh/a	kWh/m2,a	kWh/a	kWh/m2,a	tCO2/a	kgCO2/m2,a	€/a	€	a(year)
Before	99894	50	89575	45	14329	7	70	0.04	23355	-	-
After	88912	44	89575	45	16692	8	67	0.03	22853	212784	423.9
Savings	10982	6	0	0	-2363	-1	3	0	502	-	-

Figure 6: Results of studied renovation actions.

2.3 Technology stack and implementation tools

The related technology stacks and related version numbers and licenses are shown in the table below.

Table 2. The related technology, version numbers and licenses.

Library	Version	License
Apache Tomcat® for Java Servlet	9.0.53	Apache 2.0 (https://www.apache.org/licenses/LICENSE-2.0)
PostgreSQL	14 RC 1	PostgreSQL is released under the PostgreSQL License, a liberal Open Source license, similar to the BSD or MIT licenses.
NodeJS	14.17.6	Node.js uses a permissive MIT license for the main library.

Library	Version	License
Deeplearning4j	1.0.0-M1.1	These libraries are completely open-source, Apache 2.0 under open governance at the Eclipse foundation. (https://deeplearning4j.konduit.ai/

2.4 API documentation

The GUI has been integrated with the application backend using the tool engine REST JSON APIs as presented in the table below.

Table 3. The internal application APIs.

Engine API description	Type	Implementer	Purpose
POST building basic info	HTTP POST	Backend	Basic information of renovated building as json file •Building basic information: Building name, Street Address, City, Country, Building location (latitude, longitude), Building type, Building Year, Building volume (m3), Building height (m), Conditioned floor area (m²), Number of floors, Floor height (m), Number of residents (-), Cooling set point (°C), Heating set point (°C), Space heating type, Heating type auxiliary, Space cooling type, Household electricity type •Window information: Windows total area (m²), Windows U-value (W/m²K), Windows g-value (-), Windows shadings (-), Share of window area to south •Building envelope properties: Outside walls (Area m², U-Value W/m²K), Roof (Area m², U-Value W/m²K), Floor (Area m², U-Value W/m²K) •Ventilation and infiltration: Air change (1/h, optionally also hourly schedules for days of the week), Heat recovery efficiency (-), Air leakage rate n50 Pa (1/h) •User profiles and internal gains: Occupants (W/m², optionally also hourly schedules for days of the week), Appliances (W/m², optionally also hourly schedules for days of the week), Lighting (W/m², optionally also hourly schedules for days of the week) •Hot water system: Total water consumption (l/person,day), Share of hot water (-), Hot water circulation pipe losses (kWh/m²,a), Hot water temperature (°C), Cold water temperature (°C), Hot water heating type main, Hot water heating type auxiliary

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Engine API description	Type	Implementer	Purpose
Post building heating energy consumption	HTTP POST	Backend	Aggregated history data of building hourly heating energy consumption
Post building cooling energy consumption	HTTP POST	Backend	Aggregated history data of building hourly cooling energy consumption
Post building electricity consumption	HTTP POST	Backend	Aggregated history data of building electricity consumption
Post local outdoor air temperature	HTTP POST	Backend	Local weather data (at least one-year hourly history data of outdoor air temperature)
Post local outdoor air relative humidity	HTTP POST	Backend	Local weather data (at least one-year hourly history data of outdoor air relative humidity)
Post diffuse solar radiation	HTTP POST	Backend	Weather data (at least one-year hourly history data of diffuse solar radiation)
Post direct solar radiation	HTTP POST	Backend	Weather data (at least one-year hourly history data of direct solar radiation)

The status of required SYNERGY Platform APIs for AI-RDSS functionalities are shown in the table below.

Table 4. The status of required SYNERGY Platform APIs for module functionalities.

Data Retrieval Query	Type	Implementer	Purpose
Get building basic info	HTTP GET	SYNERGY Platform	Basic information of renovated building as json file •Building basic information: Building name, Street Address, City, Country, Building location (latitude, longitude), Building type, Building Year, Building volume (m3), Building height (m), Conditioned floor area (m²), Number of floors, Floor height (m), Number of residents (-), Cooling set point (°C), Heating set point (°C), Space heating type, Heating type auxiliary, Space cooling type, Household electricity type •Window information: Windows total area (m²), Windows U-value (W/m²K), Windows g-value (-), Windows shadings (-), Share of window area to south •Building envelope properties: Outside walls (Area m², U-Value W/m²K), Roof (Area m², U-Value W/m²K), Floor (Area m², U-Value W/m²K)

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Data Retrieval Query	**Type**	**Implementer**	**Purpose**
			•Ventilation and infiltration: Air change (1/h, optionally also hourly schedules for days of the week), Heat recovery efficiency (-), Air leakage rate n50 Pa (1/h) •User profiles and internal gains: Occupants (W/m², optionally also hourly schedules for days of the week), Appliances (W/m², optionally also hourly schedules for days of the week), Lighting (W/m², optionally also hourly schedules for days of the week) •Hot water system: Total water consumption (l/person,day), Share of hot water (-), Hot water circulation pipe losses (kWh/m²,a), Hot water temperature (°C), Cold water temperature (°C), Hot water heating type main, Hot water heating type auxiliary
Get building heating energy consumption	HTTP GET	SYNERGY Platform	Aggregated history data of building hourly heating energy consumption
Get building cooling energy consumption	HTTP GET	SYNERGY Platform	Aggregated history data of building hourly cooling energy consumption
Get building electricity consumption	HTTP GET	SYNERGY Platform	Aggregated history data of building electricity consumption
Get local outdoor air temperature	HTTP GET	SYNERGY Platform	Local weather data (at least one-year hourly history data of outdoor air temperature)
Get local outdoor air relative humidity	HTTP GET	SYNERGY Platform	Local weather data (at least one-year hourly history data of outdoor air relative humidity)
Get diffuse solar radiation	HTTP GET	SYNERGY Platform	Weather data (at least one-year hourly history data of diffuse solar radiation)
Get direct solar radiation	HTTP GET	SYNERGY Platform	Weather data (at least one-year hourly history data of direct solar radiation)

2.5 Installation instructions

Current version of the GUI is a standalone Windows application and needs to be installed on Windows computer using its setup package (not yet available from private repository). This standalone Windows application based GUI will be replaced with web browser based GUI (in the upcoming release) and after that no installation will be required. In addition, the tool calculation engine has REST JSON API and can be used via related API without any installation.

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2.6 Assumptions and restrictions

The application relies on the data (basic information of the building, weather data, building energy consumption data) provided by the SYNERGY Platform. In addition, the users are required to be registered as users of the SYNERGY Platform and they should be able to do the necessary data check-in jobs, in order the required datasets to be accessible through the SYNERGY platform.

2.7 Licensing and access

VTT is the owner of all intellectual property rights of AI-RDSS module. All rights are reserved. The licensing can be granted according to the SYNERGY license agreement.

The demo of this application is available at[1]: https://renovationsupport.synergy-bigdata.eu

2.8 Planned features for next release

It's planned that for the next release by M24, the focus will be put on the finalization of GUI, calculation and prioritization of renovation actions and ML algorithms for learning the studied building model (AI-RDSS _1-3, AI-RDSS _5). This will allow the start of the testing and validation of the application as a part of the WP8 activities.

The results of the testing and validation activities will be used to improve application functions towards M33, when the second phase of demonstration and validation will be started. During the period of M24-M33, the ML algorithms will be also improved by utilising and testing the algorithm with various real datasets (AI-RDSS _4). More deep study of the renovation actions will be performed (IDA-ICE_1-3). The final version of the application is to be released by M42.

2.9 Integration Plan

The data access and data sharing with SYNERGY platform is tested with test data. The application will be integrated with the platform when related data are made available through the SYNERGY platform APIs. The application will be integrated with baseline analytics developed in WP4, such as e.g. comfort profiling, when they will be made available on the SYNERGY platform.

[1] Demo credentials are available on request

3 Urban Energy Monitoring and Planning Support Application

3.1 Overview

The Urban Energy Monitoring and Planning Support application aims to monitor and visualise near real-time energy performance of buildings (public and commercial) with the objective to identify weak energy performance areas. Combined with the simulation environment, this application will allow end users such as Urban planners, Municipalities' decision makers to design effective alternative urban transformation strategies towards the realization of short-term and mid-term objectives for energy efficiency and urban sustainability to meet SECAP targets. The Urban Energy Monitoring and Planning Support includes the following two components.

- Near Real-time City Monitoring and Visualization service (NRCMV)
- Strategic Urban Planning Supporter (SUPS)

3.2 Implemented functionalities

The status of implemented functionalities is shown in the following Table.

Table 5.The status of implemented functionalities.

Feature	Status	Notes
NRCVM_1	Partially implemented	Data access and data sharing with SYNERGY platform is tested with test data but not with NRCVM input data because the specific data is not yet available via SYNERGY platform.
NRCVM_2	Partially implemented	First version of ML boosted model for district energy demand estimates is implemented by using non-SYNERGY test energy data and will be fully implemented when needed hourly district energy data is available via SYNERGY platform APIs.
NRCVM_3	Partially implemented	Implementation of building heating demand related simulation model is ready and the scaling of these models to district level model already started.
NRCVM_4	Partially implemented	Most new indicators for SUPS component are defined and the draft integration concept between KPI calculation and SUPS component is ready.
SUPS_1	Partially implemented	Initial version of qualitatively models for specific strategic electrification use cases and scenarios has been completed.
SUPS_2	Partially implemented	Initial version of system dynamics models for simulating quantitatively alternative energy electrification scenarios for urban area has been completed (e.g. PV technology & EV integration).

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The visualizations for studied area related to heating demand estimates and the results of machine learning model for studied area related to heating power estimate are shown in the Figure 7 and Figure 8 respectively.

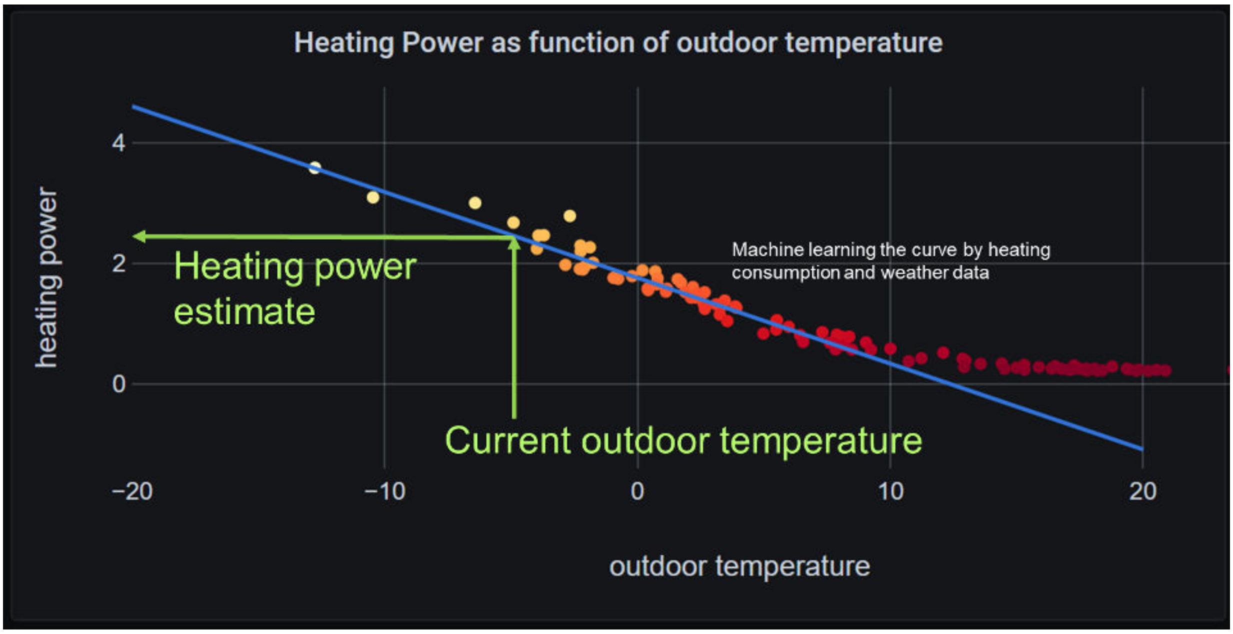

Figure 7: An example of a simple machine learning model for studied area related to heating power estimate.

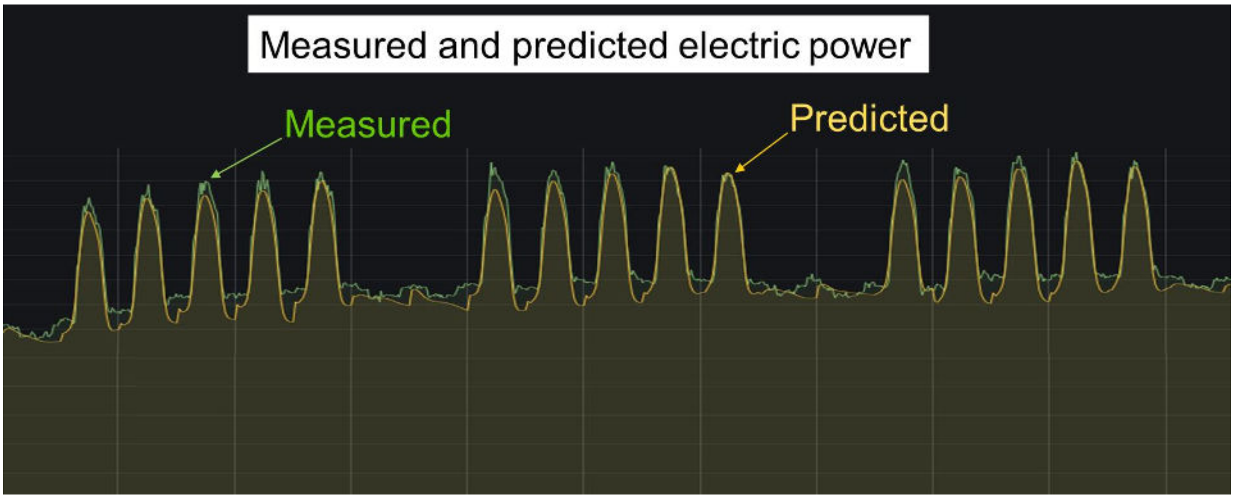

Figure 8: An example of ANN model based electric power estimate for the area.

Area electricity demand related scenarios are complemented by SUPS module, using area NRCVM_4 indicator values (area electricity production and demand and related carbon footprint) as a starting point.

Figure 9 shows an initial simulation model that seeks to explain are energy indicators as a function of area energy production and demand, specifically PV installations and EV use. Furthermore, the causal theories for both PV installations and EV adoption processes feature non-linear drivers and various potential bottlenecks. Key input points for entering data about the system state and tested policy

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interventions are marked in blue. Key indicators used for comparing the chosen interventions and assumptions are marked in green. Crucially, the models structure is flexible to accommodate the specific conditions and needs of the user of simulation knowledge. Use of empirical data is likewise possible to validate the starting values or even causal effects of any given variable.

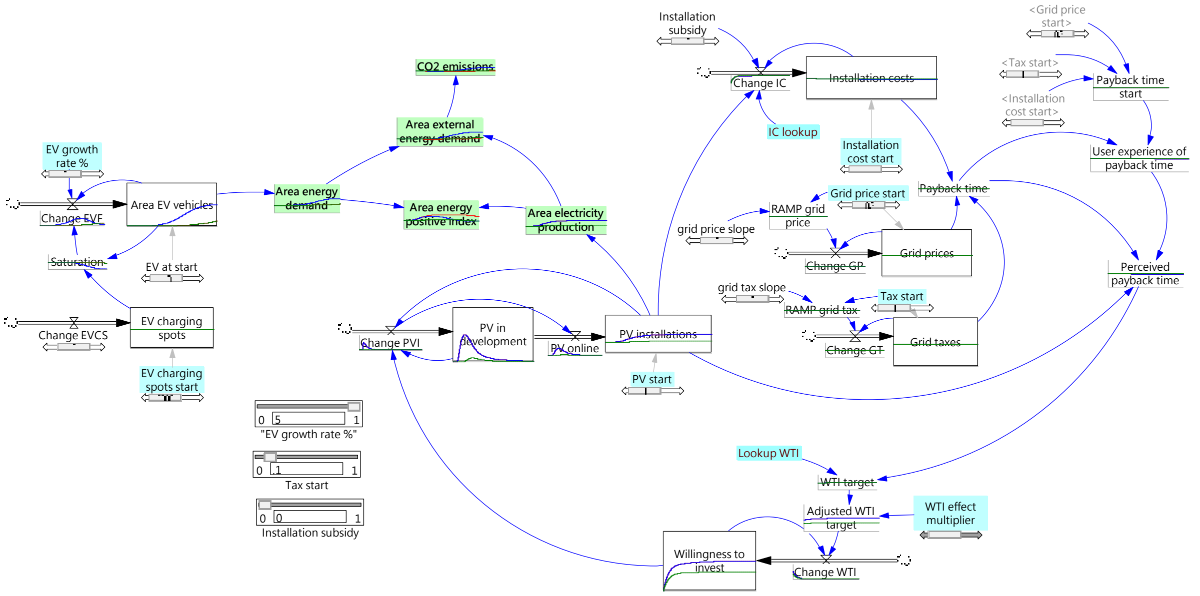

Figure 9: A SUPS simulation model.

As an example, Figure 10 shows change in the Energy Positive Index and the Energy Demand in the studied area under three sets of assumptions. The baseline run is in green, featuring modest EV growth and no particular promotion of PV installations. PV installations grow somewhat due to the assumed reinforcing effects (such as declining installation costs and increased user awareness as PV is normalized). After a slight increase in the Area Energy Positive Index the increase in EVs leads to a downturn as electricity demand increases. The red curve demonstrates the potential effect of making the PV installation bureaucracy easier. This test is operationalized in the model as more households wishing to install PV per given payback time (parameter 'WTI effect multiplier'). Though EV adoptions bring the Area Energy Positive Index down again, the initial burst of PV installations is stronger leading to a clearly higher Index at all times. Finally, the blue curve takes the prior assumptions but assumes a far faster EV adoption rate. Initial trajectory is similar to the red curve, but the downturn in energy positivity happens sooner and more steeply.

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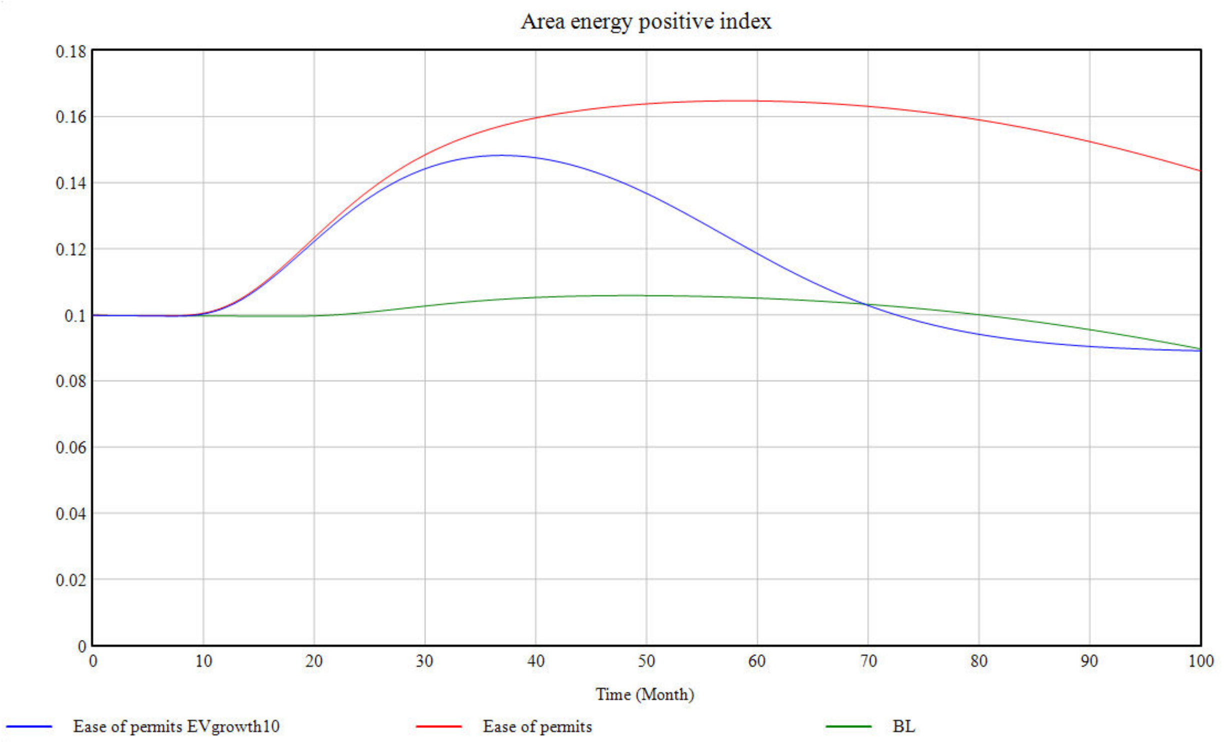

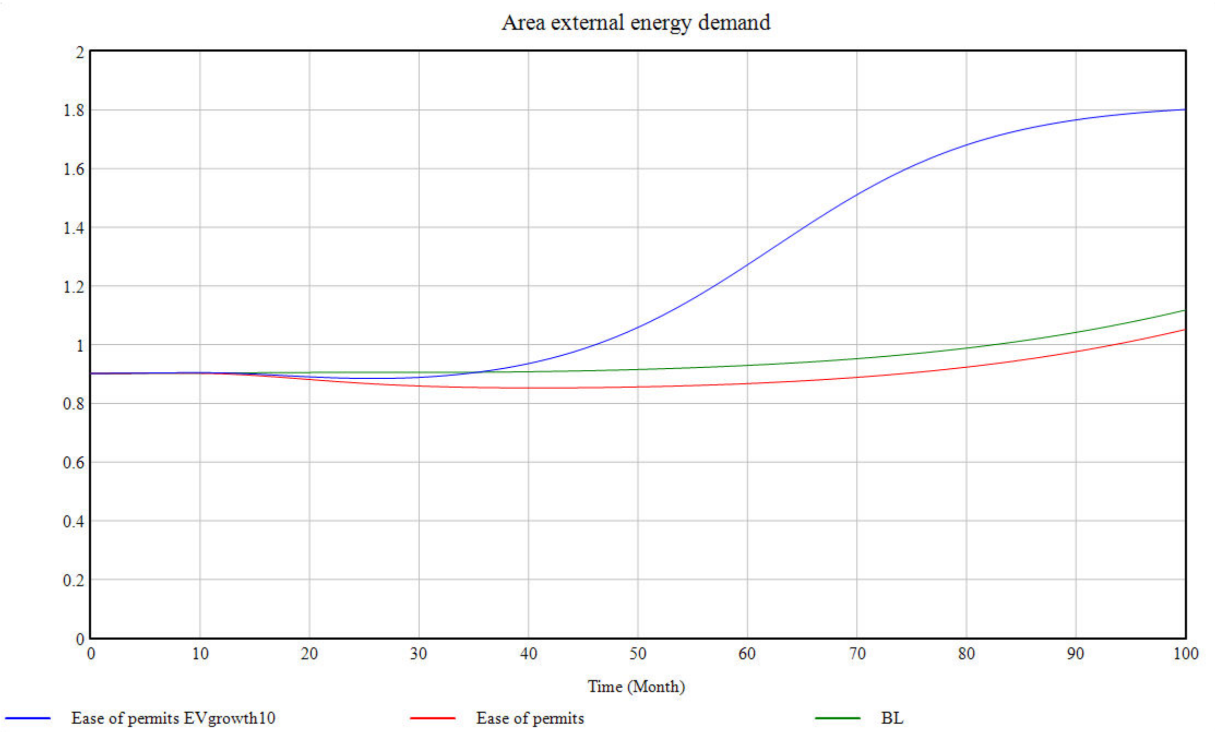

Figure 10: Change in Area External Energy Demand under three sets of assumptions.

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3.3 Technology stack and implementation tools

The technology stack, related version numbers and licenses are shown in the following table.

Table 6. The technology stack and licenses.

Library	Version	License
Apache Tomcat® for Java Servlet	9.0.53	Apache 2.0 (https://www.apache.org/licenses/LICENSE-2.0)
PostgreSQL	14 RC 1	PostgreSQL is released under the PostgreSQL License, a liberal Open Source license, similar to the BSD or MIT licenses.
Deeplearning4j	1.0.0-M1.1	These libraries are completely open-source, Apache 2.0 under open governance at the Eclipse foundation. (https://deeplearning4j.konduit.ai/
Vensim	9.0	Vensim Free Research License, https://vensim.com/license/

3.4 API documentation

The application related SYNERGY Platform data retrieval queries are show in the following table.

Table 7. The retrieval queries to interact with the SYNERFY platform.

Data Retrieval Query	Type	Implementer	Purpose
Aggregated heating energy consumption	HTTP GET	SYNERGY Platform	Aggregated history data of area (e.g. district) hourly heating energy consumption
Aggregated cooling energy consumption	HTTP GET	SYNERGY Platform	Aggregated history data of area (e.g. district) hourly cooling energy consumption
Aggregated electricity consumption	HTTP GET	SYNERGY Platform	Aggregated history data of area (e.g. district) electricity consumption
Aggregated heating energy production	HTTP GET	SYNERGY Platform	Aggregated history data of area (e.g. district) hourly heating energy production
Aggregated cooling energy production	HTTP GET	SYNERGY Platform	Aggregated history data of area (e.g. district) hourly cooling energy production
Aggregated electricity generation	HTTP GET	SYNERGY Platform	Aggregated history data of area (e.g. district) hourly electricity generation
Building eating energy consumption	HTTP GET	SYNERGY Platform	History data of area related building hourly heating energy consumption (optional)

Data Retrieval Query	Type	Implementer	Purpose
Building cooling energy consumption	HTTP GET	SYNERGY Platform	History data of area related building hourly cooling energy consumption (optional)
Building electricity consumption	HTTP GET	SYNERGY Platform	History data of area related building hourly electricity consumption (optional)
Basic information of building types	HTTP GET	SYNERGY Platform	Basic information of building types in the area (e.g. buildingType1: building type = apartment building, construction year = 1985, gross floor area = 2000 m2)
Number of different types of buildings in the area	HTTP GET	SYNERGY Platform	Number of different types of buildings in the area
Get number of people in the area	HTTP GET	SYNERGY Platform	Number of people living in the area

3.5 Installation instructions

The web browser based monitoring of NRCVM results does not required any installation. For this first release the Vensim should be downloaded to investigate and use SUPS models.

3.6 Assumptions and restrictions

The application relies on the data provided by the SYNERGY Platform. In addition, the users are required to be registered as users of the SYNERGY Platform and they should be able to do necessary data check-in jobs, so required datasets get accessible through the platform.

3.7 Licensing and access

VTT is the owner of all intellectual property rights of NRCVM. All rights are reserved. The licensing can be granted according SYNERGY license agreement.

A demo version of the application is accessible at[2]: https://urbanplanningsupport.synergy-bigdata.eu

[2] Demo credentials are available on request

This project has received funding from the European Union's Horizon 2020 Research and Innovation programme under Grant Agreement No 872734.

3.8 Planned features for next release

It's planned that for the next release by M24, the focus will be put on the integration of near-real time data at the city district level to test and improve the analytics features (NRCMV_3-4) and on the improving of SUPS models (SUPS_1-2). This will allow the start of the testing and validation of the application as a part of the WP8 activities.
The results of the testing and validation activities will be used to improve application functions towards M33, when the second phase of demonstration and validation will be started. During the period of M24-M33, the ML algorithms will be also improved by utilising and testing algorithm with various real datasets. The final version of application is to be released by M42.

3.9 Integration Plan

The data access and data sharing with SYNERGY platform is tested with test data. The application will be integrated with the platform when related data will be made available on the SYNERGY platform APIs. The application will be integrated with baseline analytics such as energy demand/consumption forecast, when they will be made available on the SYNERGY platform.

This project has received funding from the European Union's Horizon 2020 Research and Innovation programme under Grant Agreement No 872734.

4 Facility Management Energy Analytics Self-Consumption Optimization & Predictive Maintenance Application

4.1 Overview

The objective of the Facility Management Energy Analytics, Self-Consumption Optimization & Predictive Maintenance toolbox is to provide Energy Managers, Facility Mangers, Facility Owners and ESCOs a bundle of additional analytics and services for optimizing the operation and energy management of large facilities and buildings complexes (or group of buildings). This objective will be covered by the development of 4 tools/modules:

- Facility Management Monitoring Engine (FMME) will provide in-depth and comprehensive knowledge of the energy behaviour of their calculating and displaying metrics and KPIs. Therefore, the user will measure and visualize the impact on the relevant KPIs of the optimizations made by other components of the toolbox.
- HVAC Predictive Maintenance Service (HVAC-PMS) will support building managers in predictive maintenance tasks of high energy HVAC.
- Building-Level Energy Performance Optimisation Manager and District-Level Energy Performance Optimisation Manager (BL-EPOM and DL-EPOM) modules will support facility managers, in presence of flexible devices and systems, to design appropriate flexibility control strategies to maximize self-consumption and reduce energy costs for independent buildings and groups of buildings.

The architecture of the Facility Management Energy Analytics, Self-Consumption Optimization & Predictive Maintenance toolbox is represented in Figure 11. The image also incorporates the “eDECs Calculation Engine” and the “SRI Calculation Engine” under development in task 7.4 but to be integrated in the same user interface as the FMME, the BL-EPOM and the DL-EPOM.

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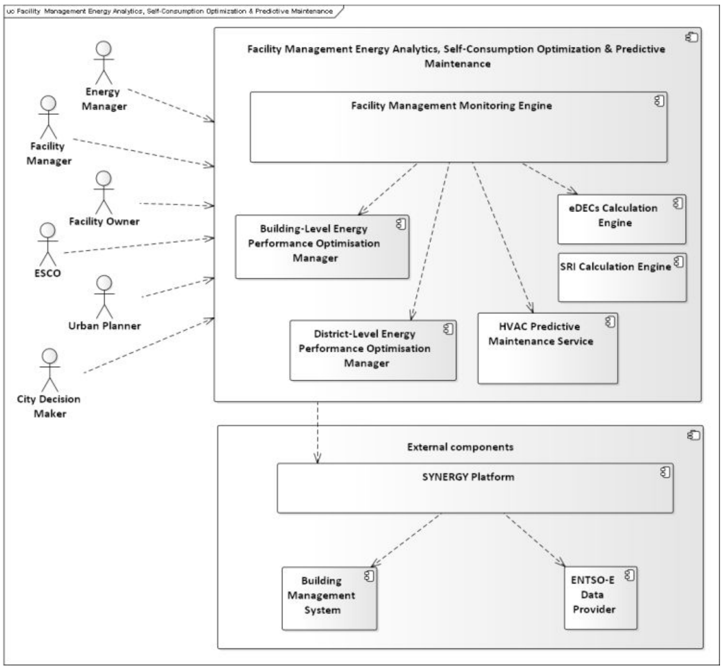

Figure 11: Facility Management Energy Analytics, Self-Consumption Optimization & Predictive Maintenance toolbox, component diagram.

4.2 Implemented functionalities

The table below shows the implemented functionalities and the status of all modules developed:

- FMME_X for the Facility Management Monitoring Engine
- HVAC-PMS_X for the HVAC Predictive Maintenance Service
- BL-EPOM_X for the Building-Level Energy Performance Optimisation Manager
- DL-EPOM_X for the District-Level Energy Performance Optimisation Manager

Table 8. The implemented features.

Feature	Status	Notes
FMME_1	Implemented	Implementation has taken place using test data from two buildings. All data processing involved has been implemented as analytic workflows in the SYNERGY Platform
FMME_2	Implemented	Implementation has taken place using test data from two buildings. All data processing involved has been implemented as analytic workflows in the SYNERGY Platform

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Feature	Status	Notes
FMME_3	Partially Implemented	Evaluation and display of evolution of KPIs is implemented. Next release will include the tagging feature. All data processing involved has been implemented as analytic workflows in the SYNERGY Platform.
FMME_4	Partially implemented	Current version calculates baselines for registered buildings. Next release will include the comparison of KPIs among different time periods feature. All data processing involved has been implemented as analytic workflows in the SYNERGY Platform.
HVAC-PMS_1	Partially implemented	Continuous monitoring and history data collection (measurement values, controllers' set point values) from studied HVAC system(s) and related indoor environment conditions including building and HVAC system level energy consumption tested with test-data from buildings.
HVAC-PMS_2	Implemented	Integrated analytics for monitoring the technical performance of AHU and Heating Network functionalities is implemented.
HVAC-PMS_3	Implemented	First version of HVAC-PMS_2 with Digital Twin based malfunctions, inefficiencies and optimization possibilities detection has been done for building level heating/cooling energy systems and human thermal comfort based approach for space heating/cooling system.
HVAC-PMS_4	Implemented	First version of neural network based malfunctions, inefficiencies and optimization possibilities detection has been done using an autoencoder-decoder model.
HVAC-PMS_5	Implemented	First version of 3D BIM based digital twin for visualising malfunction has been implemented. SmartView visualisation functionalities are implemented
BL-EPOM_1	Partially implemented	Calculation of solar PV usage The developed MILP optimization calculates the PV generation use and possible curtailments, but the results do not fully cover the objectives of

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Feature	Status	Notes
		the tools as the HVAC demand is not optimised in the previous steps
BL-EPOM_2	Partially implemented	Calculation of batteries usage The developed MILP optimization calculates the batteries use (charge and discharge powers and expected SoC), but the results do not fully cover the objectives of the tools as the HVAC demand is not optimised in the previous steps
BL-EPOM_3	Partially implemented	Calculation of EV batteries charge The developed MILP optimization calculates the EV batteries use (charge and discharge powers and expected SoC), but the results do not fully cover the objectives of the tools as the HVAC demand is not optimised in the previous steps
BL-EPOM_4	Partially implemented	Calculation of energy exchanges with the grid The developed MILP optimization calculates the energy exchanges with the grid, but the results do not fully cover the objectives of the tools as the HVAC demand is not optimised in the previous steps
BL-EPOM_5	Partially implemented	Calculation of manageable demands use The developed MILP optimization calculates the manageable demands use for every building but the results do not fully cover the objectives of the tools as the HVAC demand is not optimised in the previous steps
DL-EPOM_1	Partially implemented	Calculation of solar PV use The developed MILP optimization calculates the PV generation use and possible curtailments, but the results do not fully cover the objectives of the tools as the HVAC demand is not optimised in the previous steps
DL-EPOM_2	Partially implemented	Calculation of batteries use The developed MILP optimization calculates the batteries use (charge and discharge powers and expected SoC), but the results do not fully cover the objectives of the tools as the HVAC demand is not optimised in the previous steps

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Feature	Status	Notes
DL-EPOM_3	Partially implemented	Calculation of EV batteries charge The developed MILP optimization calculates the EV batteries use (charge and discharge powers and expected SoC), but the results do not fully cover the objectives of the tools as the HVAC demand is not optimised in the previous steps
DL-EPOM_4	Partially implemented	Calculation of energy exchanges with the grid The developed MILP optimization calculates the energy exchanges with the grid, but the results do not fully cover the objectives of the tools as the HVAC demand is not optimised in the previous steps
DL-EPOM_5	Partially implemented	Calculation of energy exchanges between buildings through the grid The developed MILP optimization calculates the energy exchanges between buildings through the grid, but the results do not fully cover the objectives of the tools as the HVAC demand is not optimised in the previous steps
DL-EPOM_6	Partially implemented	Calculation of manageable demands use The developed MILP optimization calculates the manageable demands use for every building but the results do not fully cover the objectives of the tools as the HVAC demand is not optimised in the previous steps

For this first release of the energy tools, not all the DL-EPOM and BLEPOM functionalities have been fully developed as it is shown in the previous table. These partial developments are mainly caused by the fact that the necessary data from the demos have not been yet uploaded in the SYNERGY Platform so other data resources have been used and the optimization has been simplified and limited to the MILP optimization stage, leaving the GA optimization of the HVAC systems for the next release. For this release instead of using real data and predictions based on historical data from the demos, a series of CSV files have been created to collect the information needed to run the second step of the two tools, the MILP optimisation. These CSV files are hosted on the SYNERGY platform and are queried and used to launch both BL-EPOM and DL-EPOM. As a consequence, the queries and forecasts of the actual demo data in the SYNERGY platform have not been developed, this will be done in the coming months.

The development of the FMME has been based on test data taken from the sensors at ETRA I+D Headquarters. Data corresponding to 4 months has been uploaded in a duplicate manner to the SYNERGY Platform in order to emulate 2 buildings. Most features have been already implemented, while some of them are planned to be released in the upcoming months.

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4.2.1 Application user interface

The login has been implemented by integrating with the SYNERGY Platform's Security, Authentication and Authorization mechanisms through Keycloak, an open source identity server implementing well-known authentication and authorization protocols.

Figure 12: Energy applications screen shot, login screen-I.

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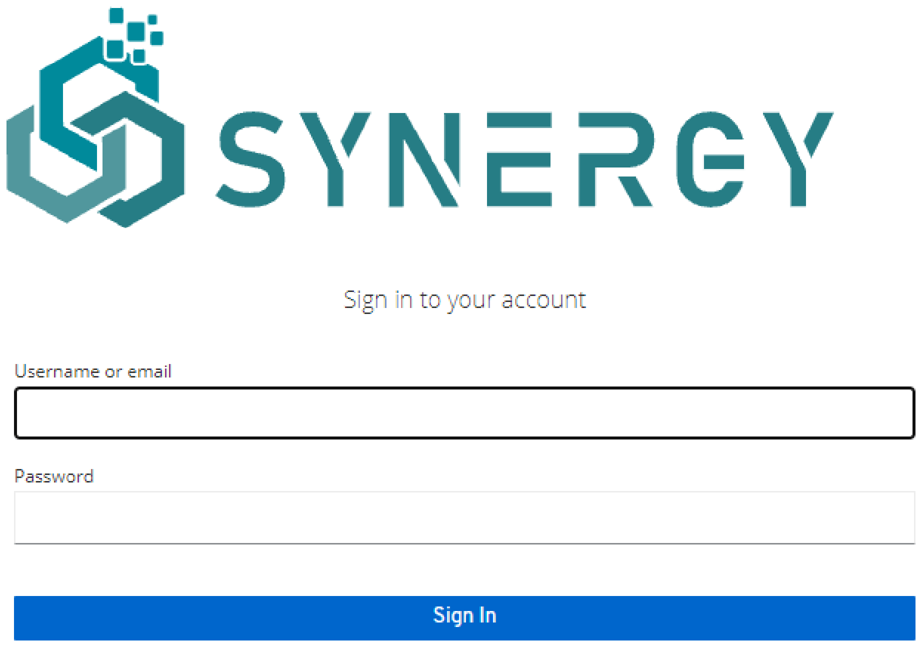

Figure 13: Energy applications screen shot, login screen-II.

The Dashboard of Facility Management Monitoring Engine site provides a summary of the facilities under management of the facility manager, including a relation of the most relevant indicators over the last 30 days, as described in the Figure 14.

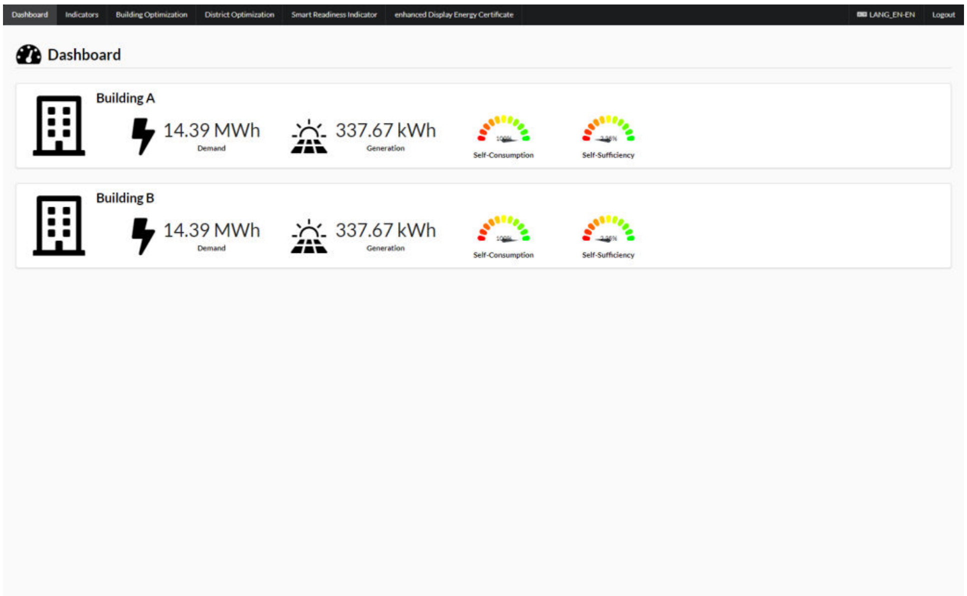

Figure 14: Energy applications screen shot, dashboard screen.

The indicators section of the application provides access to a number of visualizations over the different data retrieved from the facilities BMSs and deployed sensors and systems. Upon selection of a particular facility, the facility manager is able to navigate through the data.

The *Sensors* tab (see Figure 15) allows facility managers to navigate and drill-in on the raw data that is being sent by the sensors.

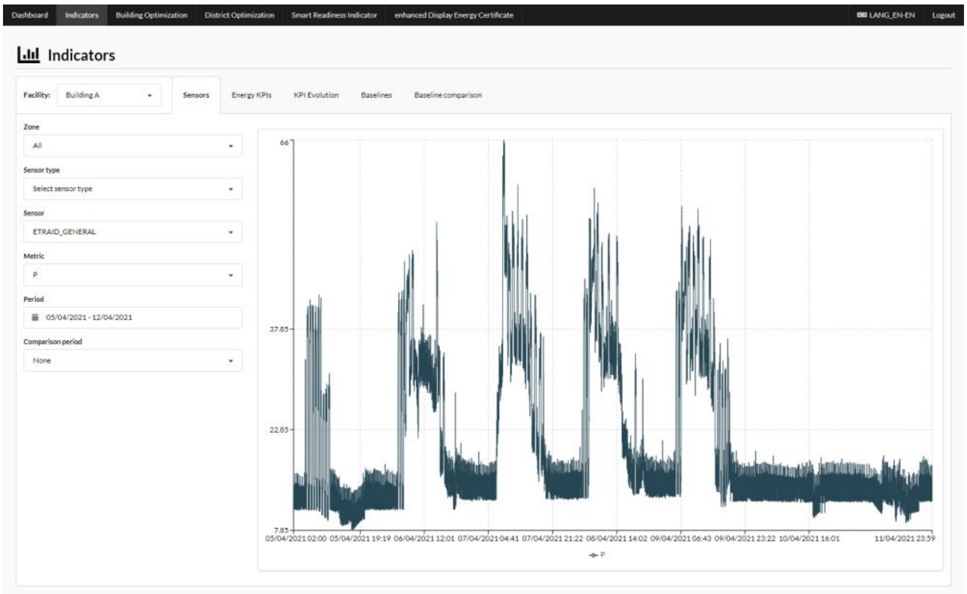

Figure 15: Energy applications screen shot, indicators screen -I.

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The *Energy KPIs* tab (see Figure 16) displays relevant indicators about the facility as a whole or about specific zones. The *Distribution sub*-section (see Figure 17) will visualize how the main indicators evolve over time.

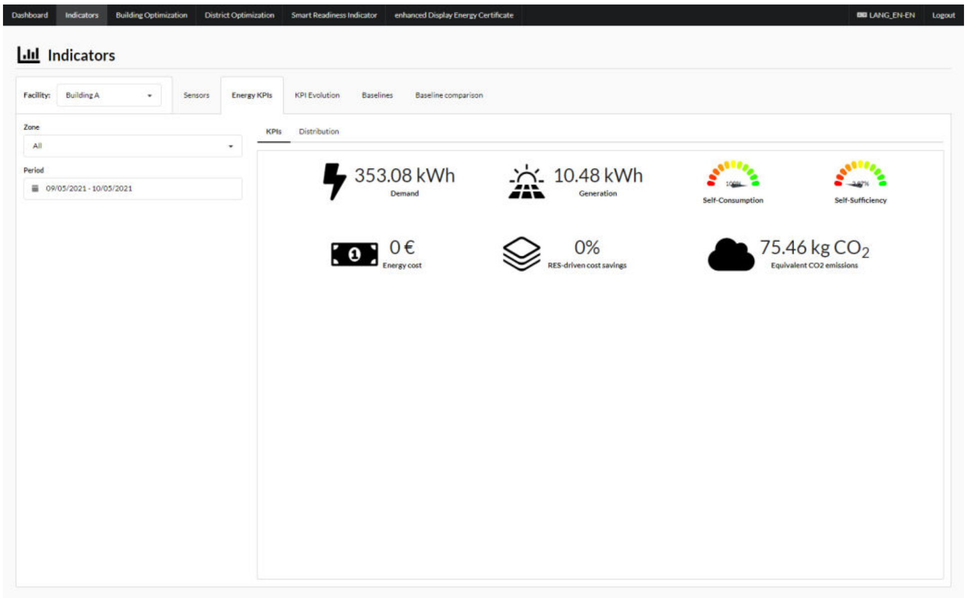

Figure 16: Energy applications screen shot, indicators screen -II.

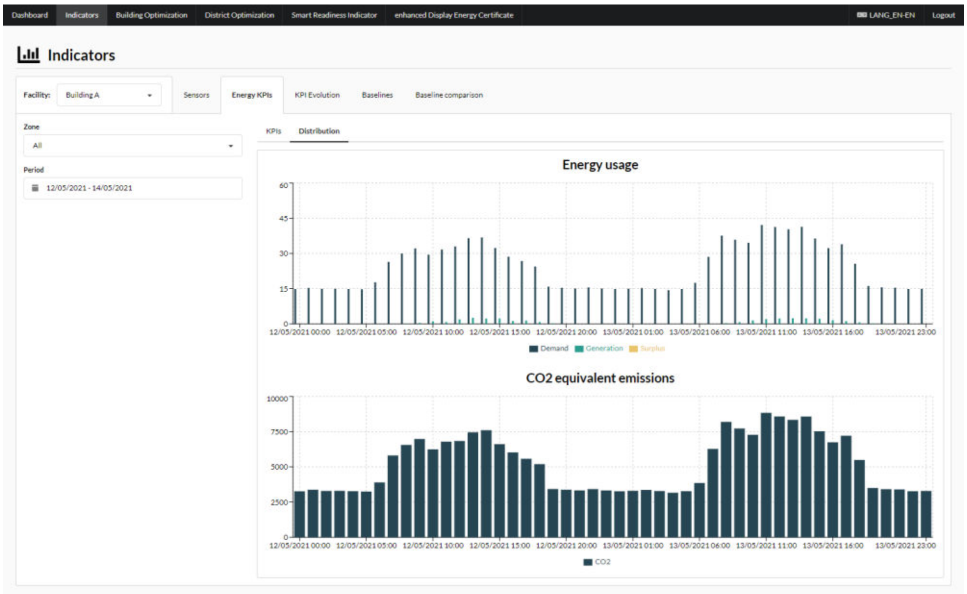

Figure 17: Energy applications screen shot, indicators screen -III.

The *Evolution* tab (see Figure 18) allows facility manager to track how the different KPIs evolve over time. This particular visualization is based on KPIs calculated on a daily basis.

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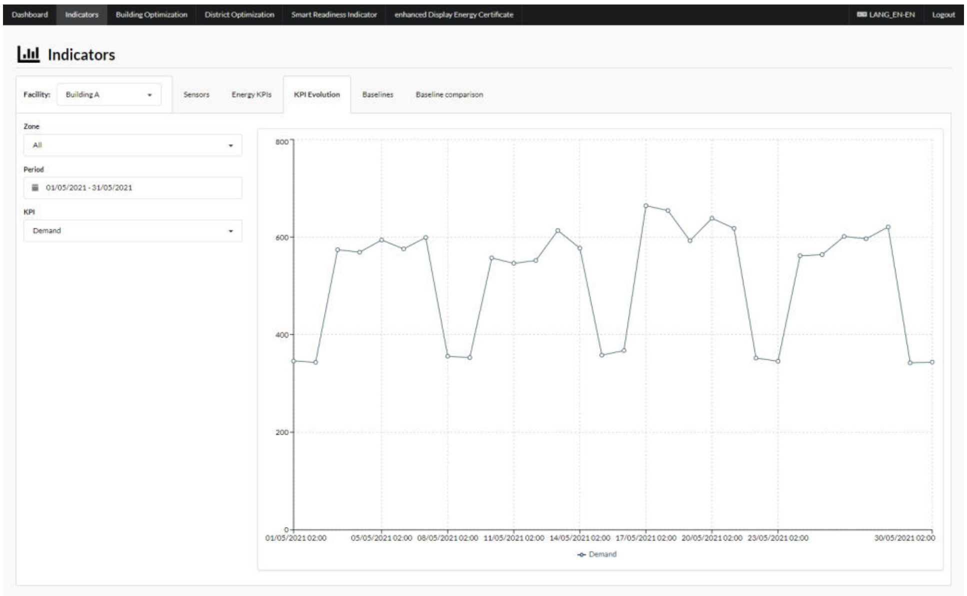

Figure 18: Energy applications screen shot, indicators screen - IV.

The *Baselines* tab (see Figure 19) displays the usual energy-usage patterns of a facility. The usage patterns consist of quarterly demand and generation curves covering 24 hours for days of a certain typology (weekday/weekend of a particular month).

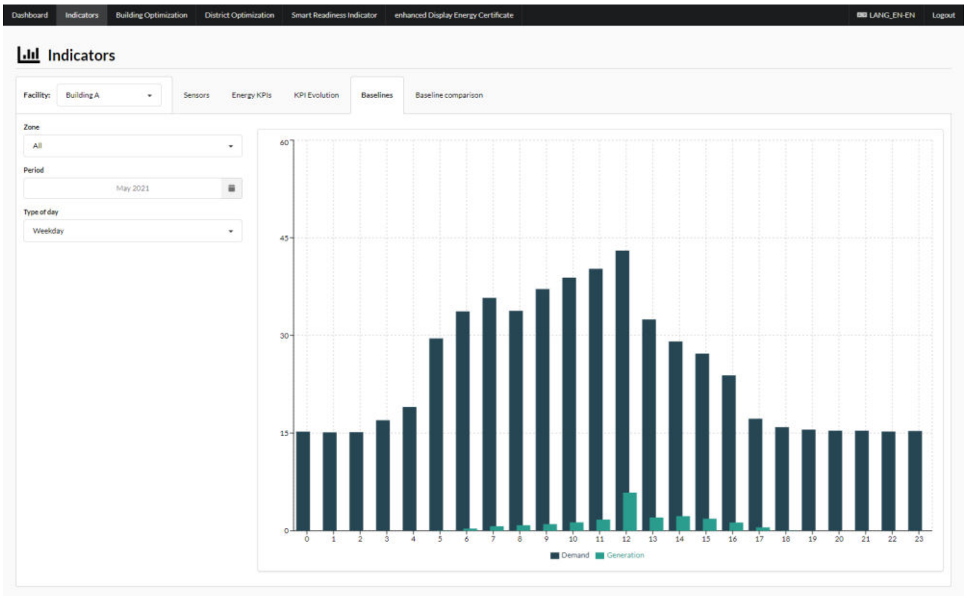

Figure 19: Energy applications screen shot, indicators screen -V.

The *Baseline comparison* tab (see Figure 20) has the objective of comparing the indicators of a particular facility/zone and date range against a given baseline, as a first insight for identification of anomalies in the energy-usage or assessment of energy efficiency.

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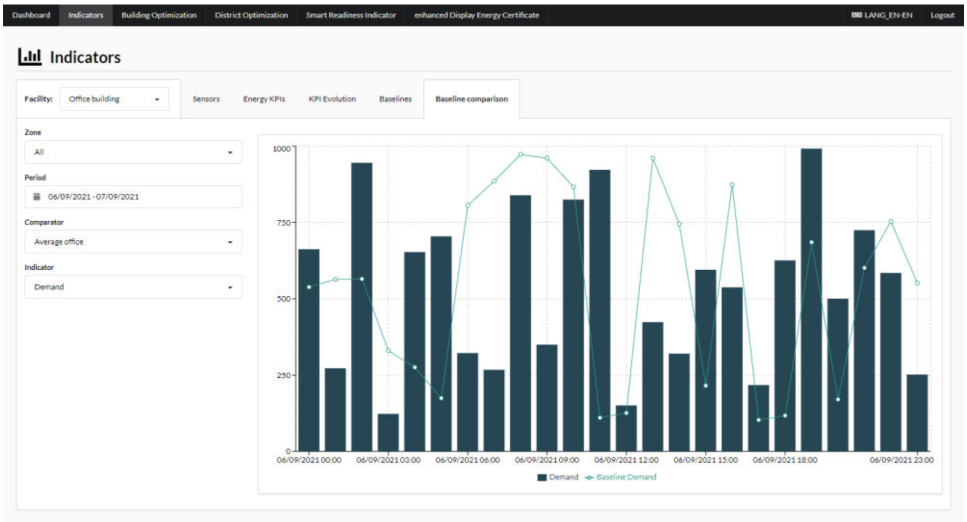

Figure 20: Energy applications screen shot, indicators screen -VI.

For the HVAC Prediction Service, as an example, the one Air Handling Unit measurements (HVAC-PMS_1) is shown in Figure 21 and related example of autoencoder-decoder based Air Handling Unit malfunction detection (HVAC-PMS_4) is shown in Figure 22.

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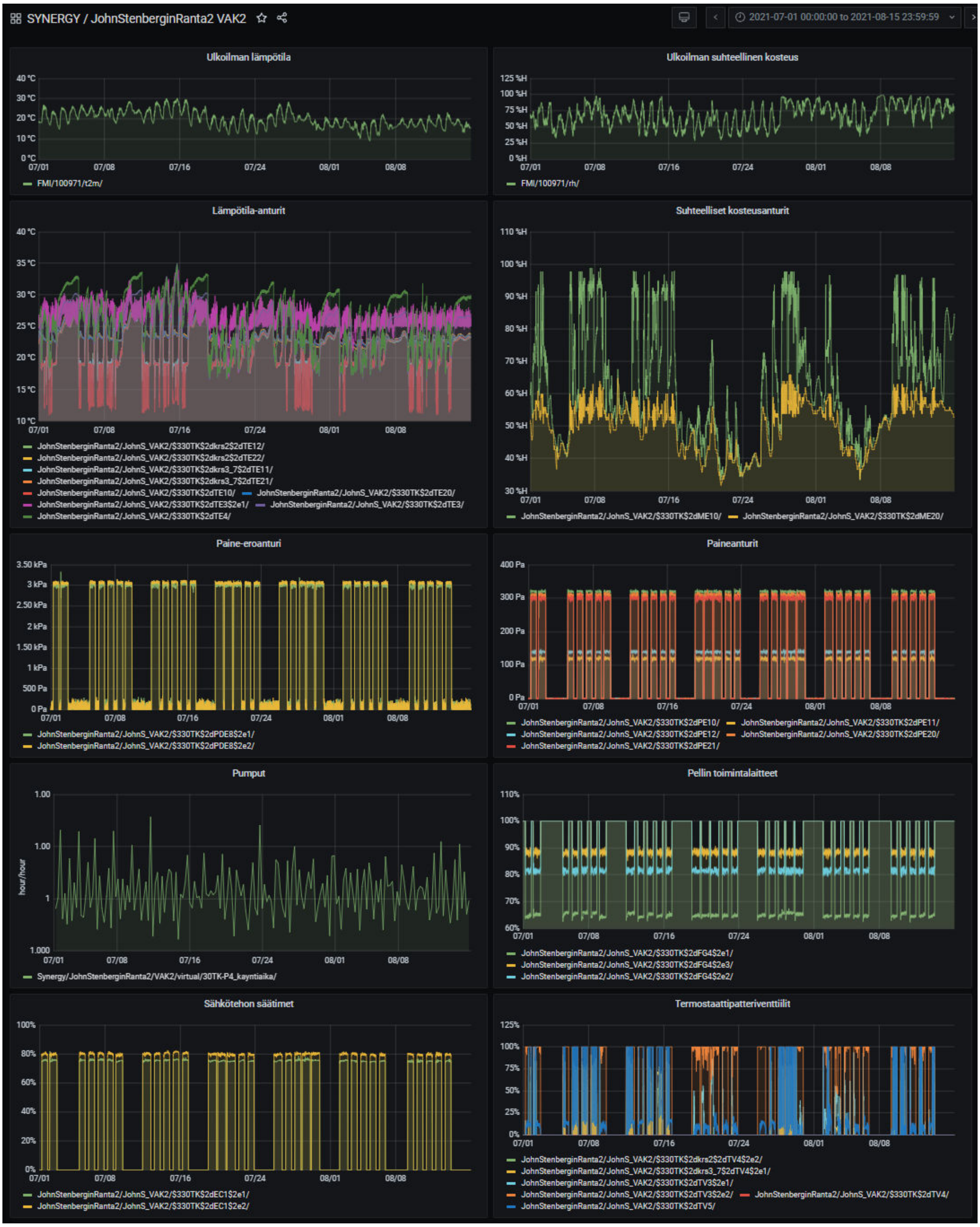

Figure 21: An Example of Air Handling Unit measurements (with test data).

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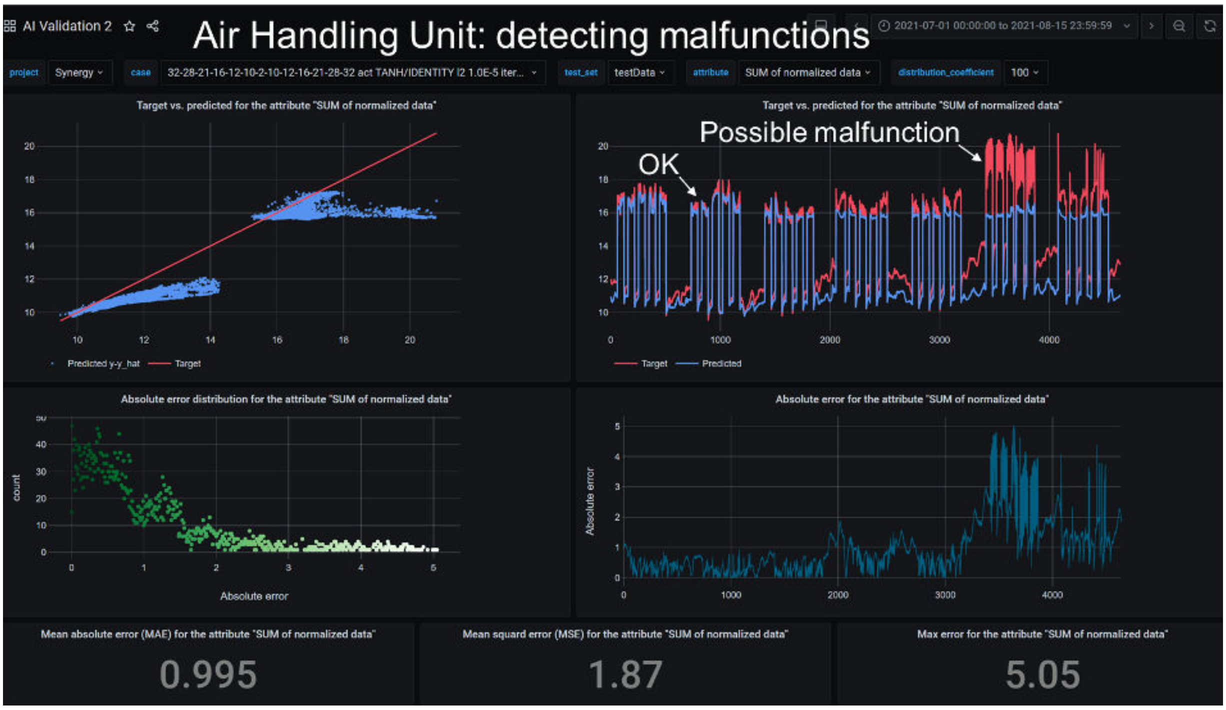

Figure 22: An Example of autoencoder-decoder based Air Handling Unit malfunction detection (with test data).

An example of 3D digital twin (HVAC-PMS_3) based visualising of detected malfunctions is shown in Figure 23. This digital twin has not yet been connected to the SYNERGY platform data, so test data from another building has been used.

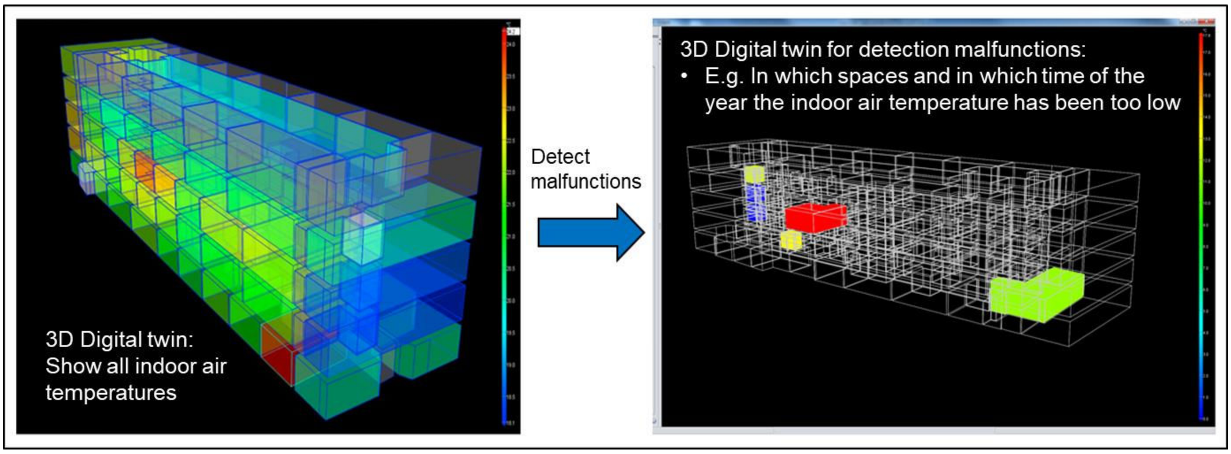

Figure 23: An example of 3D digital twin based visualising of detected malfunctions.

An example of different digital twin (HVAC-PMS_3) and machine learning (HVAC-PMS_4) boosted approaches for detecting energy system related malfunction detection are shown in Figure 24 and Figure 25, respectively.

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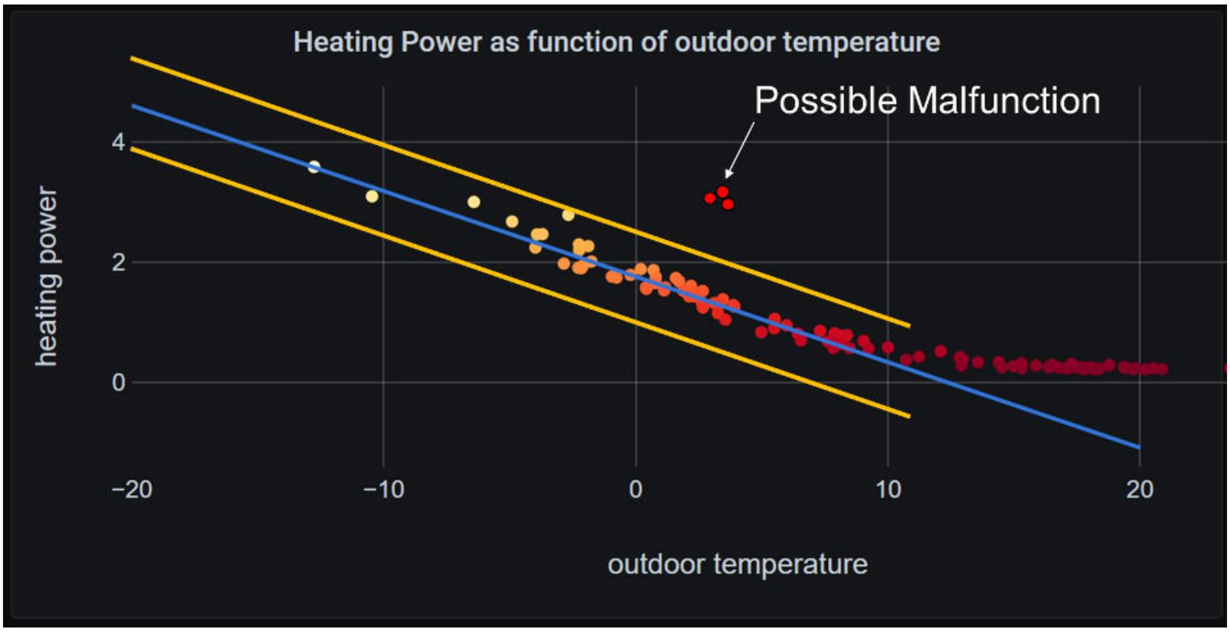

Figure 24: An example of heating system related malfunction detection.

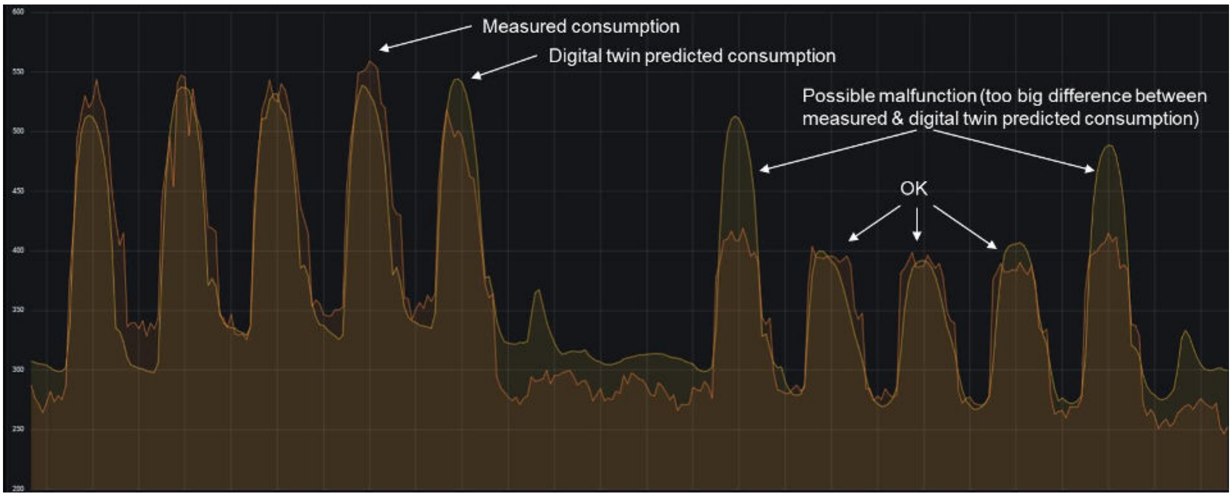

Figure 25: An example of building energy consumption related digital twin based malfunction detection.

The Caverion SmartView- integrated functionality (HVAC-PMS_2) for monitoring the technical performance of AHU and heating network functionalities has a variety of analytics that are used to detect HVAC performance discrepancies or discrepancy related occupant discomforts from the current operational conditions (see GUI in the Figure 26 & Figure 27).

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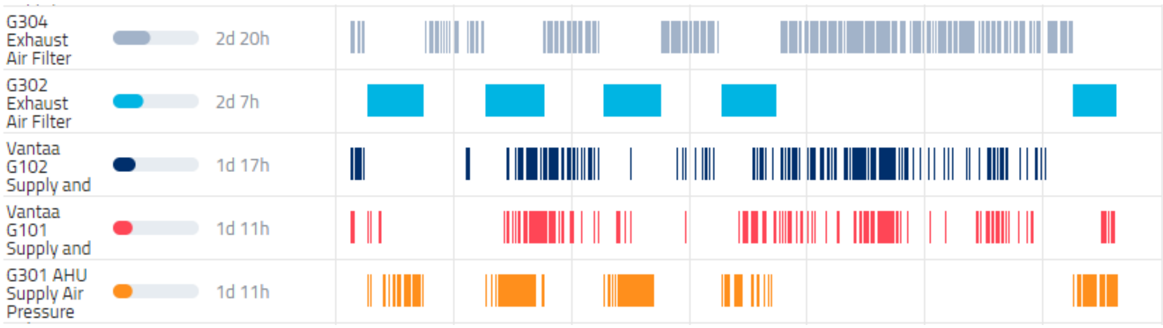

Figure 26: An example of different analytics performed in Caverion SmartView.

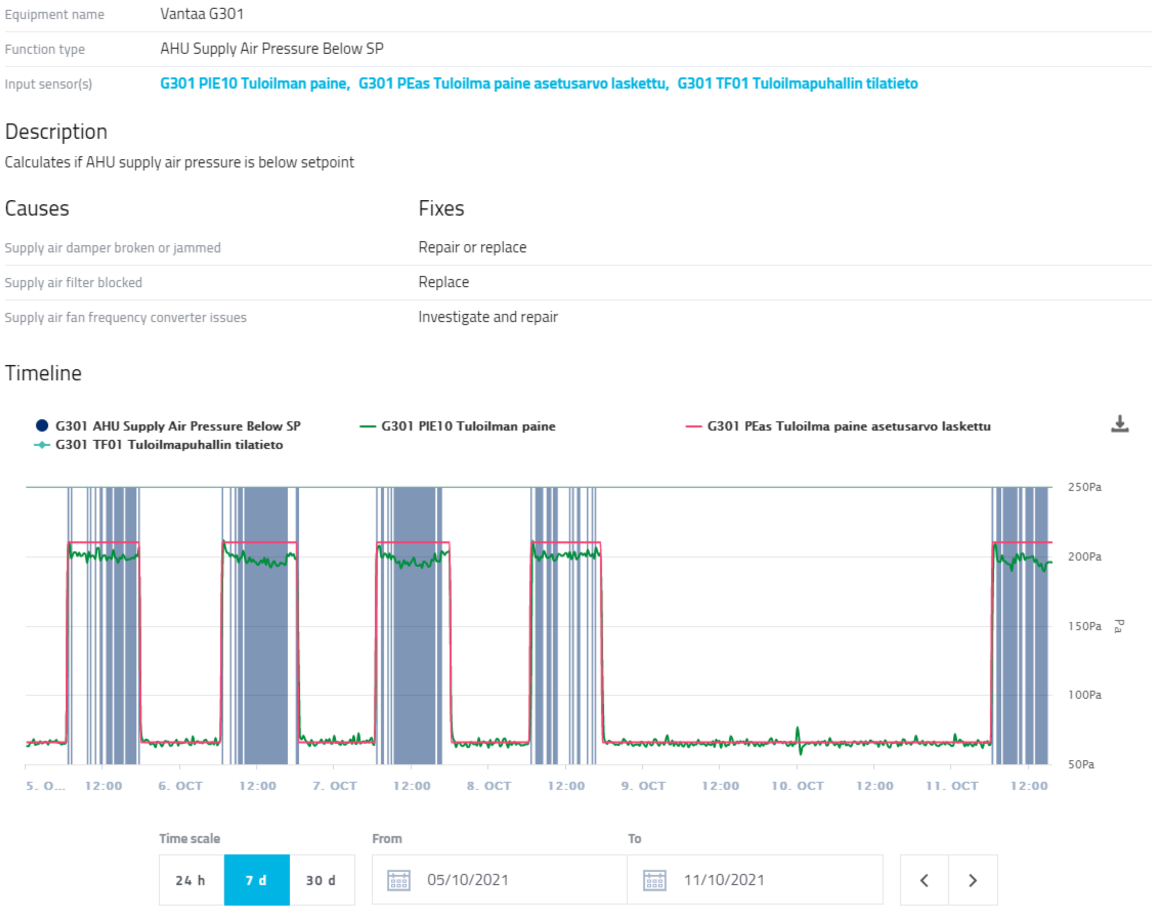

Figure 27: Example of more in-depth view of AHU supply air pressure analytic performed in Caverion SmartView.

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4.3 Technology stack and implementation tools

4.3.1 The Facility Management Monitoring Engine

The Facility Management Monitoring Engine (FMME) related technology stacks and respective licenses are shown in the following table.

Table 9. The FMME related technology stacks and related version numbers and licenses.

Library	Version	License
meteor-base	1.4.0	MIT License
mobile-experience	1.1.0	MIT License
mongo	1.10.1	MIT License
static-html		MIT License
reactive-var	1.0.11	MIT License
tracker	1.2.0	MIT License
session	1.2.0	MIT License
accounts-password	1.7.0	MIT License
standard-minifier-js	2.6.0	MIT License
es5-shim	4.8.0	MIT License
ecmascript	0.15.0	MIT License
shell-server	0.5.0	MIT License
aldeed:collection2	3.0.0	MIT License
underscore	1.0.10	MIT License
react-meteor-data		MIT License
alanning:roles		MIT License
semantic:ui		MIT License
jquery		MIT License

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flemay:less-autoprefixer		MIT License
matb33:collection-hooks		MIT License
mizzao:user-status		MIT License
etraid:accounts-openid		Proprietary
@babel/runtime	^7.12.5	MIT License
@popperjs/core	^2.6.0	MIT License
bcrypt	^5.0.0	MIT License
etra-forms	^1.0.4	Proprietary
etra-ui-components	^2.0.0	Proprietary
etraid_formats	^1.0.16	Proprietary
html-react-parser	^1.2.4	MIT License
i18next	^20.1.0	MIT License
i18next-browser-languagedetector	^6.1.0	MIT License
i18next-http-backend	^1.2.0	MIT License
jquery	^3.4.1	MIT License
lodash	^4.17.15	MIT License
luxon	^1.26.0	MIT License
meteor-node-stubs	^1.0.0	MIT License
moment-timezone	^0.5.33	MIT License
popper.js	^1.16.1	MIT License

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prop-types	^15.7.2	MIT License
react	^16.14.0	MIT License
react-dom	^16.14.0	MIT License
react-i18next	^11.8.11	MIT License
react-icons	^4.2.0	MIT License
react-live-clock	^5.0.16	MIT License
react-moment	^1.1.1	MIT License
react-month-picker	^2.2.0	MIT License
react-router-dom	^5.2.0	MIT License
react-semantic-ui-datepickers	^2.13.0	MIT License
recharts	^2.0.9	MIT License
recompose	^0.30.0	MIT License
semantic-ui-react	^1.1.1	MIT License
simpl-schema	^1.10.2	MIT License
styled-components	^5.2.1	MIT License
pandas		BSD 3-Clause "New" or "Revised" License
sklearn		BSD 3-Clause "New" or "Revised" License
requests		Apache License 2.0
numpy		BSD 3-Clause "New" or "Revised" License

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pymongo		Apache License 2.0
iso8601		MIT License

4.3.2 The HVAC Predictive Maintenance Service (HVAC-PMS)

The HVAC-PMS related technology stacks and respective licenses are shown in the following table.

Table 10. The HVAC-PMS related technology stacks and related version numbers and licenses.

Library	Version	License
Apache Tomcat® for Java Servlet	9.0.53	Apache 2.0 (https://www.apache.org/licenses/LICENSE-2.0)
PostgreSQL	14 RC 1	PostgreSQL is released under the PostgreSQL License, a liberal Open Source license, similar to the BSD or MIT licenses.
Deeplearning4j	1.0.0-M1.1	These libraries are completely open-source, Apache 2.0 under open governance at the Eclipse foundation. (https://deeplearning4j.konduit.ai/
TimescaleDB	1.1.1	Apache 2.0 https://github.com/timescale/timescaledb/blob/1.1.x/LICENSE-APACHE
Kubernetes	1.19.11	Apache 2.0 https://github.com/kubernetes/kubernetes/blob/master/LICENSE
Node.js	12.x	MIT/other https://github.com/nodejs/node/blob/v12.x/LICENSE

4.3.3 The Building-Level Energy Performance Optimisation Manager (BL-EPOM) and The District-level Energy Performance Optimisation Manager (DL-EPOM)

The main libraries used in Data Presentation, Business Logic and Data Access for this release are presented in the following table.

Table 11. Technology stack used in the Data Presentation, Business Logic and Data Access layers.

Library	Version	License
Pandas (for PYTHON)	1.3.3	Open source
Gurobipy (for PYTHON)	9.1.2	Mandatory

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Library	**Version**	**License**
React (FrontEnd)	16.14.0	MIT License
React-dom	16.14.0	MIT License
React-bootstrap	16.14.0	MIT License
Listener (.NET Core)	3.1	Microsoft
ServiceBusClient	7.3.0	MIT License
ServiceBusMessage	7.3.0	MIT License
ServiceBusMessageBatch	7.3.0	MIT License
Axios API Connect	0.23.0	MIT License

4.4 API documentation

4.4.1 The Facility Management Monitoring Engine

The majority of the analytics required by the application have been configured as analytic workflows that are executed by the SYNERGY Platform. In order to access to the results of such analytics, different data retrieval queries have been configured, all of them exposing specific REST endpoints (as presented in the following table). Authentication mechanisms are implemented within the SYNERGY Platform in order to ensure that only authorized parties (components of the Facility Management and Monitoring Engine in this context) are granted access.

Table 12. Component related SYNERGY Platform data retrieval queries.

Data Retrieval Query	Type	Implementer	Purpose
[DEV-WP7] _MERGED_ - Sensors	HTTP GET	SYNERGY Platform	Allocation of sensors per building
[DEV-WP7] _MERGED_ - Sensors ii	HTTP GET	SYNERGY Platform	Set of metrics available per sensor
[DEV-WP7] _MERGED_ - Hourly KPIs	HTTP GET	SYNERGY Platform	Aggregation of metrics per sensor on an hourly basis
[DEV-WP7] _MERGED_ - Energy data	HTTP GET	SYNERGY Platform	Raw sensor data from different buildings, merged in a single dataset

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[DEV-WP7] _MERGED_ - Daily KPIs	HTTP GET	SYNERGY Platform	Aggregation of metrics per sensor on a daily basis
[DEV-WP7] _MERGED_ - Baselines	HTTP GET	SYNERGY Platform	Average profiles per building for baselining purposes

4.4.2 The HVAC Predictive Maintenance Service (HVAC-PMS)

Application related SYNERGY Platform data retrieval queries are show in the following table.

Table 13. Component related SYNERGY Platform data retrieval queries.

Data Retrieval Query	Type	Implementer	Purpose
Get AHU fresh air temperature	HTTP GET	SYNERGY Platform	AHU fresh air temperature
Get AHU supply air temperature	HTTP GET	SYNERGY Platform	AHU supply air temperature
Get AHU return air temperature	HTTP GET	SYNERGY Platform	AHU return air temperature
Get AHU exhaust air temperature	HTTP GET	SYNERGY Platform	AHU exhaust air temperature
Get AHU fresh air relative humidity	HTTP GET	SYNERGY Platform	AHU fresh air relative humidity
Get AHU supply air relative humidity	HTTP GET	SYNERGY Platform	AHU supply air relative humidity
Get AHU return air relative humidity	HTTP GET	SYNERGY Platform	AHU return air relative humidity
Get AHU exhaust air relative humidity	HTTP GET	SYNERGY Platform	AHU exhaust air relative humidity
Get AHU supply air temperature setpoint	HTTP GET	SYNERGY Platform	AHU supply air temperature setpoint
GET AHU supply air volume flow	HTTP GET	SYNERGY Platform	AHU supply air volume flow
GET AHU return air volume flow	HTTP GET	SYNERGY Platform	AHU return air volume flow
GET AHU supply fan rotation speed	HTTP GET	SYNERGY Platform	AHU supply fan rotation speed
GET AHU exhaust fan rotation speed	HTTP GET	SYNERGY Platform	AHU exhaust fan rotation speed

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Data Retrieval Query	**Type**	**Implementer**	**Purpose**
GET AHU supply air filter pressure difference	HTTP GET	SYNERGY Platform	AHU supply air filter pressure difference
GET AHU return air filter pressure difference	HTTP GET	SYNERGY Platform	AHU return air filter pressure difference
GET AHU Heat recovery efficiency	HTTP GET	SYNERGY Platform	AHU Heat recovery efficiency
GET AHU electricity consumption	HTTP GET	SYNERGY Platform	AHU electricity consumption (optional)
GET AHU peak load	HTTP GET	SYNERGY Platform	AHU peak load (optional)
GET AHU heating consumption	HTTP GET	SYNERGY Platform	AHU heating consumption (optional)
GET AHU cooling consumption	HTTP GET	SYNERGY Platform	AHU cooling consumption (optional)
GET AHU exhaust air CO2	HTTP GET	SYNERGY Platform	AHU exhaust air CO2 (optional)
GET AHU affect area related building envelope pressure difference	HTTP GET	SYNERGY Platform	AHU affect area related building envelope pressure difference
GET AHU supply air temperature after heat recovery	HTTP GET	SYNERGY Platform	AHU supply air temperature after heat recovery (optional)
GET AHU supply air temperature after heating coil	HTTP GET	SYNERGY Platform	AHU supply air temperature after heating coil (optional)

4.4.3 The Building-Level Energy Performance Optimisation Manager (BL-EPOM) and The District-level Energy Performance Optimisation Manager (DL-EPOM)

Table 14. Component related SYNERGY Platform data retrieval queries.

Data Retrieval Query	Type	Implementer	Purpose
Buildings and district data	HTTP GET	SYNERGY Platform	Gather CSVs emulating demo data
Optimization results	HTTP POST	SYNERGY Platform	CSV with optimization results

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For the preliminary pilot to be released at late October, static data will be used due to the impossibility of having real data from SYNERGY platform as they have not been uploaded yet by the respective demo partners. From one hand, the SYNERGY Platform will be used to get data from it (through retrieval queries section). On the other hand, CIRCE OnPremises will be used both to store input files (.csv) to be used by the optimization algorithm and to store the results (output file .csv) generated after the mentioned execution.

4.5 Installation instructions

4.5.1 The Facility Management Monitoring Engine

All the components of the application have been packaged as a set of docker images. These docker images are available from a private repository at docker hub. This kind of packages facilitate the deployment in any platform supporting this technology (e.g. Kubernetes). Due to the nature of the software, being offered in the form of SaaS, no installation procedure is required by final users.

Image	Tag	Purpose
etraid/synergy_facilitymanagementui	0.0.15	Application main backend and frontend

4.5.2 The HVAC Predictive Maintenance Service (HVAC-PMS)

The web browser based monitoring of HVAC-PMS results does not need any installation.

4.5.3 The Building-Level Energy Performance Optimisation Manager (BL-EPOM) and The District-level Energy Performance Optimisation Manager (DL-EPOM)

The user interface (FrontEnd) which is being developed is packaged as a part of FMME application.

Both BL-EPOM and DL-EPOM tabs will be exported as modules of application, letting usability and ease of usage.

4.6 Assumptions and restrictions

4.6.1 The Facility Management Monitoring Engine

The architecture of the Facility Management and Monitoring Engine (see Figure 28) relies on the services provided by the SYNERGY Platform, specifically in the features related to data ingestion and data analytics.

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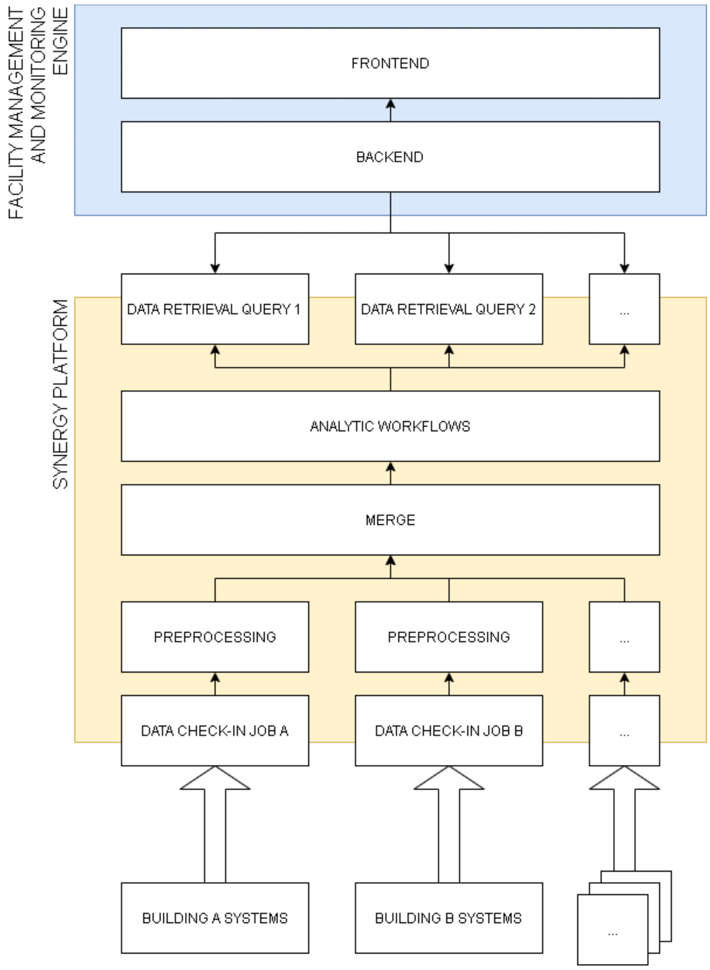

Figure 28: The architecture of the Facility Management and Monitoring Engine.

In order to be able to use the application, following configuration steps need to be taken for every new building that wishes to integrate with the application:

- Building managers are required to be registered as users of the SYNERGY Platform
- Building managers are required to configure the necessary data check-in jobs, so required datasets get accessible through the platform

Dataset	Content	Description
Raw sensor data	Device id Timestamp Active energy imported Active energy exported Active power	Merged dataset with all available measurements. Can be split in several datasets which will be merged within a single dataset using an analytic workflow

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	Reactive power Apparent power RMS current RMS voltage …	

- Building managers are required to grant access to application manager to the required datasets, so those can be incorporated to the application workflows, by signing the appropriate contracts within the SYNERGY Platform
- Application manager configures the preprocessing step – which ensures that existing datasets from any building manager are transformed from the SYNERGY CIM (followed in the SYNERGY Platform) to meet the structure required by the application.

Additionally, the following details need to be configured in the application for each building:

- Static information (name of building, location, type of use)
- Energy sensors contributing to building/zone KPIs calculations, namely:
    - Sensors/metrics that measure energy imported to the building/zone
    - Sensors/metrics that measure energy exported from the building/zone
    - Sensors/metrics that measure energy generated within the building/zone

4.6.2 The HVAC Predictive Maintenance Service (HVAC-PMS)

HVAC-PMS relies on the data provided by the SYNERGY Platform. In addition, the users are required to be registered as users of the SYNERGY Platform and they should be able to do necessary data check-in jobs, so required datasets get accessible through the platform.

4.6.3 The Building-Level Energy Performance Optimisation Manager (BL-EPOM) and The District-level Energy Performance Optimisation Manager (DL-EPOM)

For this first release of the BL-EPOM and DLEPOM tools instead of using real data and predictions based on historical data from the demos gathered form the SYNERGY Platform, different CSV files have been created to collect, emulate and provide the information needed to run the second step of the two tools, the MILP optimisation. These CSV files are hosted on the SYNERGY platform and are queried and used to launch both BL-EPOM and DL-EPOM.

4.7 Licensing and access

4.7.1 The Facility Management Monitoring Engine

Component	Licensing details

This project has received funding from the European Union's Horizon 2020 Research and Innovation programme under Grant Agreement No 872734.

Facility Management and Monitoring Engine	ETRA I+D is the owner of all intellectual property rights of this component. All rights are reserved.

A demo version of the application is accessible at[3]: https://facilitymanagement.synergy-bigdata.eu/

4.7.2 The HVAC Predictive Maintenance Service (HVAC-PMS)

VTT is the owner of all intellectual property rights of HVAC-PMS. All rights are reserved. The licensing can be granted according SYNERGY license agreement.

A demo version of the application will be accessible at[4]:

https://HVAC-predictivemaintenance.synergy-bigdata.eu

4.7.3 The Building-Level Energy Performance Optimisation Manager (BL-EPOM) and The District-level Energy Performance Optimisation Manager (DL-EPOM)

Component(s)	Licensing details
Building-Level Energy Performance Optimisation Manager (BL-EPOM) and District-level Energy Performance Optimisation Manager (DL-EPOM)	CIRCE Foundation is the owner of all intellectual property rights of this component. All rights are reserved.

A demo version of the application is accessible at[5]:

https://facilitymanagement.synergy-bigdata.eu/

4.8 Planned features for next release

4.8.1 The Facility Management Monitoring Engine

Work that is scheduled for the next release includes:

- Management of economical KPIs, by the integration and management of tariff definitions in the component (FMME_2)
- Finalization of the comparison features, both considering comparison against other buildings managed by the application (using baseline profiles) and also including the possibility to tag certain timestamps (e.g. When specific actions on building's equipment took place) and use them for comparison (FMME_3-4)

[3] Demo credentials are available on request
[4] Demo credentials are available on request
[5] Demo credentials are available on request

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- Revise the behaviour of the application with source datasets that update dynamically
- Take benefit of upcoming features of the SYNERGY Platform (e.g. query parameters on data retrieval queries for datasets that are results of analytic workflows) to enhance performance of the application

4.8.2 The HVAC Predictive Maintenance Service (HVAC-PMS)

It's planned that for the next release by M24, the focus will be put on the data collection and ML analytics (HVAC-PMS_1, HVAC-PMS_4). This will allow the start of the testing and validation of the application as a part of the WP8 activities, starting at M24. The results of testing and validation activities will be used to improve application functions towards M33, when the second phase of demonstration and validation will be started. During the period of M24-M33, the ML algorithms will be also improved by utilising and testing algorithm with various real datasets. The visualization feature will be improved (HVAC-PMS_3-5). The final version of application is to be released by M42.

4.8.3 The Building-Level Energy Performance Optimisation Manager (BL-EPOM) and The District-level Energy Performance Optimisation Manager (DL-EPOM)

For the next release (M24) all the features of the BL-EPOM and the DL-EPOM will be fully implemented and according to the data availability from the demos, basic data gathering and forecast algorithms will be implemented and if some data is still not available CSV files will be used. Along the first Demo run 1 (M23-M33) all the features of the BL-EPOM and the DL-EPOM and the data gathering and forecast algorithms will analysed and improved if needed.

4.9 Integration Plan

The integration plan for all modules is presented in the following table.

Table 15. Integration plan (for all modules) with SYNERGY platform.

APPs/ modules	Integration Status for datasets, data flow and WP4 analytics
Facility management Monitoring Engine	The module is currently integrated with the platform, but only static data (i.e. CSV files). The focus in the following months is to further test this integration by using "live" datasets.
HVAC Predictive Maintenance Service	Data access and data sharing with SYNERGY platform is tested with test data. Module will be integrated with the platform when related data is available on the SYNERGY platform APIs.
BL-EPOM and DL-EPOM	In this first release the integration with the SYNERGY platform is limited to the extraction of CSV files to provide data and launch the BL-EPOM and DL-EPOM tools. In next stages and according to demo data availability and analytics to be developed in WP4 better data gathering process will be developed.

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5 Real Time Building Energy Performance and Smart Readiness Specification

5.1 Overview

As described in D7.1 the Facility Management Energy Analytics, Self-Consumption Optimization & Predictive Maintenance toolbox will integrate the two additional components dealing with the assessment of the buildings, the enhanced Display Energy Certificates (eDECs) and the Smart Readiness Indicator (SRI).

The eDECs module will deliver dynamic certificates of building energy performance in variant resolutions (e.g. annual, monthly, daily), for the building as a whole or per designated zone. It will utilize real-time field data of the building (consumption, production, IoT [Internet of Things] data etc.), static building data and benchmark values (drawn from the SYNERGY platform) and will dynamically calculate the energy performance indicators associated with the Display Energy Performance certificate as per the standard that will be adopted. The eDECs application will automatically retrieve as much input data as possible from the different datasets uploaded by the facility managers to the SYNERGY Platform (e.g. the time series of meter readings), thus minimizing the efforts required to introduce all required inputs to the benchmark models. In any case, facility managers will be able to state any missing piece of data (mainly static properties of the facilities under study) also directly to the eDECs application, by using the corresponding forms on the user interface. The data collected through the UI will also be stored in SYNERGY platform.

The SRI module will deliver the “Smart-Readiness” assessment of a building, by calculating the capability of the building to a) apply energy savings techniques b) respond to user needs and c) offer services to the grid. The tool will utilize static building data and benchmark values (drawn from the SYNERGY platform) and will calculate various indicators (disaggregated and building total) as per the SRI methodology, also described within D7.1.

5.2 Implemented functionalities

Within this section, the implemented functionalities of eDECs and SRI module are presented along with a walkthrough of the relevant applications via the screenshots presented in the following Table.

Table 16. The status of implemented features.

Feature	Status	Notes
eDEC_CE_1	Implemented	The feature (close to real-time calculation of building’s energy performance operational rating) has been fully implemented and will be improved for the next release
eDEC_CE_2	Implemented	The feature (close to real-time calculation of CO_2 (Carbon Dioxide) emissions due to electricity consumption) has been fully implemented and will be improved for the next release.

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Feature	Status	Notes
SRI_CE_1	Implemented	The feature (calculate the total Smart-readiness score of the building) has been fully implemented and will be improved for the next release.

5.2.1 Smart Readiness Indicator

The following figure shows the table of SRI performed assessments by the user.

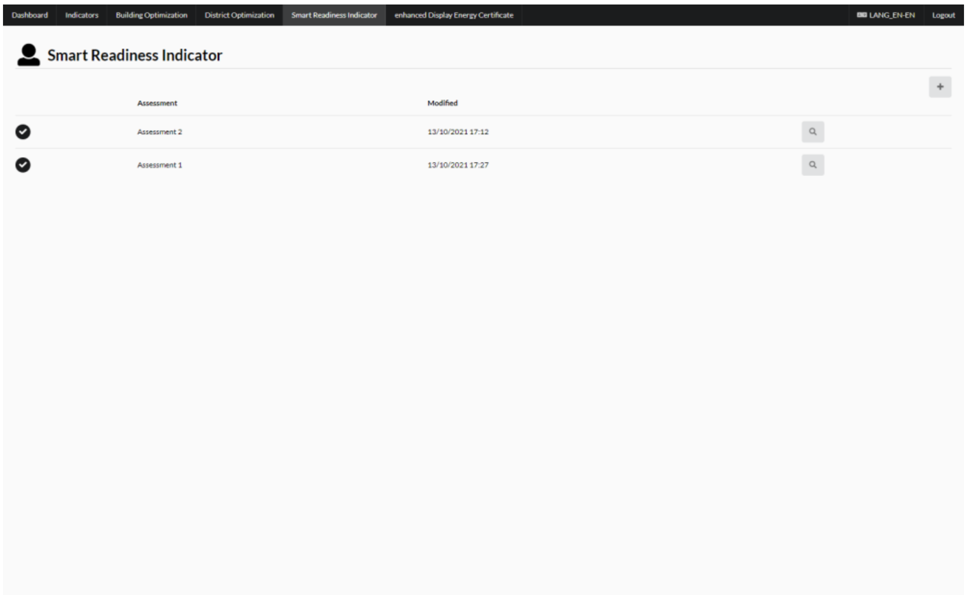

Figure 29: SRI entry page – a representation of the history of assessments.

When the users select a past assessment they can navigate through the inputs and outputs of the assessment by viewing the tabs below.

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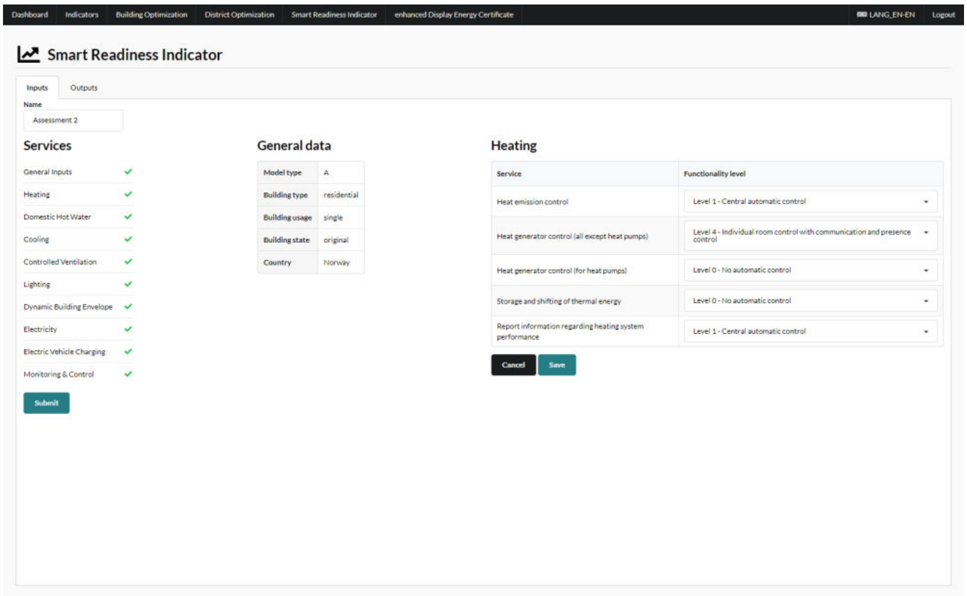

Figure 30: SRI inputs page – a representation of the heating inputs in a past assessment.

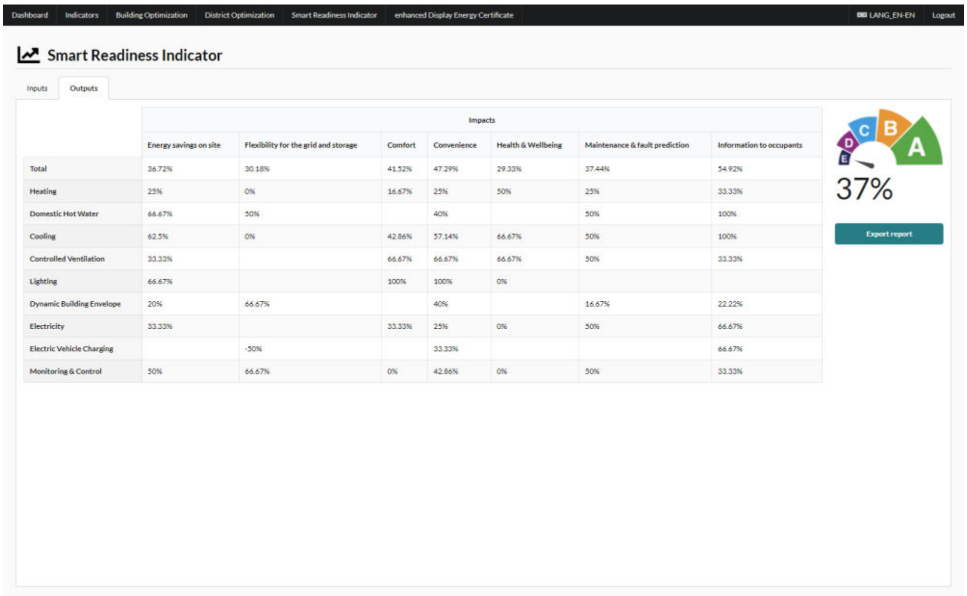

Figure 31: SRI outputs page – a representation of the results in a past assessment.

When the users select to perform a new assessment, they are asked to provide inputs as per the following figures. Upon completion of the inputs, they can see the results of the assessment and export them in pdf format

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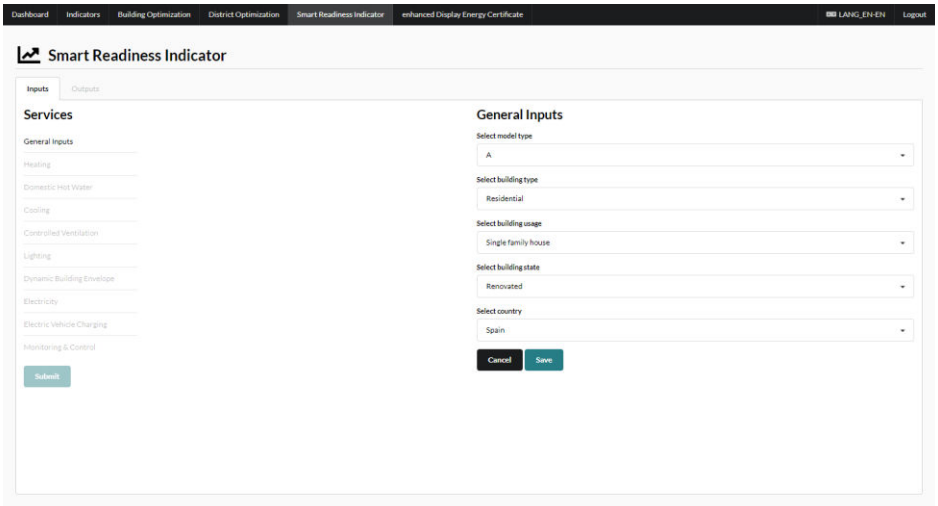


Figure 32: SRI inputs page – a representation of the general inputs' tab.

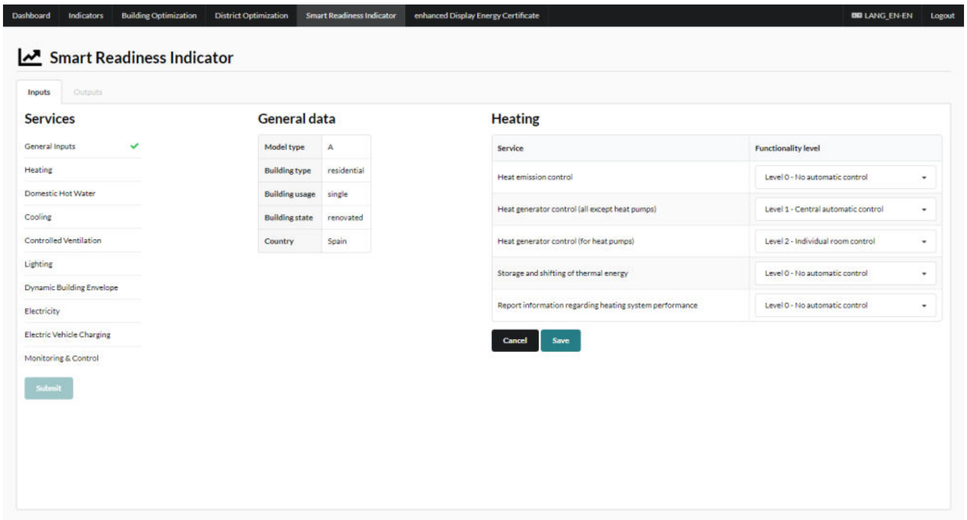
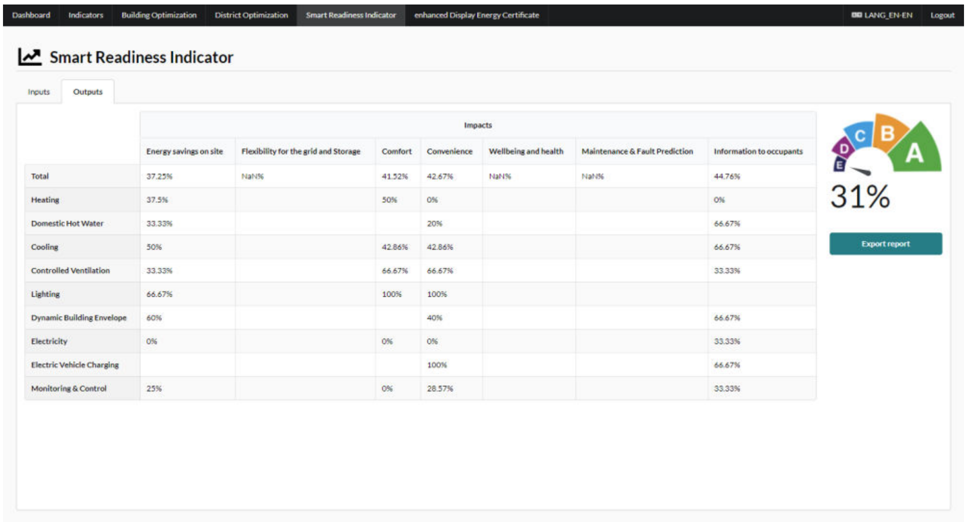


Figure 33: SRI inputs page – a representation of the heating inputs' tab.



	Impacts						
	Energy savings on site	Flexibility for the grid and Storage	Comfort	Convenience	Wellbeing and health	Maintenance & Fault Prediction	Information to occupants
Total	37.25%	NaN%	41.52%	42.67%	NaN%	NaN%	44.76%
Heating	37.5%		50%	0%			0%
Domestic Hot Water	33.33%			20%			66.67%
Cooling	50%		42.86%	42.86%			66.67%
Controlled Ventilation	33.33%		66.67%	66.67%			33.33%
Lighting	66.67%		100%	100%			
Dynamic Building Envelope	60%			40%			66.67%
Electricity	0%		0%	0%			33.33%
Electric Vehicle Charging				100%			66.67%
Monitoring & Control	25%		0%	28.57%			33.33%

Figure 34: SRI outputs page – a representation of the results' tab of an assessment.

5.2.2 Enhanced Display Energy Certificates

The following figures show the inputs and outputs' tabs for the eDECs application as will be seen by the users of the application.

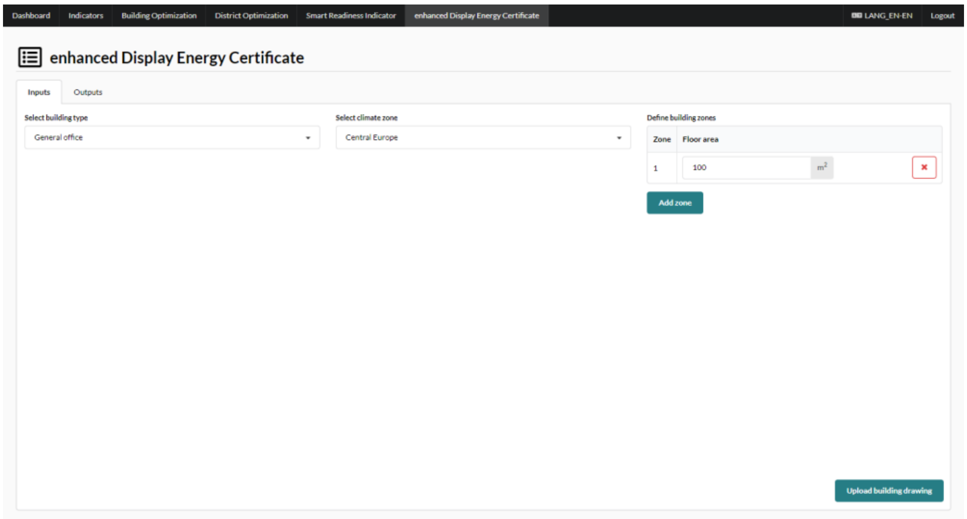


Figure 35: eDECs inputs page – a representation of the general inputs' tab.

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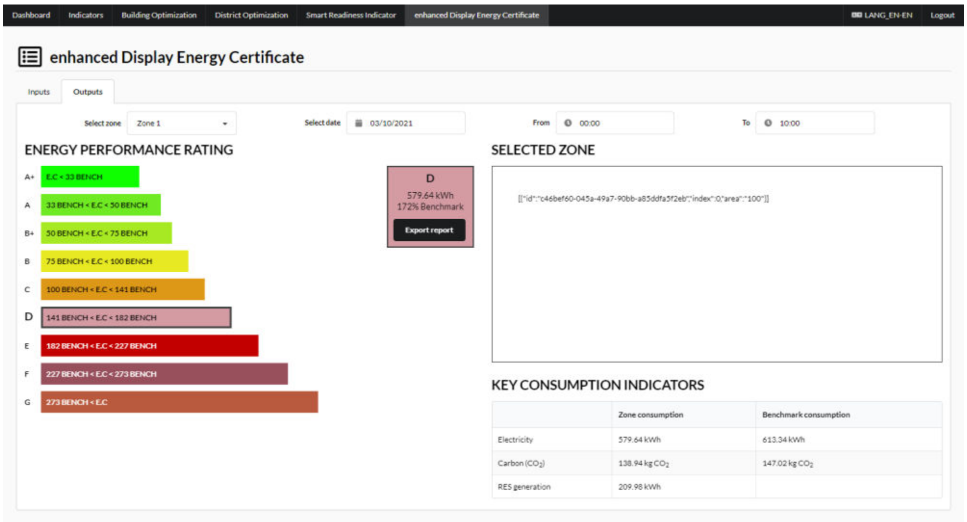


Figure 36: eDECs outputs page – a representation of the outputs' tab of the eDECs assessment where the user can select the time and zone they want to perform the assessment.

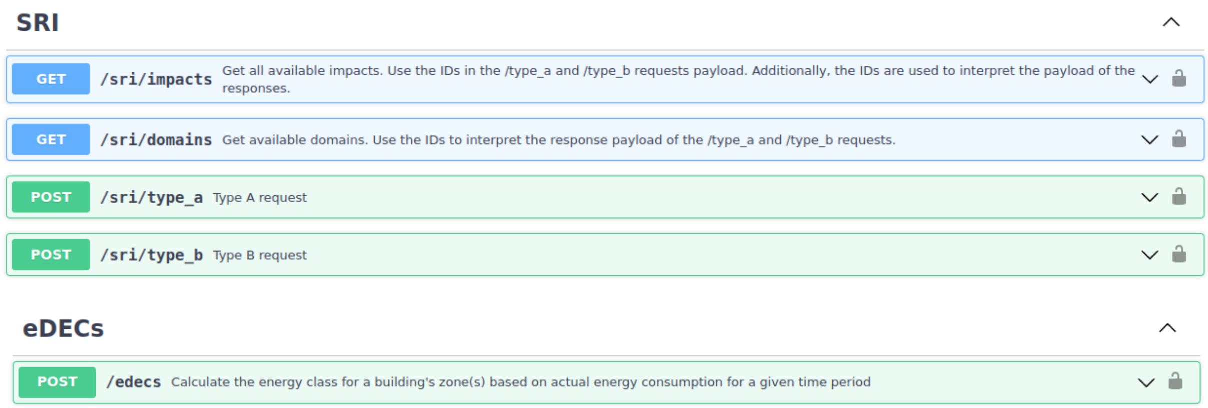
5.3 Technology stack and implementation tools

The technology that has been used for this purpose is the Go programming language for the web API service.

Library	Version	License
Echo	4.4.0	Open source

5.4 API documentation

The eDECs and SRI applications communicate with SYNERGY platform via the FMME application through selected APIs that have been created and are documented in Swagger as depicted in the following figures.



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5.5 Installation instructions

The eDECs and SRI applications are integrated within the FMME module, hence no specific installation instructions are provided here. For installation instruction of the modules please refer to section 4.5.1.

5.6 Assumptions and restrictions

eDECs and SRI rely on the data (basic information of the building, building energy consumption data) provided by the SYNERGY Platform. In addition, the users are required to be registered as users of the SYNERGY Platform and they should be able to do necessary data check-in jobs, so required datasets get accessible through the platform.

5.7 Licensing and access

VERD is the owner of all intellectual property rights of eDECs and SRI. All rights are reserved. The licensing can be granted according SYNERGY license agreement.

A demo version of the application is accessible at[6]: https://facilitymanagement.synergy-bigdata.eu/

5.8 Planned features for next release

No further features are planned for the next release of the applications.

Specific focus will be however given to improving specific elements of the developed applications as per below

- Within the eDECs application, a weather normalisation process is performed in order to calculate the baselines energy profiles of the building under assessment, as described in D7.2. Upon availability of close to real-time external temperature data of our demo sites, this process will be enhanced aiming at improving the accuracy of the calculated baselines
- Within the SRI application some of the inputs of the assessment will be prefilled based on data availability in the platform. Within the next months we will focus on improving this process aiming at raising the automation level of the assessment (offering the users the ability to perform their assessment in a much quicker way)

5.9 Integration Plan

As previously described, the eDECs and SRI applications will be integrated with SYNERGY platform via the FMME application, presented earlier in the chapter 4.

[6] Demo credentials are available on request

6 Conclusions

This deliverable has presented the details of the developments towards the 1st release of Optimized Energy Performance Management Suite. More specifically, this report has provided details on the development of the SYNERGY Building/ District-level Analytics for Optimized Energy Performance Management, which comprises several energy applications: Advanced renovation support, Urban Energy Monitoring and Planning Support, Facility Management Energy Analytics, Self-Consumption Optimization & Predictive Maintenance and Real-time Building Energy Performance and Smart Readiness Certification.

This 1st release of software applications gives a solid ground for the upcoming development work of WP7, which will be reported in the next deliverable D7.3 Final Version of Optimized Energy Performance Management Suite, due to M42. Moreover this report put a ground to start testing and demonstration activities that will take place in scope of WP8, starting from M24.

This project has received funding from the European Union's Horizon 2020 Research and Innovation programme under Grant Agreement No 872734.

7 References