Functional design options for the SENSEI Platform and smart services

Deliverable 7.4

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Smart Energy Services to Improve the Energy Efficiency of the European Building Stock

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Abbreviations and Acronyms

Acronym	Description
API	Application Programming Interface
AWS	Amazon Web Services
BMS	Building Management Systems
BEMS	Building energy management system
CIMNE	International Centre for Numeric Methods
CSS	Cascade Style Sheets
CSV	Comma Separated Values
DB	Data Base
EaaS	Energy-as-a-Service
ESCO	Energy Service COmpany
FTP	File Transfer Protocol
GENCAT	GENeralitat de CATalunya
GUI	Graphical User Interface
HA	High Availability
HTML	HyperText Markup Language
HTTP	HyperText Transfer Protocol
ICT	Information communications technology
JSON	JavaScript Object Notation
NVM	Node Version Manager
OS	Operating System
OSM	Open Street Maps
P4P	Pay 4 Performance
REST	REpresentational State Transfer
SDK	Software Development Kit
SQL	Structured Query Language
SVG	Scalable Vector Graphics
ToC	Table of Contents

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Acronym	Description
UI	User Interface
WP	Work Package
WPL	Work Package Leader
XLS	Microsoft Excel spreadsheet file

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Executive summary

This deliverable aims at describing the SENSEI platform from a perspective that illustrates how the smart services developed in the project, specifically by WP4 *The P4P Schemes from the Energy System Perspective*, WP5, *P4P schemes to compensate energy efficiency as an energy resource,* and WP6, *P4P schemes to engage third party investors in energy efficiency,* can be implemented in a real scenario and used by different actors.

The SENSEI model is a value proposition that can be substantiated by a set of different tools, mostly linking data dynamically (near real-time) from a selection of building types with complex logic (predictive modelling methods) and advanced computing to deliver new building information, energy data and performance indicators.

This report focuses on the different ways the data and the information flows identified is several tasks undertaken within SENSEI activities -like, T4.2, *Quantify the drivers of the value of energy efficiency as an energy resource*, T5.3, *Identify the effect of the compensation structure of a P4P scheme*, T5.4, *Explore and utilize the interplay between P4P and demand response incentives* or T7.3, *Define the data models and interfaces for the smart services*- can be realized through the collaboration of decentralized functionality and API (Application Programming Interface) composition. In practical terms, this work help addressing the questions of how the enterprise systems of the different actors/business roles can collaborate, from getting the data from Building Management Systems (BMS), smart meters or sensors inside a building to exchanging information about the metered energy savings and their progression by means of a cloud platform, dedicated data connectors and data analytics together with visualizations tools .

The reason for thinking in terms of API composition is that not all actors will have access to the same data. For instance, in Spain all energy providers can access a repository of detailed energy consumption data of all consumers, but they cannot share it. The same energy providers, however, could provide an API end-point that allows the part of the computational workflow that operates on this data to remain exclusively inside their enterprise systems. This type of insights can help pinpoint the opportunities and/or obstacles for service integration between different stakeholders.

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1 Introduction

Increasing energy prices and managing energy costs for commercial as well as residential buildings is expected to boost building energy management systems market size over the next few years. These sectors have been adopting various appropriate technologies for controlling, conserving, and monitoring energy analytics. Building Energy Management Systems (BEMS) involves the effective integration of software, hardware, ICT technologies and services, helping to monitor, control and automate functions to manage energy efficiency in buildings. Utilities, energy service companies (ESCO) and other large power users in the commercial and industrial sector no less are moving toward Energy-as-a-Service (EaaS) solutions that offer continuous monitoring and reporting of energy consumption trends, measurement of equipment performance and benchmarking. Digitalisation offers great potential to change this and enhance energy efficiency policies by providing better information and much clearer vision on distributed energy resources. This can enable new policy design options which allow markets for energy efficiency to operate at a much greater scale. Digitalisation can also improve the implementation and monitoring of programme delivery through resources such as smartphone apps and online tools. The use of such tools can potentially benefit a wide range of stakeholders. Moreover, digital tools can be particularly valuable in fostering engagement more tailored to community needs, not only delivering the most cost-effective energy savings, but also helping address energy vulnerability and a range of health, social and gender equity considerations.

The SENSEI project is the first in Europe to adopt a P4P financing scheme. The model allows utility operators to repay building energy efficiency investments based on actual energy savings. The P4P concept not only incentivises private financing into green and efficiency-enhancing projects, but also brings added value to energy retrofits.

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2 The SENSEI Platform

2.1 Overview

Figure 1 below provides a high-level view of the platform and services, and its interactions with the rest of the SENSEI components.

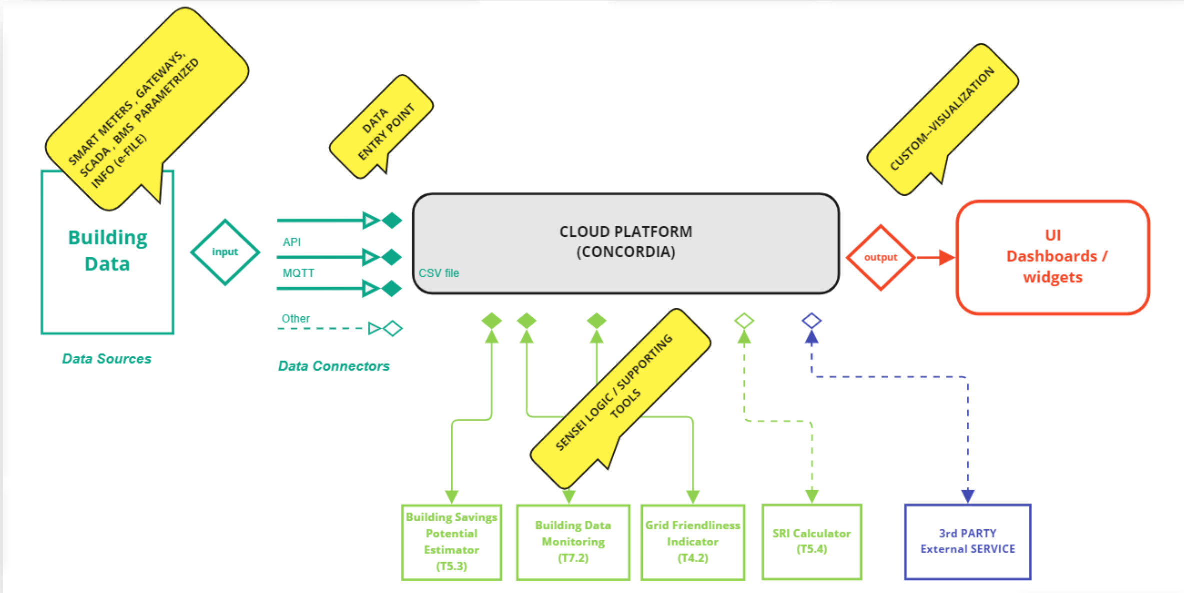

Figure 1: SENSEI Platform

2.1.1 Functional description

The platform component securely stores and easily retrieves data, making it accessible for management, inspection, and third-party retrieval. It serves as a centralized and consistent data source. Deployed on the Cloud, it leverages remote configuration and scalability. Data is collected from various sources through services, while data management and communication with other components are managed through an integrated API and UI. The component features a role-based access interface for managing and viewing data in table and graphic formats. JSON is used for API data exchange. Its overall aim is to provide a secure and standardized environment for centralized information exchange with configurable and parameterizable options, and seamless integration with other components.

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The SENSEI cloud platform is equipped with an intuitive and user-friendly interface, allowing an administrator to define and manage data interactions. Three user roles are available: SuperAdmin, Admin, and User. The interface is used to create and configure settings for data acquisition, and access to both GUI and API is secure by using credentials. The platform can store and display data, enabling basic chart interactions.

Additionally, the platform leverages services for connectivity, enabling configuration of various data source types and protocols which are used to perform connection, extraction, transformation, and normalization, and then passing results to the back end for storage. The platform also supports REST connectivity, allowing users to make simple HTTP requests to access entities and their traces, either filtered or unfiltered.

The SENSEI platform is built using Laravel[1] and PHP as primary technologies. It utilizes two databases, MariaDB[2] for internal configurations and MongoDB[3] for data storage. JSON and REST format and transfer data between UI and back end. The UI is built with JavaScript, HTML, CSS, and libraries such as D3.js and Datatables.js. It has been designed with scalability and high availability scenarios in mind; it can employ technologies like load balancers and distributed databases for handling high traffic demands. The system offers low-latency data access.

The SENSEI platform is internally structured around different types of entities that abstract the various types of configurations and memberships.

- Nodes represent the highest level of abstraction; they gather multiple signals, enabling them to be manipulated as a single unit.
- Data Sources are entities that allow for setting up communications, determining basic parameters such as protocols, document templates, and time considerations, and monitoring data extraction in real-time. It also allows for creating alerts for value thresholds.
- Raw Signals are the lowest-level representations of the data extracted. They are associated with a Data Source as a basic form of configuration. Their reading values can

[1] https://laravel.com/

[2] https://mariadb.org/

[3] https://www.mongodb.com/

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be queried for use within other components, and they hold the units, labels, ranges, and formats expected for the input data.

- Signals are entities that define operations over readings of raw signals, they allow for storing the transformations over Raw Signals belonging to a Data Source.
- Document templates are a set of configurations that allow for mapping fields within a JSON message, providing a common structure and general pattern to expect from the input.
- Transformations/Conversions define the operations to be performed over raw signals in order to correct values or homogenize them.
- Dashboards allow for creating visualizations based on a set of data from signal readings.

These entities work together to provide centralized, standardized information exchange, with configurable and parameterizable options, and seamless integration with other components.

2.1.2 Fitting into overall SENSEI Architecture

The SENSEI Platform component is a key part of the proposed SENSEI system It is designed to interact seamlessly with other elements of the system's architecture, both within the component and with external systems.

Built with industry-standard technologies and best practices, this component ensures reliability, scalability, and maintainability while supplying centralized data access. It offers features such as data storage, management, and communication with other components through APIs. Additionally, it features an intuitive user interface for data visualization and manipulation, and it is configurable for easy customization and integration with other systems. In a nutshell, the SENSEI platform component plays a vital role in the project's architecture, providing a secure, efficient and user-friendly environment for the centralized and standardized exchange of information. The component's conceptual design can be seen in figure 2.

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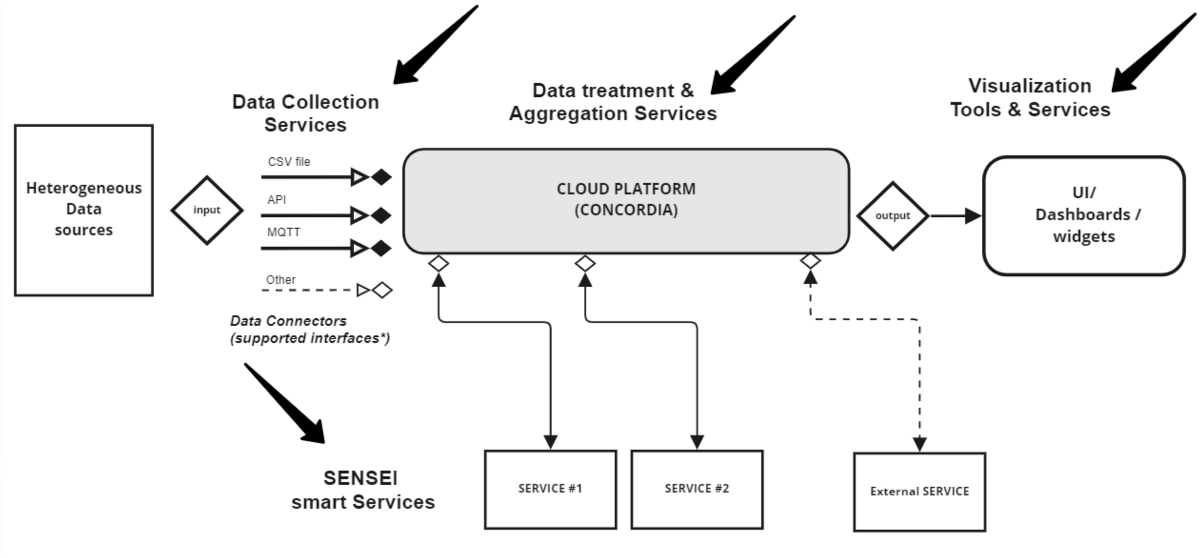

Figure 2: Overall architecture of the system

The SENSEI Platform uses its own dashboards to expose the data, exploiting services for data retrieval. In this way it can:

- be available to all users in a secure way,
- be available to all the components that wish to exploit the stored data in a standardized manner,
- to retrieve data from the Project sources, so that visualizations can be exploited by users in an easy manner,
- be as obfuscated as desired within the platform, using access validation services provided by other components such as the Identity and Access Service.

The data exchange capabilities are:

- JSON-REST API driven in coordination with other components,
- operates asynchronously, allowing for independent data requests to be made without affecting the operation of other components,
- secure, in the sense of security measures are in place, including the implementation of authorization mechanisms.

In summary, the SENSEI platform is a layer within the SENSEI project for data storage and management, with the aim to visualize and exploit is outcomes by means of integrated tools. It

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is a cloud deployment that can be scaled, if necessary, which requires the incorporation of new configurations and/or software technologies.

2.2 Technical description

This technical description section provides an overview of the underlying technology and architecture used to develop the platform. It covers the various components, their functionalities and interconnections, as well as the methods used for data storage, retrieval, and processing, and addition information about other important issues. The aim of this section is to offer a deep understanding of the platform's technical aspects and its operational capabilities within the context of the document. The internal data flow through the overall architecture can be defined as seen in figure 2.

SENSEI platform high-level layout:

- The components are deployed in a single instance in the cloud. In this way, a deployment with the flexibility capabilities that this implies both in terms of scalability -possibility of re-instancing- and connectivity -ease of configuration and access control in terms of security- and selection of resources -management of hardware resources on demand-, thus being accessible from the rest of the SENSEI components.
- The GUI user interface allows to interact with the Smart services and the retrieved data in a more flexible/intuitive manner than the API. The GUI is called to be the regular access method for administrator users, being the API the one destined to interact with the entities and to collect the data for its exploitation by third parties.
- The internal API allows to:
    - To retrieve the information stored in the database through queries in a uniform and secure manner with embedded authentication and authorization, thus enabling third parties to access it.
    - To extract information about the available entities, their configuration and characteristics, enabling:
        - Platform management by external interfaces
        - Operating interfaces as independent components

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        - For further details on using the platform, there is a context help integrated in the UI.
    - To manage data extraction configurations, and to record incoming data from the services set up for this purpose. The services are individual implementations of data extraction methods, whose functioning depends on the particularities of the protocol used on the building gathering systems.
    - Keep in mind that the API primarily serves a read-oriented purpose for data flows, that is a source-typed asset. This is due to the designed automation of data recording through configurations, the management of entities through the GUI, and the availability of endpoints being subject to agreement with other platform components.
- The storage layer is responsible for maintaining the information, by utilizing databases as a means of storage.
    - One aspect of the storage layer is configurations necessary for the SENSEI Platform's operation, such as users, data sources, or entities.
    - Another aspect is storing structured information from buildings, ready to be accessed via the API.

All the described items above are deployed within the same cloud instance, which hold all the inside components of the SENSEI Platform. A deeper sight on the components and a brief explanation on every software tool used is provided within the next section.

2.2.1 Components and technical specifications

The SENSEI platform employs various technologies to deliver desired functionality with recognized standards and protocols. Figure 3 shows the technology components from a functional perspective. Software versions are not a critical factor but could be relevant for potential compatibility issues in the future. The most stable versions of all libraries were used, managed with tools such as Composer and NVM.

The technology stack of the component includes modern web technologies like PHP, JavaScript, and databases like MySQL and MongoDB, and leverages third-party libraries and frameworks like Laravel.

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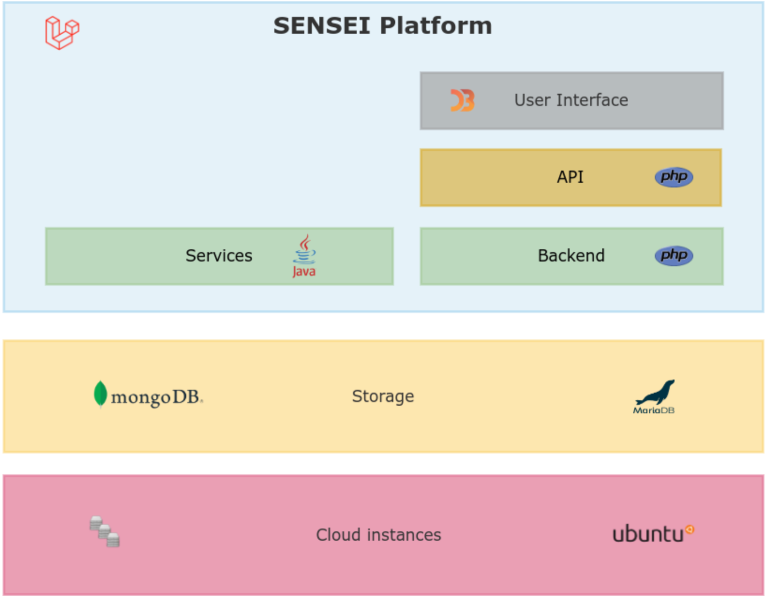

Figure 3: Components & technologies associated.

Cloud instances host the software components and their hardware resources (or virtualized versions). Virtualization methods like virtual machines or docker deployment may offer finer control over resource tenancy and can be considered in further stages in case of necessity. Currently, a basic bare-metal deployment is being used.

The persistence layer consists of two databases: MariaDB manages platform elements (structured entities) and entities, while MongoDB handles data from pilots. MongoDB's use of JSON as a flexible storage method, especially for APIs, avoids extra transformations and facilitates fast key-value mapping between fields.

The API serves as a bridge between the back end and storage, and the rest of the architecture. It uses REST and JSON structures in communication and secures access through authentication and authorization of user roles to endpoints.

The interface provides a gateway for data management and decouples it from the API and the back end. Both have been developed using Laravel + PHP, a simple and efficient web development tool, offering the following benefits:

- To use a single, versatile, simple and high-performance programming language.
- To have a fast and flexible development structure.

Laravel's built-in HTML templating engine, Blade templates, were used for web GUI development. Deployment and management of static assets was made simpler with Gulp and

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Composer, and DevOps tasks are handled with generated scripts. Code is stored in BitBucket and versioned with GIT.

These technologies used in current software development standards. This aims to ease the development process while facilitating maintenance.

- **Cloud infrastructure**
  - It allows dynamic allocation of resources and instances with a suite of tools for DevOps quick management. Its features make it suitable for a highly available deployment. Instances can be dynamically activated for balanced, resilient delivery of data, as viewed from the perspective of Infrastructure as a Service.
- **OS**
  - The Ubuntu Linux distro, particularly its Long-Term Service flavors, provides a highly reliable, user-friendly, and easily configurable OS. Other distributions like Debian, CentOS, and SuSe are also suitable, but lack the same level of convenience. In this case we are sticking with Ubuntu 20.04 LTS.
- **Languages/frameworks**
  - Laravel/PHP is a widely used, lightweight framework for developing web applications with PHP - a versatile and efficient language for fast development. The platform and its API are based on PHP 7.4 for enhanced compatibility.
- **Management of dependencies**
  - Gulp is a JavaScript tool that eases web resources bundling and optimisation for deployment. It is based on node.js.
  - NVM is a node.js tool to manage version dependencies.
  - Composer is a PHP dependency manager that simplifies version management of project libraries.
- **Databases**
  - MariaDB is a SQL database to store platform configurations, information about the users and their permissions and basic data features related to the platform operation.

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- MongoDB is an Open Source No-SQL JSON-based database to store the incoming data, with distributed execution possibilities and a powerful query API. Version is 3.6.

- **Web servers and gateways**
  - Apache web server consists in an Open Sourced, widely known reliable web server with a broad set of modules and configuration options.
- **Deployment & code management**
  - Docker represents a containerization system which allows to fully control the deployment of applications, tuning-up the resources by fine-grain settings and avoiding software conflicts by isolating running environments. It is used with pipelines and cloud providers to both ease maintenance with no downtimes and deliver HA applications.
  - GIT is a software tool to manage code versions, delivering a fast and simple branches system to allow developers keeping a registry of their work while avoiding crashes between them.
  - Bitbucket is a platform based on GIT which, supported its web GUI, makes possible to integrate code development phases by providing repositories and tools, to enhance team collaboration and ease deployments.
- **Communication format technologies and standards**
  - Please refer to the Data collection services section within this document.

2.2.2 Package information

The platform consists of two distinct packages: the first package deals with platform logic and manages the interface through communication with the MariaDB database, while the second package provides API access to the platform methods and facilitates interaction with the data stored in MongoDB.

The first package features a graphical user interface (GUI) as part of its design. Due to the different code and functionalities, both packages must be installed separately on the same machine and configured for communication. Both packages utilize the Laravel framework for building their respective applications.

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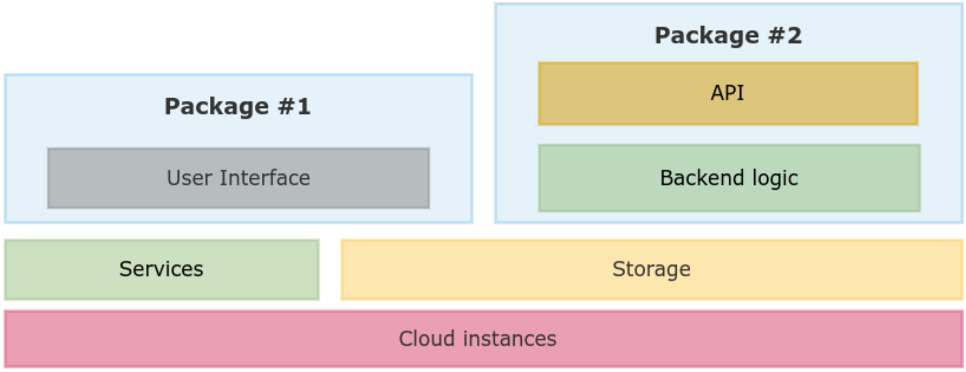

Figure 4: Package distribution of the platform components

2.2.3 User Manual

The GUI offers comprehensive contextual assistance throughout the platform, including settings and visualization flow.

Access to the platform is delivered at https://demo.senseih2020.eu//login?site=sensei. The credentials can be requested through following email: info@advanticsys.com

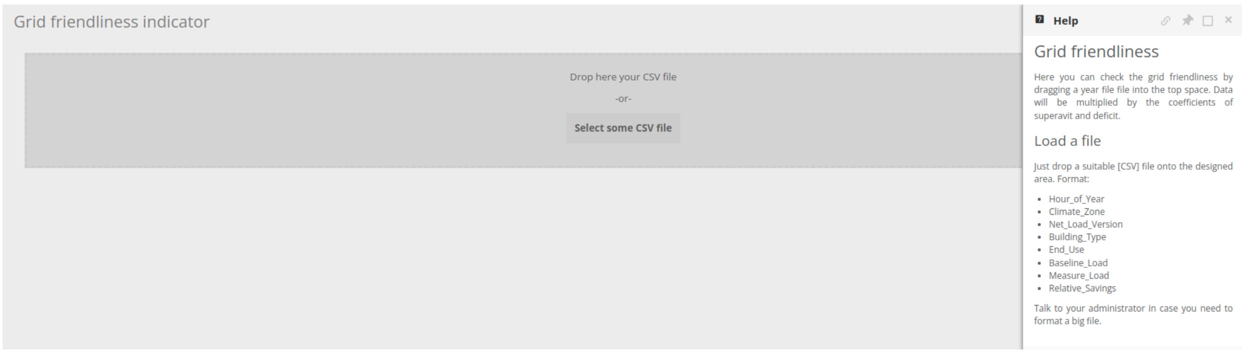

Figure 5: Context-sensitive help within the SENSEI Platform GUI

2.2.4 Licensing information

The software is released as is described in the Consortium Agreement document.

"For the avoidance of doubt, the general provisions for Access Rights provided for in this Section 9 are applicable also to Software as far as not modified by this Section 9.8. Parties' Access Rights to Software do not include any right to receive source code or object code ported to a certain hardware platform or

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any right to receive respective Software documentation in any particular form or detail, but only as available from the Party granting the Access Rights.” ***[CA-Section 9.8]***

3 SENSEI Platform Inputs

3.1 Data collection services

The utilization of data for decision making and application development is becoming increasingly crucial for modern businesses. Gaining insights from data can lead to cost savings, increased efficiency, and a competitive edge. As more companies collect both streaming and batch data, the challenge arises in incorporating both types of data in their analysis for comprehensive and current insights.

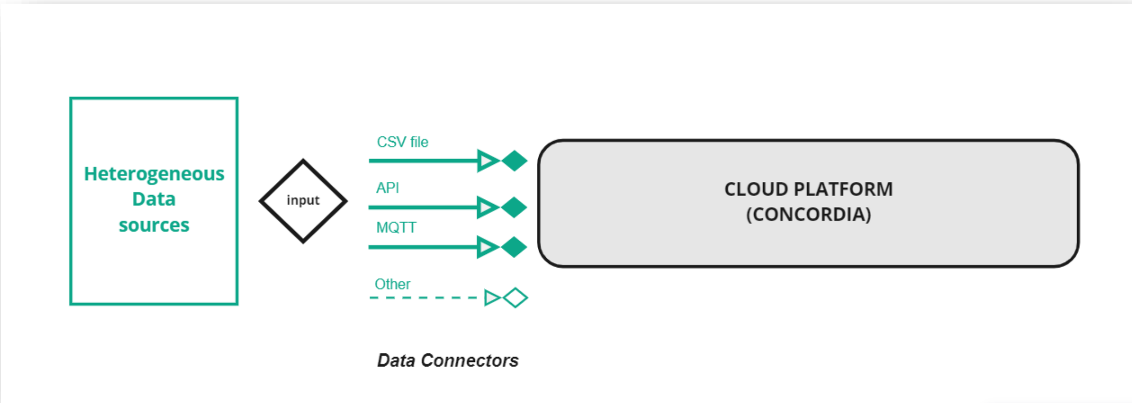

Figure 6: Platform INPUTS

3.1.1 Data connectors

Data connectors are software components that automatically extract data, sometimes periodically, from one or more upstream data sources and land that data in another database. Data connectors are common in most business intelligence, analytics and data science applications and frameworks. Data connectors simplify data source administration and configuration, and separate credential management and data usage from applications.

These services, in case of the SENSEI platform, are developed in Java and designed to fit specific connection protocols. Java services can connect to different data sources using different communication protocols. Some examples are:

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- HTTP: It is one of the most common protocols for connecting to web services. Java services can use the Java URL class to connect to a web service through HTTP. This class provides methods for opening a connection, sending requests and receiving responses, for example, from an API.
- MQTT: It is a publish/subscribe messaging protocol designed for real-time connectivity in connected device networks. There are Java libraries such as Paho, which provide an application programming interface (API) for connecting to an MQTT server.
- FTP: It is a protocol used for file transfer. Java provides the Apache Commons Net FTPClient class for connecting to an FTP server and performing operations such as uploading and downloading files.
- OPC UA: It is a communication protocol used in industrial automation and Internet of Things. It allows data exchange between different devices and systems. There are libraries and SDKs available in Java which allow to implement OPC UA clients and servers.
- Modbus: It is a serial communication protocol used in industrial control systems. It allows data exchange between different devices and systems. There are libraries and SDKs available in Java which allow to implement Modbus clients and servers.
- JMS: Java Message Service is a Java specification for message exchange between applications. There are several JMS implementations such as Apache ActiveMQ, IBM WebSphere MQ among others, which allow connecting to a message queue system through a standardized interface.
- JDBC: Java Database Connectivity is a Java specification that provides an interface for connecting to relational databases. JDBC allows developers to write Java code that is independent of the database management system used.

Services have to use common language formats to carry the data depending on the application they are suited for. Some of the observed types are:

- JSON: JavaScript Object Notation is a lightweight data-interchange format that is easy for humans to read and write and easy for machines to parse and generate. Java has built-in support for JSON through classes such as JSONObject and JSONArray, and there are also third-party libraries like Gson and Jackson that provide additional functionality

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for working with JSON data. This is the format selected for most of the API data exchanges.

- CSV: Comma Separated Values is a simple file format that is widely supported by many applications and systems. Java has built-in support for reading and writing CSV files through the use of the Scanner and PrintWriter classes. There are also third-party libraries like OpenCSV and Apache Commons CSV that provide additional functionality for working with CSV data.
- XML: Extensible Markup Language is a markup language that is used to store and transport data. Java has built-in support for XML through classes such as Document and Element, and there are also third-party libraries like JAXB and dom4j that provide additional functionality for working with XML data.

Information can be anywhere from real-time to static, so services have to be scheduled for their execution in different ways to be able to catch up without while being performant and resilient to failures. There are several scheduling services approaches that can be used to execute data gathering tasks, some of them are:

- Cron: A Linux utility that allows to schedule tasks to be executed at specific times or intervals. Cron uses a simple syntax to specify the schedule, making it easy to set up and manage. This is the selected approach, as services and their management are simpler while data overlapping is controlled via MariaDB database records.
- Quartz Scheduler: Java-based scheduling service that provides more advanced features than Cron. Quartz allows you to schedule tasks using a variety of triggers, including cron-like schedules, providing also support for clustering and failover.
- Windows Task Scheduler: Built-in scheduling service for Windows operating systems. It allows you to schedule tasks to be executed at specific times or intervals, similarly to Cron, but also provides more advanced features such as the ability to run tasks as a specific user or on a specific computer. This approach does not apply because of the OS used -Linux-.
- Celery: It is an open-source task queue system for Python. It permits scheduling and executing tasks asynchronously, while provides support for distributed processing and result storage.

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- Kubernetes CronJobs: Google's Kubernetes provides a built-in mechanism for scheduling tasks using cron-like syntax. This approach does not apply because of the deployment type.
- AWS Lambda: It is an event-driven, serverless computing platform provided by Amazon Web Services. Allows to run code without provisioning or managing servers, hence it can be used to schedule tasks at specific times or intervals, or by trigger of events.

3.1.2 Input data

The platform successfully retrieves both static and dynamic data via the API, in either CSV or other formats such as JSON. These data sets are intended to be primarily accessed and viewed through the platform's dashboards and services, providing users with an intuitive and comprehensive way to analyze the data.

4 Platform Core

4.1 Data treatment and aggregation services

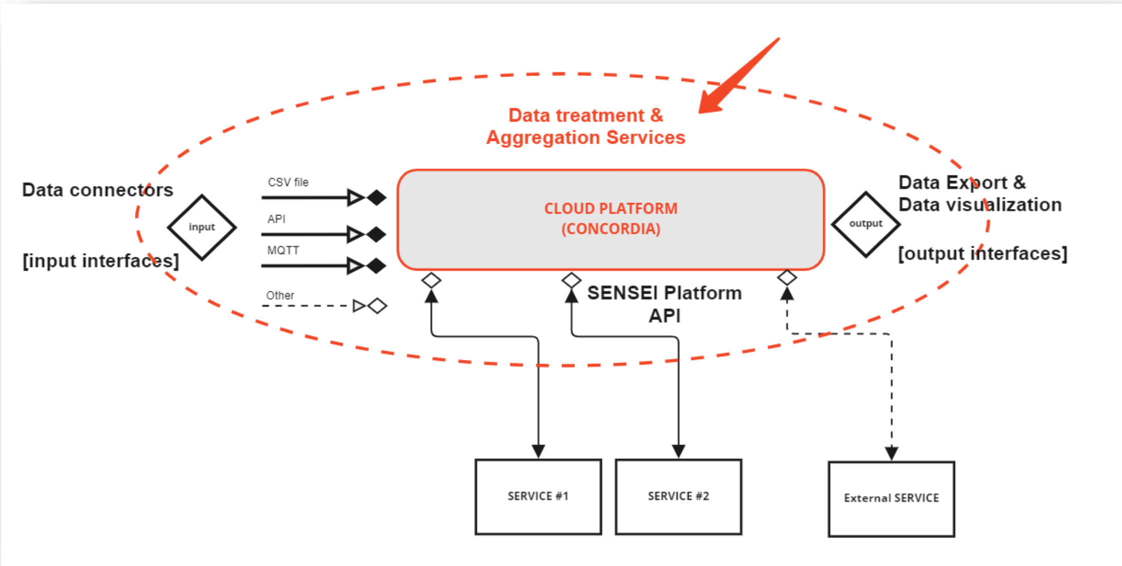

Figure 7: Platform CORE

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The core of the platform lies in its data treatment and aggregation services. These services are responsible for collecting, processing, and organizing large amounts of data from various sources. The goal of these services is to retrieve the data for a comprehensive and accurate view of them, allowing users to make informed decisions and drive efficiencies in their operations.

The data treatment and aggregation services act as communication hubs for the SENSEI system, connecting the platform to various data sources and facilitating the collection, processing, and storage of data. These services provide the core functionality of the platform by enabling data communication, transformation, normalization, and aggregation. They ensure that data is collected from a wide range of sources, and that it is accurately processed and stored in the platform's databases. As a result, these services play a critical role in ensuring that the SENSEI platform can provide accurate and useful insights into the data collected from the various data sources of the SENSEI system.

The platform uses data aggregation as a method of enhancing the information by normalizing it and tracking what has already been processed. This is accomplished through the scheduled execution of services, which gather and process the data on a regular basis. The result is organized, consistent, and easily accessible data for analysis and reporting purposes. This process not only provides a final-user comprehensive view, but it also ensures that the data is up to date. By using data aggregation, the platform can keep track of what data has been processed and ensure that any new data that is added is integrated into the existing structures in a consistent and efficient manner. This allows for better data analysis and decision-making, as well as more accurate reporting.

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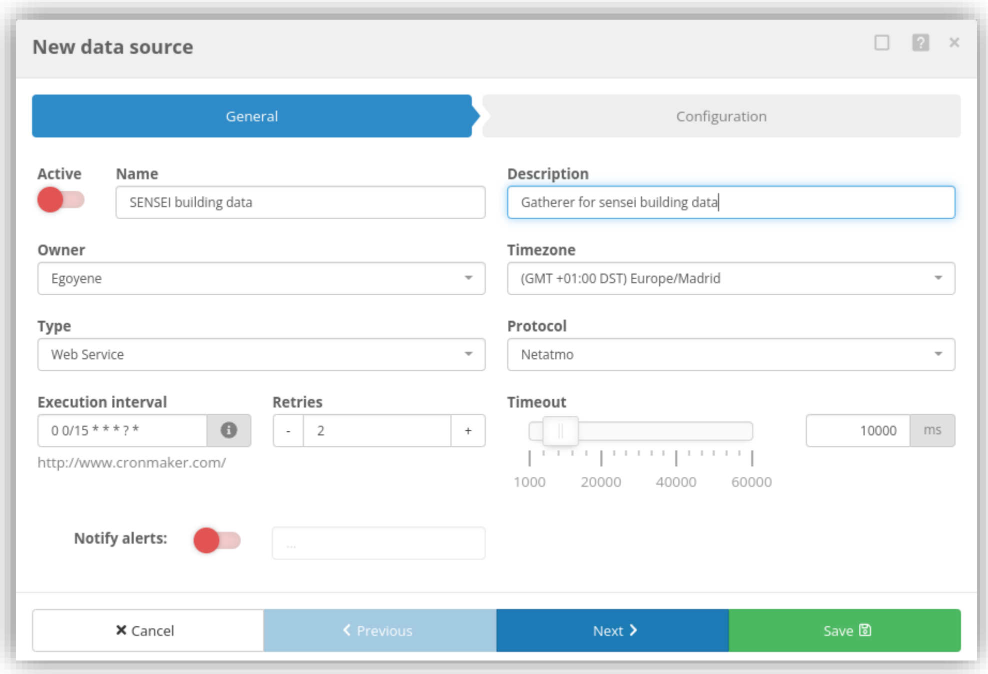

Figure 8: Platform admin extraction configuration

As an example of one of these under-the-hood extraction services, the SENSEI CIMNE API Gatherer can be used.

4.1.1 SENSEI CIMNE API Gatherer service

This Java-implemented service is in charge of connecting with the CIMNE endpoints, to extract data both of meteorological and building efficiency metrics. It gathers them and operates to build integrated CSV files which are exposed in an FTP server.

Its execution is scheduled in hour fractions, to gather data while avoiding time frames overlapping with adequate performance. Thus, the extracted data are stored along with the last execution status. Service runs as a daemon within a UNIX server, checking scheduled extractions constantly. At that execution point, the CIMNE API is asked for all results within a period. System checks the returned results to see if more data are to come –paginated data-, and if so, repeats the query before gathering them.

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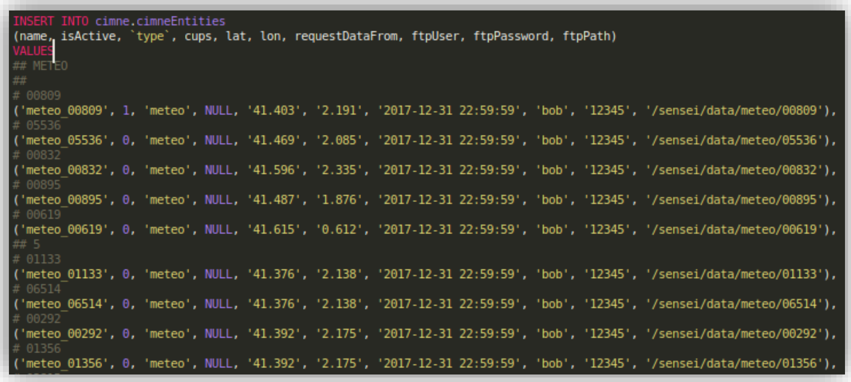


```
INSERT INTO cimne.cimneEntities
(name, isActive, `type`, cups, lat, lon, requestDataFrom, ftpUser, ftpPassword, ftpPath)
VALUES
## METEO
##
# 00809
('meteo_00809', 1, 'meteo', NULL, '41.403', '2.191', '2017-12-31 22:59:59', 'bob', '12345', '/sensei/data/meteo/00809'),
# 05536
('meteo_05536', 0, 'meteo', NULL, '41.469', '2.085', '2017-12-31 22:59:59', 'bob', '12345', '/sensei/data/meteo/05536'),
# 00832
('meteo_00832', 0, 'meteo', NULL, '41.596', '2.335', '2017-12-31 22:59:59', 'bob', '12345', '/sensei/data/meteo/00832'),
# 00895
('meteo_00895', 0, 'meteo', NULL, '41.487', '1.876', '2017-12-31 22:59:59', 'bob', '12345', '/sensei/data/meteo/00895'),
# 00619
('meteo_00619', 0, 'meteo', NULL, '41.615', '0.612', '2017-12-31 22:59:59', 'bob', '12345', '/sensei/data/meteo/00619'),
## 5
# 01133
('meteo_01133', 0, 'meteo', NULL, '41.376', '2.138', '2017-12-31 22:59:59', 'bob', '12345', '/sensei/data/meteo/01133'),
# 06514
('meteo_06514', 0, 'meteo', NULL, '41.376', '2.138', '2017-12-31 22:59:59', 'bob', '12345', '/sensei/data/meteo/06514'),
# 00292
('meteo_00292', 0, 'meteo', NULL, '41.392', '2.175', '2017-12-31 22:59:59', 'bob', '12345', '/sensei/data/meteo/00292'),
# 01356
('meteo_01356', 0, 'meteo', NULL, '41.392', '2.175', '2017-12-31 22:59:59', 'bob', '12345', '/sensei/data/meteo/01356'),
```

Figure 9: DB endpoint creation. Note the fields

The data once fetched are parsed and transformed to suit the platform needs. That is, combining them into one single CSV and uploading them to a FTP server for later exploitation. This combination follows a set of rules to make the files a homogenous source, such as decimal separators and timezones. Once the gathering is performed, the resulting file is sent to the FTP.

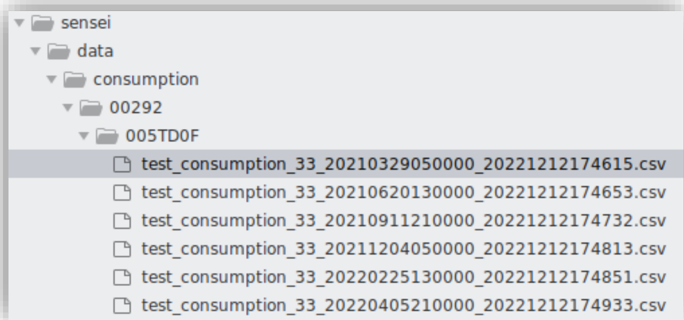
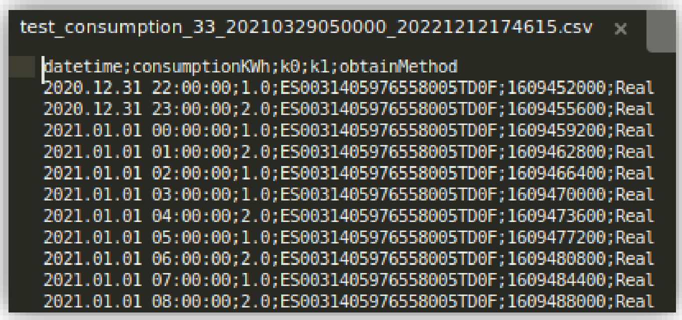


Figure 10: CSV output files structure and naming



```
test_consumption_33_20210329050000_20221212174615.csv
datetime;consumptionKWh;k0;k1;obtainMethod
2020.12.31 22:00:00;1.0;ES0031405976558005TD0F;1609452000;Real
2020.12.31 23:00:00;2.0;ES0031405976558005TD0F;1609455600;Real
2021.01.01 00:00:00;1.0;ES0031405976558005TD0F;1609459200;Real
2021.01.01 01:00:00;2.0;ES0031405976558005TD0F;1609462800;Real
2021.01.01 02:00:00;1.0;ES0031405976558005TD0F;1609466400;Real
2021.01.01 03:00:00;1.0;ES0031405976558005TD0F;1609470000;Real
2021.01.01 04:00:00;2.0;ES0031405976558005TD0F;1609473600;Real
2021.01.01 05:00:00;1.0;ES0031405976558005TD0F;1609477200;Real
2021.01.01 06:00:00;2.0;ES0031405976558005TD0F;1609480800;Real
2021.01.01 07:00:00;1.0;ES0031405976558005TD0F;1609484400;Real
2021.01.01 08:00:00;2.0;ES0031405976558005TD0F;1609488000;Real
```

Figure 11: Output CSV file. Note date and data format

The CIMNE endpoints are predefined following Consortium information, as seen in figure 9.

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5 Smart services – SENSEI Tools

In order to give some context between SENSEI integrated and non-integrated services, we can consider a non-integrated service as one that works outside of our system, typically as a self-contained cloud or web solution. The outsourced service we are leveraging will show the results in their own dashboard. Manual intervention would be necessary to load the input data and prepare it for use. In an integrated service, the process is more automated. The results are fed directly into our system in real-time, the calculations are made locally, and the result delivered to the corresponding widgets and/or dashboards exposed by the GUI.

5.1 Integrated smart services

Under this section, we will introduce three (3) tools developed as SENSEI platform integrated services based on the work done in dedicated task within WP4, WP5 and WP7.

5.1.1 Building Data Monitoring tool (BDM)

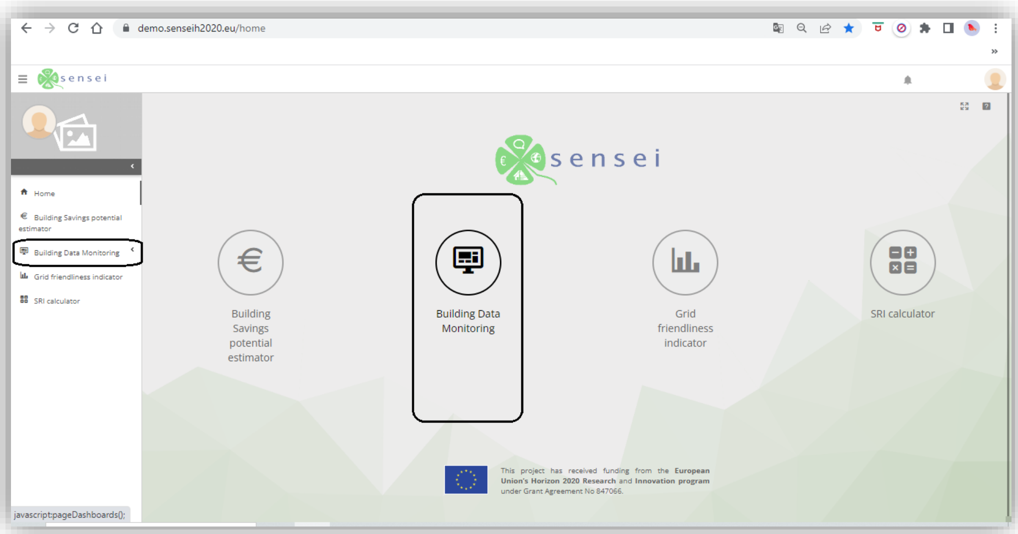

Figure 12 SENSEI platform - BDM access from flat menu & shortcut

The Building Data Monitoring tool is a smart service that provides information about building performance, basing its outputs in dashboards for each building considered. It utilizes data from CIMNE (International Center for Numerical Methods in Engineering) that is extracted through

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an API using a Java service specifically developed to this end. This meteorological and energy consumption data is then analyzed and presented in an easy-to-use interface, allowing users to assess the buildings and make informed decisions about their maintenance and energy management. A range of data topics is covered such as energy consumption, temperature, humidity, and other important metrics. It enables users to take proactive measures to optimize building performance and reduce costs.

The Building Data Monitoring tool features a few user-friendly widgets that allow users to easily access and analyze building performance data. The dashboards are designed with a variety of charts (widgets) and tables that are developed using d3.js, a JavaScript library for creating interactive data visualizations.

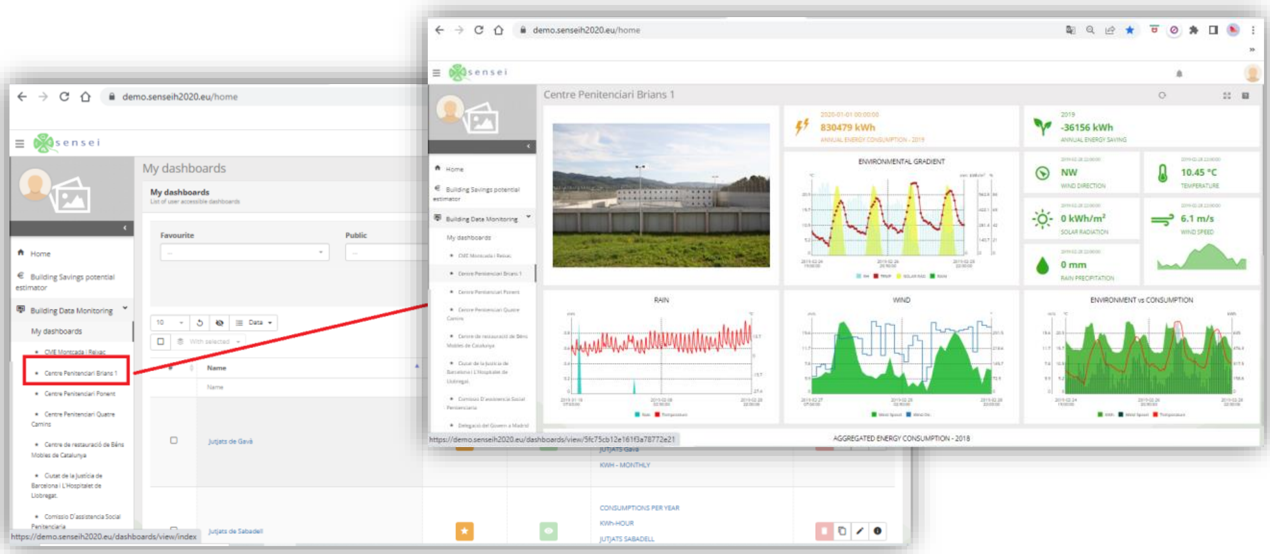

Figure 13: Dashboards created for the Building Data Monitoring tool.

Heat maps and line charts are important visualizations in the Building Data Monitoring tool as they provide a clear and concise way to understand and analyze the building's performance data. Heat maps are particularly useful for identifying patterns and trends in the data by displaying it in a graphical format that is easy to understand. They can be used to represent data such as energy consumption, temperature and humidity, and can help users quickly identify areas of the building where there may be issues or inefficiencies.

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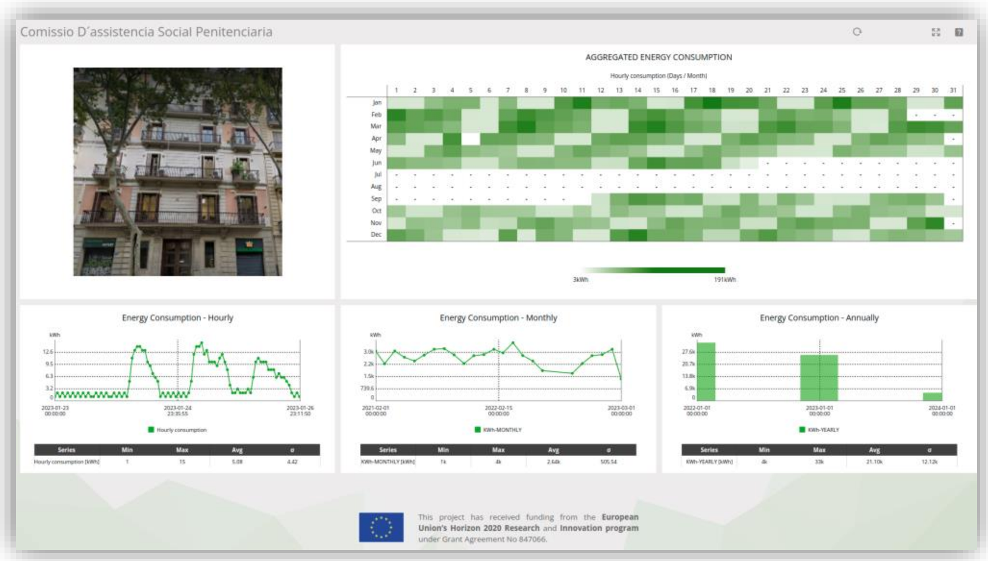

Figure 14: Example of a monitoring dashboard using different widgets.

Line charts, on the other hand, are useful for displaying data over time and can help users understand how the building's performance changes over time. They can be used to display data such as energy consumption, temperature, and humidity over a specific period, such as daily, weekly, or monthly. This allows users to identify patterns and trends that may not be easy to discern from looking at the data in a tabular format.

Both heat maps and line charts are important tools for making forecasts about the building's performance. By identifying patterns and trends in the data, users can make informed predictions about how the building will perform in the future and take proactive measures to optimize its performance. These visualizations allow users to quickly understand and analyze large amounts of gathered data.

In addition to the various charts and tables, the Building Data Monitoring tool also exploits a layout-modifying feature by using GridStack.js, which allows administrator users to customize the layout of the dashboard. Thus, the administrator can arrange different widgets in a way that best suits the user needs. This means they can change the position of the widgets, resize them, and even add or remove items as needed. This feature provides a high level of flexibility, allowing users to tailor the dashboard to their specific requirements and create a personalized view of the building's performance data. It also enables the administrator to focus on the most important data for their specific case, making it easy to identify issues and make informed decisions about building maintenance and energy management.

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5.1.1.1 BDM data gathering

The data extraction process is scheduled to execute at regular intervals to ensure that the information displayed on the dashboard is always up to date. The scheduled execution allows to have the most recent data, to make more accurate predictions and decisions.

The API gathering service is designed to handle large amounts of data without any performance issues. This is achieved by using optimization techniques and caching mechanisms, which help to minimize the number of requests made to the CIMNE endpoints and reduce the load on the database. As a result, the system is able to handle large amounts of data without problems, ensuring that the dashboard is always responsive and the users can access the data in near real-time.

The Building Data Monitoring tool is a valuable tool for building managers and facility operators to evaluate the energy efficiency and sustainability of their buildings.

5.1.2 Building Savings Potential Estimator tool (BSPE)

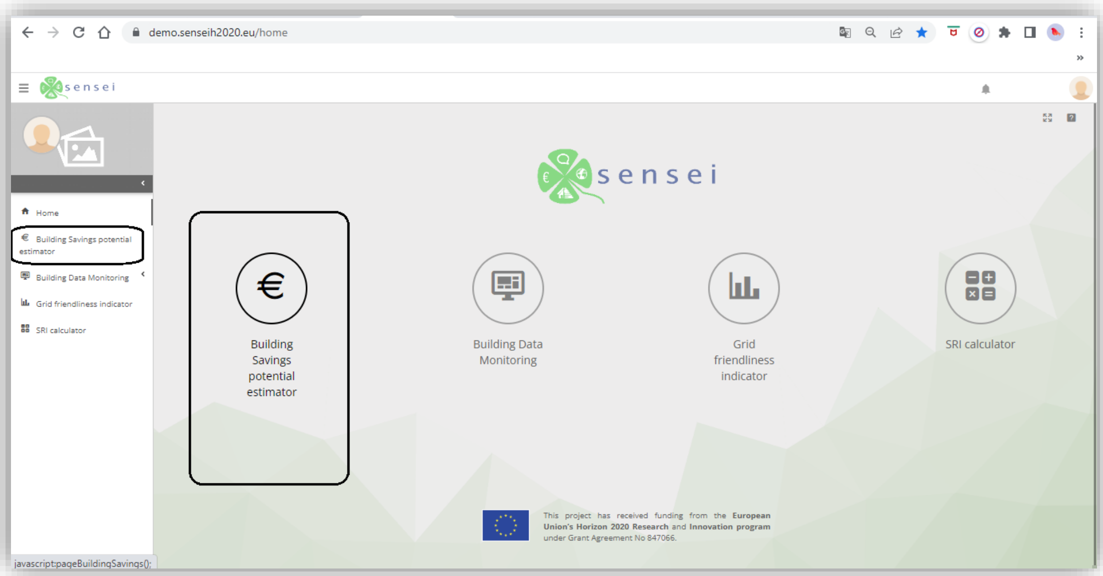

Figure 15: SENSEI platform - BSPE access from flat menu & shortcut

The Building Saving Potential Estimator tool is a smart service that allows building managers to assess the potential savings that can be achieved by implementing energy-efficient measures.

The tool features a user-friendly dashboard interface that provides information about the best GENCAT buildings depending on the exposed criteria.

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The dashboard includes a variety of charts and tables that are developed using d3.js, a JavaScript library for creating interactive data visualizations, and DataTables, a powerful jQuery plugin that provides advanced interaction controls for HTML tables. These visualizations include heat maps and line charts, which provide a clear and concise way to understand and analyze the building's performance data. Heat maps are particularly useful for identifying patterns and trends in the data by displaying it in a graphical format that is easy to understand. Line charts, on the other hand, are useful for displaying data over time and can help users understand how the building's performance changes over time.

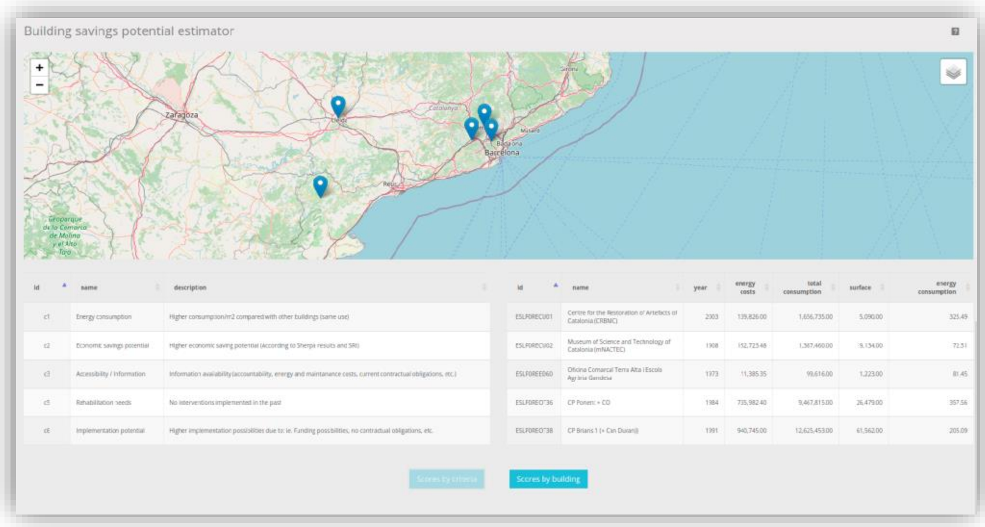

Figure 16: The Building Saving Potential Estimator

One of the key features of the dashboard is the use of radar charts. These charts provide a visual representation of the building's performance across multiple criteria. Users can quickly identify trends in the data and make informed decisions based on the information presented.

Another important feature is the use of bar charts, which allow users to compare performance in a single glance.

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Figure 17: Example of radar charts (scores by criteria)

In addition, the Building Saving Potential Estimator tool also includes widgets that display data in a tabular format. These tables can be sorted, filtered and searched easily, allowing users to quickly find the information they need.

Figure 18: Example of radar & bars charts (scores by building)

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5.1.3 Grid Friendliness Indicator tool (GFI)

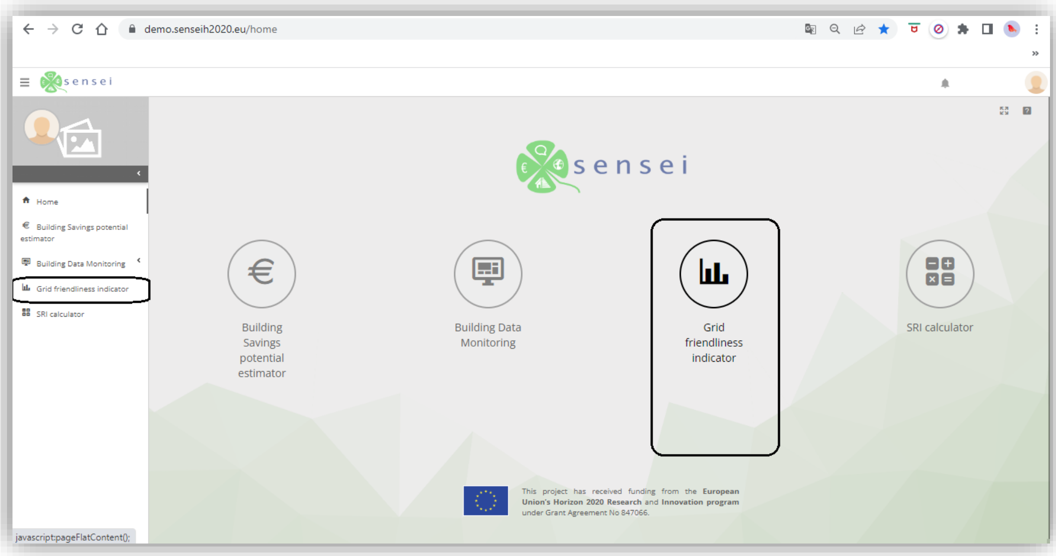

Figure 19: SENSEI platform - GFI access from flat menu & shortcut

The Grid Friendliness Indicator tool, concept developed under T4.2 and fully detailed in [D4.2, *The drivers of the value of energy efficiency as an energy resource*], is a smart service that allows building managers and facility operators to quickly and easily estimate the potential savings that can be achieved by implementing energy-efficient measures. The tool utilizes energy data from different buildings, which is loaded into the system in the form of CSV files and merges them with coefficient matrixes designed by HEBES.

The tool is based on a dashboard interface that provides several charts to sum up the intricacies while allowing to go to detailed inputs.

Charts and tables that are developed using d3.js, a JavaScript library for creating interactive data visualizations. The tool includes a couple of line charts to compare the baseline consumptions and the measured consumption along a year, which makes it easy to identify areas where improvements can be made.

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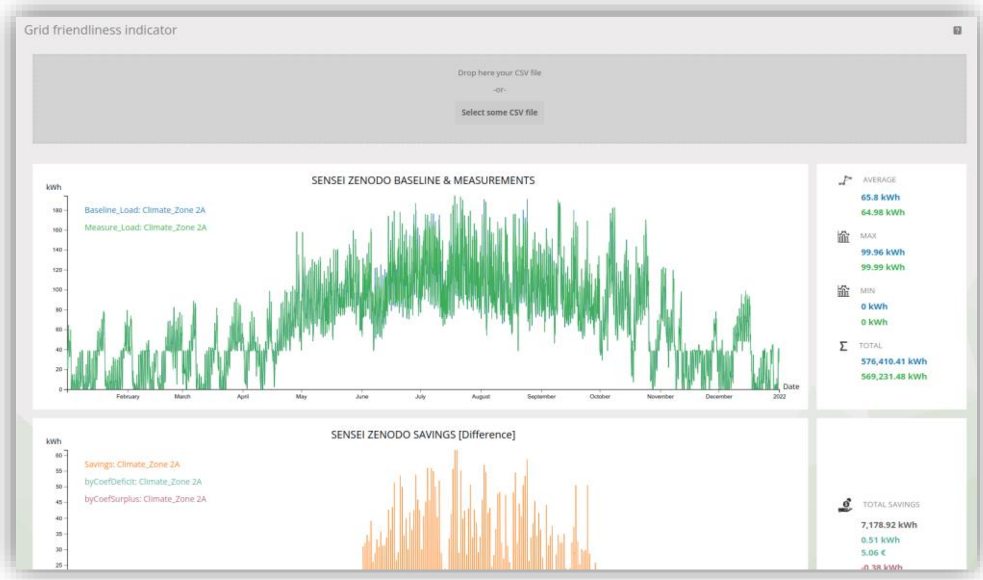

Figure 20: The Grid Friendliness Indicator

Furthermore, the tool features two heat maps which multiply the savings by deficit or surplus coefficients to translate the savings into energy or money. This allows users to understand how their building is performing and identify areas where improvements can be made. The heat maps are particularly useful for identifying patterns and trends in the data by displaying it in a graphical format that is easy to understand. The Estimator also provides summary tables and the use of colours to ease the visualization with different degrees of time granularity. These summary tables provide a quick overview of the key data. The use of colours also helps to highlight important information and make it easier to understand the data.

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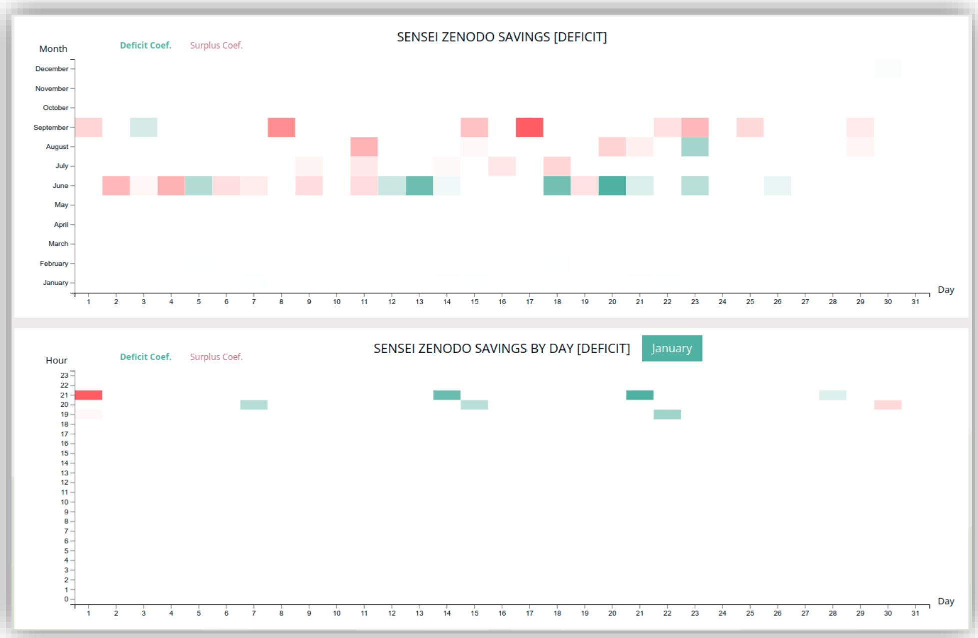

Figure 21: The heat maps of Grid Friendliness Indicator

For example, the summary tables can display data on energy consumption with different units and time granularity, such as daily, monthly, and yearly. This allows to check the data at different levels of detail, making it easier to identify patterns. The use of colour coding also helps to highlight important information, such as the periods of highest energy consumption or negative improvements, which can help identify areas where enhancements can be made.

TOTAL SAVINGS	kWh | €
December:	0.01467
November:	-0.00020
October:	-0.00078
September:	-1.21237
August:	-0.04391
July:	-0.26673
June:	1.98177
May:	0.00021
April:	0.00007
March:	0.00000
February:	0.01323
January:	0.01999

TOTAL SAVINGS	kWh | €	
23H: 0.00000	22H: 0.00000	21H: 0.01186
20H: 0.00487	19H: 0.00326	18H: 0.00000
17H: 0.00000	16H: 0.00000	15H: 0.00000
14H: 0.00000	13H: 0.00000	12H: 0.00000
11H: 0.00000	10H: 0.00000	9H: 0.00000
8H: 0.00000	7H: 0.00000	6H: 0.00000
5H: 0.00000	4H: 0.00000	3H: 0.00000
2H: 0.00000	1H: 0.00000	0H: 0.00000

Figure 22: The summary tables of Grid Friendliness Indicator

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By providing a variety of visualization options and using colours to rank important information, the Grid Friendliness Estimator makes it easy for users to understand their building's energy performance, assess which the improvements were, and take action to optimize energy efficiency and reduce costs.

5.2 Non-Integrated Smart services

Under this section, we will briefly introduce the SRI tool, developed by UNICAL within T5.4 activities (full details about the SRI tool can be found in D5.4) and also the possibility of adding 3rd party services/tools through SENSEI Platform API.

5.2.1 SRI tool (SRI)

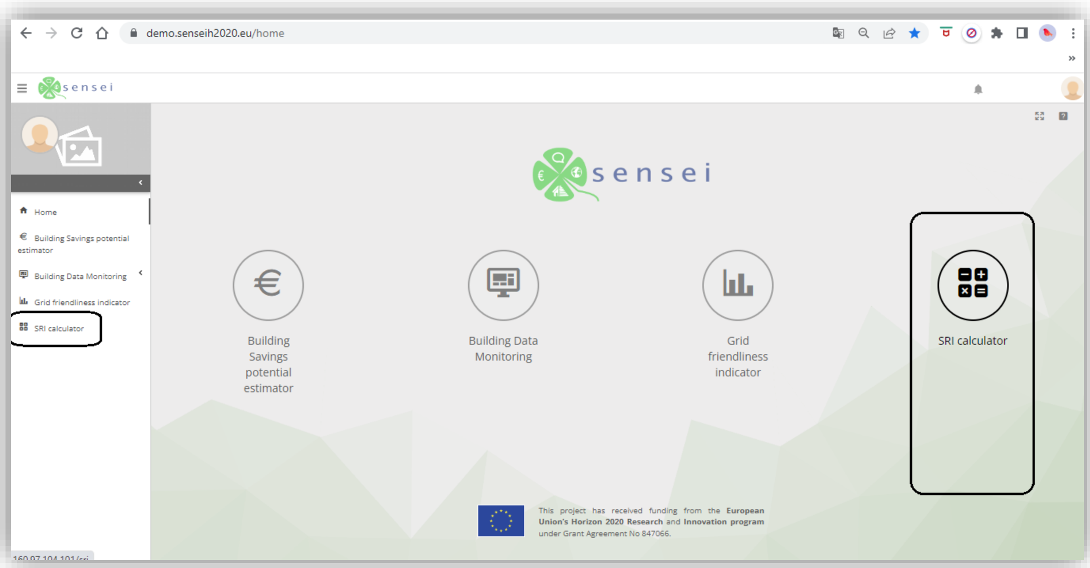

Figure 23 SENSEI platform - SRI access from flat menu & shortcut

The SRI tool, concept developed under T5.4 and fully detailed in [D5.4, The interplay between P4P and Demand Response incentives](), is a web app through which, by utilising the results obtained from simulated or real pilots, it is possible to evaluate the SRI efficiency index and also the so-called DR index related to demand response, in order to obtain a measure of the interplay value between EE and DR.

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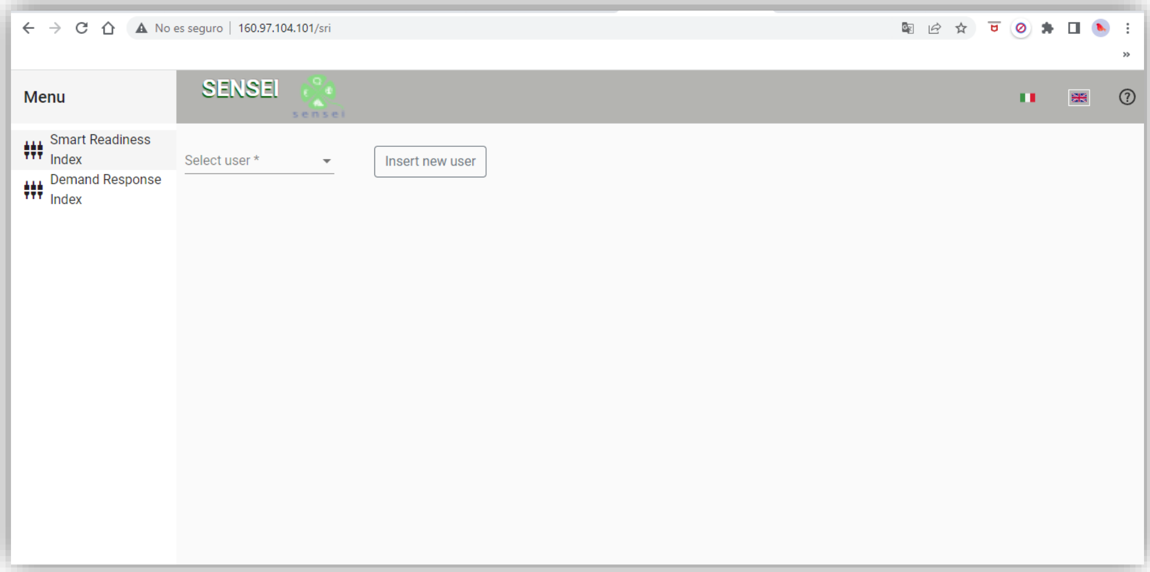

Figure 24: SRI web interface

The SRI is a tool that allows to investigate interventions carried out in the field to give a measure of the value of the existing interplay between EE and DR, establishing a relationship based on the intervention of EE. The information, data and results reported in Deliverable D5.1 about the Selected buildings, SRI and comfort assessments were considered for the tool development. In practice, two indicators are used in the web app: 1. SRI indicator related to EE intervention 2. DR index that can evaluate the performance of the building in terms of DR.

The purpose is to use this service and contribute to the discussion on the interplay between P4P and DR incentives. Through this approach, a service to evaluate the impact in terms of DR in consequence of EE has been developed. The Web app was created to collect data referring to the SRI and DR from pilot projects, which can quickly calculate and share the Smartness Readiness Indicator and DR assessments and the resulting revenues from providing flexible services.

5.2.2 Third-party service /tools

SENSEI Platform API can be used by third-party developers to help maximising the value of the large amount of data collected by energy services companies and utilities, connecting their applications to the platform and exposing their data and functionalities. An API basically refers to the code that enables software programs to talk to each other.

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Any third-party developer interested in sharing their energy-related tools or applications with the SENSEI platform can contact the platform developers for further information through the following email: info@advanticsys.com

5.3 Data models and interfaces for the smart services

Two high-level interfaces can be defined for the interactions of data with/to the SENSEI platform. One is about the sources of the data retrieved, and the other is about the exploitation that partners can do once they are processed by the Platform.

The data models are handled by the services, and they are statically defined in XLS documents provided by the Consortium. On the other hand, for more-generic sources of data, the platform can be set by an administrator user to gather their inputs.

Interface name	CIMNE API
Interface description	CIMNE REST API to expose building data
Provider	CIMNE
Consumer	ADV
Input	Building consumption and meteorological data
Input format	JSON with the requested signal values
Output	Aggregated, homogenized signal values
Output format	CSV

Table 1 Interface A

Interface name	SENSEI Platform GUI
Interface description	SENSEI graphical UI to expose the different data gathered into the platform
Provider	ADV

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Consumer	All partners interested in data exploitation
Input	User interactions, user CSV files with data in case of the Grid Friendliness estimator
Input format	Parameters on the requested data
Output	Charts and tables with the requested data
Output format	Dashboards

Table 2 Interface B

6 SENSEI Platform Outputs

6.1.1 Visualization Tools

As seen before, the data collection platform generates results in the form of interactive dashboards to help improve building efficiency. These dashboards provide visual representations of data, including graphs, charts and tables, to give users a comprehensive view of building performance. Data is organized and displayed in a way that makes it easy to identify patterns and trends, allowing users to make informed decisions about energy use, resource allocation and maintenance schedules. Dashboards can also be customized to suit specific needs, allowing the creation of data views tailored to different stakeholders. The goal is to provide building managers and operators with the information they need to make their buildings more efficient and sustainable.

The dashboards generated can either be static or dynamic, depending on the type of inputs received. Static dashboards provide a fixed view of data and do not change based on user interactions or updates to the data. On the other hand, dynamic dashboards are interactive and respond to user inputs and data updates in real-time. For example, if a user wants to see the energy consumption of a particular building over a certain period, they can select the date range, and the dashboard will automatically update to reflect the new data. This level of interactivity makes dynamic dashboards more useful for identifying trends and making informed decisions, as they provide up-to-date information and allow users to explore different aspects of the data. The choice between static and dynamic dashboards depends on the specific requirements of the user and the intended use of the data.

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Static dashboards are those that display data without the ability to update or change it in real-time. This type of dashboard is ideal for showing information that doesn't change frequently and is meant to be used as a reference.

Dynamic dashboards, on the other hand, are interactive and allow users to update the data displayed in real-time. This type of dashboard is ideal for monitoring data that changes frequently and for tracking progress towards specific goals.

In a deeper level, widgets such as sortable tabular data, heat maps, radar charts, line charts, etc. are chosen for their ability to display data in an intuitive and easily understandable format, and to highlight trends, patterns, and anomalies in the data.

The benefits of using dashboards in building efficiency improvement include the ability to:

- Quickly identify trends, patterns, and anomalies in the data.
- Display data in an easily understandable format.
- Monitor progress towards specific goals.
- Make data-driven decisions.
- Enhance communication and collaboration among energy team members.
- Provide a centralized and consistent source of information.

These items are described more in detail in the section 5, particularly concerning their specific purposes, but a general list of the items is: a) lines, b) tables and summary tables, c) bars, d) radars, e) maps and f) heat maps. Each of them has been selected for a reason to build informative and comprehensive dashboards, here the advantages and disadvantages for each of them.

Advantages and disadvantages of graphical representations:

- Lines:
    - Advantages:
        - Clearly show trend and change over time.
        - Easy to understand and compare.
        - Acceptable for large data sets.
    - Disadvantages:

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- Can be difficult to identify individual points.
- Can be misleading if axes are not scaled correctly.

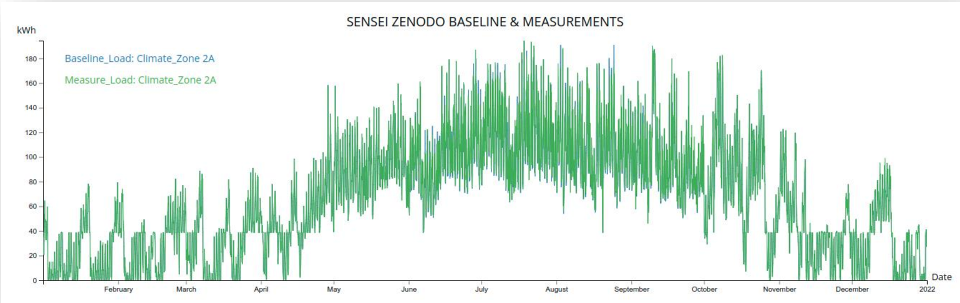

Figure 25: Example of line chart

- Tables:
  - Advantages:
    - Easy to read and compare. Particularly adding sorting and fetching capabilities.
    - Allow accurate detail to be seen if well designed.
    - Suitable for comparing numerical values.
  - Disadvantages:
    - Can be overwhelming if there is a lot of data.
    - Can be difficult to visualize trends and patterns.

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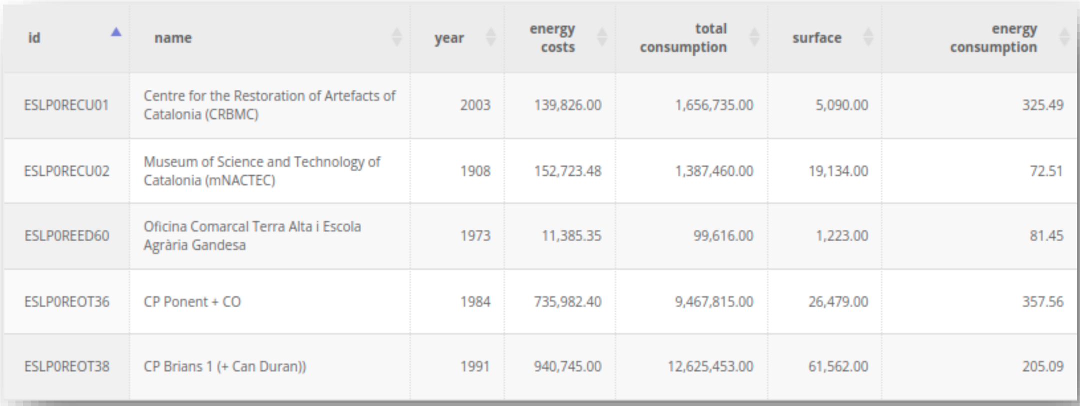

id	name	year	energy costs	total consumption	surface	energy consumption
ESLPORECU01	Centre for the Restoration of Artefacts of Catalonia (CRBMC)	2003	139,826.00	1,656,735.00	5,090.00	325.49
ESLPORECU02	Museum of Science and Technology of Catalonia (mNACTEC)	1908	152,723.48	1,387,460.00	19,134.00	72.51
ESLPOREED60	Oficina Comarcal Terra Alta i Escola Agrària Gandesa	1973	11,385.35	99,616.00	1,223.00	81.45
ESLPOREOT36	CP Ponent + CO	1984	735,982.40	9,467,815.00	26,479.00	357.56
ESLPOREOT38	CP Brians 1 (+ Can Duran))	1991	940,745.00	12,625,453.00	61,562.00	205.09

Figure 26: Example of table chart

- Bars:
    - Advantages:
        - Easy to read and compare.
        - Useful for comparing categories. In this case they will serve the comparison between buildings.
    - Disadvantages:
        - Can be misleading if axes are not scaled correctly.
        - Can be difficult to compare accurate values.

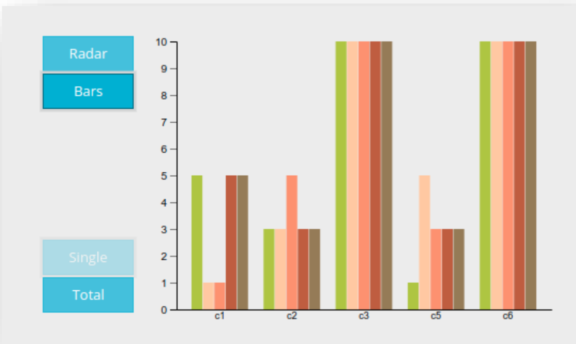

Figure 27: Example of bar chart

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- Radars:
  - Advantages:
    - Useful for comparing multiple dimensions in a single chart.
  - Disadvantages:
    - Can be difficult to understand and read for some users.
    - Not effective for showing trends over time.

Figure 28. Example of radar chart

- Maps:
  - Advantages:
    - Clearly show geographic location of data.
    - Useful for comparing specific regions and areas.
    - Easy to understand and compare.
  - Disadvantages:
    - Can be difficult to read if there is a lot of detail on the map.
    - May require more geographic knowledge to understand the data.

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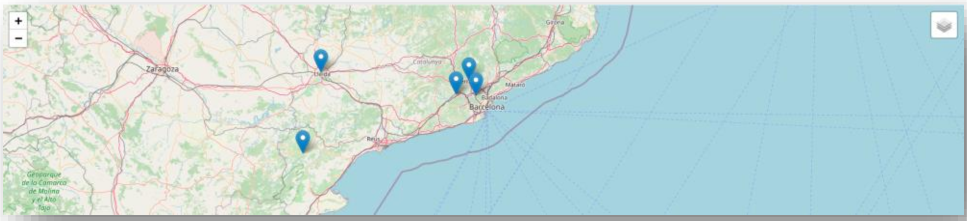

Figure 29: Example of map

- Heat maps
    - Advantages of Heat Maps:
        - Visually appealing and easy to understand.
        - Show dense data in a compact form.
        - Highlight patterns and trends in the data.
        - Useful for comparing multiple variables at once.
    - Disadvantages:
        - May not be suitable for representing complex data.
        - Can be hard to interpret for large data sets.
        - Lack of precision in individual data points
        - May be misleading if the data is not properly scaled or coloured.

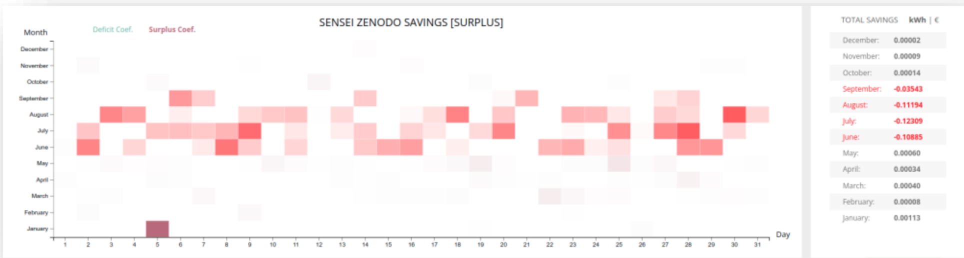

Figure 30: Example of heat map chart with linked summary table

In case of the dashboards, attention has been paid to connecting elements by making them interactive, meaning hovering over different elements highlights related data or elements that assist in understanding the selected data.

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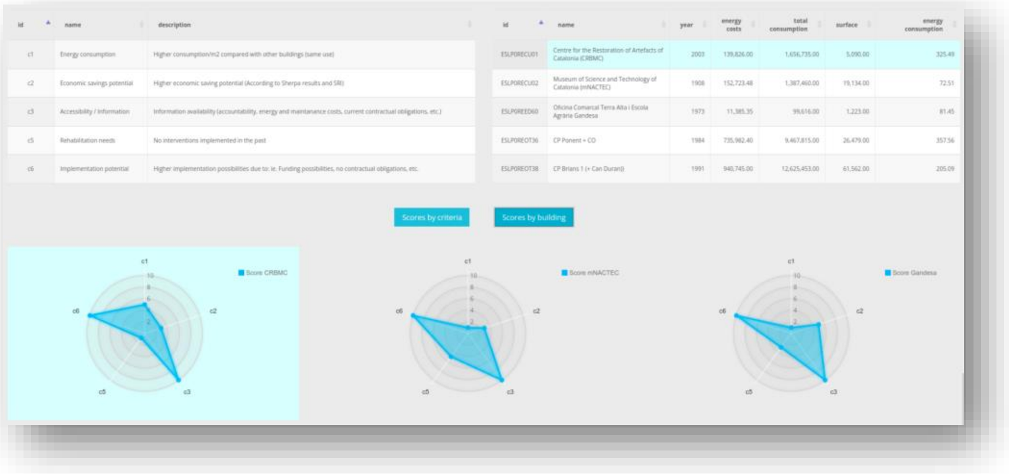

Figure 31: Interrelated charts

As for the technological aspects of the tools, d3.js (Data-Driven Documents) is a JavaScript library for creating interactive data visualizations for the web. It uses HTML, CSS, and SVG to dynamically update the visualizations, if needed. It's known for its manipulation capabilities – low-level prone- and ability to bind data to elements in the document, enabling highly customizable visualizations. Some popular use cases include bar charts, line graphs, pie charts, scatter plots, and more. It's also designed to be extensible, allowing developers to create complex visualizations by building on the basic components provided by the library, which is the case of radar.js employed. d3.js is a popular choice for data visualization due to its versatility, performance, and compatibility with modern web technologies. DataTables is a library for creating dynamic and interactive tables on websites. It is a highly-flexible library that makes it easy to add advanced functionality to HTML tables. DataTables provides built-in support for searching, ordering, pagination and more, making it ideal for complex data management tasks. Additionally, it supports a variety of data sources including arrays, Ajax calls and server-side processing, allowing it to easily work with a wide range of data sets. The library is also highly customizable, with a range of options available for styling and customization to suit different design requirements. Finally, plain Vanilla JavaScript code has been used to develop the base to all former charts and trigger the events needed to make visualizations interactive. Finally, regarding maps generation, Leaflet is an open-source JavaScript library for interactive maps, while OpenStreetMap (OSM) is a free, editable map of the world. When combined, Leaflet and OpenStreetMap allow developers to create and customize maps with various features such as markers, popups, and different map tiles. This combination is used to create interactive web maps for various purposes, such as displaying location data, building listings, or weather

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information. Leaflet provides an API for accessing and styling the maps, while OSM provides the underlying map data, making it possible to create rich, highly customized maps for several applications.

7 SENSEI web-based demos

To this end, please refer to document D7.2, *Web-based demonstrations of the SENSEI model tools (reference guide)*, where the web tools and interactions are thoroughly explained. Basically, the interaction with the SENSEI smart services is described from a final user perspective. It covers topics such as logging in the platform, navigating to the resources and exploiting them, with a graphical description of what to expect.

8 Conclusions

In conclusion, this document has provided a comprehensive overview of the platform, from a functional view to a detailed examination of the technologies used in its development. Additionally, a thorough description of the visualization methods employed has been presented, offering deeper insights into how the platform operates. By presenting this information, it is clear that the platform has been carefully designed to provide a high-quality, smooth user experience. The document also highlights the inputs to outputs process and described the different components involved. This information showcases the platform ability to effectively process data and deliver the desired outcomes, helping to understand how it is a tool for enhancing building efficiency.

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