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PLATOON

Digital platform and analytic tools for energy

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V2 Large Scale Pilot implementation strategy and validation plan

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Abstract:	The present document is the second version of the deliverable describing the work carried out within the Task 6.1. Considering the business cases defined in WP1 and the specificities of each pilot site, this task defines the detailed implementation and validation plan for each LSP, where specific reference implementations of the PLATOON architecture will be instantiated, and specific data analytical tools will be demonstrated on each local site and within the local context. An implementation plan is drafted for each location to break the strategy into identifiable steps that will ensure a timely start and completion of each pilot activity. A common framework is initially defined and then used across all locations. An initial monitoring plan and set of Key Performance Indicators (KPIs) is identified as part of the Validation Plan, and during this task the baselines values will be clearly measured. The validation plan has a specific chapter for the validation of each component of the PLATOON architecture, with special emphasis on the interoperability, governance and data security components, Edge Computing and Real Time Processing solutions or Big Data Collection (if applies to pilots), as well as the features of the Data Analytics Toolbox.
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V0.6	22/12/2020	Document total structure review and updates, update 4a,3C,2b requirements	ENGIE
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Executive Summary

This deliverable lies under the scope of work package WP6 - Large Scale Pilot Implementation and Validation. Its content is based on the work of the Task 6.1 -Implementation & Validation Plan led by ENGIE. The present document is the second version of the deliverable describing the work carried out within the Task 6.1. The deliverable has been divided into two main parts:

The first part of this document covers the main steps and actions planned to allow a smooth and successful implementation of each Pilot, where specific reference implementations of the PLATOON architecture will be instantiated, and specific data analytical tools will be demonstrated on each local site and within the local context. To achieve these objectives, an Implementation Plan is presented here for each low-level use case (identified in WP1) and demonstrator, addressing functional requirements, the provider of each component and the implementation timeline.

The second part of this document covers a validation test plan for each component that will be implemented in the Pilots, with special emphasis on the Interoperability, Governance and Data Security components, Edge Computing and Real Time Processing solutions or Big Data Collection (if applies to pilots), as well as the features of the Data Analytics Toolbox.

This plan will help the pilot owners and the project partners to minimize the risks involved in the implementation in their pilot-compliant component and to assure a correct functionality and operability.

The implementation and validation plan, described in this deliverable, depends strongly on the results of different work packages, namely:

- WP1 - Energy System Management Challenges
- WP2 - Reference Architecture, Interoperability and Standardization
- WP3 - Data Governance, Security and Privacy
- WP4 - Analytical Toolboxes

The outcomes of these WPs are crucial for the implementation preparation of the implementation related to all PLATOON Pilots. The business cases defined in WP1 and the specificities of each pilot was the base line of the Implementation and Validation Plan. The Reference Architecture and specifications and associated components to be implemented within the context of each pilot were provided by the tasks carried out in WP2. The data governance framework that ensures data security and respects data privacy and sovereignty were provided by the work conducted in WP3. Consequently, WP4 has developed the analytical toolbox component of the PLATOON platform formed by both generic big data tools and energy specific analytical tools for different application related to Pilot objectives. The interactions between the WP6 PLATOON Pilots and the PLATOON Technical Core were an important key to fulfil the requirements of each demonstrator and to define the compliance of each component of the PLATOON Reference Architecture with each demonstrator.

Table of Contents

List of Tables

List of Figures

Terms and abbreviations

B2B	back-to-back
BESS	Battery Energy Storage System
BMS	Building Management System
BtM	Behind the Meter
CHP	Combined Heat and Power
DER	Producers from distributed and renewable sources
E-Bike	electric bikes
EC	Energy Consumptions
EV	Electric Vehicles
FN	False negative
FP	False positive
HMI	Human Machine Interface
HVAC	Heating, Ventilation and Air-Conditioning
HyESS	Hydrogen hybrid Energy Storage System
IPP	Independent producers
LMC	Laboratory of Micro-Cogeneration
MC	Master Controller
NTL	Non-technical losses
NZEB	Non- zero energy building
PC	Power Centers
PV	Photo voltaic
RES	Renewable energy source
SCADA	Supervisory Control and Data Acquisition
sqm	Square meters
TN	True negative
TP	True positive

Part I: Implementation Plan

1. Introduction

While the use case definition is completed in WP1 and while the PLATOON reference architecture, its different layers and their specifications are being elaborated in WP2, the basis for secure data sharing is being identified in WP3 and the PLATOON data analytical toolbox is being designed and developed within the activities of WP4. During T6.1-Large Scale Pilot Implementation and Validation Plan First Phase (M06 - M12), the PLATOON consortium initiated the implementation of the innovative tools, and services to be offered by the PLATOON reference architecture defined in D2.1 - PLATOON Reference Architecture**. Figure 1** below shows the main building blocks of PLATOON platform and their relations.

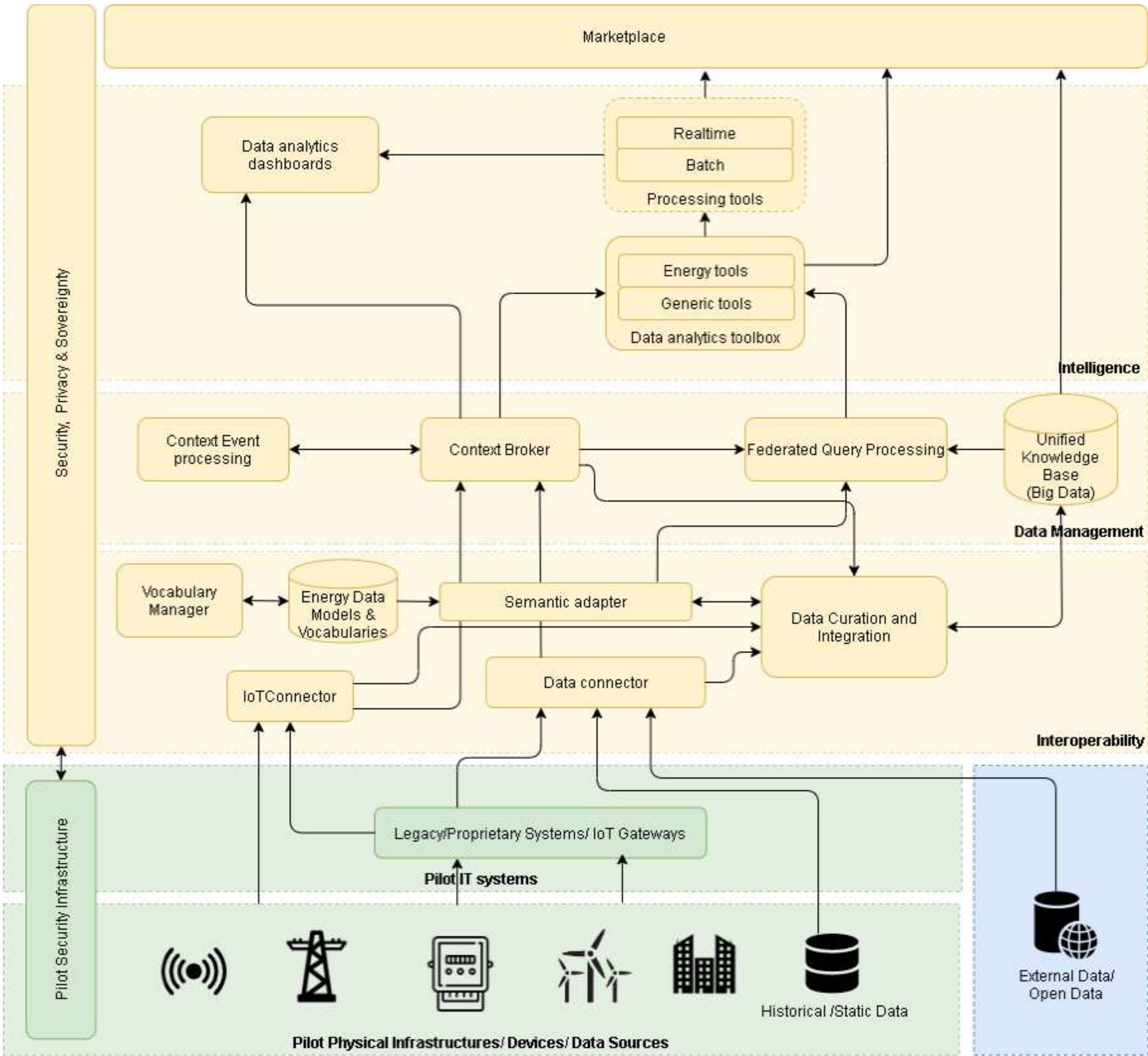


Figure 1: PLATOON Reference Architecture

PLATOON T6.1 Large Scale Pilot Implementation and Validation Plan is considered of major importance, since it really integrates all projects dimensions.

The implementation perspectives regarding interoperability, data governance and data security components, Edge Computing and Real Time Processing solutions or Big Data Collection, as well as the features of the Data Analytics Toolbox are described in the next sections aiming a smooth and successful implementation of the Pilots at their respective locations for the next twelve months of the project, also assuring that the implementation results will be measurable and fitting the expected outcomes.

Reminding the PLATOON objectives:

- To enhance the role of the energy sector stakeholders to let them reliably, fairly, and securely extract knowledge from their own data.
- To foster new business models in the energy sector using digital technologies.
- To enhance the multi-party cooperation between technology providers and data owners.
- To contribute to standardization of the energy management systems by assessing whether current standards offer the proper roles interfaces to enable business processes, including new ones and identify where new standards may be needed.

To achieve these objectives, PLATOON will be demonstrated in seven pilots in five different countries and implemented in 19 different low level use cases as depicted in the next figure (from D1.1).

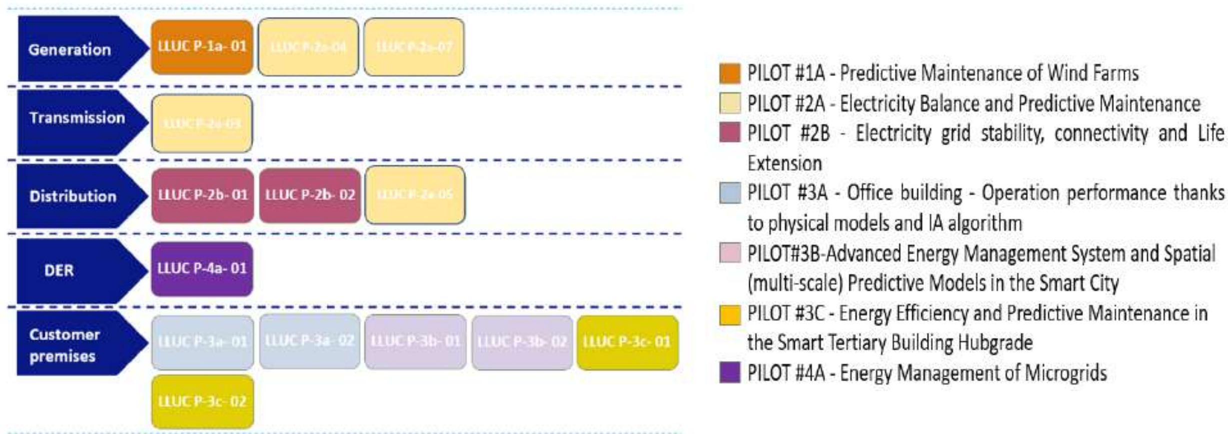


Figure 2: PLATOON's LLUC Classification according to SGAM – Domains from D1.1

2. Methodology and Work Process

The PLATOON Implementation Plan described in this document has the main objective to achieve the demonstration conditions for each pilot and build a big data platform for each large-scale demonstration based on the reference architecture on the one hand and to guarantee that the results are measurable and comparable on the other hand, enabling effective tests and evaluations using the KPIs defined in section 2.1 of PLATOON GA.

In this sense, the general objectives of the implementation methodology are the following:

- Promote discussion between PLATOON Technical Core (WP2-WP3-WP4-WP5 leaders) and Pilot Teams to discuss specific PLATOON components implementation.

- Have a detailed Implementation Plan for each Pilot considering the LLUC defined in WP1 to:

    a. Instantiate specific reference implementations of the Platoon architecture on each demonstrator.
    b. Demonstrate specific data analytical toolbox on each local site and within the local context.

- Determine strategy steps addressing implementation objectives to ensure a timely start and completion of each pilot activity.
- Specify a monitoring plan for each KPI to be measured.
- Detail a Validation Plan (detailed in Chapter II) of each component of PLATOON Architecture: The Interoperability, Governance and Data Security components, Edge Computing and Real Time Processing solutions or Big Data Collection (if it applies to the considered Pilots).

Having the objectives identified, the proposed implementation methodology has been divided into four main steps, as next described:

1. **Preparation Phase**
    - Review and update if needed the requirements of each use cases targeting Pilot's conditions defined in WP1-D1.1.
    - Determine concerns and risks from Pilots' leaders and T6.1 participants regarding pilot implementation.
    - Issue of Pilot preparation template to characterize implementation requirements and concerns from the partners, having as final objectives to anticipate risks and capability needs and clarify concepts and ideas.

2. **Condition Definition Phase**
    - Organize workshops with PLATOON Technical Core (WP2-WP3-WP4-WP5 leaders) and Pilot Teams to discuss specific PLATOON components implementation. This first step was undertaken in two separate workshops.

3. Pilot-Specific Workshop Part 01

This interaction was among the Pilot Leaders, Pilot Participants and PLATOON Technical Core Leaders (WP2-WP3-WP4-WP5 leaders) to:

- Clarify concepts, ideas and identify any concerns around the Pilot and its objectives.
- Promote discussions for each dedicated workshop. These discussions will help to describe the Pilot from functional and technical point of view.
- Focus on the Implementation & Validation plan for the considered Pilot.

- Clarify the implementation of the specific PLATOON architectural components for the specific pilot, the information to be provided by the Pilots to the PLATOON Technical Core and the expected from each of them to fulfil the Pilot's UCs goals.

The table below contains the Pilot-Specific Workshop - Part01 Planning (2020)

#	Date	Start	End	
1	Wednesday, October 7 2020	9:00	11:00	Pilot 1a
2	Thursday, October 8 2020	10:00	12:00	Pilot 2b
3	Thursday, October 8 2020	14:00	16:00	Pilot 3c
4	Wednesday, October 14 2020	10:00	12:00	Pilot 4a
5	Wednesday, October 14 2020	14:00	16:00	Pilot 2a
6	Thursday, October 15 2020	9:00	11:00	Pilot 3b
7	Friday, October 16 2020	10:00	12:00	Pilot 3a

Table 1: Pilot-Specific Workshop Part 01 Planning

4. Pilot-Specific Workshop Part 02

This interaction was among the Pilot Leaders, Pilot Participants and PLATOON Technical Core Leaders (WP2-WP3-WP4-WP5 leaders) to:

- Provide technical feedback from the perspective of WP2, WP3, WP4, WP5 to the pilot owners regarding the results of the first workshop.
- Identify PLATOON pilot- compliant components.
- Define the requirements related to the implementation of each of this component as well as their provider.
- Define implementation timeline where possible: For this second part of the pilot's specific workshops, an updated implementation template has been used to comply with the workshop objectives.
- Issue of a final implementation plan template, to be used as an interaction tool by each pilot leader and component provider to update implementation conditions and refine timeline if needed.

The table below contains the pilot's specific workshop-02 planning.

#	Date	Start	End	
1	Wednesday, November 18 2020	14:00	16:00	Pilot 1a
2	Thursday, November 19 2020	14:00	16:00	Pilot 3c
3	Friday, November 20 2020	9:00	11:00	Pilot 4a
4	Friday, November 20 2020	14:00	16:00	Pilot 3b (ROM)
5	Wednesday, November 25 2020	14:00	16:00	Pilot 2a
6	Thursday, November 26 2020	9:00	11:00	Pilot 3a
7	Thursday, November 26 2020	13:00	15:00	Pilot 2b
8	Friday, November 27 2020	10:00	12:00	Pilot 3b (PI)

Table 2: Pilot-Specific Workshop Part 02 Planning

5. Implementation Workshop

After the pilot specific workshops and once the technical partners had identified the pilot requirements, several implementation workshops were held. The workshops were led by technical partners from WP2-4 with the objective of.

- Provide corresponding training to the pilot owners and solve questions on how to implement the corresponding components developed in WP2, WP3, WP4.
- Get feedback from pilot owners to further improve the components developed in WP2, WP3 and WP4.

The table below contains the pilot's specific workshop-02 planning.

#	Date	Start	End	WP
1	Thursday, April 22nd 2021	13:00	15:00	WP4-Data Analytics Toolbox
2	Wednesday, May 12th 2021	11:00	13:00	WP3-IDS-Part 1
3	Monday, June 14th 2021	11:00	12:00	WP2-Semantic pipeline
4	Thursday, October 21st 2021	09:00	12:30	WP3-IDS-Part 2

Table 3: Implementation Workshops Planning

6. **Commitment Phase**

- The list of KPIs, previously defined in WP1, was issued, to be confirmed or not, for future measurement and evaluations defined in PLATOON GA, by each Pilot Leader.
- The KPI template was issued for Pilot Leaders to fill it for each of the KPI above confirmed.
- The level of agreement between the Pilot Leaders and technology providers on requirements of the equipment/software tools was not total in some cases.
- Each Pilot implementation timeline, equipment and resources constraints were done, and alternatives were proposed when needed.
- First valuation of implementation risks was made.

7. **Validation Phase (detailed in Part II of the present document)**

- Description of each component to test and its main functionalities.
- High-level testing approach that defines the validation methods to be used.
- Explanation of the test protocol, which constitutes a pass/fail criterion, test setup and test program.
- Issue of Pilot Full Validation Plan template.

The outputs of Task 6.1, illustrated in the figures below, translates its evolution along the four mentioned phases along the task lifetime (M06-M24).

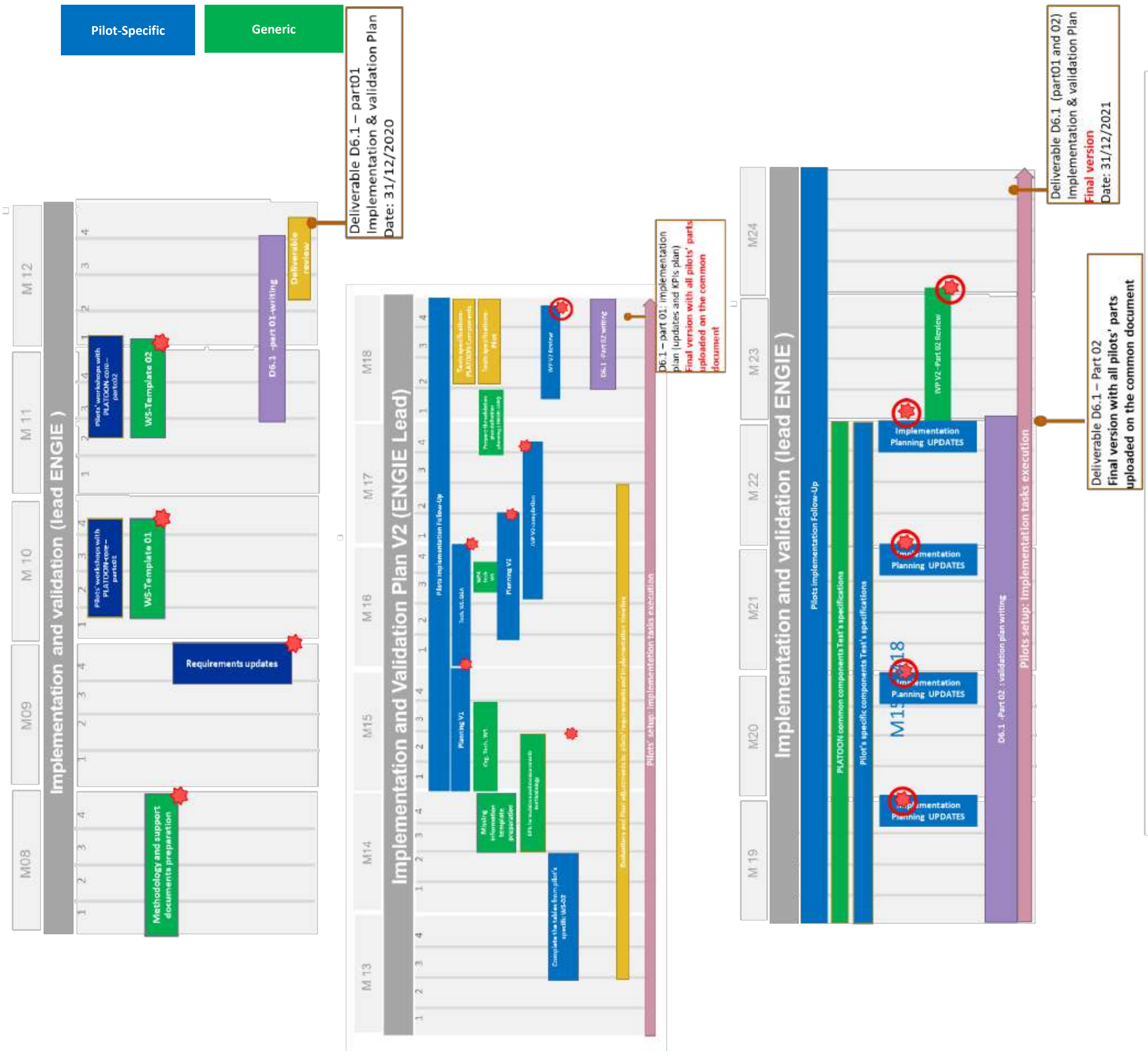


Figure 3: Implementation Methodology

3. Pilot-Specific Implementation Plan

3.1. Pilot 1a Predictive Maintenance of Wind Farms

3.1.1. Pilot Characterization

3.1.1.1. General Characterization of Pilot 1a

Scope

This pilot targets one aspect of the energy domain: predictive maintenance of wind turbines. In the last decade, there has been an extensive increase in the share of renewable energy sources in the overall electricity mix. As such it is important to have predictability about the availability of these renewable energy sources since there is increasing dependency in the grid on their availability. Gaining better insights in the chances of failure for the wind turbines in the fleet is a key aspect in this regard. At the same time can predictive maintenance reduce the cost of energy from wind to help the EU in its target to increase the contribution of renewable energy sources.

This pilot focuses on this societal challenge. It makes use of fleet data from many wind turbines to diagnose failures by pinpointing to the specific failure mode responsible for the failure. The main data streams that are used in this pilot are data streams that are typically standardly available for wind turbines (onshore and offshore): Supervisory Control and Data Acquisition (SCADA) data. This is timeseries data of sensors embedded in the turbine sampled by the SCADA system and aggregated to 10-minute averages. In addition, edge computing is used to locally aggregate and process high frequency measurements.

The use case at hand focusses on the predictive maintenance of wind turbine electrical drivetrain components: generator and power converter. The other subcomponents of the wind turbine are not in scope. A combination of data-driven and physics-based modelling is used.

Pilot objectives

This translates in the following objectives for the pilot:

a. Develop, implement, and validate accurate physical and data-driven models of the wind turbine electrical drivetrain components: generator and power converter.
b. Develop anomaly detection methods for identification of unhealthy behaviour of the components in scope.
c. Develop an approach to convert the identified anomalies towards health metrics to create a diagnostic tool.

d. Develop a methodology to reason on the anomalies detected by the different models to pinpoint the potential cause for the failure.

Pilot contributors
This pilot is coordinated by Vrije Universiteit Brussel (VUB) in participation with TECNALIA and ENGIE. University of Bonn is involved.

Related business cases
This pilot originates from clearly identified business cases for the different partners working in the pilot. The main business cases for this pilot are linked to the objectives of three partners:

1. **TECNALIA**: The objective of TECNALIA is to further enhance its physics-based digital twin and develop new data analytics tools for predictive maintenance for electrical drivetrain components (generator and power converter) to reduce maintenance costs and increase availability of wind turbines.
2. **ENGIE:** The objective of ENGIE is to increase availability and optimize maintenance of electrical drivetrain components of wind turbines in a fleet perspective. Physics-based models are expected to leverage the information that can be obtained from existing fleet data (e.g. SCADA tags, status logs) to enhance insight of the appearance and severity of failures or risks for failure initiation.
3. **VUB:** The main business case linked to this pilot is the development of end-to-end diagnostics tools for the detection and follow-up of electrical component failures. The unique aspect of the VUB approach is in the hybrid data-driven-physics based approach

3.1.1.2. General Characterization of Local Environment

The pilot focuses on wind turbines and will use datasets of different granularity. Two main data sources are used:

a. SCADA data coming from a part of the ENGIE fleet of turbines. This consists of historic datasets that are used. The data itself is continuously connected and updated in batches. This also includes status logs/ fault messages for the different systems.
b. High frequency measurements coming from targeted measurement campaigns on the turbine electrical components.

The details about the test objects and the data properties will be discussed in detail in the following section.

3.1.2. Overall Pilot Architecture

3.1.2.1. ICT Architecture and Model Flows

The overall ICT architecture of the pilot is shown in Figure 4. In general, it can be stated that ENGIE is the data provider and the technical expert party who interprets the outcome of the analytics models using domain knowledge. As such the data lake as well as the visualization and interpretation layer are at the ENGIE premises. VUB and TECNALIA provide data analytics modules. Each of these models can at a different physical location. The outcomes of the TECNALIA modelling approach will be provided to ENGIE directly and be used as inputs for the VUB modelling approach. The outcomes of the VUB modelling approach will be send to ENGIE. All data exchange will be facilitated using IDS connectors.

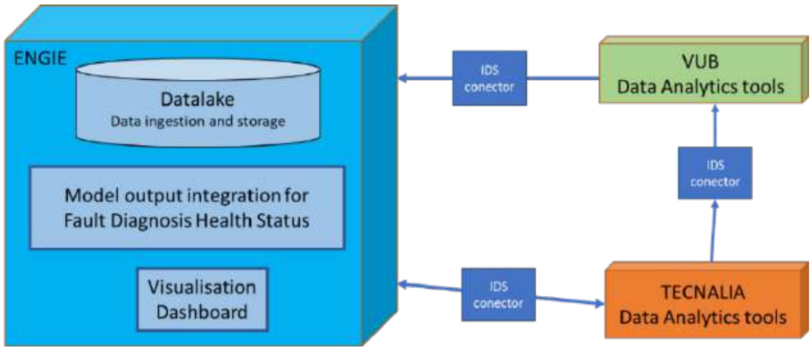


Figure 4: Pilot 1a Overview of the ICT Architecture

For one data source (high frequency current data) edge computing will be used to aggregate the data closely to the sensors. This will be done using the architecture shown in Figure 5.

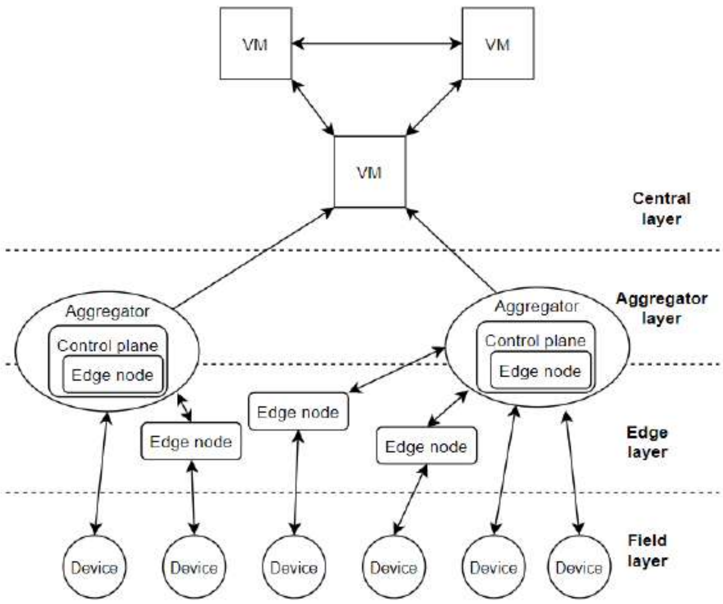


Figure 5: Pilot 1a Edge Computing Scenario for Aggregations of the High Frequency Sensor Data (VM stands for "Virtual Machine")

Pilot Data Processing Flow from an Architecture Point-of-View

This section provides a more detailed overview of the different components used in the overall data processing pipeline. First, the data is integrated and different datasets for the pilot are extracted, as shown in Figure 6. These data are stored at the ENGIE data lake.

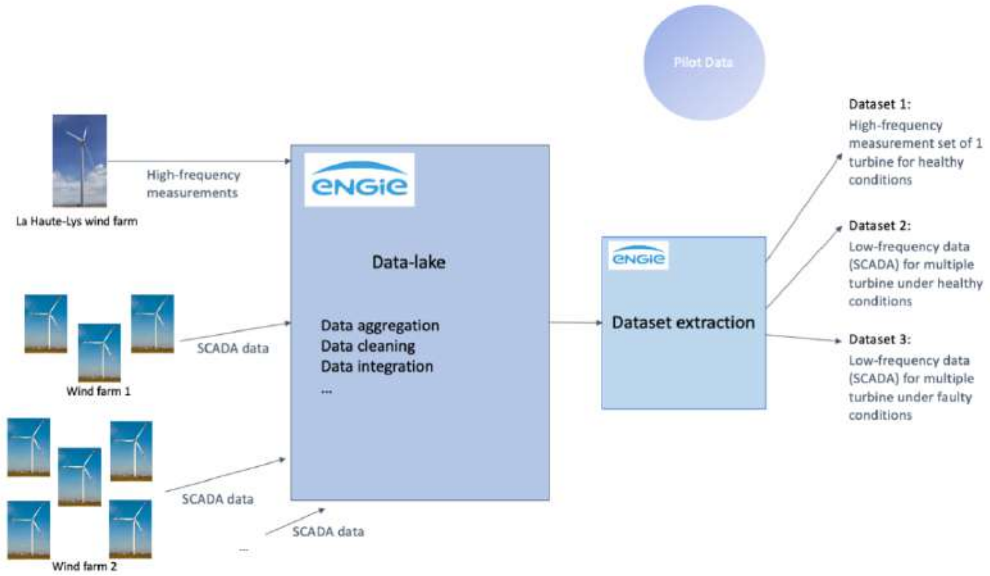


Figure 6: Pilot 1a Pilot Dataset Extraction

Different modelling approaches are integrated to detect abnormal behaviour, as shown in Figure 7. As previously mentioned, different modelling methods are used (digital twin based on physical model, data-driven healthy behaviour models). These are interacting towards fault isolation and diagnosis.

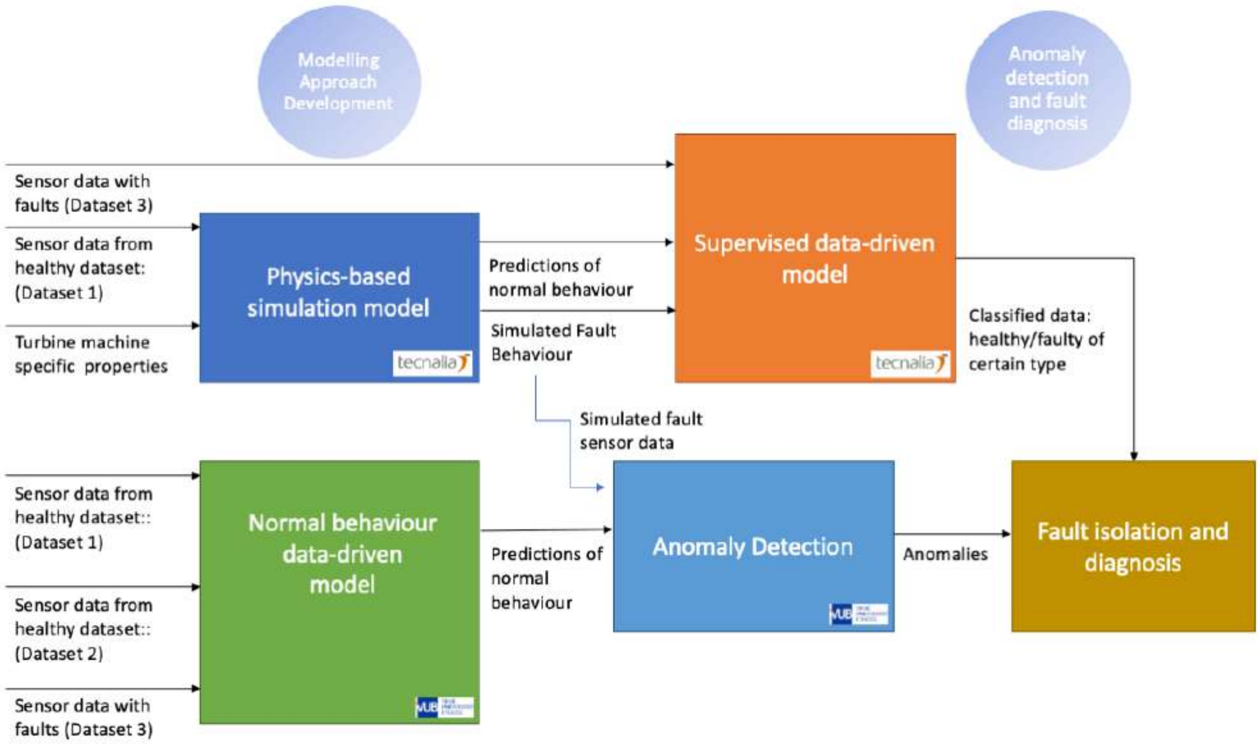


Figure 7: Pilot 1a Overview of Models and their Interaction

As shown in Figure 8, once the data is classified in normal and abnormal, we aim to assign each of these labels to a subcomponent of the turbine. We aim to do this for all sensor signals on which analysis was done. Anomaly reasoning is used to reason on these labels and assess the health for each subcomponent. This should result in a health label for each subcomponent of the wind turbine. This health label is then sent back to ENGIE for visualization on a dashboard.

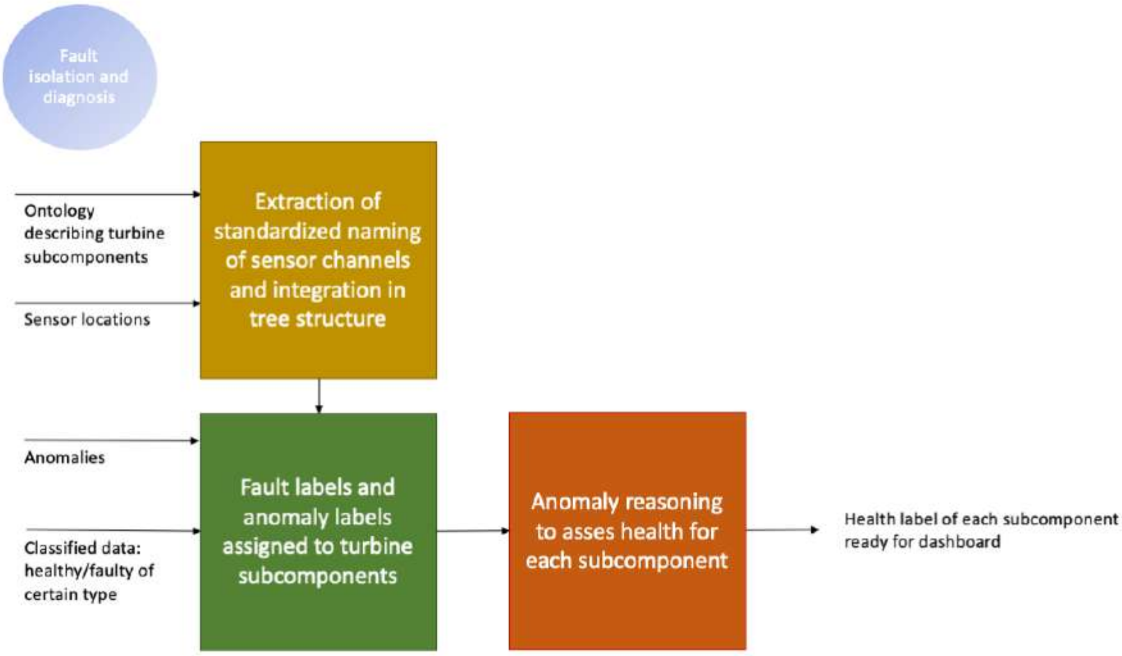


Figure 8: Pilot 1a Extraction of Health Information

3.1.2.2. Site Assessment and Existing Infrastructures

All analytics in this pilot will be done using operational data of the current fleet of wind turbines of ENGIE. In addition, data of measurement campaigns that were done in the past is used. If needed additional measurements will be conducted during the pilot phase of the project. Feasibility is currently being investigated.

Figure 10 and 11 show a setup that is used to acquire current measurements on the three phases of the generator. Chauvin Arnoux A130-80 current clamps are being connected around each phase. These clamps are based on the Rogowski coil principle and have a range from 0,5 A to 3000 A and are rated at CAT IV 1000 V. In turn these clamps are connected to the acquisition boards. These boards will sample the voltages generated by the clamps at a sampling rate of 64000 Hz. Afterwards, the samples are then transmitted over ethernet to an IMX8 board where they are stored. The power and ethernet are supplied via a PoE (Power over Ethernet) switch.

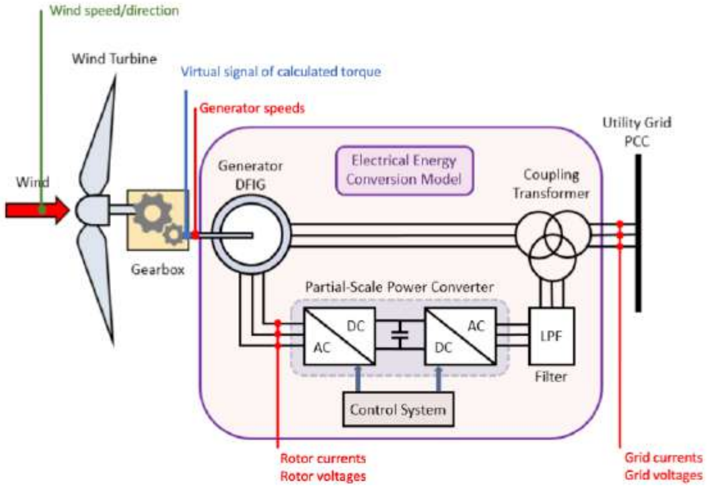


Figure 9: Turbine schematic with indication of electrical properties of the generator that were measured during the La Haute-Lys measurement campaign.

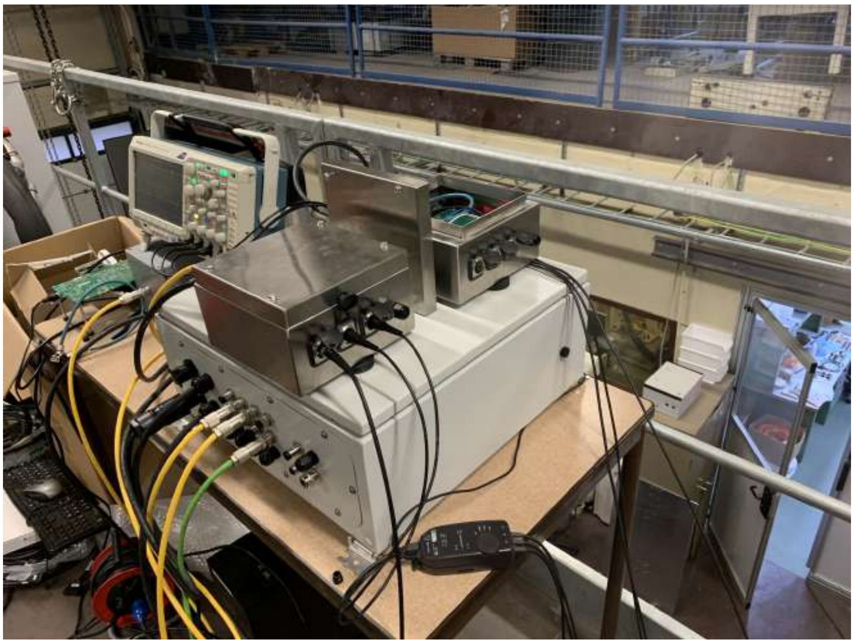


Figure 10: Picture of the setup that is used to acquire current measurements on the three phases of the generator.

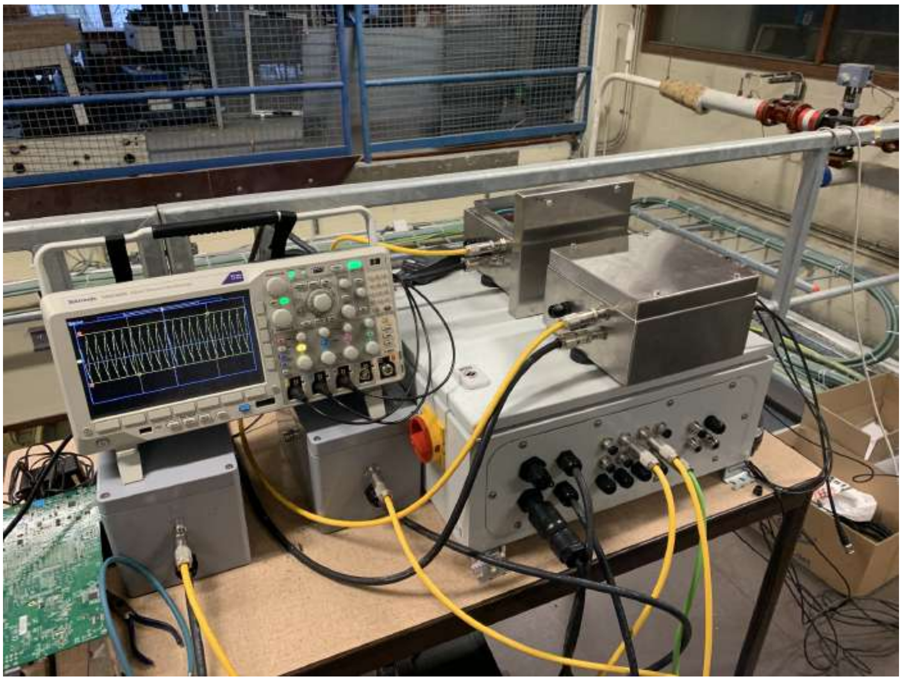


Figure 11: Picture of the setup that is used to acquire current measurements on the three phases of the generator.

3.1.3. Pilot 1A Requirements

Interoperability layer

Component /service	Provider	Demonstration requirements	Readiness *(if the requirements can be met on the pilot location)*	
			Yes	No
Data Connector	ENGIE	there is a basic scenario for a connection with a central repository for all wind data. It could be extended to a more complex scenario to connect directly to other databases. For VUB and TECN this will have no impact since the IDS connectors will be used. The basic scenario contains time series only which is non-semantic. In addition, there will an attempt to complete a potentially more complex scenario to use semantic data.	Already implemented for the basic scenario.	Not implemented for the more complex scenario with fully semantic data exchange.

		Two data connectors are identified: 3.6.1.1. Batch: SCADA datasets 3.6.1.2. Batch: High frequency measurement set of turbines.		
IoT Connector	-	Not required.	-	-
Data Curation and Integration	ENGIE and TIB	Basic scenario time series is non-semantic. In addition, we will try to put a potential more complex scenario exploiting semantic data.	For Basic scenario time series non-semantic.	For A complete a potential more complex scenario to use semantic data.
Semantic Adapter	ENGIE and TIB	Basic scenario: time series which is non-semantic. In addition, will try to put a potential more complex scenario to use with semantic data.	For Basic scenario time series non-semantic.	For a complete a potential more complex scenario to use semantic data.
Energy Data model (PLATOON Data models from T2.3)	ENGIE , VUB and TECN	For the interoperability. Also, it could be useful to use it for the data analytics.	For the interoperability.	Failure modes for the data analytics.
Vocabulary manager	TECN and IAIS	Regarding interoperability define 3 levels: • Raw data with IDS. • Semantic data with IDS. • Semantic data with IDS and used for Data Analytics. In this pilot we will target at least level 2.		Vocabulary manager is part of IDS vocabulary provider. This will be done in WP3. Not able to define now how this can be implemented with IDS vocab provider.

Table 4: Pilot 1a Interoperability Layer Requirements

Data Management Layer

Component /service	Provider	Demonstration requirements	Readiness *(if the requirements can be met on the pilot location)*	
			Yes	No
Unified Knowledge Base	ENGIE and TIB	Not consolidated on whether it is necessary		Not implemented yet.

Table 5: Pilot 1a Data Management Layer Requirements

Intelligence Layer

Component /service	Provider	Demonstration requirements	Readiness *(if the requirements can be met on the pilot location)*	
			Yes	No
Data Analytics Toolbox and Processing Tools	TECN and VUB	For sure implemented as a service but might consider as well to do a test on the infrastructure using dummy code.	Yes. We will use the Data Analytics Tool container defined in T4.1.	
Data Analytics Dashboard – Visualization	ENGIE	Visualization Dashboard to show outputs from data analytics tools from VUB and TECN.	A visualization dashboard is already available.	Need to be integrated with data analytics tools/storage.

Table 6: Pilot 1a Intelligence Layer Requirements

Marketplace

Component /service	Provider	Demonstration requirements	Readiness *(if the requirements can be met on the pilot location)*	
			Yes	No
Marketplace	IAIS	VUB and TECN will show metadata of proprietary tools in the marketplace. ENGIE – will show metadata for datasets and potentially also for apps/tools		No this will be developed as part of T3.4.

Table 7: Pilot 1a Marketplace Requirements

3.1.4. Equipment and System Specification

All data that is used in the pilot is collected using equipment that is either standard available in the wind turbine or the data was collected during historical measurement campaigns. In order to increase the available dataset even further, the installation of current probes in an additional test turbine is being planned. The goal of this measurement campaign is to perform edge computing tests and acquire an additional dataset to support the implementation of the pilot. The installation and measurement campaign are planned to be performed in January 2022.

3.1.5. Plan for Implementation of Pilot Services and Systems

The figure presented below covers the different stages concerning the implementation of the predictive maintenance for wind farm components previously identified in Table 1 to Table 04.

The plan is divided into 6 different stages of implementation, being (1) Data Availability, (2) Interoperability, (3) Data Management, (4) Data Security, Privacy and Sovereignty, (5) Intelligence and (6) Edge Computing. As shown here below, the bulk of the work is planned in 2021 Q1 and Q2, followed up by the last steps in 2022 Q1. Each of these stages and their respective tasks are detailed in the Implementation Template of Pilot 1A in Annex I.

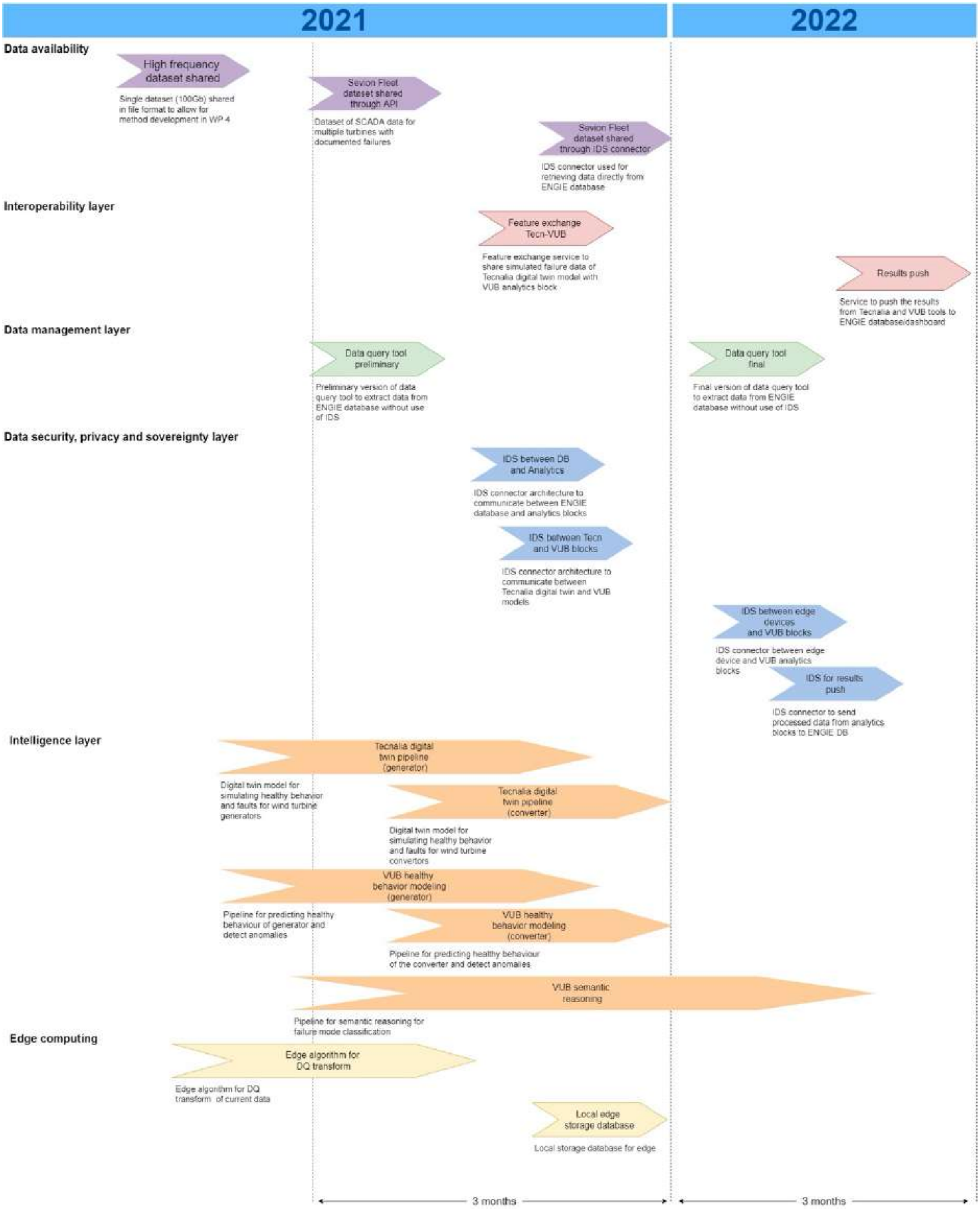


Figure 12: Components and Services to be Implemented under the Scope of Pilot 1a

3.2. Pilot 2a Electricity Balance and Predictive Maintenance

3.2.1. Pilot Characterization

3.2.1.1. General Characterization of Pilot 2a

Electricity balancing is a set of actions and processes performed by a TSO to ensure that total electricity withdrawals (including losses) equal total injections in a control area at any given moment. Electricity production from solar and wind plants is subject to considerable forecast errors that drive the demand for accurate forecasting of the production of electricity. At each point in time, total production, combined with interchange, i.e., export or import of energy from/to control area, must be equal to total consumption to stabilize system frequency and to maintain exchange at scheduled levels; it is therefore also called load-frequency control. If the system runs out of balance, power stability and quality will deteriorate, which may trigger the disconnection of system components, and ultimately, power blackouts.

In the future, independent producers (IPP) and producers from distributed and renewable sources (DER) will be actors in the balance reserve market. The increasing number of renewable energy resources such as photovoltaic and wind power plants has a significant impact on the stability and power quality of electricity transmission. Therefore, one of the goals of Pilot #2a is to develop and test PLATOON services for more accurate prediction of renewable energy generation as well as more accurate load forecast. In pilot #2a, we are also interested in the adoption of PLATOON analytical services for analysis of unexpected variations (voltage profile of the power system) before and after RES integration to the power system. Finally, in pilot #2a we are interested in monitoring and analyzing the output from the RES power plant for an asset management scenario.

3.2.1.2. General Characterization of Local Environment

PLATOON Pilot #2a will take place in Serbia, while the overall goal of the pilot is to integrate and deploy different PLATOON analytical services with the Institute Mihajlo Pupin (IMP), proprietary VIEW4 Supervisory control and data acquisition (system). The VIEW4 SCADA is deployed along the energy value chain in Serbia, for example, in the renewable energy source (RES). This is accomplished via transmission management of distribution and electricity dispatching. To better understand the needs, several different scenarios have been defined in the WP1 framework (please refer to document LLUC-2a). These scenarios refer to different Smart Grid domains, as follows:

- Market-related domain:
  - LLUC P-2a-01 Balancing on regional level;
  - LLUC P-2a-02 Balancing on country level, reserve/energy exchange process.
- Grid-related domains transmission, distribution, micro-grids:
- LLUC P-2a-03 Load/Demand forecasting.
- Resource-connected-to-the-Grid domains (Distributed Energy Resources):

- LLUC P-2a-04 RES forecasting;
- LLUC P-2a-05 RES effects on the Power System.
- Support functions domains (Asset Management):
  - LLUC P-2a-07 Predictive maintenance in RES power plants.
- Scenarios were originally prioritized in Task 1.1/Task 1.4 framework, as follows:
- High priority (LLUC P-2a- 03, LLUC P-2a-04, LLUC P-2a-07);
- Medium (LLUC P-2a-05);
- Low (LLUC P-2a-01 and LLUC P-2a-02).

At the very beginning of the project, LLUC P-2a-06 (Research Data Management) was defined to showcase how the process of storing and retrieval of artefacts (data models, external datasets, research results/outputs) can be managed with a CKAN repository. Because of the low priority, in the second project year, this scenario was omitted from further analysis and elaboration.

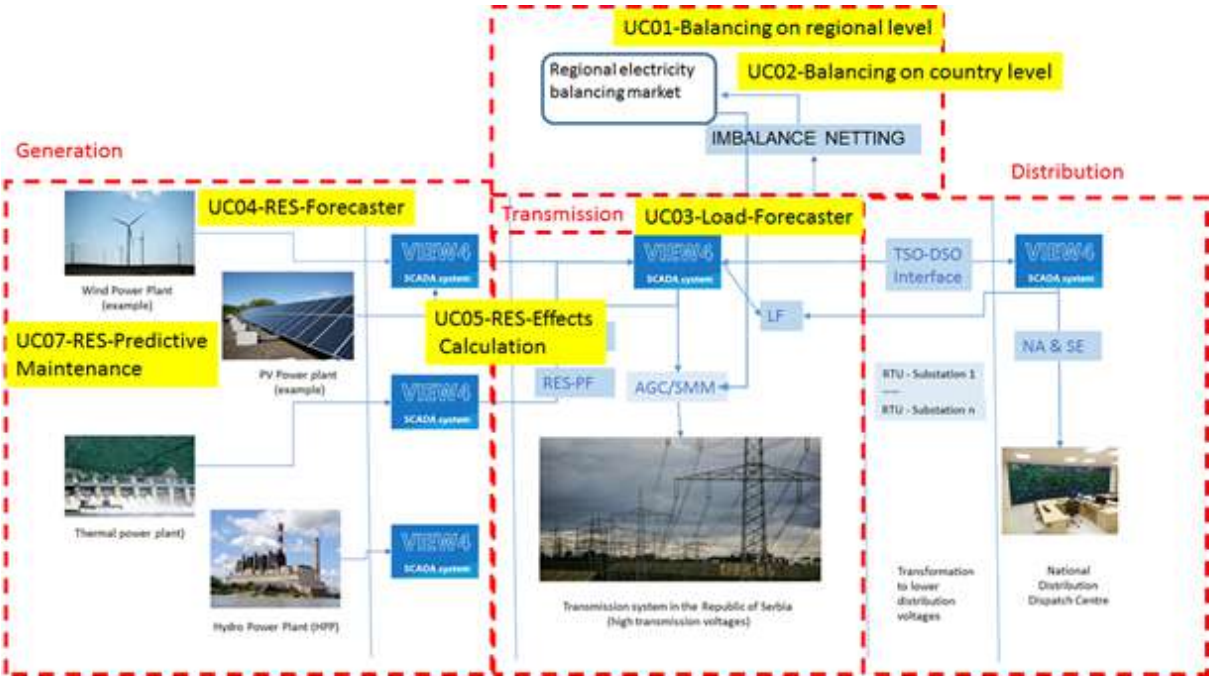


Figure 13: Pilot 2a Overview

3.2.2. Overall Pilot Architecture

3.2.2.1. Power Grid Architecture

As part of Pilot #2a, two different renewable power plants have been included:

1. A wind power plant located in Montenegro. It is connected to the grid monitored by the SCADA system. SCADA contains various telemetric data about production, generator state and current meteorological parameters. Therefore, to develop and integrated PLATOON platform in the Pilot #2a, connection with the SCADA system will be crucial.

2. A Photo-Voltaic (PV) plant, with 50 kWp capacity, located at the roof of the IMP. The produced electricity is directly fed into the grid, while the institute consumes its demands from the grid. In accordance with the Serbian regulation, the electricity from some sources can be either used locally (and not sold to grid) or vice versa. Since IMP is a privileged producer, it is more economically viable to sell the energy than to use it. This plant is, similarly to the previous one, controlled and monitored by the SCADA system, which contains extensive amount of data regarding the PV plant parameters, such as production, currents, voltages and measured meteorological parameters. Again, integration with the SCADA system will be crucial for PLATOON platform.

3.2.2.2. ICT Architecture

The vision of deployment of the PLATOON reference architecture in Pilot #2a scenarios is presented in Figure 14. It was designed as a six-layers structure, which as a combination covers all the LLUC belonging to Pilot #2a. The lowest layer is composed of a PMU and a units' inverter connected to the PV plant, located in the IMP campus. It is followed by the Pilot Edge Node Layer, which provides low-level edge computing analytics, such as RES Effect Calculator and Predictive Maintenance, which will be exploited as a part of LLUC 2a-05 and 2a-07. The following layers are for interoperability and control, enabling the collection and exchange of measurements and control action from various sources. Finally, a cloud platform, as a part of platform #2a at IMP, is the last layer and it contains analytical tools for LLUC 2a-03 and 2a-04 together with MySQL data, semantic data, and IDS connector.

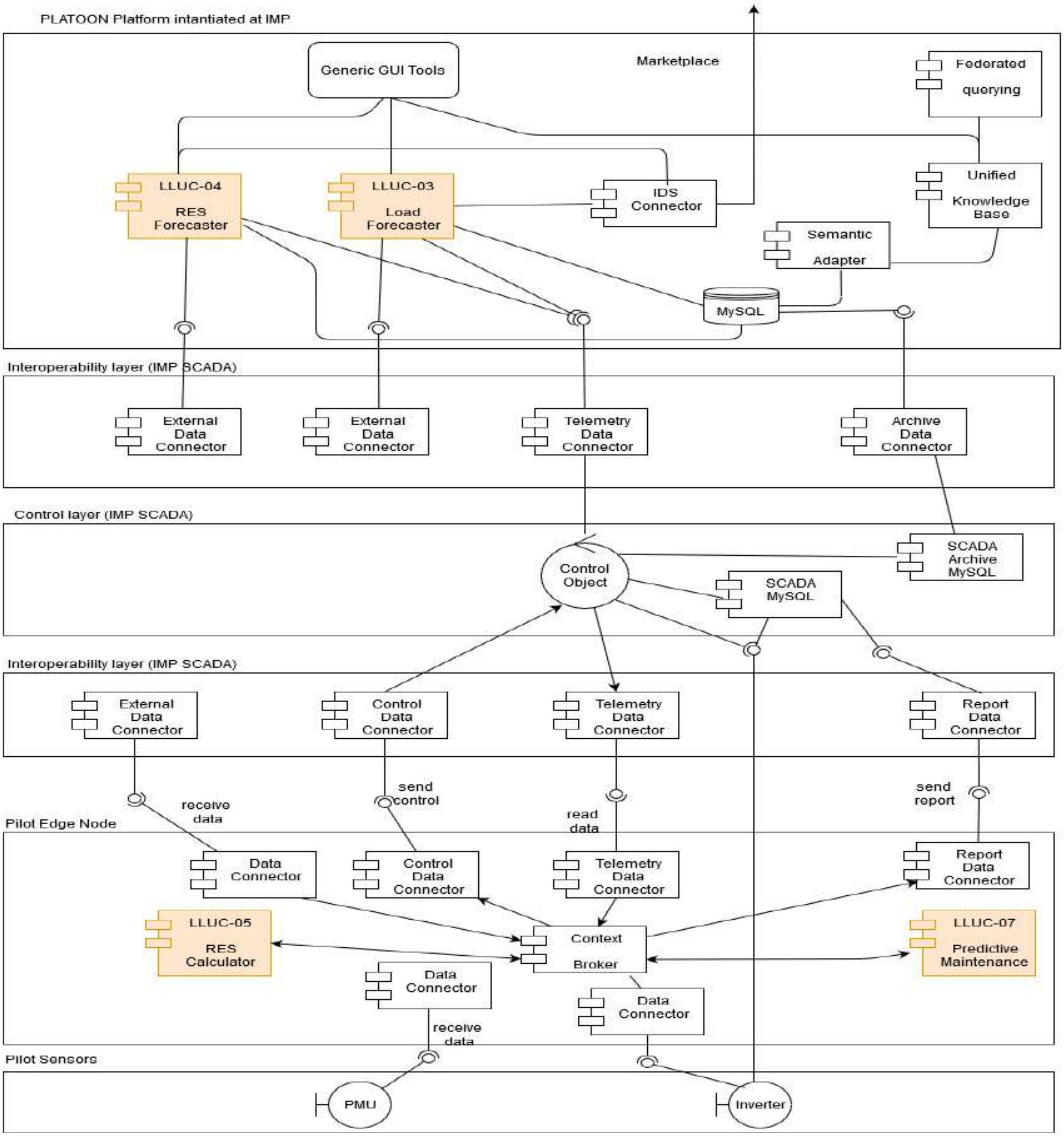


Figure 14: Pilot 2a ICT Architecture

LLUC 2a-03 and LLUC 2a-04

In Figure 15, a simplified version of the pilot architecture is given, specifically for LLUC 2a-03 and 2a-4. These LLUC will provide advanced analytics for the RES production forecast, specifically for wind energy, and for the load forecast on the country level. These models will have as basis the historical data stored in SCADA which contains production, demand and meteorological conditions and semantic data stored as a part of the unified knowledge base. According to the LLUC definitions and previously shown tables, these LLUCs will require the following components: Data Connector, Data Curation and Integration, Semantic Adapter, Federated Query Processing, Data Analytic Toolbox and Processing Tools and Marketplace.

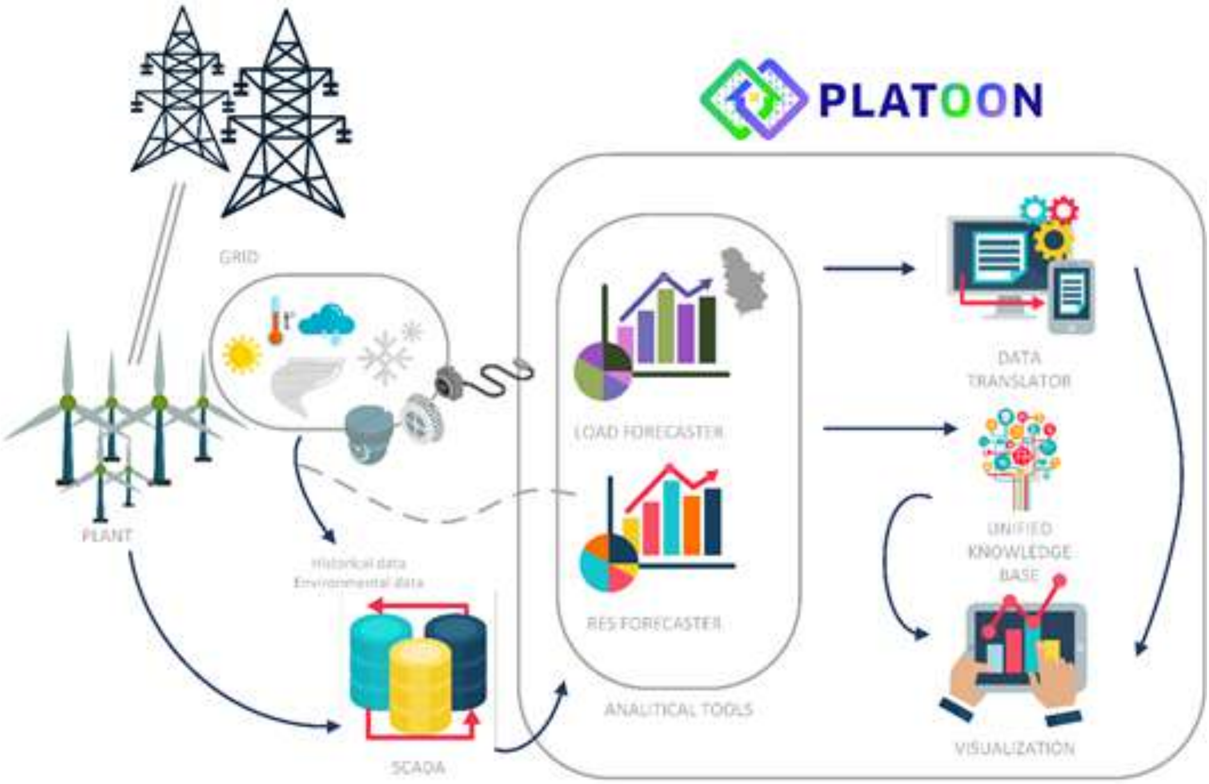


Figure 15: Pilot 2a LLUC 2a-03 and 2a-04 architecture

LLUC 2a-05 and LLUC 2a-07

In Figure 16, a simplified version of the pilot architecture is given, specifically for LLUC 2a-05 and 2a-7. These LLUC will provide low-level analytics on the edge, such RES Effects Calculator and Predictive Maintenance. These analytics will be provided using PMUs and by exploiting sensors measurements, collected by the SCADA system. According to previously shown tables, following development will be needed: Data Connector, IoT connector and Context Data Broker.

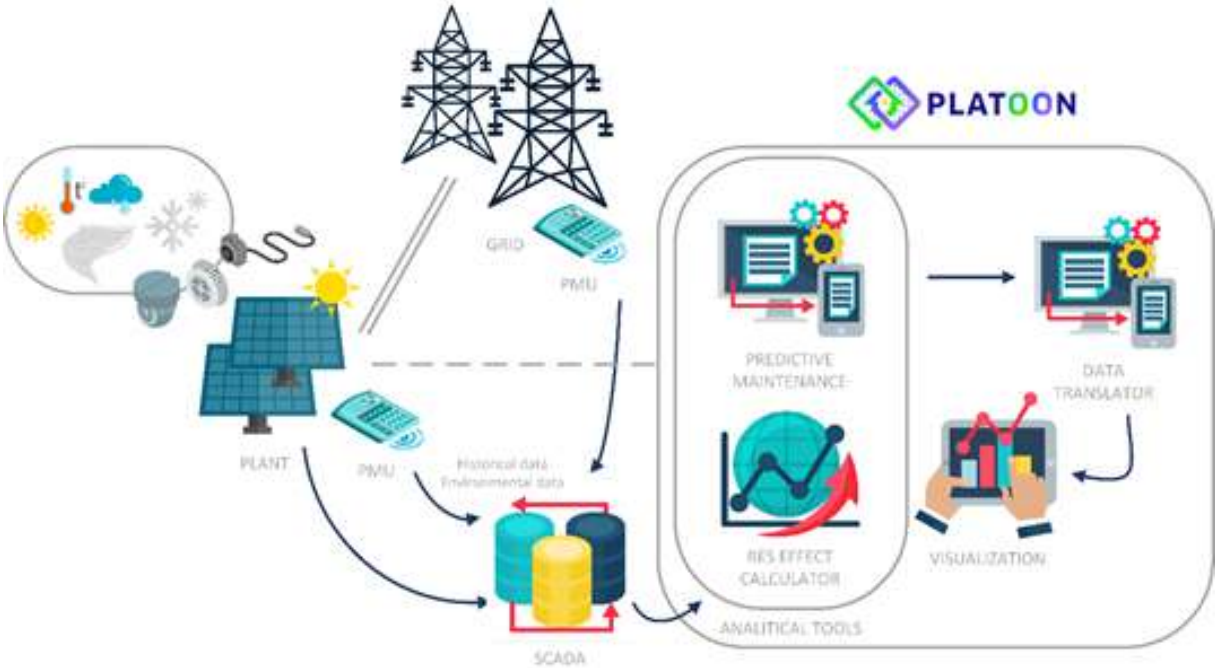


Figure 16: Pilot 2a LLUC 2a-05 and 2a-07 Architecture

3.2.3. Pilot 2a Requirements

Using the PLATOON methodology in the WP1 framework, the general requirements were identified and reported in Deliverable 1.1 *Business case definition, requirements and KPIs*. Herein, the requirements related to scenarios that will be tested in WP6 framework includes:

a. **LLUC P-2a-03 Demand Forecast on Transmission level**
b. **LLUC P-2a-04 RES (Wind Generation) Forecasters**
c. **LLUC P-2a-05 Effects of Renewable Energy Sources on the Power System (Distribution Level)**
d. **LLUC P-2a- 07 Predictive Maintenance in RES Power Plants**

The requirements within Pilot #2a are divided into four categories: Interoperability Layer, Data Management Layer, Intelligence Layer and Marketplace, as shown in Table 7, Table 8, Table 9 and Table 10, respectively.

Interoperability layer

Component /service	Provider	Demonstration requirements	Readiness *(if the requirements can be met on the pilot location)*	
			Yes	No
Data Connector	IMP	**Study mode:** non-semantic data. Time series data extracted from SCADA Archive and stored in MySQL server. **Operational mode:** Telemetry data connector for reading data from SCADA system.	**Operational mode:** SCADA – Platoon Platform connectors will be developed, which are relevant for LLUC-04. LLUC-05, LLUC-07.	
IoT Connector	CS/IMP	Yes		**Operational mode:** IMP SCADA – Edge Computer interfaces should be implemented for LLUC-05 and LLUC-07.
Data Curation and Integration	TIB/IMP	**Study mode:** useful for LLUC-03 and LLUC-04.		Semantic integration is mainly based on TIB-components, that will be installed on the Platoon Platform. Knowledge graph will be developed and uploaded.
Semantic Adapter	TIB	**Study mode:** Semantic Transformation for adapting pilot data to the semantic data model.		Tools (SDM RDFizer) will be provided by TIB.
Energy Data model (PLATOON Data models from T2.3)	ENGIE / IMP	**Study mode:** Consolidated Data Model.	**Study mode:** Consolidated data model will be used for advanced querying scenarios.	

Table 8: Pilot #2a Interoperability Layer Requirements

Data management layer

Component /service	Provider	Demonstration requirements	Readiness *(if the requirements can be met on the pilot location)*	
			Yes	No
Context Data Broker	CS	**Operational mode:** Needed in LLUC05 and LLUC07.		It will be demonstrated when edge computer (CS) development is ready.
Federated Query Processing	TIB	**Study mode:** useful for LLUC-03 and LLUC-04.		It will be demonstrate based on data in LLUC03 and LLUC-04.
Unified Knowledge Base	TIB	**Study mode:** Needed to host data from SCADA archives and open data collected from the Web. Could host the Consolidated Data Model and IMP specific vocabularies.		TIB will provide a Docker Compose images for all tools related to semantic integration.

Table 9: Pilot #2a Data Management Requirements

Intelligence layer

Component /service	Provider	Demonstration requirements	Readiness *(if the requirements can be met on the pilot location)*	
			Yes	No
Data Analytics Toolbox and Processing Tools	IMP	Four scenarios elaborated: **Study mode:** LLUC-03, 04 **Operational mode:** LLUC-05, 07	Data Analytics Tool container approach defined in T4.1, it will be used for LLUC 2a-03 and LLUC 2a-04.	
Data Analytics Dashboard – Visualization	IMP	UIs need to be integrated with data analytics tools/storage.	**Study/Operational mode: IMP** will develop custom dashboards and an open-source component in Task 4.6	

Table 10: Pilot #2a Intelligence Layer Requirements

Marketplace

Component /service	Provider	Demonstration requirements	Readiness *(if the requirements can be met on the pilot location)*	
			Yes	No
Marketplace	IAIS	Forecasters (LLUC-03, LLUC-04) might be registered on the marketplace.	Metadata will be provided in WP3 framework.	No this will be developed as part of T3.4.

Table 11: **Pilot #2a Marketplace Requirements**

3.2.4. Equipment and System Specification

3.2.4.1. Equipment – level

To fulfil the requirements given by the PLATOON project, within Pilot #2a a PMU will be installed for LLUC 2a-05 and 2a-07. Namely, it will be necessary to provide hardware architecture for edge computing able to perform analytical calculations regarding RES Effect and Predictive Maintenance. Apart from the PMUs and hardware which will be used for platform hosting, no additional hardware will be required, since the pilot is already equipped with various sensors.

3.2.4.2. System - level

The main part of the work will be placed on the development of the various software components which would provide a fully functional platform. As listed in the requirements section, various adapters for communication purposes will be developed, both for the edge and cloud sides of the platform. Additionally, sematic storage will be included together with relational data base which is a part of the SCADA system. Finally, analytical services will be developed, deployed, and integrated – cloud based for LLUC 2a-03 and 2a-04 and edge ones for 2a-05 and 2a-07.

3.2.5. Plan for the Implementation of Pilot Services and Systems

Figure 14, the expected timeline of the electricity balance and predictive maintenance solutions is shown. Furthermore, it covers the different categories concerning the implementation, presented in Table 8 to Table 11. The detailed implementation, from the first action (bringing the component into the pilot scope) until the test stage (ensuring the component is correctly installed), is shown in Annex I.

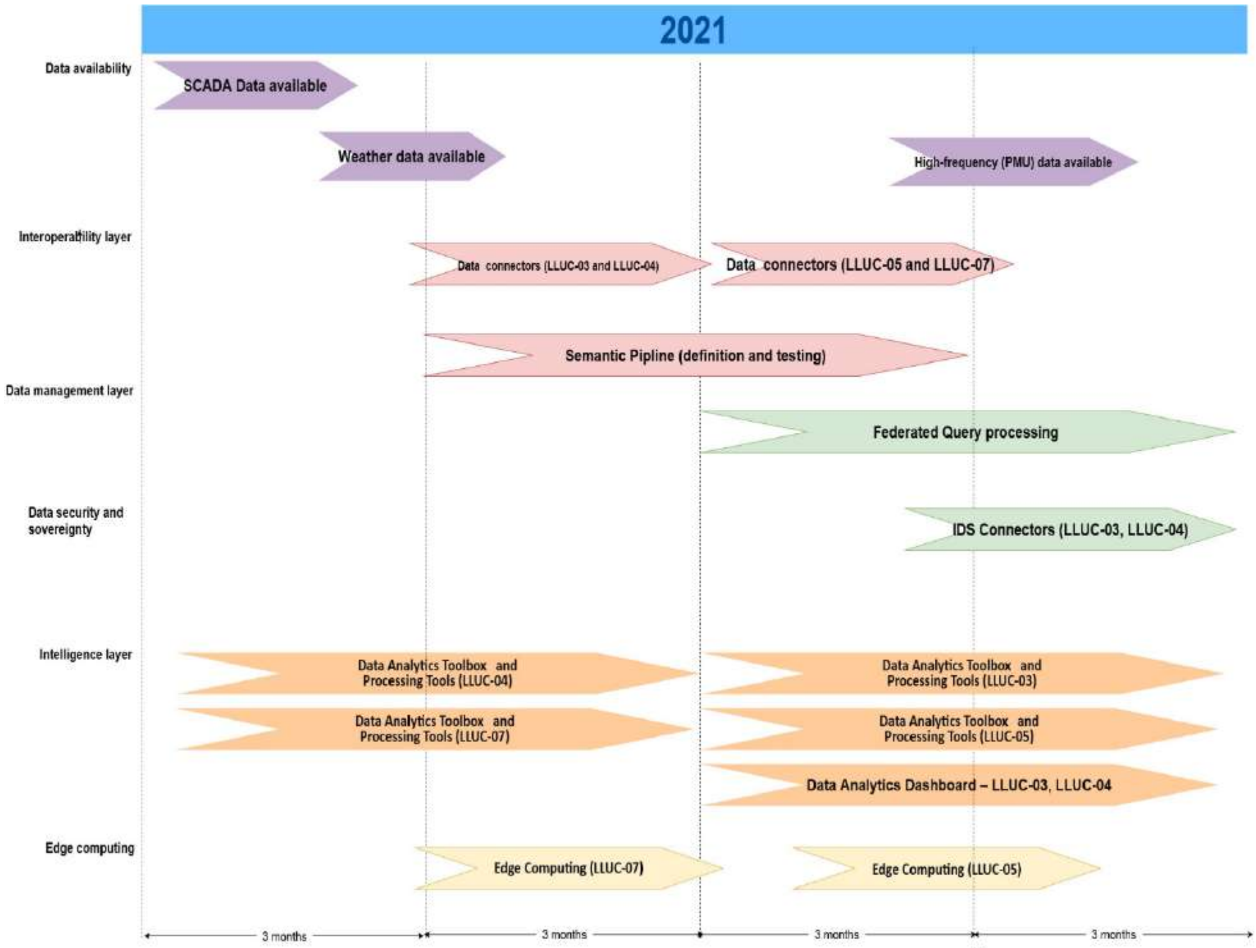


Figure 17: Components and Services to be Implemented under the Scope of Pilot 2a

3.3. Pilot 2b Electricity Grid Stability, Connectivity and Life Cycle

3.3.1. Pilot Characterization

3.3.1.1. General Characterization of Pilot 2b

Pilot 2b concerns 65.000 m² of buildings, located in Palma de Mallorca, Spain. SAMPOL is the DSO of the park and the PLATOON partners will develop a tool for the grid stability, connectivity and life cycle.

In this pilot, two different Use Cases will be developed within the project:

- Predictive Maintenance for MV/LV Transformers: Focus on transformer predictive maintenance, estimating transformer components health and its maintenance costs, planning maintenance actions, monitoring transformer alarms and studying different grid scenarios in case of replacing old transformers or adding complementary transformers.
- Non-technical loss detection in Smart Grids: quantification of losses in the distribution grid of a DSO and the detection of non-technical losses (NTL)

Pilot Objectives

Considering the two UC defined, the following objectives are defined in the present pilot:

a. O.1 To develop, implement and validate a predictive maintenance tool for LV/MV transformers considering available data in this kind of installations. First estimating the health index of the transformer considering different failures modes of the transformer critical components. Define transformer maintenance plan considering the health index and maintenance and failure costs.
1. O.2. To develop, implement and validate a prescriptive analytics tool to evaluate the effect of different operational actions in the grid O&M cost sheet.
    1. O.3. To develop, implement and validate a tool for the quantification of losses in the distribution grid of a DSO and the detection of non-technical losses (NTL)

Related Business Cases

The main business cases for this pilot are linked to the business cases of three partners:

a. **TECNALIA:** The objective of TECN in UC1 is to develop a virtual/soft sensor of the oil temperature to estimate the Remaining Useful Life (RUL) of the transformer and reduce maintenance costs and increase availability. In the UC2, the goal of TECN is to develop data analytics tools to identify NTL and improve the track of losses in its grid.
b. **SAMPOL:** in UC1 the objective for SAMPOL is to increase availability and optimize maintenance of transformers in Smart Grids. In the UC2, the goal of SAMPOL is to identify NTL and improve the track of losses in its grid.
c. **Indra:** The overall objective of INDRA is to improve its tools in predictive maintenance and monitoring platform OneSait.

3.3.1.2. General Characterization of Local Environment

Parc Bit electric Distribution System (DS) comprises an electric substation 66/15 kV and the distribution is done at 15kV. This DS provides electricity on one branch: to the Innovation Parc of the Balearic Islands, an urban waste plant and a school; and with two others to the hospital “Son Espases”. It feeds electricity to 6 big customers in Medium Voltage (MV), to 137 small customers in Low Voltage (LV) and to 5 EV charging stations in Parc Bit parking lot.
The distribution in Parc Bit is done in 15kV for MV and in 400V in LV. The MV and LV distribution comprises 5km and 6km of underground cable. The distribution system has one transforming center 66/15kV and 15 transforming centers 15/0.4 kV.

The energy consumption varies depending upon the customer. The DSO has a base load of about 90MWh/day with an increase in the summer season up till 150MWh/day; the maximum power demand reaches 15MW. The annual consumption on the DSO is around 40GWh. The different customers have different profiles but most of them have present seasonality with an increase of demand during summer.

The DS comprises an energy generation power plant connected to the line feeding the Innovation Parc (branch #1). The electric generation side consists of 2 CHP gas generators of 1.36MW each and 7kWp PV array. The generation power plant has an electric consumption for pumping inside the power plant and in the DHC, cooling generation through electrical chillers of about 650kW and one EV charging & discharging point.

3.3.2. Overall Pilot Architecture

3.3.2.1. Power Grid Architecture

Parc Bit's grid is formed by 5 km long mid voltage network and 5 km low voltage network, a main substation rated 80MVA, and 16 transformation centers in ring configuration, with 16 MVA in total. The grid comprises 166 clients with 10MW of power hired and 41GWh of energy consumed last year. Smart meters have been deployed in all the customers and data are transferred through PLC PRIME communication channel to the concentrators in transformer centers. From there, data are sent via TCP/IP connection to the SAMPOL's back office.

3.3.2.2. ICT Architecture

The Spanish pilot comprises an electrical grid with data from transformers and distribution. All this data is collected in a MySQL database and distributed among the project partners. In the next picture, it is shown a diagram of the ICT architecture for both LLUCs:

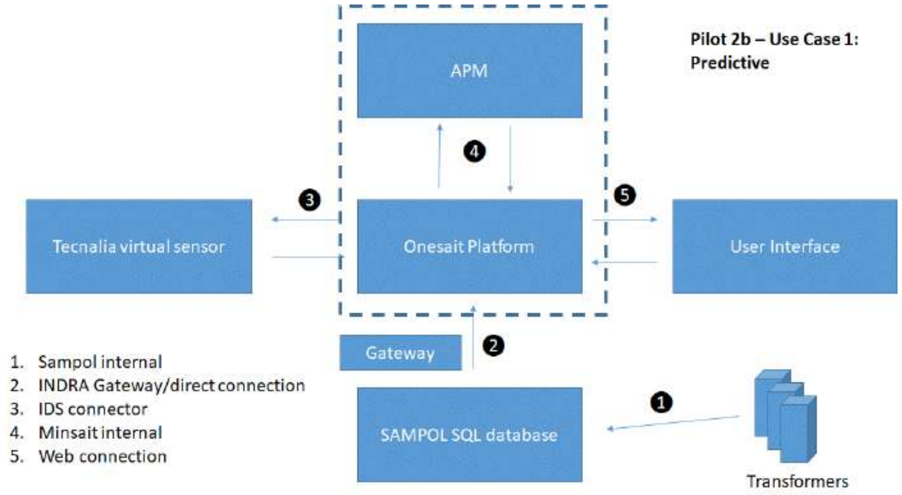


Figure 18: Pilot 2b - LLUC 01 ICT architecture

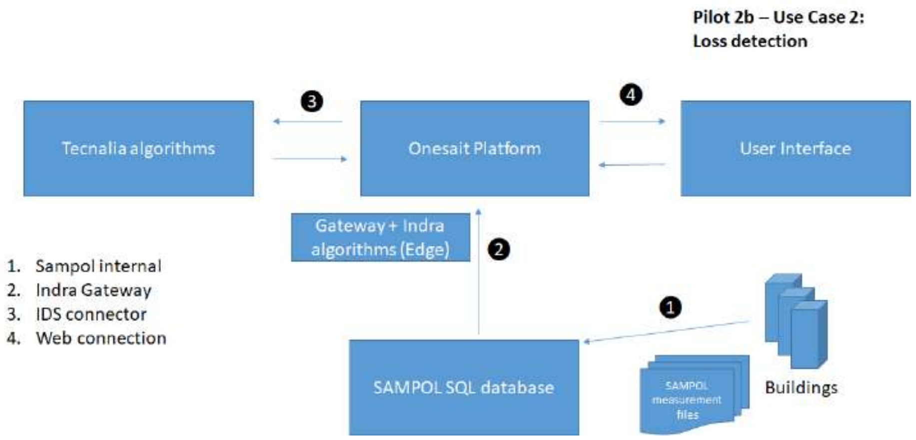


Figure 19: Pilot 2b - LLUC 02 ICT architecture

All data collected from the transformers (temperature, humidity, pressure, oil temperature, electrical measurements) and distribution (client's smart meters and data concentrators) is stored in a local MySQL database. Tecnalia, in collaboration with Sampol, will develop the tools described before in this document, and afterwards data from the tools and the pilot will be used in Indra platform for visualization.

3.3.3. Pilot 2b Requirements

Interoperability layer

Component /service	Provider	Demonstration requirements	Readiness *(if the requirements can be met on the pilot location)*	
			Yes	No
Data Connector	Indra/Tecnalia	On Onesait side an IDS compliant connector will have to be implemented to exchange data with Tecnalia. Data model translation from internal Onesait structure will also be a requirement	Will be implemented in the pilot for both use cases (starting point from Engineering Open Source)	
IoT Connector	Indra	Onesait gateway will most probably used to upload field data. There is a simpler scenario with direct connection to Sampol's database but will not be the ultimate solution	Onesait Gateway technology is intended to be used. Maybe a Indra-based instance of the gateway will be temporarily implemented due to COVID restrictions.	
Data Curation and Integration	Indra	Data will be consolidated in Onesait storage, mainly time series data	Covered in the pilot	
Semantic Adapter	Indra and Tecnalia	Semantic translations between Indra/Tecnalia and the Platoon model will be implemented. Several options are available (3 options). A decision will be made on this.	Covered in the pilot	
Energy Data model (PLATOON Data models from T2.3)	Indra and Tecnalia	Both for interoperability and data analytics.	Covered in the pilot	

Vocabulary manager	Indra and Tecnalia	Is it necessary to have a common VM? The role of Vocabulary Provider is being defined. Not applicable here.		

Table 12: Pilot 2b Interoperability Layer Requirements

Data Management Layer

Component /service	Provider	Demonstration requirements	Readiness *(if the requirements can be met on the pilot location)*	
			Yes	No
Context Data Broker	Sampol + Indra	Needed (Sampol data acquisition + gateway + Digital broker)).	*Yes*	
Federated Query Processing		Not applicable		
Unified Knowledge Base	Indra	Onesait Platform DB	*Yes*	
Context Event Processing		Not required		

Table 13: Pilot 2b Data Management Requirements

Intelligence Layer

Component /service	Provider	Demonstration requirements	Readiness *(if the requirements can be met on the pilot location)*	
			Yes	No
Data Analytics Toolbox and Processing Tools	Indra and Tecnalia	Will be implemented in the case of Tecnalia algorithms. Not so sure for Indra algorithms, both predictive/asset health in APM and loss detection on edge (similar case in Sisteplan)	Tecnalia algorithms	Indra algorithms
Data Analytics Dashboard – Visualization	Indra	Based on Onesait platform capabilities	Covered in the pilot	

Table 14: Pilot 2b Intelligence Layer Requirements

Marketplace

Component /service	Provider	Demonstration requirements	Readiness *(if the requirements can be met on the pilot location)*	
			Yes	No
Marketplace	Franhofer, Tecnalia	Tecnalia algorithms (oil temp virtual sensor, RUL calc, non-technical losses) in data analytics. Not decided yet for Indra algorithms. Sampol tools depending on results. Market place with catalogue of tools and datasets + IDS components	Covered in pilot for some algorithms	

Table 15: Pilot 2b Marketplace Requirements

IDS

Component /service	Provider	Demonstration requirements	Readiness *(if the requirements can be met on the pilot location)*	
			Yes	No
Connector	Engineering	Tecnalia and Indra	Yes	
DAPS	Franhofer AISEC	Tecnalia and Indra	Yes	
Broker/App store (metadata registry)	Franhofer IAIS	Central component	Yes	
Clearing House	Franhofer IAIS	Central component	Yes	
Vocabulary provider	Tecnalia	Central component	Yes	

Table 16: Pilot 2b IDS Requirements

3.3.4. Equipment and System Specification

As mentioned before, the data required in this pilot comes from two sources depending on the Use Case: Parc Bit transformers for Transformer predictive Maintenance and DSO data for Non-Technical Losses detection. In the following table, the equipment to be used in the pilot is described:

Equipment and System Specification		
Transformers	External temperature sensors	(8x3) Wireless sensors which measure the temperature of the outer surface of the transformer metallic casing, and the ambient temperature inside and outside the transformation center. Model IP68 WTS-O.
	External temperature receivers	(1x3) Wireless Mbus receivers that receive the measurements from the external temperature sensors and forwards the measurements to the Advantics data concentrator by Mbus protocol.
	External multiparametric sensors	(2x3) Wireless sensors which measure ambient temperature, humidity and pressure. Model WES-THP.
	Top oil temperature sensor	(1x3) Sensor which measures the oil temperature at the top layer, and additionally provides pressure and level measurements. Model BB211 (control unit) +TPL503 (sensor)
	Medium voltage electrical measurements	(1x3) Electrical network analyzer EM271-72DMV53 with (9) current transformers TCD1M-10080
	Modbus converters	(1x3 + 1) Modbus converters NBB-EN272501 that connect the data concentrators and the electrical network analyzers
	Advantics data concentrators	(1x3 + 1) data concentrators Model UCM-316.
Distribution feeder level	Smart meters	Existing ZIV smart meters
	PRIME data concentrators	Data concentrators that receive the measurement reports from the customers smart meters

Table 17: Pilot 2b Equipment and System Specification

3.3.5. Plan for Implementation of Pilot Services and Systems

In the following graph, it is presented the implementation plan for the pilot 2b.

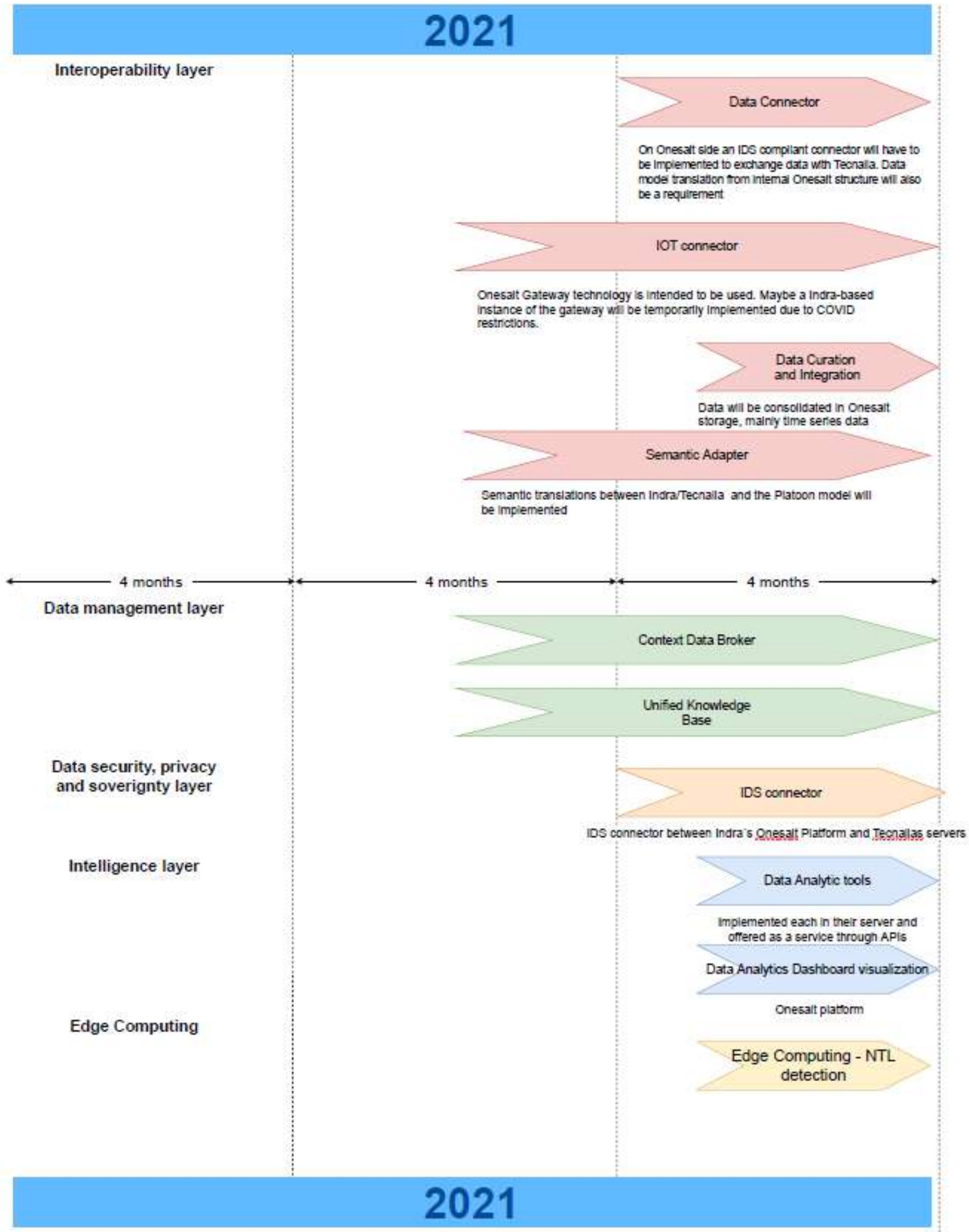


Figure 20 Components and Services to be Implemented under the Scope of Pilot 2b

Regarding LLUC 01, during the first year of the project 2020, all equipment required is defined and installed in the pilot. In the same way, the SQL database is planned to the accessible by the end of 2020.At the beginning of 2021, when the database is running and accessible for all partners, pilot data will be analyzed, and tool development will start. During 2021 also the SAMPOL database will be integrated with Indra´s OneSait platform.

Regarding LLUC02, data is already available in the SQL database. During 2020 smart meter data has been analyzed and has started the development of data analytics tools for NTL detection.

By the end of 2021 tools are expected to be in a first version for running tests during 2022. By the end of 2022, tools and test will be evaluated and reported.

Each of these stages and their respective tasks are detailed in the Implementation Template of Pilot 2A in Annex I.

3.4. Pilot 3a Office Building: Operation Performance Thanks to Physical Models and IA Algorithms

3.4.1. Pilot Characterization

3.4.1.1. General Characterization of Pilot 3a

Pilot 3a will occur in the ENGIE Lab CRIGEN building office located in the Paris region. The pilot targets optimizing the HVAC system performance and providing innovative services to help with energy management. The use cases to be implemented within this pilot focus on:

- **Optimizing heating and cooling of the different zones of the building regarding occupancy**

  Occupancy data are available via dedicated sensors and the comfort, and HVAC controls are available via the Building Management System (BMS) of the building. Using historical data, learning algorithms are implemented to predict occupancy and anticipate heating and cooling periods in the building and its different zones. A first optimization loop can be implemented to control the overall building occupancy planning and HVAC operation. A second optimization loop is used to adapt HVAC controls in the different zones of the building. The building manager can supervise and update some parameters in the system and access some regular assessments of the system controls. It also collects data from the occupancy sensor to map the occupancy in the different zones of the building.

- **Controlling the HVAC load of an office building to provide demand response services while maintaining a reasonable level of comfort for the occupant thanks to the building's thermal inertia.**

  Building parameters and weather forecast data will be used to provide predictions of the HVAC load and the potential flexibility available in the building, considering that a certain thermal comfort level must be maintained. These predictions are regularly transmitted to an aggregator that can engage reliable flexibility services with the grid operator. The aggregator can then send or plan orders to stop the HVAC system of the building for a given time. If the orders are validated (within conditions of the contract and minimum comfort parameter are respected), they are implemented in the BMS. Feedback and KPI are shared with the aggregator concerning the load shifting operations.

3.4.1.2. General Characterization of Local Environment

Pilot 3a demonstrator site is the ENGIE Lab CRIGEN building located in Paris. It is a new office building constructed to the latest requirements of the French regulatory framework. Designed according to the E+C- French label by ENGIE researchers, the office building is more efficient than New Zero Energy Building (NZEB). The building is part of a large project campaign within the “Inventons la Metropole du Grand Paris”, a competition where Paris’s most innovative building project was selected. The heating needs of the building are 30% lower than those of a NZEB. The building occupation started in January 2020 and involve an office part (±4650m²) and laboratory part (±4120m²).

Figure 21: Pilot 3a ENGIE Lab CRIGEN building

The main characteristics of the NZEB office are: highly insulated building with a light wood structure, 15cm of insulation; double glazing; balanced ventilation with recovery heat exchanger; hybrid heat pump with hydronic and air distribution and fan coil units for heat and cold emission and control; active floors; PV plant on the roof for electricity self-consumption; hydrogen panels producing hydrogen from renewable; Building Energy Management System based on BACNET controlling the HVAC and comfort in the different zones of the building.

3.4.2. Overall Pilot Architecture

3.4.2.1. Pilot Architecture

The figure below presents a simplified architecture of the Pilot 3a.

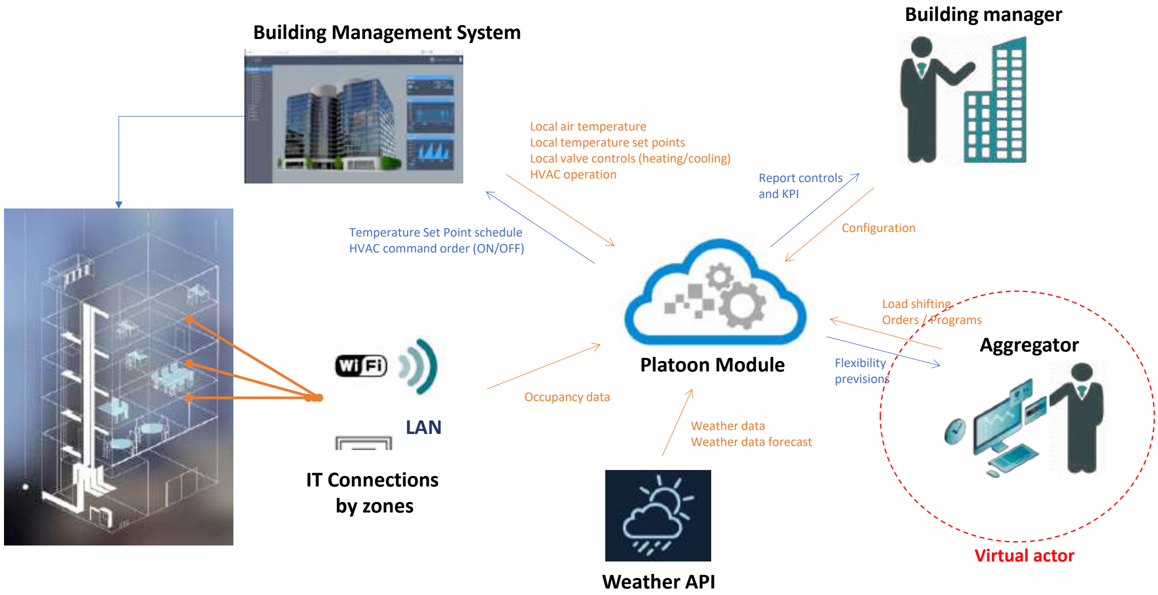


Figure 22: Pilot 3a Architecture

ENGIE office building is equipped with a BMS (Building Management System) that enables to monitor the air temperature and the level of comfort in the different zones of the building. This BMS provides an overview of the different valves in the different zones, so the overall HVAC operation in the building, and allows to manage the level of comfort of the building by controlling the different temperature set points.

Weather Data Source allows collecting weather data to control the HVAC load. This first allows maintaining a reasonable level of comfort for the occupants of the building. Second, it can anticipate the preheating and the precooling of the building temperature required by the occupants upon their arrival.

IT connection information is collected to monitor the occupancy of the building, more precisely, Wi-Fi connection and LAN connections to have an overview of the occupancy of the building.

The building manager oversees the building operation. They supervise the different KPIs and ensure that the level of the comfort of the building is suitable for the occupants. The aggregator is implicated in valuing the load flexibility on the French energy and capacity markets. A contract is signed between the Building Manager and the aggregator specifying the conditions and compensations related to the demand response services implementation.

3.4.2.2. ICT Architecture

Building Management System (BMS)

The BMS is based on BACNET IP and Modbus IP protocols to supervise HVAC operation and controls. The data will be available to the platoon project through a local server that will request data on the BMS using UPC-UA protocol. The different equipment of the BMS is the following:

- Bacnet IP Zones controller with temperature monitoring, heating, and cooling emission regulation (around a hundred units distributed in the building)
- Bacnet IP controller for gas boiler, gas heat pump, cooling system, and air handling unit (potential ON/OFF controls)
- ModBUS IP Meter for gas and electricity consumption of the different heating and cooling equipment
- Supervision PC

For the pilot's need, real-time interaction with the building is required (with the possibility to send orders). Based on the protocol OPC-UA used on other ENGIE projects, a direct interaction will be implemented through a gateway or through the supervision and control unit (discussions on the architecture are being discussed).

Specific gateway accessible for local ENGIE server will be deployed to collect data and send orders to the building BMS.

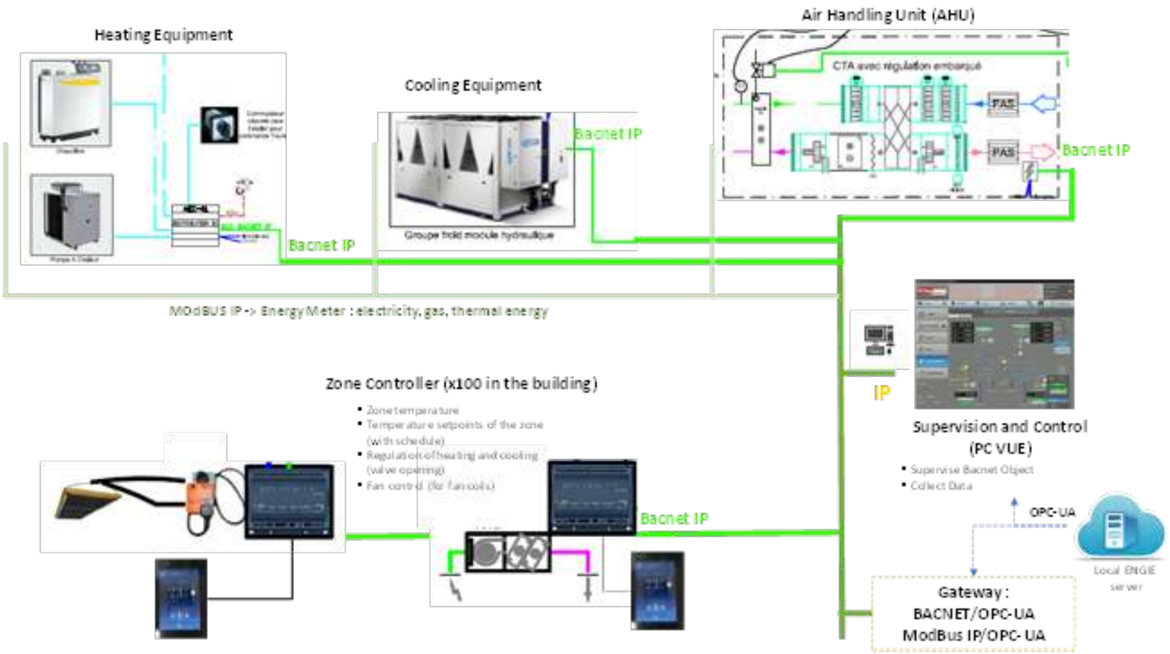


Figure 23: Stains Office Building ICT schema

IT Data for Occupancy

Data from WIFI and LAN connection will be provided by IT department in the different zones of the building. The frequency constraints and zone definition are currently being discussed:

- Possible frequency: 15min data refreshment (10min and 5min also studied).
- 15 independent zones defined for now.
- Data provided under csv format (detailed to be provided).

These data will enable to map the occupancy of the different zones of the building.

3.4.3. Pilot 3a Requirements

Considering the two LLUC defined in WP1 by the Pilot 3a owners and their requirements, the following table is the Pilot-Specific Workshops' results. They present PLATOON Pilot-compliant components to be implemented and tested within this demonstrator and define the requirements of each component to enable effective implementation.

The requirements have been classified according to the different layers of the PLATOON reference architecture.

Interoperability layer

Component /service	Provider	Demonstration requirements	Readiness *(if the requirements can be met on the pilot location)*	
			Yes	No
Data Connector	ENGIE	There are 2 data connectors. • Batch: data coming from BMS • Realtime: Data coming from external service provider	Currently handled by data ingestion framework, most data integration requirements are met with several out of the box connection types	No - Data **sovereignty** (IDS) aspects interacting with the Security & Privacy module of PLATOON's reference architecture will be new
IoT Connector	ENGIE	There is 1 IoT connector. Edge computing service will be transmitting data every 5 minutes interval related to the number of people present in a zone	Same module as above	Same module as above
Data Curation and Integration	TIB	Data ingested from BMS is from HVAC systems. Knowledge curation (duplication, knowledge graph enrichment, etc.) would be needed on new semantic data	Data curation part is currently covered through data pipelines by data ingestion/transformation component	Knowledge curation capability of DCI module in platoon is of special interest
Semantic Adapter	ENGIE	Semantic data model adaptation is needed for all data coming from data/IoT connectors	Data ingestion/ transformation framework already takes care of semantic adaptation using sparql generate	

Energy Data model (PLATOON Data models from T2.3)	ENGIE	Pilot 3a data models	Yes	
Vocabulary manager	TECNALIA	Data semantic adaptation pipelines will have embedded sparqlGen statements according to vocabulary for each data stream pipeline. Needed if changes to ontologies, the key thing is to investigate IDS vocabulary provider (under consideration)	For the scope mentioned	For keeping PLATOON vocabularies offline or any other use.

Table 18: Pilot 3a Interoperability Requirements

Data Management Layer

Component /service	Provider	Demonstration requirements	Readiness *(if the requirements can be met on the pilot location)*	
			Yes	No
Context Data Broker	Engineering	Service specific context information retrieval, update of context information and, real-time data transmission to Services from IoT connectors (raw + semantic) to services	Currently based on Kafka – publish/subscription model of real-time data streams is supported	Context availability, Entity management are new functions
Federated Query Processing	TIB	Services querying data from semantic store + raw historical data from Unified KB		No
Unified Knowledge Base	Engie	Store raw data (non-semantic) as well as semantic data and results of services forecasting	As per understanding of current services, we will need to store data in the raw and semantic form and at least require two data stores (semantic and non-semantic) continuing UKB. No historical data query from pilot	-

			systems is identified yet.	
Context Event Processing	Engineering	Service failure estimation through event patterns for HVAC systems	Non	- pattern management - event processing management

Table 19: Pilot 3a Data Management Layer Requirements

Intelligence Layer

Component /service	Provider	Demonstration requirements	Readiness *(if the requirements can be met on the pilot location)*	
			Yes	No
Data Analytics Toolbox and Processing Tools	Tecnalia (tools design) / Engie (development of tools specific to pilot)	<refer: Pilot-3a services document>		Five identified services would require development based on tools specifications
Data Analytics Dashboard – Visualization	Engie			Analytics dashboard would be required to search each service/tool

Table 20: Pilot 3a Intelligence Layer Requirements

Edge computing

Component /service	Provider	Demonstration requirements	Readiness *(if the requirements can be met on the pilot location)*	
			Yes	No
Edge Tool	ENGIE	Occupancy determination in a specific building zone by counting the number of people who entered/left the zone through image processing on cameras installed at entry/exit of the zone		

Table 21: Pilot 3a Edge Computing Requirements

IDS

Component /service	Provider	Demonstration requirements	Readiness *(if the requirements can be met on the pilot location)*	
			Yes	No
/	/	/		IDS is not within the scope of pilot 3A

Table 22: Pilot 3a IDS Requirements

3.4.4. Plan for Implementation of Pilot Services & Systems

The figure presented below covers the different stages concerning implementing the operation performance of an office building component previously identified in Table 18 to Table 21.

To implement the Pilot 3A components, ENGIE's platform that focuses on AI/ML services with a data model based on semantics will be extended to incorporate the architectural components introduced by Platoon targeting a broader ecosystem to serve the pilot's needs. Each of these stages and their respective tasks are detailed in the Implementation Template of Pilot 3A in Annex I.

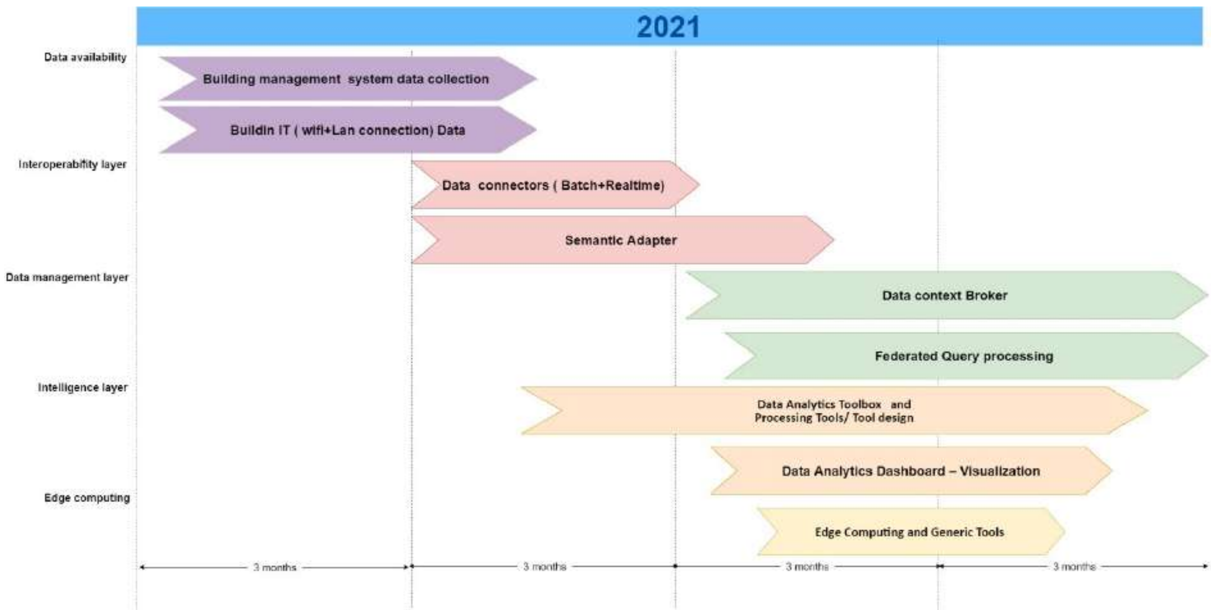


Figure 24: Components to be Implemented under the Scope of Pilot 3a

3.5. Pilot 3b – PI Advanced Energy Management System and Spatial (Multi-Scale) Predictive Models in the Smart City

3.5.1. Pilot Characterization

3.5.1.1. General Characterization of Pilot 3b-PI

Poste Italiane manages buildings for around 5,0 million sqm (owned or rented) distributed in more than 13.500 building with three main destinations: Postal Offices open to public (retail business), logistics distribution and cross docking (mail & parcels) and directional offices covering all municipalities in Italy.

The distribution of the Poste Italiane network in all climate areas and its heterogeneity (dimension from 50 to more than 30.000 sqm) allow it to be considered as a perfect use case to cover a wide area of energy analysis and correlation with climate situation and type of buildings. Poste Italiane already collects and manages a large amount of data related to energy use and consumption mainly from mid and big size buildings but needs to be supported with AI tools to determine benchmark, best practices and areas of opportunities for initiatives to increase energy efficiency and reduce CO2 production.

Scope of the Pilot is to create a new way of working in order to not only optimize energy usage and identify behaviors to be changed but also opportunity to reduce maintenance and service interruptions through a better usage of cooling / heating and lighting plants but also with AI defining predictive maintenance planning. In this scenario Poste Italiane has selected a group of buildings to be considered in the Pilot that are all located in Rome Municipality Area to test the mechanism of detection and analysis of energy consumption derived from HVAC and lighting systems in order to perform forecasting and benchmarking of energy consumption, as well as improve maintenance processes. They span from 180 to 28.000 sqm and has four different destinations: Datacenter, Logistics, Retail and Offices (Directional), for a total of 16 buildings.

Figure 25: Pilot 3b General Characterization

The pilot will address the following themes:

a. Building Heating & Cooling consumption Analysis and Forecast.
b. Predictive maintenance of cooling & heating plants.
   Lighting Consumption Estimation & Benchmarking.

1 LLUC 3b-01 Building Heating & Cooling consumption Analysis and Forecast

The comfort of the working environments can positively affect the productivity of working human resources and quality of customer interactions in retail offices. Creating favorable conditions in terms of temperature and humidity with the minimum usage of resources is the general scope of the use case. It will be done by applying a common methodology in 16 different buildings. Objectives concern the opportunity to test and benchmark results with a continuous improvement loop approach.

For these purposes, metrics will be identified that allow to determine solutions that jointly guarantee comfort and energy savings. The measurement of correlation between energy consumption and occupancy in the building could help the energy expert to identify the best strategies for providing heating, cooling and lighting services. The correlation with external weather conditions, building characteristics and past performances together with benchmark with similar building, represent an area of optimization for both cooling and heating systems and lighting. Sensors, meters and other hardware produce information that, through processing with forecasting algorithms and machine learning techniques, could be used to predict plants consumption and for the energy efficiency benchmarking.

Objectives:

1. Energy efficiency plans (heating, cooling, lighting).
2. Daily and hourly energy consumption forecast.
3. Building energy usage benchmark.
4. Reduction of emissions (CO2 / TOE correlation).

2 LLUC 3b-02 Predictive maintenance of cooling & heating plants

Nowadays, plant maintenance is carried out according to fixed schedules with planned actions with specific timing related to plants complexity and building dimension and through on demand tickets to solve plants failures or fixing issues (change temperature for better comfort).

Maintenance efforts could be optimized through monitoring techniques that can track equipment performance during normal operation and identify behavior anomalies (anomaly detection) before the result in actual failures.

Objectives:

3.5.1.1. Comfort improvement of employees and customers
3.5.1.2. Availability increasing of heating/cooling systems
3.5.1.3. Increasing operational efficiency
3.5.1.4. Maintenance Costs reduction

Due to the lack of sufficient failure data, in the second part of T6.1 the scope of this usecase was adapted to anomaly prediction instead of predictive maintenance.

3 LLUC 3b-03 Lighting Consumption Estimation & Benchmarking

The weight of consumption due to lighting is estimated to be greater than 20% of the overall electrical consumption of buildings. A deeper understanding of the lighting optimization levers and correlation (hours of artificial lighting use, number of users, sqm, …) can be useful to reduce lighting consumption.

Understanding lighting consumptions as accurately as possible is crucial; on the other hand, they are often aggregated with other energy usage, so the specific consumption is often estimated using algorithms and benchmark tools. Knowing other consumption usage data (such as heating and cooling...), total consumption of the building, lighting installations number and type and other building characteristics (such as category, square meters, generic occupancy profiles...) we want to estimate the specific building lighting consumption, to plan optimization actions and detect anomalies and outliers.

Objectives:

- Optimization and reduction of lighting consumption
- Costs reduction

3.5.1.2. General Characterization of Local Environment

Four different destinations for the building spaces are considered in the city or Rome (Italy): Datacenter, Logistics, Retail and Offices (Directional), for a total of 16 buildings. The buildings were constructed at different time and have different structures and materials.

3.5.2. Overall Pilot Architecture

3.5.2.1. ICT Architecture

The figure below presents a simplified architecture of Poste Italiane Pilot:

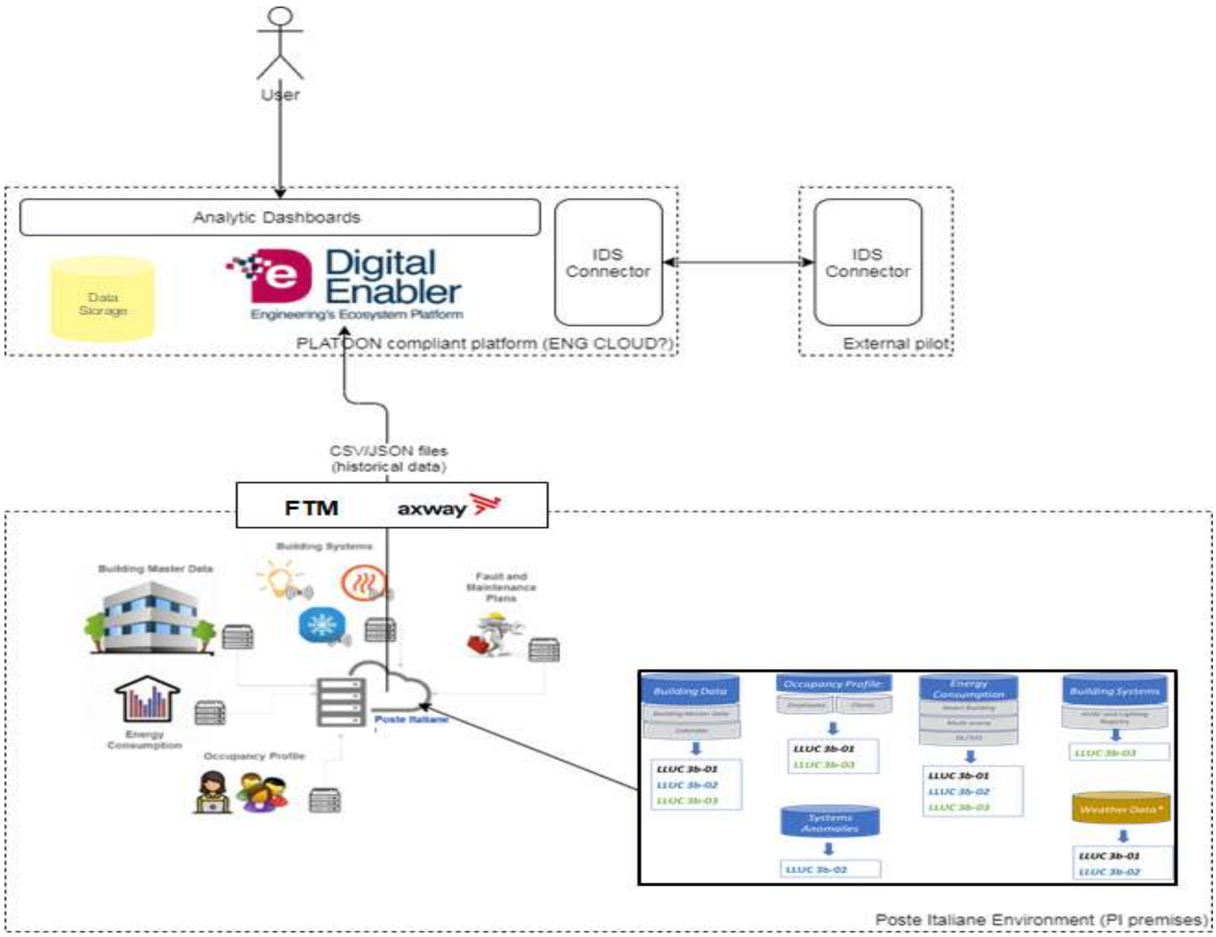


Figure 26: Pilot 3b ICT Architecture

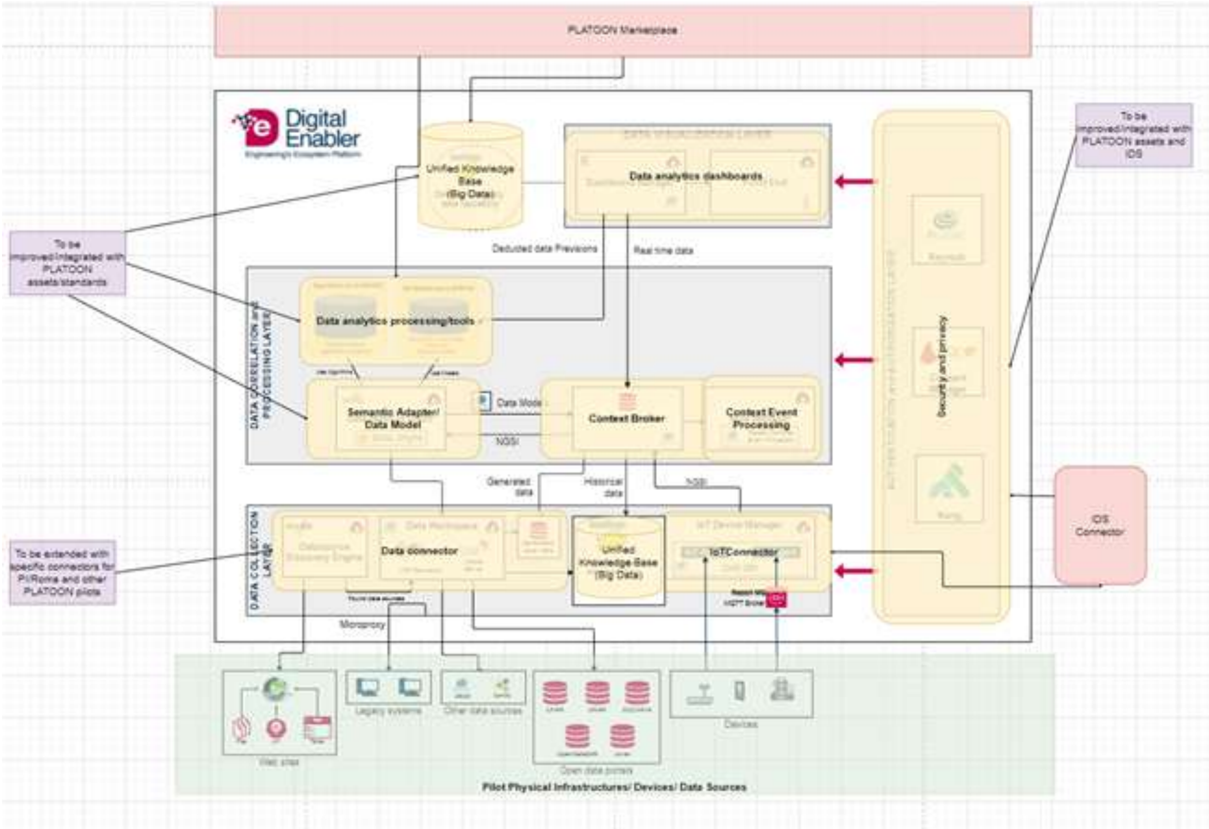


Figure 27: Pilot 3b Detailed Architecture

The Poste Italiane Pilot is focused on gathering energetic (and related) data / concept for two main purposes:

a. Constitute the PLATOON database, modules, and application,
b. Develop and acquire application and algorithms from PLATOON for data analysis and for defining energetic optimization actions.

For this, it is very important within the framework of the Pilot that Poste Italiane clearly defines the dataset and the ways these data will be gathered and transferred to PLATOON.

IT data

The Pilot #3b dataset is comprised by the following data (recovered by different Poste Italiane Systems and aggregated) that will be sent to the Digital Enabler Platform (an Engineering data analytics platform). The Digital Enabler Platform will manage Data Storage and interactions with Platoon.

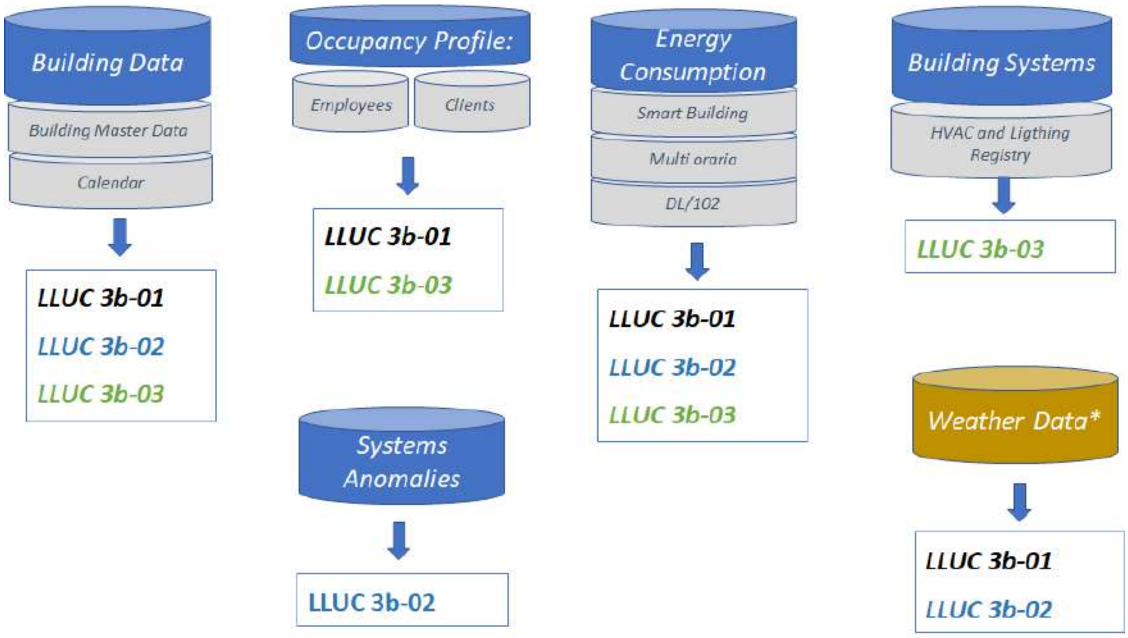


Figure 28: Pilot 3b Data Source Overview

- **Building Master Data:** detailed static data for each building. These data give information about building characteristics (destination, climate zone, square meter, etc.).
- **Calendar:** Information on office openings and shifts.
- There will also be in its info regarding offices calendar (opening time, closing time…).
- **Building Occupancy Profile:** daily number of employees and clients for each building.
- **Energy Consumption**: data are aggregated at building level, for energy line: cooling, heating, lighting (where available) and for plant (where available). They include data regarding internal temperature and humidity of the buildings.
- For Smart Buildings there will also be info about systems faults.
- **Building Systems**: information about plants (cooling, heating or lighting), technical characteristics, and numbers.
- **Systems Anomalies:** Information based on monitoring of in-building temperature measurements. The system provides alarms when it detects temperatures outside defined thresholds.
- **Weather Data**: historical data on external temperature and humidity (will be recovered by Platoon Platform) - Open*External Data.*

For some data, it will be necessary to maintain track of any changes. This requirement is applicable on data whose change are very slow (e.g.: Building Master Data, System registry). The different data containers provide information and data useful for specific use cases.

PI have different management system that produce information useful to the pilot. These data are not aggregated and not necessarily coherent in terms of time frame and detail. The data, before to be sent to the Digital Enabler Platform data will be:

- Pre-Filtered.
- Aggregated.
- Made Coherent.
- Transformed in the CSV format.

The goal is to aggregate data creating a new organized dataset and send it to PLATOON platform with monthly or daily frequency (static data, such as building master data, building characteristics, will be re-sent too).

Data Exchange Summary Process

PI will collect data from its internal systems through batch processes and will transfer it periodically (daily or monthly, depending on the typology of data), to an external Data Storage in a secure way, through SFTP managed by Axway Gateway product. The Data format will be CSV.

Axway will provide a centralized and secure way to transfer data externally with total end-to end visibility. Once received by the Digital Enabler Platform, they will be stored in a cloud repository external to PI.

Axway will ensure the following requirements:

- End-to-end visibility across all transfers.
- Monitoring and alerts for real-time issue resolution.
- Audit and archive file transfer activity to meet reporting and auditing needs.

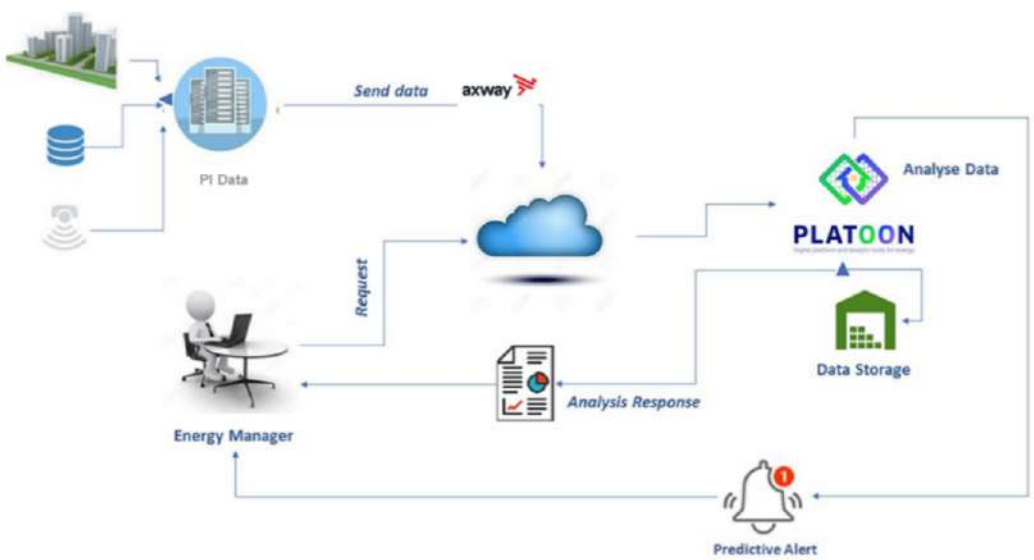


Figure 29: Pilot 3b Data Exchange Summary Process

3.5.2.2. Site Assessment and Existing Infrastructures

All analytics in this pilot will be done using consumption and operational data of 16 building of Poste Italiane. In addition, some data of measurement campaigns that were done in the past is used. If needed additional measurements will be conducted during the pilot phase of the project. Feasibility is currently being investigated.

3.5.3. Pilot 3b Requirements

Using the PLATOON methodology in the WP1 framework the general requirements were identified and reported in Deliverable 1.1 Business case definition, requirements and KPIs. Here are the synthesis of the component/services needed by LLUC #3b (01-PI; 02-PI; 03-PI).

Interoperability layer

Component /service	Provider	Demonstration requirements	Readiness *(if the requirements can be met on the pilot location)*	
			Yes	No
Data Connector	ENG	Data will be exchange with the pilot through a file exchange protocol (e.g., SFTP) provided by AXWAY gateway	Existing connector will be customized to be compliant with the final chosen protocol	
IoT Connector		Not required. Only historical data will be managed		
Data Curation and Integration	ENG/TIB	Not necessary in the first iteration of the pilot. Basic data integration capabilities will be implemented by the DE platform		
Semantic Adapter	ENG/TIB/ENGIE	Yes, to adapt pilot data to the data model	DE already has data model adapted/mapper, anyway we want also to reuse and integrate with the solution developed in platoon	
Energy Data model (PLATOON Data models from T2.3)		Yes	We will reuse the ones developed in T2.3. The data mapping is ongoing	
Vocabulary manager		Not necessary in this stage		

Table 23: Pilot 3b-PI Interoperability Layer Requirements

Data Management Layer

Component /service	Provider	Demonstration requirements	Readiness *(if the requirements can be met on the pilot location)*	
			Yes	No
Context Data Broker	ENG	Not needed since we will not deal with real-time data		
Federated Query Processing	TIB	Not needed in this initial phase of the pilot development, but it will be included in the deployment for future use.		
Unified Knowledge Base	ENG/TIB	Yes, Required for the pilot data	DE already provided solution for unified repository (e.g. Hadoop based), but we want also to reuse and integrate with the solution developed in platoon	-
Context Event Processing		Not needed		-

Table 24: Pilot 3b-PI Data Management Layer Requirements

Intelligence Layer :

Component /service	Provider	Demonstration requirements	Readiness *(if the requirements can be met on the pilot location)*	
			Yes	No
Data Analytics Toolbox and Processing Tools	ENG	Yes, needed to analyze data based on pilot requirements	DE already has data analytics capabilities and machine learning algorithms, that will be customized and configured for the project needs.	
Data Analytics Dashboard Visualization	ENG	Yes, needed to analyze data based on pilot requirements	DE already has data visualization capabilities provided by the suite KNOWAGE already integrated in the platform	

Table 25: Pilot 3b-PI Intelligence Layer Requirements

IDS

Component /service	Provider	Demonstration requirements	Readiness *(if the requirements can be met on the pilot location)*	
			Yes	No
Connector	ENG	Not needed in the initial pilot scenario	ENG is the developer of an open-source IDS connector (TRUE) that we will integrate in the DE	
DAPS	IAIS	Not needed in the initial pilot scenario	Already developed will use the version from Fraunhofer AISEC.	Need to define the tokes.
Broker/App store (metadata registry)	IAIS	Not needed in the initial pilot scenario		No, this will be developed as part of T3.4.
Clearing House	IAIS	Not needed in the initial pilot scenario		No, this will be developed as part of T3.4.
Vocabulary provider	TECN	Not needed in the initial pilot scenario		No, this will be developed as part of WP3.

Table 26: Pilot 3b-PI IDS Requirements

Marketplace

Component /service	Provider	Demonstration requirements	Readiness *(if the requirements can be met on the pilot location)*	
			Yes	No
Marketplace	IAIS	Show metadata of available datasets.		DE has its own marketplace but for PLATOON we are going to use what is provided in T3.4.

Table 27: Pilot 3b-PI Marketplace Requirements

3.5.4. Equipment and System Specification

Building-level

Equipment and System Specifications					
Level	Equipment	System Specification	status	data source site typology	notes
Building level	Sensors	Indoor environmental Temperature and humidity sensors	Ready for Platoon test	Smart building	9 sites, comprehensive environmental monitoring

		Outdoor environmental Temperature and humidity sensors	Ready for Platoon test	Smart building	2 sites (1 medium and 1 large smart building)
	Meters	Energy meters (electricity consumption for heating, cooling, lighting)	Ready for Platoon test	Smart building; Dlgs 102/14	accuracy>99%. 9+2 sites
	Lighting	All the installation with led lamps	Installed	All sites	16 sites
Headquarter	Smart Building SW	Building & Energy Management system (SIELTE). Reporting and storaging data from sensors and energy meters and from weather web site.	Ready for Platoon test	Smart building	9 sites
	102/14 meters Platform	Energy Management system (SEICA Z_Energy). Reporting and storaging data from energy meters.	Ready for Platoon test	Dlgs 102/14	2 sites
	Energy quarterly data	Billing platform (Elyx) and Database of data consumption.	Available	Local energy distributor	5 sites

Table 28: Pilot 3b-PI Building-Level

3.5.5. Plan for the Implementation of Pilot Services and Systems

All the technical equipment required is defined and installed in the pilot. In the first 4 month of 2021 will be implemented the data collection and transfer flow for the alimentation of the database. By the end of 2021 tools are expected to be in a first version for running tests during 2022. By the end of 2022, tools and test will be evaluated and reported.

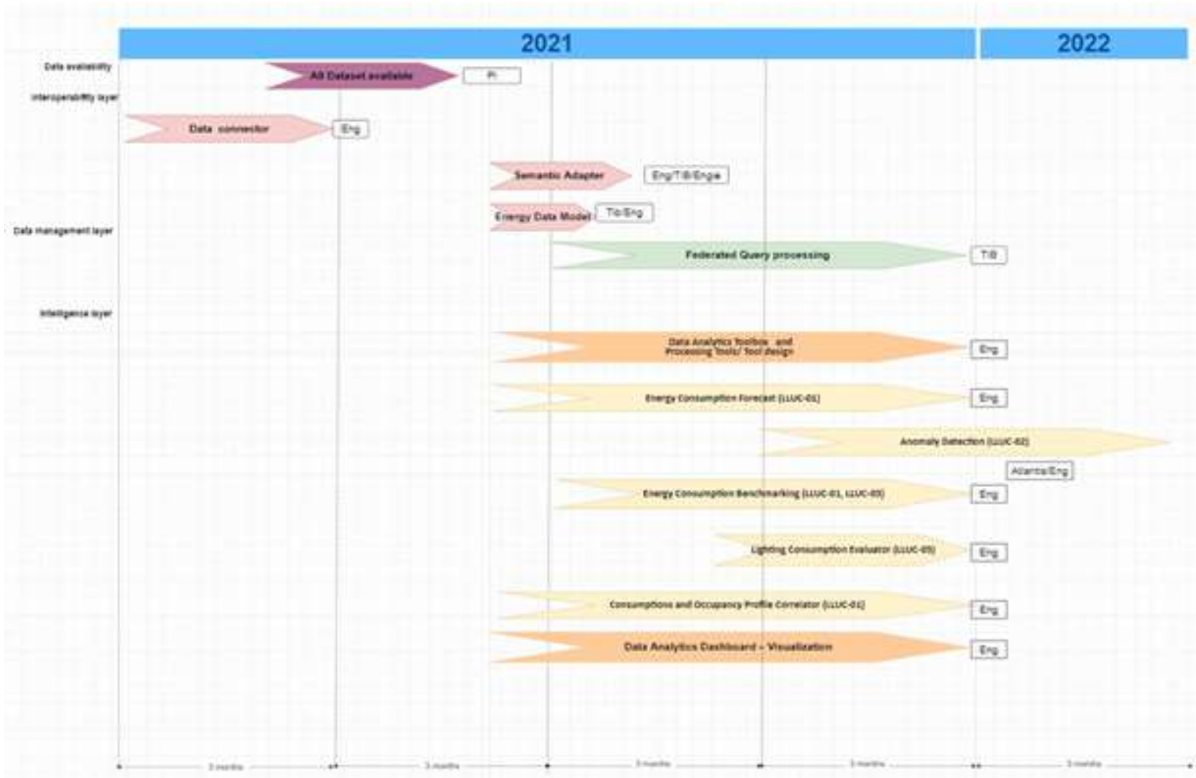


Figure 30: **Components and Services to be Implemented under the Scope of Pilot 3b-PI**

Each of these stages and their respective tasks are detailed in the Implementation Template of Pilot 3B in Annex I. The Predictive Maintenance (Anomaly Prediction) LLUC02 follows another plan as the tool is included in the activities related to the 1st Open Call. In this case the tool will be delivered by Atlantis on March 2022.

3.6. Pilot 3b – ROM Advanced Energy Management System and Spatial (Multi-Scale) Predictive Models in the Smart City

3.6.1. Pilot characterization

3.6.1.1. General Characterization of Pilot 3b-ROM

The Public Works and Infrastructures Department of Roma Capitale (SIMU Department) includes Plants Division with at least 3 offices managing energy issues: the Energy Manager Office of Roma Capitale (EMO), the Utilities Meters Office (UMO) and the Thermal Plants Office (TPO). This Unit manages around 8950 energy meters (6500 electric meters and 2450 gas meters) related to almost 2000 buildings owned by the municipality. To help the offices in this activity, considering the huge amount of data coming from the meters each month, an integrated monitor and analysis system shall be implemented. The data should be analyzed automatically to highlight anomalies, to generate reports for different purposes, to produce forecasts in terms of energy consumptions, to help building energy efficiency scenarios, in brief to support the offices personnel thus freeing up time and resources to tackle energy efficiency activities more effectively, addressing specific interventions.

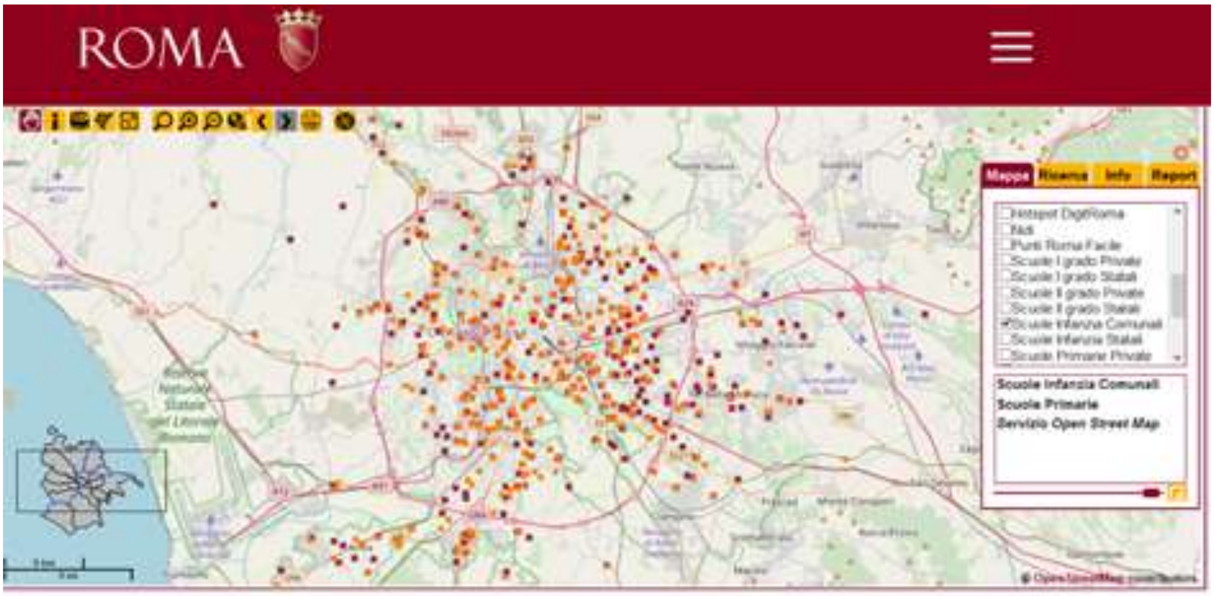


Figure 31: Pilot 3b-ROM - Rome Municipality Buildings hosting the Energy Meters

The pilot will address the following Use Cases corresponding to specific services:

- LL_UC ROM_01 Spatial Reporting
- LL_UC ROM_02 Benchmarking Analysis
- LL_UC ROM_03 Forecast on energy consumptions.
- LL_UC ROM_04 RES potentialities for Energy Communities

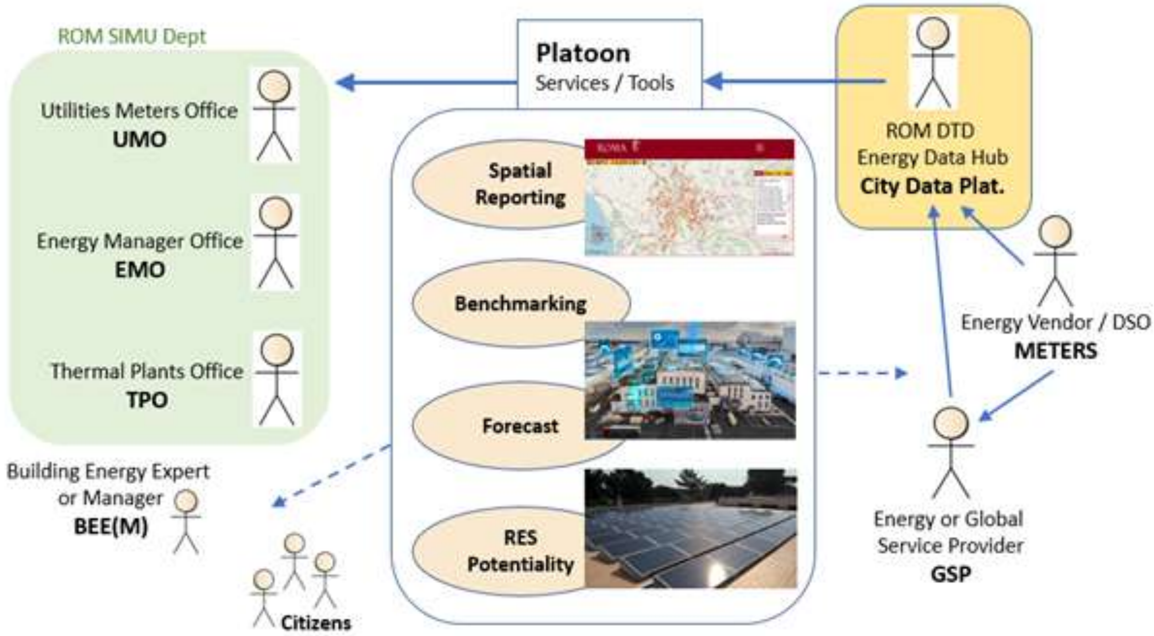


Figure 32: Pilot 3b-ROM – Diagram of the Services and Actors Involved

- **LL_UC ROM_01 - Spatial Reporting:**

GIS visualization for the Buildings Energy Consumptions (EC) and general energy performances (EP).

Subservices: Updating the EC baselines

Output Expected:

- Spatial visualization (GIS and WebGIS) of the Buildings EC & EP data.
- Spatial and attributes-based queries produce Flash Reports and aggregated results.
- Structured Summary Reports are available, with graphs and maps.
- For thermal consumptions, converting high frequency data coming from *Conta-Termie* sensors into gas consumption profiles, to improve the detail of the energy representation in accordance with the profiles coming from electrical meters.

Subservice Outputs:

- Updating ENERGY AUDITS, produced in past years, with recent baselines on energy consumptions.

- **LL_UC ROM_02 - Benchmarking Analysis**

Benchmarking serves to measure building EC & EP relative to other similar buildings, or to modelled simulations of a reference buildings set, or to the same building past data.

SUB-SERVICES: Consumptions Anomalies Detection, Alerting, Support to general asset maintenance planning.

Output Expected:

- All data are available to elaborate and report the values of EC & EP in terms of benchmarking analysis (Ref: BS EN 16231);
- Definition of Normalization criteria and reference buildings per each typology, where users can create new classes;
- Ranking of buildings base on performances, with different normalization of the indicators (kWh on heated volume, heated surface, dispersing surface, or weighted with aspect ratio, occupancy factors, etc...);
- Deviations and Anomalies, compared to the reference buildings or to threshold set by users (warning conditions).

Subservice Outputs:

- Automatic Alert delivered to specific Actors

- **LL_UC ROM_03 - Forecast on energy consumptions.**

Predicting energy usage of the buildings by analyzing multiple factors. Simulating future consumptions scenarios for different time/functional use profiles of buildings or changes in performances (control factors).

Output Expected:

- Reports on Future energy consumptions (1 month ahead + next year forecast)
- Reports for Simulated Scenarios, changing control factors
- Reports on CO_2/TOE impact for Energy Management Office
- Reports on Economical (estimated) impact.

- **LL_UC ROM_04 - RES potentialities for Energy Communities**

Identifying potentialities and scenarios in terms of:

- RES productions, mainly from PV plants, based on the surfaces available on the building roofs, where PV production is foreseen for each building on the basis of meteo/irradiance forecast service
- Energy Storage to maximize PV self-consumptions of the building
- Energy Storage to maximize PV in the local Energy Community scheme (incentivized scheme where the building is sharing energy with other proximity users.

Note that Renewable Energy Communities (RECs) are promoted by *REDII* Directive and in Italy they can be developed under the same secondary cabin grid section, up to 200 kwp of RES peak production. This service is oriented to assess the existing RES plants efficiency and to estimate possible extension and upgrade of these plants. Furthermore, for the buildings not equipped with PV plants this tool will periodically calculate the peak power and total PV production installable, based on the available techonologies. External updated data service to effectively implement this tool are: *meteo/irradiance forecast service; expected PV production*; *efficiency factors for PV technologies.*

Subservice Outputs: updating ENERGY AUDITS with including reports on existing RES Plant efficiency.

Output Expected:
RES (PV) potentialities plan is delivered as outputs after selecting one building or a sub-set of buildings, in terms of:

1. assessing the existing RES plants efficiency, compared to expected PV production
2. Installable PV plants power, PV energy production, Plants dimensions
3. Storage capacity based on the max potential self-consumptions in building
4. Max exceeding energy to share with other eventual proximity users (energy Community scheme)
5. To update ENERGY AUDITS (export function)

3.6.1.2. General Characterization of Local Environment

The municipal building assets of ROM are composed by almost 2000 buildings or building complexes equipped with 8950 energy meters (6685 electric meters and 2450 gas meters, owned respectively by ARETI and ITALGAS). The spatial distribution of the meters and the served buildings is a relevant aspect of the municipal building assets in relation of the governance structure of the asset itself, considering that the municipality is divided into 14 Districts (Municipi) having in charge several maintenance duties in buildings and plants.

3.6.2. Overall Pilot ICT architecture

The ROM Pilot Architecture will be based on the “Digital Enabler”, which is an open-source, FIWARE-based platform developed by Engineering that will provide the main PLATOON framework functionalities in compliance with the project specification.

Roma Capitale is also developing the CITY DATA PLATFORM – CDP -, a FIWARE-based data storage and processing platform. This platform will provide, in the future, data analytics and AI algorithms to be applied to the data collected in Rome by different data sources in the city. The plan is to integrate, by the end of the project, the data collected and processed by PLATOON platform inside the CDP. The specific integration activities between PLATOON platform (i.e., Digital Enabler) and CDP will be established in the next months based the progress of the CDP developments.

In the following section are presented some key components provided by the Pilot Architecture:

- **Data Exchange:**

The Energy Consumption data flow of the building asset of ROM building is now enclosed inside the contractual relationships between ROM offices and the engaged vendors and concessionaries. The policies and procedures to exchange and exploit this data outside this relationship must be defined within the WP3 works based on the PLATOON needs and objectives, and then authorized by the competent offices of ROM. From technical point of view, the Digital Enabler will oversee collecting directly from the different data provider involved in the pilot use case. This data exchange will be performed through specific connectors that will interact with the data providers platforms API, or directly through file exchange (for instance, in case of historical data).

Energy Data are collected from different sources managed by the ROM offices:

a. from Vendor, DSO and concessionary actors (ARETI, CPL, ESTRA, ENEL) that are managing the power and gas meters for the ROM buildings asset.
b. from other ROM offices that will pre-process some of these data (for example, Master Data for the buildings related to the general energy performances and uses).
c. from SIMU Technological Plants Unit offices that will collect and transmit data to DTD energy Data hub whenever the modality n.1 would not be possible.

For a general picture of the datasets collected and involved in the Pilot 3b-ROM, a Dataset Matrix was prepared and is frequently updated by the pilot team mainly to track the relations with the Data Providers and sources:

ROM PILOT 3B	SOURCES – DATA PROVIDERS					legend
	DSO - origin of data		VENDOR - concessionar. - commerc. partners		SIMU / ROM - energy users	
DATASETS MATRIX Energy Flows Data from Meters (1,2,3,4)	HISTORICAL DATA	CURRENT DATA	HISTORICAL DATA	CURRENT DATA	HISTORICAL DATA	CURRENT DATA
1 Electric Meters Data – consumptions on 6685 meters	ARETI, can give data (2015-2018) to SIMU or directly to Platoon	ARETI ... to the vendor; meters description *	GALA (2015 – 2017) ; ENEL (2018 - june 2021); n.2 datasets TRASMITTED TO ENG	ENEL - Consip Contract Lotto6 Lazio ENEL WEB SERVICE IS ACCESSIBLE (*)	SIMU has access to ENEL web portal and to old dataset GALA	SIMU has access to ENEL web portal ; dedicated sensors on meters are foreseen in 2022-2023
2 Gas THERMAL PLANT Meters Data – consumptions on 1250 meters	ITALGAS, SIMU is asking for data pre nov.2018; also CPL is obtaining form DSO	ITALGAS (sending data to ESTRA that sells gas to CPL that sells comfort to SIMU)	meters managed by SIE3 concessionary CPL since nov 2018 (**); datasets TRASMITTED TO ENG	meters and sensors managed by SIE3 concessionary CPL - Cloud Server Service by EFM**	meters managed by SIE3 concessionary CPL since 2019; Gas paid by SIMU before nov 2018	meters managed by SIE3 concessionary CPL – Cloud Server Service by EFM**
3 Gas OTHERS Meters Data – consumptions on 1200 meters	ITALGAS, SIMU has to ask for data pre 2018	ITALGAS ; check SIM frequency transmission from digital meters***	meters managed by ESTRA related to small thermal plants TRASMITTED TO ENG	meters managed by ESTRA related to small thermal plants ; next year by HERA	meters consumptions paid by SIMU - can ask data to ESTRA and ITALGAS***	meters consumptions paid by SIMU - can ask data to ESTRA and ITALGAS***
4 PV plants Electric Meters – Energy Productions on 170 x 2 meters	ARETI ; monitoring systems on the plants	ARETI ; monitoring systems on the plants	GSE & ARETI data for 120 plants; 60 PV plants managed by concessionary with own monitoring	GSE & ARETI data for 120 plants; 60 PV plants managed by concessionary with own monitoring	SIMU will transmit GSE datasets on past years productions; 60 PV plants managed concessionary with monitoring	SIMU new monitoring system installed by SIMU is accessible **** TRASMITTED TO ENG + 60 PV plants managed by concessionary with monitoring;
background data (5,6,7)						
5 Structural Data on building/plant system (MASTER DATA)	meters localization/mapping & correlation with buildings	meters localization/mapping & correlation with buildings	nn	nn	data from Energy Audits & CPL/EFM for each building (SIMU)	data from Energy Audits & CPL/EFM for each building (SIMU)
7 Meteo Data (EXTERNAL)	nn	nn	TBD - Platoon	TBD - Platoon	nn	nn

Figure 33: Pilot 3b-ROM Datasets Matrix, describing Data Sources. In green, the Supplied Datasets.

- **Edge Computing**

No edge computing solutions are foreseen.

- **Storage and Processing Solutions:**

Data storage and processing capabilities will be provided by the Digital Enabler that will oversee collecting, pre-process and store data from the data providers. The datasets will be pre-processed to clean and improve data quality and to perform data mapping to achieve semantic interoperability through the PLATOON data model. The data will be stored in the Engineering cloud in compliance with security and privacy requirements in relation to the project and European Legislation.

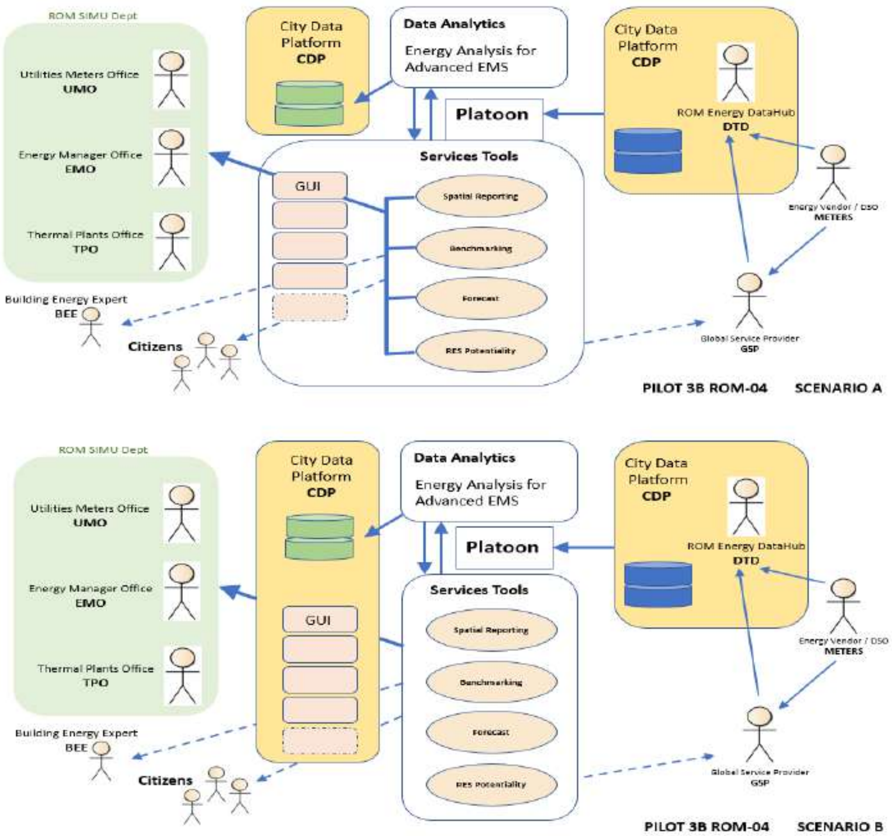


Figure 34: Architecture 3b-ROM with 2 Scenarios concerning City Data Platform Role

3.6.2.1. Site Assessment and Existing Infrastructures

The 6685 electric meters are managed by a different energy vendor that stipulated energy contract with ROM (ENEL – Consip Contract) but are owned and monitored by DSO ARETI, that must be considered the Data Originator, sending energy data to the vendor for each meter. The frequency of the energy data (monthly/daily/hourly/15 minutes/4 seconds) depends on the type of meters (mechanical or electronic) but considering that the replacement of all meters is foreseen and ongoing, it is not easy to give a picture of the classification of the meters based on data frequency.

The gas meters, owned in Rome by ITALGAS, are managed in the case of ROM by 2 actors depending on the building's typologies:

- a gas vendor (ESTRA) for residential housing buildings (excluded by the pilot use cases) and minor thermal plants (1200 gas meters owned and monitored by gas DSO ITALGAS);
- a concessionary for Integrated Energy Service (CPL Concordia) who pays the bills and sells energy comfort services for the rest of the buildings (GSP in fig.31). All these 1250 gas meters are owned and monitored by gas DSO ITALGAS.

For gas meters the frequency of the energy data (monthly/daily/hourly) depends on the type of meters (mechanical, electronic, with SIM for last generation), considering that the replacement of all meters is foreseen and ongoing but its planning by ITALGAS it is not known.

Furthermore, Sensors called *Conta-termie* are installed, in couple (CT1-CT2), by each thermal generator to measure heat flux sorting out (CT1) and returning in (CT2) the thermal central. For these 2500 sensors measurements the toolbox will calculate the equivalent kWh consumed and the hourly profile, completing the thermal energy consumptions picture coming from the gas meters. Other sensors in the buildings measure the temperature and the umidity but in this phase their datasets will be stored without a specific design for their exploitation.

The proposed use cases in the 3b-ROM Pilot are mainly addressed to exploit the big data coming from meters, and from sensors next to meters, to offer analytical services for energy efficiency purposes extended to the whole buildings' asset of the municipality. These use cases are not focused on the power grid side of the general infrastructure although the main objective of the pilot aiming the reduction of consumptions and peaks will likely impact on the power grid, for both electricity and gas.

Note: ARETI the electric power DSO signed a LOS to Platoon project and is working within a parallel H2020 project (PlatONE) to set up and implement solutions to increase energy flexibility through innovative user-interactive and automated actions

3.6.3. Pilot 3B-ROM Requirements

Interoperability layer

Component /service	Provider	Demonstration requirements	Readiness (if the requirements can be met on the pilot location)	
			Yes	No
Data Connector	ENG	Existing connector will be customized to be compliant with the final chosen protocol / otherwise a dedicated Connector with DE will be implemented in ROM data platform (this option is now the one selected waiting for CDP solution to be ready)	Some connectors are already deployed, others are to be defined (further API information are needed by data provider)	
IoT Connector	-	Not required. Data collection will be through data provider middleware and not directly through device	-	-
Data Curation and Integration	ENG/TIB	Not necessary in the first iteration of the pilot. Basic data integration capabilities will be implemented by the DE platform		ENG/TIB
Semantic Adapter	ENG/TIB/ENGIE	To adapt pilot data to the data model	DE already has data model adapted/mapper, anyway we want also to reuse and integrate with the solution developed in PLATOON	ENG/TIB/ENGIE
Energy Data model (PLATOON Data models from T2.3)		For the interoperability. Also, it could be useful to use it for the data analytics.	We will reuse the ones developed in T2.3. The data mapping is ongoing	
Vocabulary manager		Not necessary in this stage		

Table 29: Pilot 3b-ROM Interoperability Requirements

Data Management Layer

Component /service	Provider	Demonstration requirements	Readiness (*if the requirements can be met on the pilot location)*	
			Yes	No
Context Data Broker	ENG	Not needed since it will not deal with real-time data		
Federated Query Processing	TIB	Not needed in this initial phase of the pilot development		
Unified Knowledge Base	ENG-TIB	yes, Required for the pilot data	DE already provided solution for unified repository (e.g. Hadoop based), but we want also to reuse and integrate with the solution developed in platoon	

Table 30: Pilot 3b-ROM Data Management Requirements

Intelligence Layer :

Component /service	Provider	Demonstration requirements	Readiness (*if the requirements can be met on the pilot location)*	
			Yes	No
Data Analytics Toolbox and Processing Tools	ENG / ENGIE	Yes, needed to analyze data based on pilot requirements	Yes. We will use the Data Analytics Tool container defined in T4.1.	ENG / ENGIE
Data Analytics Dashboard Visualization	ENG	Yes, needed to analyze data based on pilot requirements	DE already has data visualization capabilities provided by the suite KNOWAGE already integrated in the platform	

Table 31: Pilot 3b-ROM Intelligence Layer Requirements

IDS

Component /service	Provider	Demonstration requirements	Readiness (if the requirements can be met on the pilot location)	
			Yes	No
Connector	ENG	Not needed in the initial pilot scenario	ENG is the developer of an open-source IDS connector (TRUE) that we will integrate in the DE	
DAPS	IAIS	Not needed in the initial pilot scenario	Already developed will use the version from Fraunhofer AISEC.	Need to define the tokes.
Broker/App store (metadata registry)	IAIS	Not needed in the initial pilot scenario		No, this will be developed as part of T3.4.
Clearing House	IAIS	Not needed in the initial pilot scenario		No, this will be developed as part of T3.4.
Vocabulary provider	TECN	Not needed in the initial pilot scenario		No, this will be developed as part of WP3.

Table 32: Pilot 3b-ROM IDS Requirements

Marketplace

Component /service	Provider	Demonstration requirements	Readiness (if the requirements can be met on the pilot location)	
			Yes	No
Marketplace	IAIS	Show metadata of available datasets in compliance with the requirements set by City Data Platform project of Roma Capitale and DTD Dept.		IAIS

Table 33: Pilot 3b-ROM Marketplace Requirements

3.6.4. Equipment and System Specification

Equipment and System Specification		
E.g. Building level	sensor	ROM pilot's use cases do not foresee, at this stage, the use of other devices other than the power meters. So, we can consider the meter itself the main sensor in the use case.

		Note1: It would be possible later that few large office buildings equipped with BMS and sensors could participate to the PLATOON test-beds phase, if both parts (platoon consortium and ROM) would consider this eventuality useful and interesting. Note2: 2500 sensors Conta-termie are the source of a large dataset on thermal consumptions, but the concessionary CPL/EFM is already collecting and managing this dataset, pushing it toward Platoon. In 2023 these sensors will be managed directly by SIMU and a specific data collection service will be deployed, therefore a connector should be designed for this purpose.
	Building PV system	165 buildings are equipped with PV plants, all connected to the grid through the power meters to exchange (exceeding energy) with the DSO grid and configured for self-consumption of the RES production. Most of the PV plants (115) are equipped with monitoring systems (SYNERGY-LOVATO) that are accessible via web service: http://88.44.119.188:9876/Login.aspx?ReturnUrl=%2fPage%2fView_6.aspx%3fid%3d6&id=6
	BMS	BMS are not involved in the project at this state. Note: It would be possible later that one large office building equipped with BMS and sensors could participate to the PLATOON test-beds phase, if both parts (platoon consortium and ROM) would consider this eventuality useful and interesting.
E.g. Community level	Community storage	No
	Municipal Level	1. The Thermal Plants office (SIMU) is using a Web Service managed by the concessionary CPL/EFM called "SIE3 Platform" visualizing the main parameters from the 1200 buildings thermal plants and the related contracted Energy Service. In this phase the Pilot 3b is defining the data acquisition procedure either directly by the Web Services or in terms of historical data as data packages. These data are not only related to the energy consumptions and performances but also to the structural data of the served buildings (Master Data) and to the Energy Audits for most of the buildings. 2. The under-development ROME CITY DATA PLATFORM (CDP - fiware based) could host the energy data to be exchanged between ROM and PLATOON. Looking to an advanced future scenario the platform could even host the PLATOON services and tools. The timing of the CDP development is managed externally, and it is better NOT to create dependencies for Platoon objectives and deadlines, therefore only when this CDP service will be fully available Platoon could consider the opportunity to use it. The data exchanges necessary to the ROM pilot will be managed through ENGINEERING SharePoint services.

Table 34: Pilot 3B-ROM Equipment and System Specification

3.6.5. Plan for Implementation of Pilot Services and Systems

As for Figure 28, it identifies the expected implementation timeline of Advanced energy management system and spatial (multi-scale) predictive models in the smart city solutions.

The figure presented below cover the different stages concerning the implementation of the toolbox components previously identified in tables from 28 to 32.

Each of these stages and their respective tasks are detailed in the Implementation Template of Pilot 3B in Annex I.

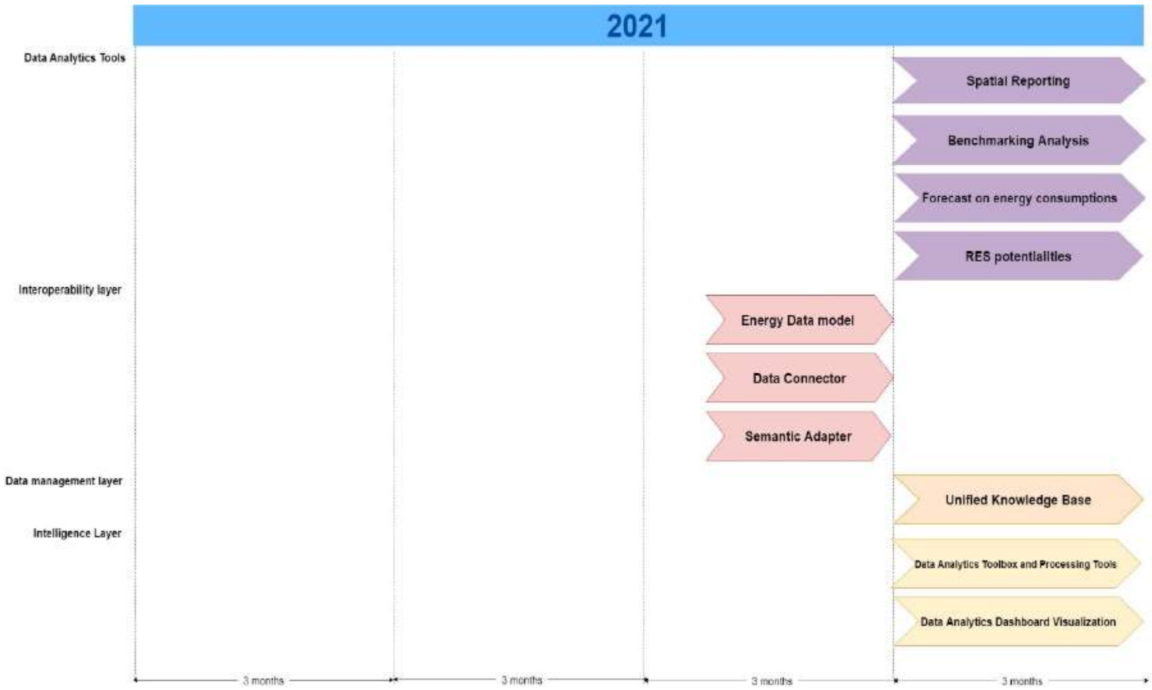


Figure 35: Components and Services to be Implemented under the Scope of Pilot 3b-ROM

Due to unviability of sufficient PV data the RES Potentialities tool could not be developed within 2021 according to the plan. New datasets have been received with enough data. This tool is planned to be developed within the first months of 2022.

3.7. Pilot 3c Energy Efficiency and Predictive Maintenance in the Smart Tertiary Building Hub Grade.

3.7.1. Pilot Characterization

3.7.1.1. General Characterization of Pilot 3c

Nanogune is a public research center located in San Sebastian (SPAIN). The building has 7319 m² distributed over six floors. Nanogune was inaugurated in January 2009, and it houses offices, 15 ultra-sensitive laboratories and a cleanroom of nearly 300 m² where the air purity is under strict supervision. The Pilot deploys an Advanced EMS - HVAC Control and RES usage optimization regarding energy bill and Predictive Maintenance in Smart Tertiary Building Assets. The use cases to be implemented within this pilot focus on:

- The current use case applies to tertiary buildings that have already in place a BMS system that allows the monitoring and control of HVAC loads and local RES.
  a. The implementation of the EMS as described before, targets to minimize the energy bill maximizing the RES usage by shifting the HVAC loads anticipating the energy cooling or heating demands.

Building cooling or heating demands can be anticipated by pre-cooling or pre-heating strategies implementation. The availability of RES increases the HVAC loads, shifting profitability not only in dynamic energy prices scenarios, but also in scenarios in which the energy prices are constant.

The use case applies to tertiary buildings in which there is already a BMS implemented that enables a seamless access to building usage data (HVAC, lighting, occupancy schedules). On top of the BMS, the PLATOON project will implement analytical models that based on machine learning techniques will predict the building thermal demands as well as the local energy production. Based on those predictions, optimization algorithms will be implemented.

Improve the maintenance policies in the tertiary buildings implementing the predictive maintenance in some specific assets trying to increase the availability and useful life of these assets reducing the general maintenance costs. Achieving good maintenance on the assets of a tertiary building requires determining which of those assets must be maintained through a corrective policy (cheap and easily replaceable assets), a preventive policy (assets that for legal aspects must be reviewed and controlled every 15 minutes) or a predictive policy (based on knowledge of your health condition). In the latter case, it is important to know if the cost of controlling future failures of an asset (knowing when the next failure will occur) is less than the solution to the problem. Thus, if we know when the asset is going to fail, we can anticipate and act in coordination with all the resources we have. Since predictive maintenance and its methodology are used in expensive assets whose breakdowns cause high costs or significant availability losses, it is necessary to know in almost real time the situation of the corresponding asset and be able to act accordingly.

Pilot contributors

This pilot is coordinated by GIROA-VEOLIA (GIR) in participation with TECNALIA and SISTEPLANT.

Related business cases

The main business cases for this pilot are linked to the objectives of three partners:

a. **GIROA-VEOLIA:** The objective of GIROA-VEOLIA is to offer a better service to their customers by reducing the energy bill, increase RES usage and reducing maintenance costs and downtimes.
b. **TECNALIA**: The objective of TECNALIA is to develop an innovative Advanced EMS to reducing the energy bill and increase RES usage. Also, they develop a predictive maintenance tool for hydraulic pumps at the edge.

c. **SISTEPLAN:** SISTEPLANT focuses on the predictive maintenance usec case. SISTEPLANT provides their PRISMA platform to integrate the analytics and dashboards. Also, they develop failure mode detection and health status tools for chillers.

3.7.1.2. General Characterization of Local Environment

A building's primary energy sources are gas and grid electricity. There are two gas boilers that provide heat to the facilities and an air/water chiller with heat recovery for cooling. The BMS of the building controls the lighting and HVAC system.

In Nanogune, three different types of users are involved: energy managers, facility managers and occupants. GIROA-VEOLIA is the energy manager who oversees the analysis of historical energy data (energy consumption and production) and improving energy efficiency of the building. The facility manager oversees the building infrastructure and its correct functioning. The facility manager and GIROA-VEOLIA, as energy manager, are the end-user of the modules developed in PLATOON. Finally, building occupants refer to researchers and workers that make use of the facilities.

In Nanogune, considering the electrical and thermal energy meters, there are 79 sensors connected to the BMS and database. Apart of that, 200 more variables of temperature, humidity and pressure will be connected to the project database.

To establish the reference consumption of the Nanogune building, monthly energy bills were collected and used for gas and electricity. The natural gas is used to produce energy for space heating, laboratory equipment and hot water for sanitary use as shown in the figure below.

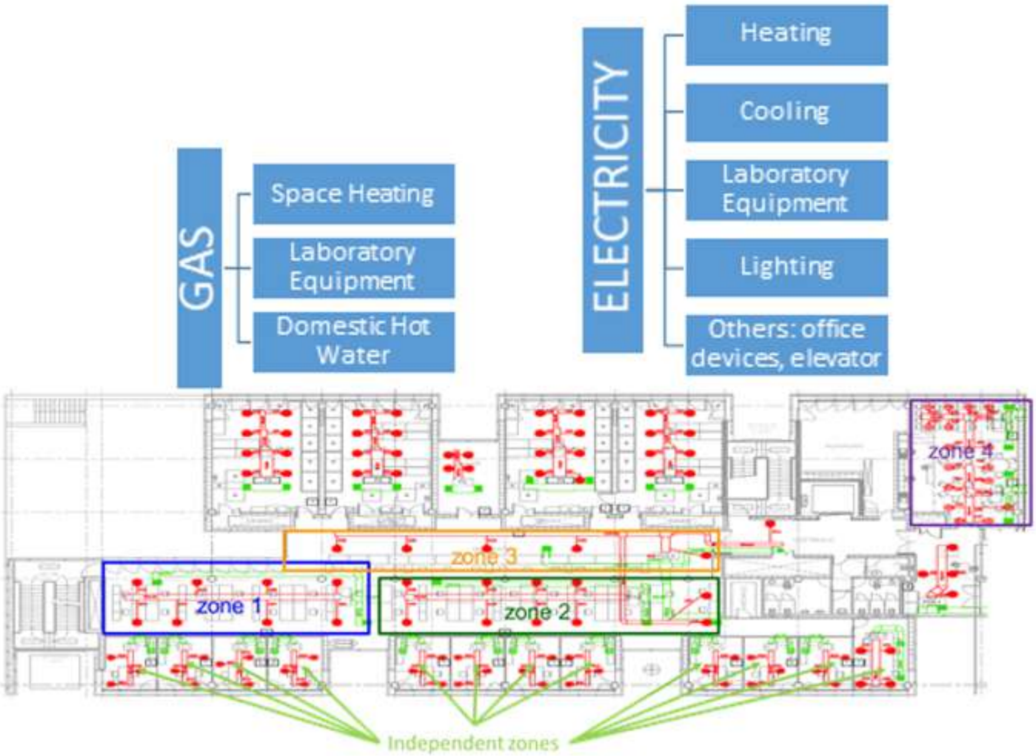


Figure 36: Pilot 3c- General Characterization of Local Environment

3.7.2. Overall Pilot Architecture

3.7.2.1. ICT Architecture

The figure below presents a simplified architecture of the Pilot 3c.

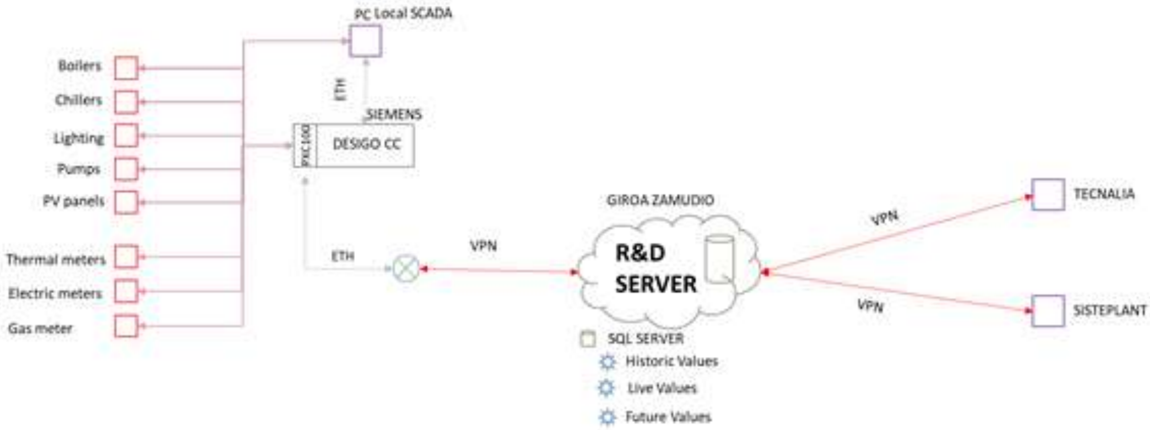


Figure 37: Pilot 3C ICT architecture

All the signals are collected via Modbus IP or Bacnet IP and are centralized in two PLCs, one for local SCADA and the other for communication with PLATOON.

All Project data, together with the weather forecasting services, are centralized in an SQL database on GIROA-VEOLIA's servers and a space is reserved on this server for the installation of developments made by SISTEPLANT and TECNALIA if necessary. This is where they have two Linux virtual machines and another Windows virtual machine where the partners connect to them via client VPN connections. In the database the values are recorded with a periodicity of 15 minutes but, if necessary, the sampling time can be reduced to every minute.

3.7.2.2. Site Assessment and Existing Infrastructures

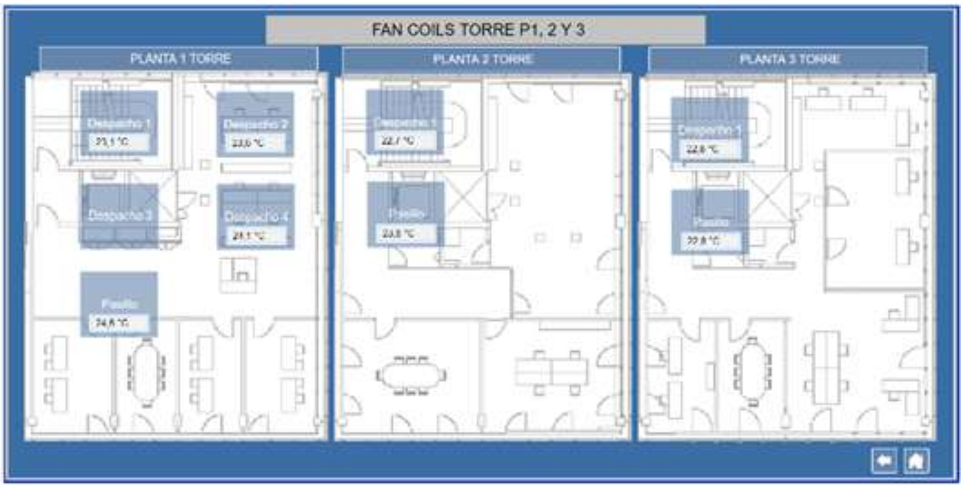
Building Management System (BMS)

A SIEMENS DESIGO DC BMS has been installed in Nanogune. A second PLC has also been installed to allow communication with the outside world and to be able to store all the data in the SQL database. The data will be available to the platoon project through a local PLC that will request data on the BMS using OPC-UA protocol.

The different equipment of the BMS is the following:

a. Bacnet IP Zones controller with temperature monitoring, heating, and cooling emission regulation (around hundred unit distributed in the building)
b. Bacnet IP controller for gas boiler, gas heat pump, cooling system and air handling unit (potential ON/OFF controls)
c. ModBUS IP Meter for gas and electricity consumption of the different heating and cooling equipment

In principle, direct action on equipment is not foreseen, although it could be done. In this case, a series of operating recommendations will be sent to the building's facilities manager.



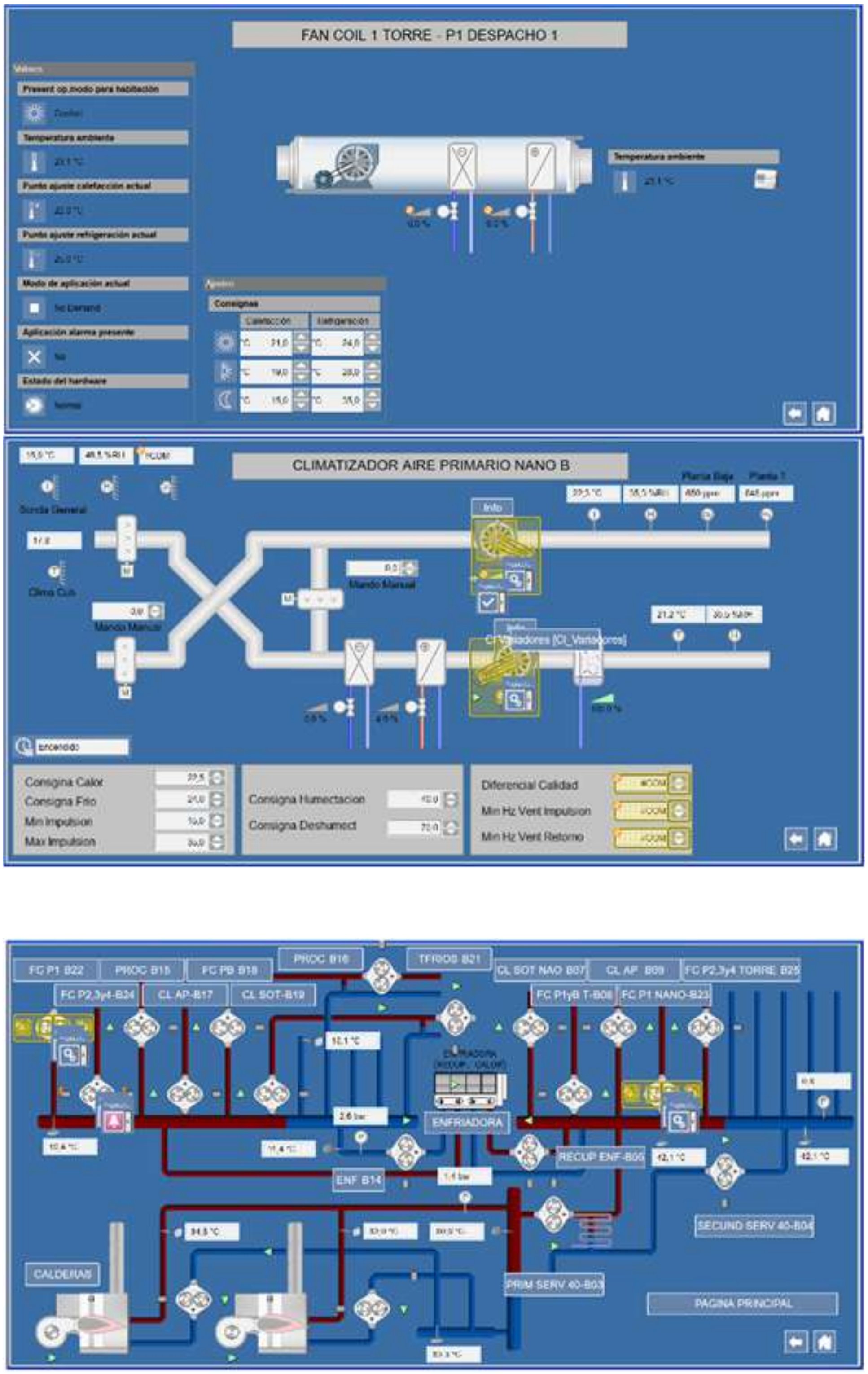


Figure 38: Pilot 3c BMS Zones

3.7.3. Pilot 3c Requirements

Interoperability layer

Component /service	Provider	Demonstration requirements	Readiness *(if the requirements can be met on the pilot location)*	
			Yes	No
Data Connector	GIR	Non-semantic data. It will be just simple time series data stored in SQL server of Giroa.	Yes, connection is working since april 2021	
IoT Connector	GIR	Non-semantic data. It will be just simple time series data stored in SQL server of Giroa.	Yes, connection is working since april 2021	
Data Curation and Integration	GIR	Non-semantic data. It will be just simple time series data stored in SQL server of Giroa.	Curation (data quality check) already implemented.	
Semantic Adapter		Not required. Non-semantic data.		
Energy Data model (PLATOON Data models from T2.3)	GIR, SIS and TECN	Yes for the interoperability.	Yes, it is already in T2.3 for the interoperability.	
Vocabulary manager	TECN and IAIS	Regarding interoperability define 3 levels:	Vocabulary manager	TECN and IAIS

Table 35: Data Management Layer Requirements

Data Management layer

Component /service	Provider	**Demonstration requirements**	Readiness *(if the requirements can be met on the pilot location)*	
			Yes	No
Context Data Broker	GIR	Something similar but we do an API call every 6 hours for getting meteo data from Merasoda and store in the database. We do it ever 6 hours because they update solar radiation data every 6 hours. Similar for electric prices but only one call every day at 12 to	Already implemented.	

		one service and then at 1pm connect to OMIE (official source).		
Federated Query Processing	-	Not required. Non-semantic data.	-	-
Unfied Knowledge Base	-	Not required.		
Context Event Processing	-	Not required.		

Table 36: Pilot 3c Data Management Requirements

Intelligence Layer

Component /service	Provider	Demonstration requirements	Readiness *(if the requirements can be met on the pilot location)*	
			Yes	**No**
Data Analytics Toolbox and Processing Tools	TECN and SIS	For sure implemented as a service but might consider as well to do a test on the infrastructure using dummy code.		No. We will use the Data Analytics Tool container defined in T4.1.
Data Analytics Dashboard – Visualization	SIS	Use Promindcapabilities - Visualization Dashnobard to show outputs from data analytics tools from SIS and TECN. Also GIR want to show some results in another dashboard that they use internally in Giroa.	Yes they already have the visualization dashboard in Promind/Prisma.	Will need to be integrated with data analytics tools/storage. GIR dashboard ongoing. Operative for september 2021.

Table 37: Pilot 3c Intelligence Layer Requirements

Marketplace

Component /service	Provider	Demonstration requirements	Readiness *(if the requirements can be met on the pilot location)*	
			Yes	**No**
Marketplace	IAIS	TECN will show metadata of proprietary tools in the marketplace. GIR will not publish in the marketplace. The data acutally belongs to the building owner (CIC Nanogune) so they cannot comercialise the data. Only offer additional services using the data. SIS will show metadata of proprietary tools in the marketplace and offer additional engineering services using the data (e.g. similar to what they do		No this will be developed as part of T3.4.

		for optimizing plant layout in industry)		

Table 38: Pilot 3c Marketplace Requirements

IDS

Component /service	Provider	Demonstration requirements	Readiness *(if the requirements can be met on the pilot location)*	
			Yes	No
Connector	ENG	Data usage. Between GIR and TECN.		No this will be developed as part of T3.2-T3.3.
DAPS	IAIS	Identity provider	Already developed will use the version from Fraunhofer AISEC.	Need to define the tokes.
Broker/App store (metadata registry)	IAIS	Look for data and tools metadata.		No, this will be developed as part of T3.4.
Clearing House	IAIS	Track data exchange		No, this will be developed as part of T3.4.
Vocabulary provider	TECN	yes		No, this will be developed as part of WP3.

Table 39: Pilot 3c IDS Requirements

3.7.4. Equipment and System Specification

Equipment and System Specifications					
Level	**Equipment**	**System Specification**	**status**	**data source site typology**	**notes**
Building level	Sensors	Indoor environmental Temperature and humidity sensors	Ready for Platoon test	BMS	Access through SQL database
		Outdoor environmental Temperature and humidity sensors	Ready for Platoon test	BMS	Access through SQL database
		Real time monitorization of the heating and cooling production systems(Boilers, chillers, AHU, Fancoils) such as pressure,	Ready for Platoon test	BMS	Access through SQL database

		temperature, humidity, frequency…			
	Meters	Energy meters (electricity consumption for heating, cooling, lighting)	Ready for Platoon test	BMS	Access through SQL database
		Gas meters for heating production	Ready for Platoon test	BMS	Access through SQL database
	PV panel	For electrical production, only data is radiation and produced energy	Ready for Platoon test	Energy meter	Access through SQL database
Headquarters level	GMAO	Maintenance work order analysis for chillers and pumps	Ready for Platoon test	PRISMA	
City level	Forecast	Weather prediction by 3 days in advance	Ready for Platoon test	Web provider	Access through SQL database
	Electricity prices	Electricity buying and selling prices for the next 24 hours	Ongoing for platoon	Web provider	Working on the transferring to the SQL database

Table 40: Pilot 3c Equipment and System Specification

3.7.5. Plan for Implementation of Pilot Services & Systems

The figure presented below cover the different stages concerning the implementation of the predictive maintenance for wind farm components previously identified in Table 35: Data Management Layer Requirements

to **Error! Reference source not found.**. Each of these stages and their respective tasks are detailed in the Implementation Template of Pilot 3C in Annex I.

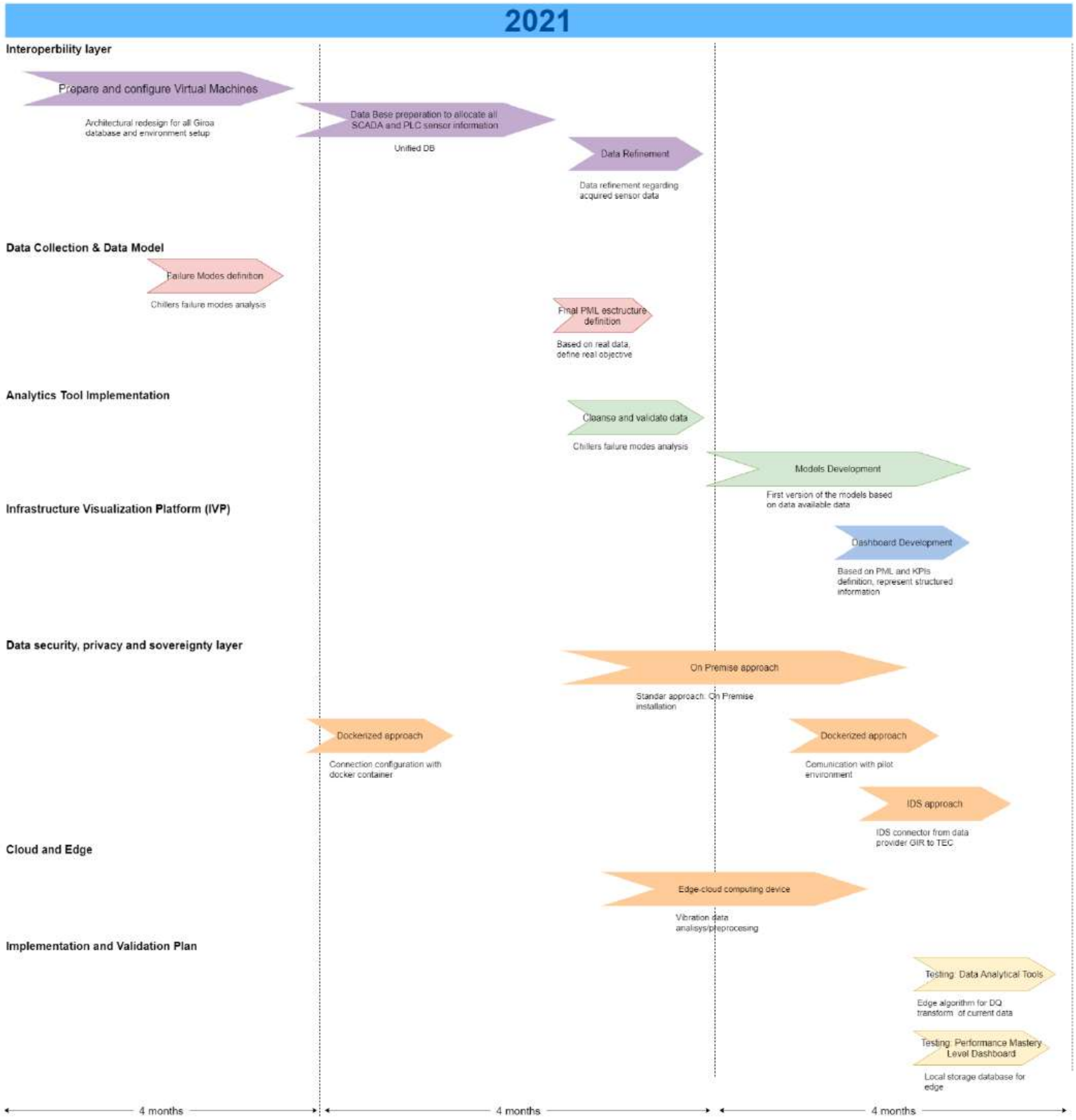


Figure 39: Components and Services to be Implemented under the Scope of Pilot 3c

3.8. Pilot 4a Energy Management of Microgrids

3.8.1. Pilot Characterization

3.8.1.1. General Characterization of Pilot 4a

The MG2lab in the Department of Energy, Politecnico di Milano, is a cutting edge microgrid integrating different Distributed Energy Resources (DERs) like solar, combined heat and power, battery and hydrogen storage (thus being multi-fluid) and serving both electric and thermal load to power lighting, heating, desalination, electrical vehicles, and electrical bikes (thus being multi-good).

The implemented microgrid, integrating various technologies for distributed energy generation and storage, constitutes an active network that supplies heat, electricity, potable water and energy-related services, therefore it is multi-good and multi-fluid: in recent years, in fact, the microgrid definition has been extended leading to a broader concept of multi-energy systems, or multi-goods microgrids: these systems, indeed, have the goal of accounting for multiple needs leveraging on the synergies among different energy forms and energy-related services (e.g., electricity, heating, cooling and potable water). In addition, multiple storages can be adopted (i.e., batteries for the short term and hydrogen for the long term), making the system flexible and more efficient.

Additionally, it features the ability to be operated both on-grid and off-grid modes and it is flexible with multiple configurations (single/multi node), including an Artificial Intelligence (AI) implementation for optimal management. Thus, the objectives of this pilots are the development and on-field testing of predictive optimization algorithms end energy management system for optimal planning of multi-good energy systems, to ensure their secure and efficient operation also when featuring a high penetration of renewable energy sources.

This pilot provides an analysis facility for real-life scale research, simulation, and test purposes, thus allowing to study new data-driven paradigms for energy management able to deal with increased complexity of the energy systems and to assess the advantages of innovative strategies.

Additionally, this experimental facility further aims at the following goals:

a. Grid-connected Distributed Energy: optimally manage Behind the Meter (BtM) grid connected storages and renewables in combination with onsite load and distributed generators.
b. Off-Grid Microgrids: furtherly increase the fuel savings and add robustness in off-grid microgrids, through a novel optimization layer making use of load and photovoltaic forecasters to achieve 100% load coverage.
c. Prosumer Aggregation: test and improve a commercial Virtual Power Plant platform for enabling the access of storages and other prosumers to the electricity market, leveraging on the new regulatory framework.
d. EVs as a Distributed Energy Resource: analyze the viability of EV battery usage for supporting the grid frequency, through so called Vehicle to Grid (V2G) service.
e. Storage as EV Fast Charge enabler: design an EV fast charging solution infrastructure, enabling a real deployment of fast charge infrastructures in urban areas.

In particular, the microgrid interconnects:

1. Dispatchable generators, which operation can be scheduled, as the Combined Heat and Power (CHP) generator.
2. Non-dispatchable generators, associated with the exploitation of renewable energy sources, such as Photovoltaic (PV) fields.
3. Three different kinds of storage systems: thermal storage system, lithium-ion Battery Energy Storage System (BESS) and hydrogen Hybrid Energy Storage System (HyESS);
4. Three Power Centers (PCs), acting as electric hub.
5. A back-to-back (B2B) inverter, acting either as load or grid simulator. Its main purpose is to simulate electricity user as well as, if needed, connection point with the electric grid.
6. Some controllable units, that are electric loads but employed in several goods production such as heat pumps and water purification system.
7. Three charging stations for Electric Vehicles (EV), two of which for electric cars and the other for electric bikes (E-Bike).

3.8.1.2. General Characterization of Local Environment

The microgrid is placed at the Department of Energy of Politecnico di Milano. In particular, the non-dispatchable units (PV modules) are located on the building's roofs, the BL25 and BL25A aka Laboratory of Micro-Cogeneration (LMC). The thermal loads and generator, the grid simulator and the HyESS are placed in the LMC – the gas storage system is placed nearby, outside LMC. All the remaining units are in a container located outside the LMC in a parking area known as B37.

Figure 40: Pilot 4a Demonstration Site

3.8.2. Overall Pilot Architecture

The architecture of the pilot is provided in the following, with brief details on the physical on-site devices, including the pilot's power grid schema presenting the set of devices and systems that will enable the functionalities to be demonstrated.

3.8.2.1. Power Grid Architecture of Pilot 4a

The experimental microgrid interconnects the following systems and subsystems:

1. **Power Centers (PC)**, acting as electric hub;
2. **Generators:** dispatchable and non-dispatchable units for Heat, Power and Combined Heat and Power (CHP) generation:
   a. three photovoltaic fields:
      a. PV1: 25 kW
      b. PV2: 24 kW
      c. PV3: 26 kW
   b. a natural gas Micro-CHP system (TOTEM)
      a. Electric power 25 kW, Thermal power 25 kW
3. **Storage**: three different systems:
   c. a thermal storage system (50 kWh)
   d. two lithium-ion Battery Energy Storage Systems (BESS):
      a. BESS1: 70 kWh Lithium batteries
      b. BESS2: 70 kWh Lithium batteries
   e. a hydrogen Hybrid Energy Storage System (HyESS):
      a. 30 kWh storage coupled with power-to-power system- Alkaline Electrolyzer (25 kW) PEM Fuel Cell (25kW)
4. **Loads**:

- an electric grid simulator, that acts as virtual electricity user as well as (if needed) connection point with the electric grid: 100kW;
- some programmable electric loads:
  - Two heat pumps Smart-grid ready: 2 x 6 kW
  - Potable water production (Sireg Hydros): 6 kW
  - Lights: 5 kW
- three charging stations:

- two fast charging stations for 2 Electric Vehicles (EV): 2 x 50kW
- one for 10 Electric bikes (BMW): 10 x 250 W

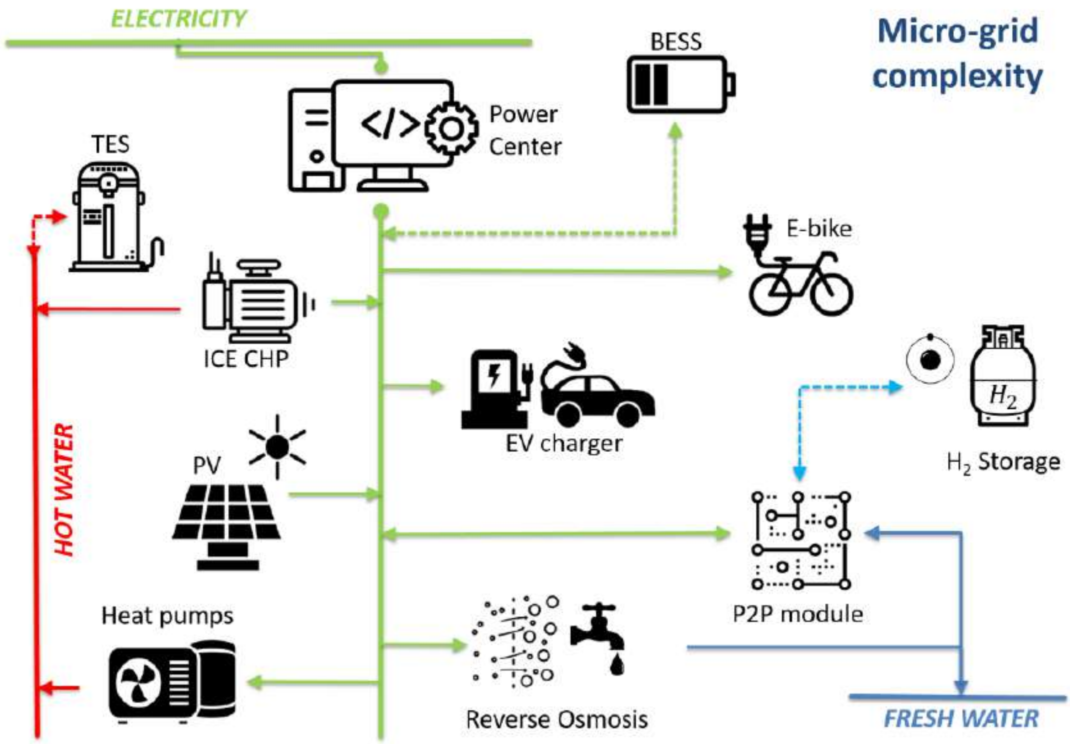


Figure 41: Pilot 4a MG2lab Micro-Grid Interconnections

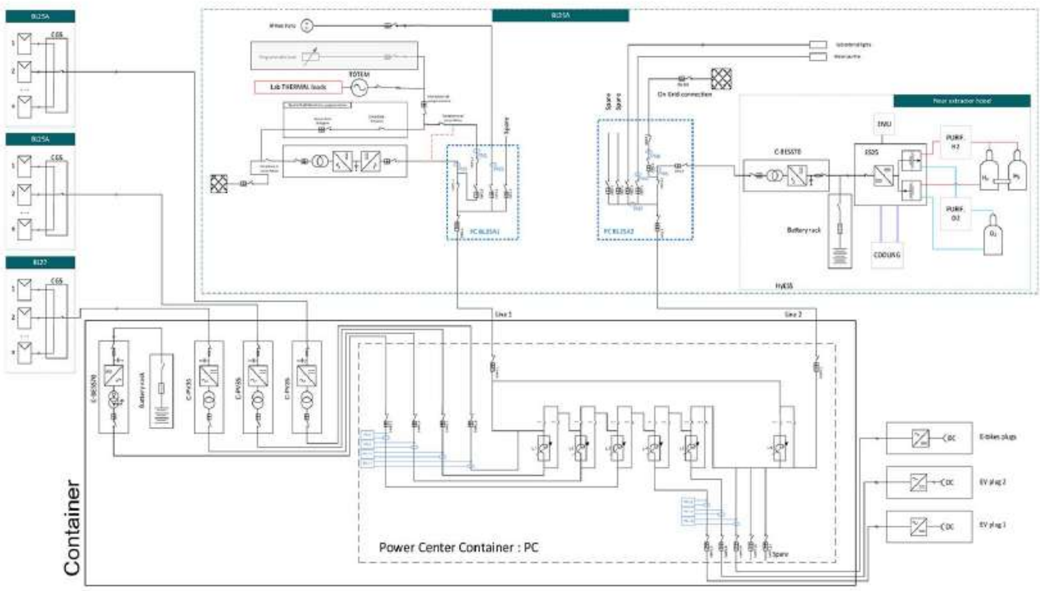


Figure 42: Pilot 4a MG2lab Detailed Layout

3.8.2.2. ICT Architecture

The microgrid is organized in three different **Power Centers** (PC), each connected to the others, which work together, as shown in the following figures describing the microgrid communication diagram and power centers, components, and controllers.

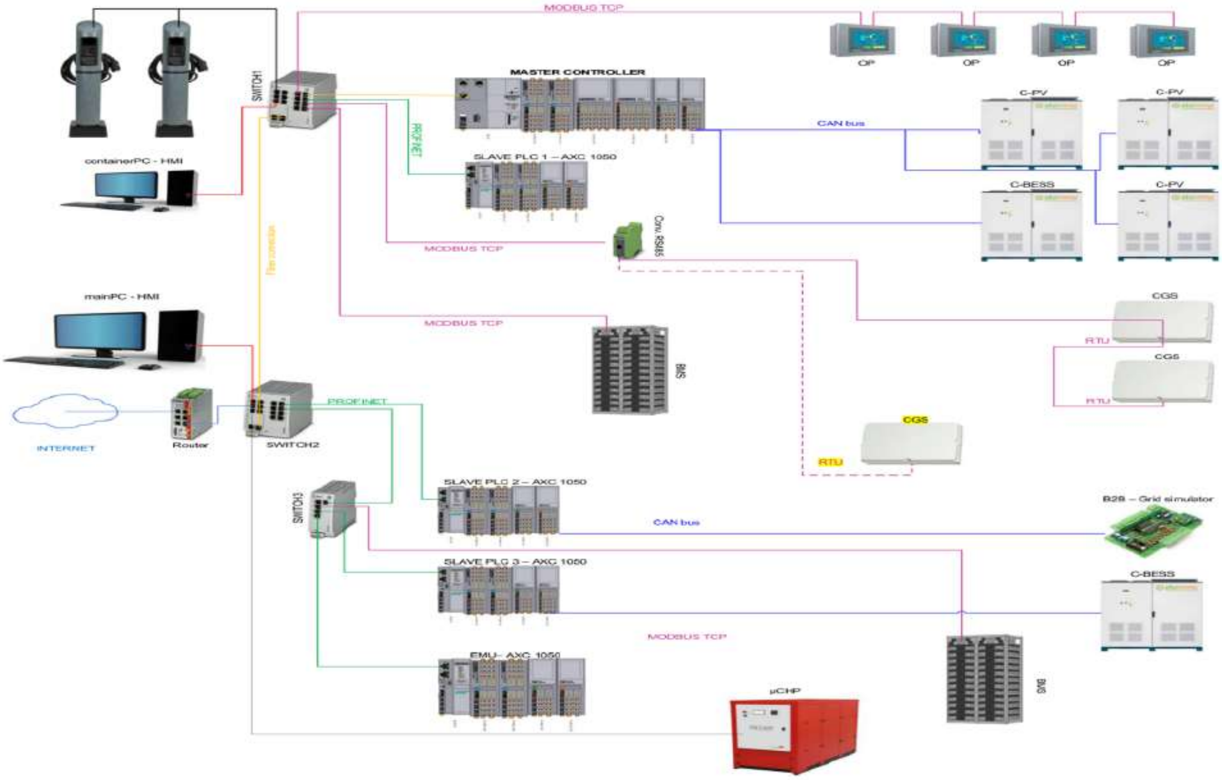


Figure 43: Pilot 4a Microgrid Communication Diagram

Power Center	Components	Controller
PC1	Photovoltaic fields, PV1 and PV2	Master
	Battery Energy Storage System, BESS	Slave 1
	Electrical Vehicle plugs, EVs	Slave 1
	Spare connections	Slave 1
PC2	Heat pumps	Slave 2
	Back-To-Back simulator, B2B	Slave 2
	Combined Heat and Power generator, TOTEM	Slave 2
	Water Purifier, WP	Master
	Spare connection	Slave 2
PC3	Hybrid Energy Storage System, HyESS	Slave 3
	Grid connection	Slave 3
	External lights	Slave 3
	Spare connections	Slave 3

Figure 44: Pilot 4a Power Centers, Components and Controllers

3.8.2.3. Site Assessment and Existing Infrastructures

PC1: This is the main Power Center and it is composed by two photovoltaic systems, plus a third one which must be installed, a storage system, a master controller and three electro-vehicle plugs. It also comprehends two free spares for further development - most of its components are placed inside the container in the parking space named B37.

Elements in PC1 are:

- two operative photovoltaic fields are placed on the roof of the BL25A building; the first field, called PV1, is composed by 6 strings of 13 modules each, for a total of 78 modules, the second one, called PV2, is composed by 6 strings of 12 modules each, for a total of 72 modules; three C-PV35 photovoltaic inverters are used for DC to AC conversion. A junction box (CGS) can monitor:
  - The current of each string.
  - The environmental temperature.
  - The PV modules temperatures.
- the BESS system constituted by: 70kWh Lithium-ion Samsung battery string: it needs to cope with sudden changes in electrical load and thus to ensure operation of the microgrid in the first 5 minutes of transient, during which the P2P settle down to steady state – a converter (C-BESS70) manages the bidirectional energy flow between the microgrid and the first ESS; it is fundamental to provide inertia to the system and stabilize the microgrid operation.
- The Electric Vehicle charging stations are placed just outside the container. There are three different recharge stations: two of them are for electric cars and the last one is for electric bikes. The recharge stations were installed to simulate real-life-load.
- The Master Controller represents the control and supervision system. This determines and imposes the set-points of each subsystem with which it communicates – a Human Machine Interface (HMI), which is basically an industrial PC allows the operator to interact with the system and modify the parameters and commands of the network.
- The last component inside the container is the auxiliary's cabinet; it is powered directly from the microgrid and guarantees the supply of the container auxiliary systems and the Master Controller (MC). The auxiliary system comprehends:
  - Container lights and plugs.
  - HVAC system: Heating, Ventilation and Air Conditioning system to control the temperature which is fundamental for the correct operation of the inverters and the battery strings.
  - A fire detection system, constituted by a fire alarm control panel, a fire detection sensor, a fire extinguisher, and a manual device.

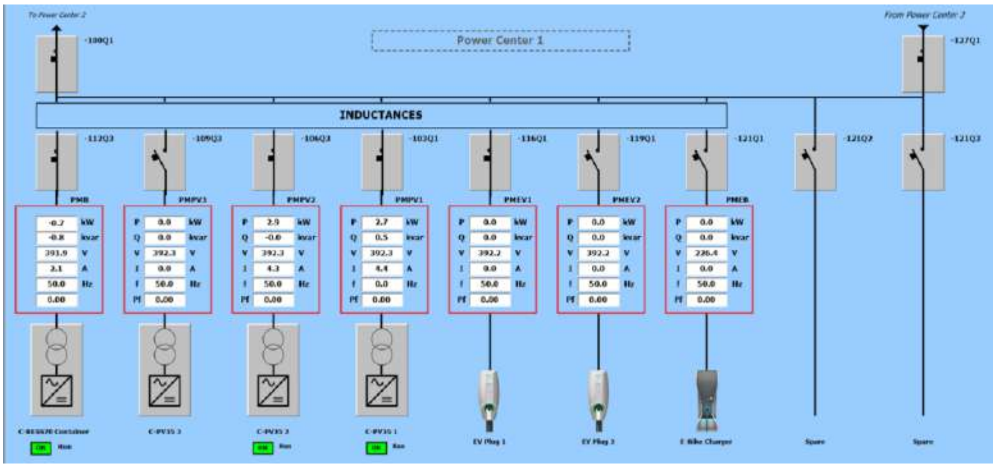


Figure 45: Pilot 4a PC1 Detailed View

The **PC2** is composed by two heat pumps, one back-to-back, one TOTEM, one water purifier, two spares for further development.

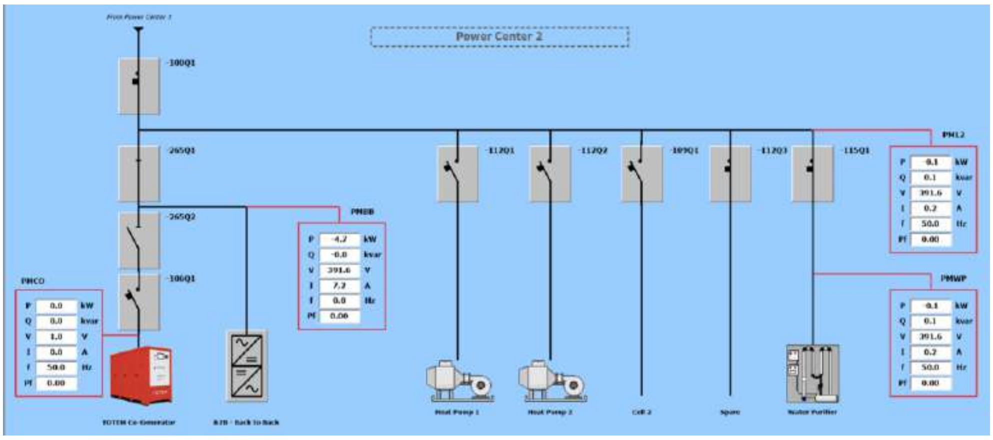


Figure 46: Pilot 4a PC2 Detailed View

The **PC3** is composed by the links to the PC1, the external lights, a hybrid-storage system BESS and two spares for further development of the microgrid.

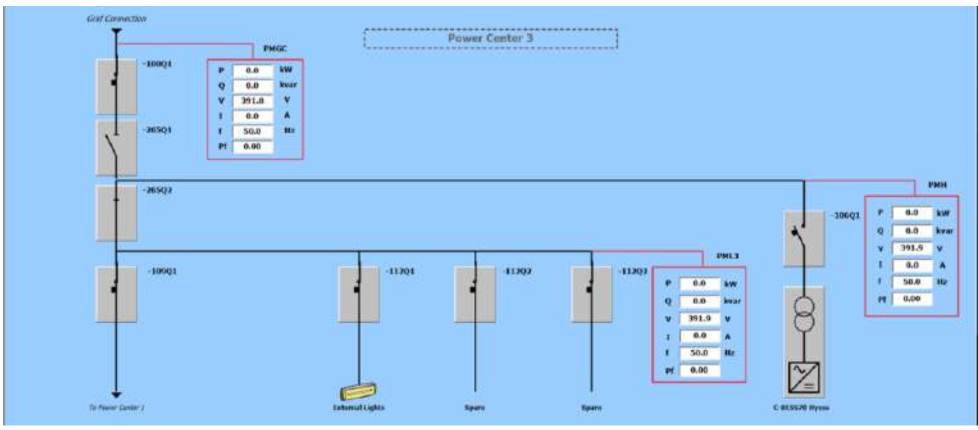


Figure 47: Pilot 4a PC3 Detailed View

3.8.3. Pilot 4a Requirements

Interoperability layer

Component /service	Provider	Demonstration requirements	Readiness *(if the requirements can be met on the pilot location)*	
			Yes	No
Data Connector	ENGIE (Transfer Data from Legacy system to Platoon System)	Now there is basic scenario a connection with a central rep for all wind data. They could extend it to a more complex scenario to connect directly to other DBs. Engie to confirm. For VUB and TECN will have no impact. Engie Identify 3Vs of data (volume, velocity and variety – format) – this should be provided to T2.4. Basic scenario time series non-semantic. Also, will try to put a complete a potential more complex scenario to use semantic data. [POLIMI] In case of Polimi it will be the "Server" of MG that is already deployed on site. DC is responsible to collect Data from any Data Source (legacy system, DB, Rest API …). It is a software component. Data Connector should be able to access Interfaces to collect it.	interfaces to query the SQL DB (TBC by POLIMI)	Will depend on the configuration of the Pilot. Data Policies, Data Access, Cyber restrictions. The deployment of the data connector will be highly depending on the constraints of POLIMI (cloud, on premise, …). MaM (POLIMI) consider that the internal implementation should be the one considered for stability concerns.
IoT Connector	-	Not required. They have a block on Azure for this. [POLIMI] Already have IT setup to collect data from Assets.	-Already working	N/A
Data Curation and Integration	ENGIE and TIB	Basic scenario time series non-semantic. Also, will try to put a complete a potential more complex scenario to use semantic data. [POLIMI] Times Series / Non-Semantic. RAW data directly in the DB.	for Basic scenario time series non-semantic. POLIMI Same	No for a complete a potential more complex scenario to use semantic data. POLIMI Same
Semantic Adapter	ENGIE and TIB	Basic scenario time series non-semantic. Also, will try to put a complete a potential more complex scenario to use semantic data. POLIMI Aims to convert data (non-semantic one) to	for Basic scenario time series non-semantic. POLIMI Not ready	No for a complete a potential more complex scenario to use semantic data. POLIMI Should be used in the Pilot for basic scenario.

		semantized Data to expose them to Data Curation and Integration part. In the case of POLIMI : some data can be in real time, but mostly it is now in Batch approach. Some Algorithms (forecasting) are almost real time (30'). Batch – Almost real time – Real time capabilities of POLIMI MG		
Energy Data model (PLATOON Data models from T2.3)	ENGIE, VUB and TECN	Yes, for the interoperability. Also, it could be useful to use it for the data analytics. POLIMI Yes, for the interoperability (ongoing definition in 2.3)	for the interoperability. POLIMI Not ready, will be implemented for the pilot	Pending failure modes for the data analytics. POLIMI TBD on which"Analytic"/Model part it will be considered
Vocabulary manager	TECN and IAIS	Regarding interoperability define 3 levels: 1)Raw data with IDS 2)Semantic data with IDS 3)Semantic data with IDS and used for Data Analytics In this pilot we will target at least level 2. POLIMI Should be useful for POLIMI. TBC. 1)Raw data with IDS 2)Semantic data with IDS 3)Semantic data with IDS and used for Data Analytics In this pilot we will target at least level 2.	POLIMI No Should be useful for POLIMI. TBC	No. Vocabulary manager is part of IDS vocabulary provider. This will be done in WP3. Not able to define now how this can be implemented with IDS vocab provider.

Table 41: Pilot 4a Interoperability Layer Requirements

Data Management Layer

Component /service	Provider	Demonstration requirements	Readiness (if the requirements can be met on the pilot location)	
			Yes	No
Context Data Broker	ENGIE	Not Sure if it is required- Engie to confirm. POLIMI Definition: Data Broker that provides access to context information. Information about	POLIMI to confirm.	POLIMI to confirm.

		entities in Real env. (e.g. Real time information from sensor, …). We are focusing on information that change with a certain frequency. Weather information is a good example that can be considered when it comes to use Context Data Broker. If it is only historical data, CDB is not needed. POLIMI to confirm		
Federated Query Processing	ENGIE and TIB	4 scenarios – 1)Without 2)Inside Engie 3)Outside Engie 4)Inside and outside Engie Engie to confirm which one is needed POLIMI to confirm	Engie need to confirm POLIMI to confirm No Ready	Engie need to confirm POLIMI to confirm Could be implemented in some function/tools
Unified Knowledge Base	ENGIE and TIB	They will try to implement but need to specify with TIB exactly what it is POLIMI Need to assess if it makes sense for POLIMI.	POLIMI Need to assess if it makes sense for POLIMI.	Not implemented ye POLIMI Need to assess if it makes sense for POLIMI.
Context Event Processing	ENGIE	Not required Software Component (inside/outside POLIMI) to analyze context information (that change very quickly) focusing on specific events , situation (e.g. Streams) – using Triggers / Rules applied to these information/events. Ex: Critical Situation identification,… Can be applied to historical information too.	POLIMI Depending on capacity to extend a semantic view of events in the POLIMI MG	POLIMI Depending on capacity to extend a semantic view of events in the POLIMI MG

		This component is linked to the Context Data Broker. POLIMI Already existing in POLIMI. But can be useful if extended to a semantic description of event		

Table 42: Pilot 4a Data Management Requirements

Intelligence Layer

Component /service	Provider	Demonstration requirements	Readiness *(if the requirements can be met on the pilot location)*	
			Yes	No
Data Analytics Toolbox and Processing Tools	TECN (Procedure > Container) POLIMI (Code > Container) ENGIE (Implementation with Semantic)	For sure implemented as a service but might consider as well to do a test on the infrastructure using dummy code. POLIMI Owns Algo/Models for POLIMI MG.	Yes. We will use the Data Analytics Tool container defined in T4.1. POLIMI Not ready can be tested (EPS)	POLIMI
Data Analytics Dashboard – Visualization	POLIMI	Visualization Dashboard to show outputs from data analytics tools from VUB and TECN. POLIMI Already Dashboard.	Already have the visualization dashboard.	Will need to be integrated with data analytics tools/storage. POLIMI Will need to be integrated / Linked if needed in PLATOON Ecosystem

Table 43: Pilot 4a Intelligence Layer Requirements

IDS

Component /service	Provider	Demonstration requirements	Readiness *(if the requirements can be met on the pilot location)*	
			Yes	No
/	/	/		IDS is not within the scope of pilot 4A

Table 44: Pilot 4a IDS Requirements

3.8.4. Equipment and System Specification

The equipment to be integrated and developed in the scope of Pilot 4a is reported in the following table:

Power Center 1 (PC1)	PC1	The first Power Center (PC1) is composed by: • Three photovoltaic systems. • A Battery Energy Storage System (BESS); • An electro-vehicle plug, plus other two to be installed. • Two spares' connections for further development. Sometimes it is referred as "Container", since most of its components, except for the PVs, are placed inside the container in the parking space named B37
	PV system	The first field, identified as PV1, is composed by 6 strings of 13 modules each, for a total of 78 modules. The second one, identified as PV2, is composed by 6 strings of 12 modules each, for a total of 72 modules. The third one, identified as PV3, is composed by 4 arrays of 22 modules each, for a total of 88 modules. All fields have the same configuration: every module in the string is connected in series, while the strings are connected among themselves in parallel through a string box, in turn connected to the PC1. Moreover, each field has a dedicated inverter, referred as C-PV35, which with all the remaining components of the system, is on the inside of the container. The version of the modules adopted is the SPR-X20-327-COM, which has a nominal power of 327W. The junction box can monitor: • The current of each string. • The environmental temperature. • The PV modules temperatures.
	BESS	Inside the container is also placed the Battery Energy Storage System, constituted by: a. 70kWh Lithium-Ion Samsung battery string. b. C-BESS70, for DC to AC conversion. The C-BESS70 converter manages the bidirectional energy flow between the MG and the first ESS; it is fundamental to provide inertia to the system and stabilize the micro-grid operation.
	AUX	The last component inside the container is the auxiliary's cabinet; it guarantees the supply of the container auxiliary systems and the Master Controller (MC). The auxiliary system comprehends: 1. Container lights and plugs. 2. HVAC system: Heating, Ventilation and Air Conditioning system to control the temperature which is fundamental for the correct operation of the inverters and the battery strings. 3. A fire detection system, constituted by a fire alarm control panel, a fire detection sensor, a fire extinguisher, and a manual device. The Master Controller represents the control and supervision system. This one is obtained from three hardware components: 1. Master Controller, which determines and imposes the setpoints of each subsystem with which it communicates.

		2. Human Machine Interface (HMI), which is basically an industrial PC that allows the operator to interact with the system and modify the parameters and commands of the network. 3. Router, which enables the internet connection for controlling and monitoring the network remotely. The real HMI is placed in LMG while in the container there is the possibility to connect an addition monitor remotely controlled.
	EV charging station	The Electric Vehicle charging stations represent the last component of the PC1 and they are placed just outside the container. There are three different recharge stations: two of them are for electric cars and the last one is for electric bikes. The EV charging stations have a nominal power of 50kW and they are capable of fast charging; they were installed to simulate real-life-load, and, for the moment, they represent an opportunity for further development of the micro-grid.
Power Center 2 (PC2)	PC2	The PC2 is placed in the Laboratory of Micro-Cogeneration (LMC), in the same building of LMG, and it is composed by: 3.7.1. two heat pumps. 3.7.2. one back-to-back. 3.7.3. one CHP generator from TOTEM. 3.7.4. one water purifier. 3.7.5. two spares connections for further development. This Power Centre is focused on a cogeneration system and it is organized in two different cells in the laboratory.
	Heat pump	The two heat pumps are a 6kW Daikin pumps (EHBX08DA6V)
	Water purifier	The water purifier installed in the micro-grid is a four-stage reverse osmosis system that works in a closed cycle. Each stage consists of a single pressure vessel, which contains a single membrane element. The brine solution at the end of a membrane becomes the feed solution of the next membrane. The permeate streams are collected from each membrane and they are mixed, in parallel, in the permeate pipe. The desalination system has a nominal power of 1,2kW and a nominal flow rate of 10 m^3/h
	Totem	The engine is one of the main components of this Power Center and it is a modified motor of the FIAT 500, called TOTEM; it is a 25kw natural gas micro-cogenerator that can produce contemporarily electrical power and heat. Designed to be fueled with natural gas and propane, it is coupled with a water-cooled alternator for electrical power production. Thanks to an efficient heat exchanger system, heat is recovered from the internal combustion engine as well as the alternator and provided as a by-pass product. In addition, it is equipped with the Engine Controlled Unit developed by Magneti Marelli for a real time and precise control of the engine. The TOTEM generator is connected through a circulating water circuit to the tank serving as thermal storage. From the tank, an additional circuit leads the hot water to the virtual thermal user, where heat is dissipated. The cooled water is in turn be rerouted back to the component.
	B2B converter	The grid simulator, or back-to-back inverter represents a conversion control center that can work as a grid or charge simulator. The B2B can both inject and withdraw electric energy from the grid and modulate the electric parameters on the micro-grid side to meet specific criteria. It will thus allow to reproduce the effect of grid connected operation mode when MG frequency and voltage are imposed by the main grid.

		Reversely, the grid simulator can also behave just like a virtual electric load, injecting the equivalent of the desired electric load power profile on the electric grid without interfering with the evolution of frequency and voltage on the micro-grid side.
Power Center 3 (PC3)	PC3	The PC3 is in the LMG and it is composed by: • Hybrid Energy Storage System (HyESS); • point of connection to the network. • external lights. • two spares' connections for further development.
	HESS	Basically, it is the main component of PC3 and in turn is composed of subsystems, such as: a. Hydrogen Power-to-Power (P2P) system. b. battery pack, a 70 kWh Lithium-ion Samsung battery string. c. two conversion modules: DC-DC conversion module and DC-AC conversion module, which is another C-BESS70 converter. d. Hydrogen and Oxygen storage tanks. e. Hydrogen and Oxygen treatment system. f. cooling system for P2P.
	P2P	The Hydrogen Power-To-Power (P2P) system is the vertical integration of two modules in a unique composed cabinet: respectively a 25kW Gas-To-Power (G2P) module coupled with a 25kW Power-To-Gas (P2G) module, with hydrogen and oxygen treatment systems and storage capacity in between. The P2G module is based on a high-pressure alkaline electrolyser that converts electrical energy into chemical energy. Through electrical energy electrolysis of water is performed, producing hydrogen and oxygen. After the drying from the residual electrolytic solution, which is performed by the gas treatment system, the gases can be directly storable in suitable tanks. The G2P module is based on a H2/O2-fed Proton Exchange Membrane (PEM) fuel cell, which re-converts chemical energy into electrical energy, recombining the stored gases and giving water as the only by-product. The whole P2P system can then be a battery with a charging phase with gas production by P2G and a discharge phase with electricity production by G2P. The BESS, which is identical as the one for PV, and the Hydrogen P2P system are connected by means of a DC-DC converter, in parallel on a common DC bus.
External	**Weather station**	Installed next to the photovoltaic field, the meteorological station allows to collect environmental parameters of interest. It is equipped with two secondaries standard pyranometers to detect the total solar irradiance on horizontal and tilted plane (30°). The latter measurement is directly implemented to define the solar irradiation on the modules, since they have the same tilt angle. Additionally, a thermohydrometer for temperature and humidity measurements is installed. Remaining sensors are a combined speed-direction anemometer for wind detection, a rain collector and two additional pyranometers, one for diffuse radiation and the other one for global radiation measurement. The meteorological station performs ambient conditions measurements every ten seconds.

Table 45: Pilot 4a Equipment and System Specification

3.8.5. Plan for Implementation of Pilot Services and Systems

The figure presented below covers the different stages concerning the implementation of the components for energy management of microgrids. Each of these stages and their respective tasks are detailed in the Implementation Template of Pilot 3C in Annex I.

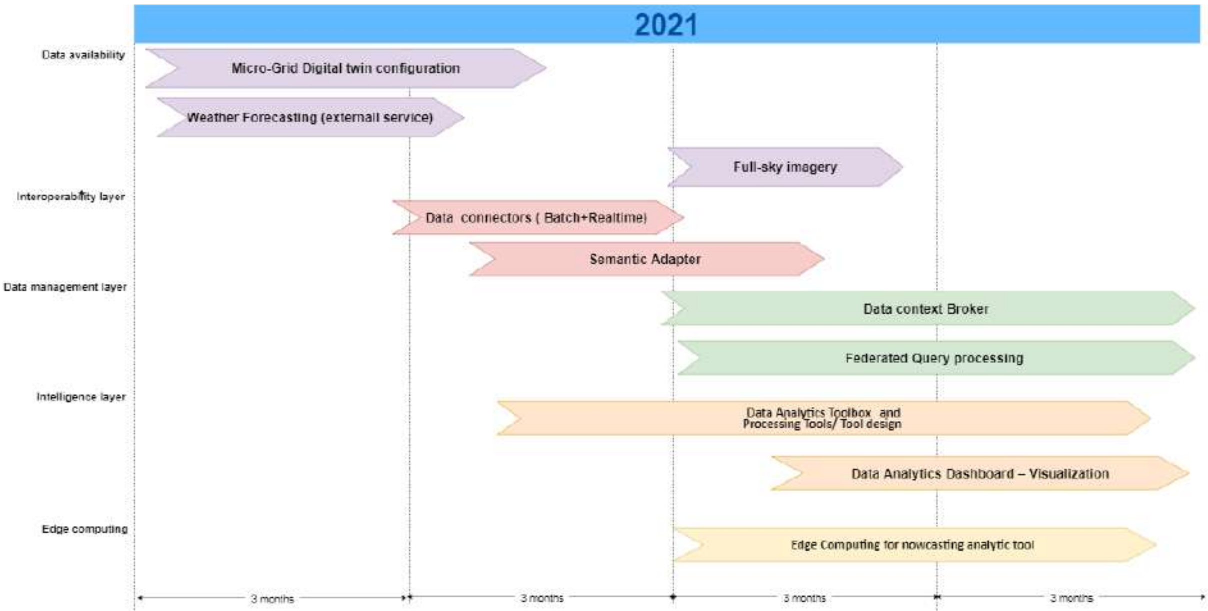


Figure 48: Components and Services to be Implemented under the Scope of Pilot 4a

4. PLATOON Common Components Implementation Plan

In WP2, WP3 and WP4 some of the main components of the reference architecture have been developed. Specifically, the following components have been developed:

1. Semantic Pipeline including: Data Models, Semantic Adapters, Federated Query Processing and Unified Knowledgebase.
2. IDS Connector
3. Metadata Registry (Broker + App Store)
4. Vocabulary Provider
5. Marketplace
6. Data Analytics Toolbox
7. Edge-cloud framework

Also, there are other components that will be reused and implemented from other projects developped by third parties. These cover the DAPS and the Clearing House which are provided as a service by Fraunhoffer AISEC. From these components most of them will be specifically implemented in each pilots as per explained in the previous sections.

However, there are some central components that will implemented in a central server and the rest of the pilots will connect to them. Namely these are IDS Metadata Registry, Marketplace, DAPS, Clearing House and Vocabulary Provider. The Vocabulary Provider will be implemented by TECN while the rest will be implemented by IAIS.

The figure below covers the implementation of PLATOON common components developed within the work package WP2- Reference Architecture, Interoperability and Standardization, WP3- Data Governance, Security and Privacy and WP4- Analytical Toolboxes. The timeline of the different stages concerning the readiness and the implementation of this components is detailed in PLATOON common components implementation template in Annex I.

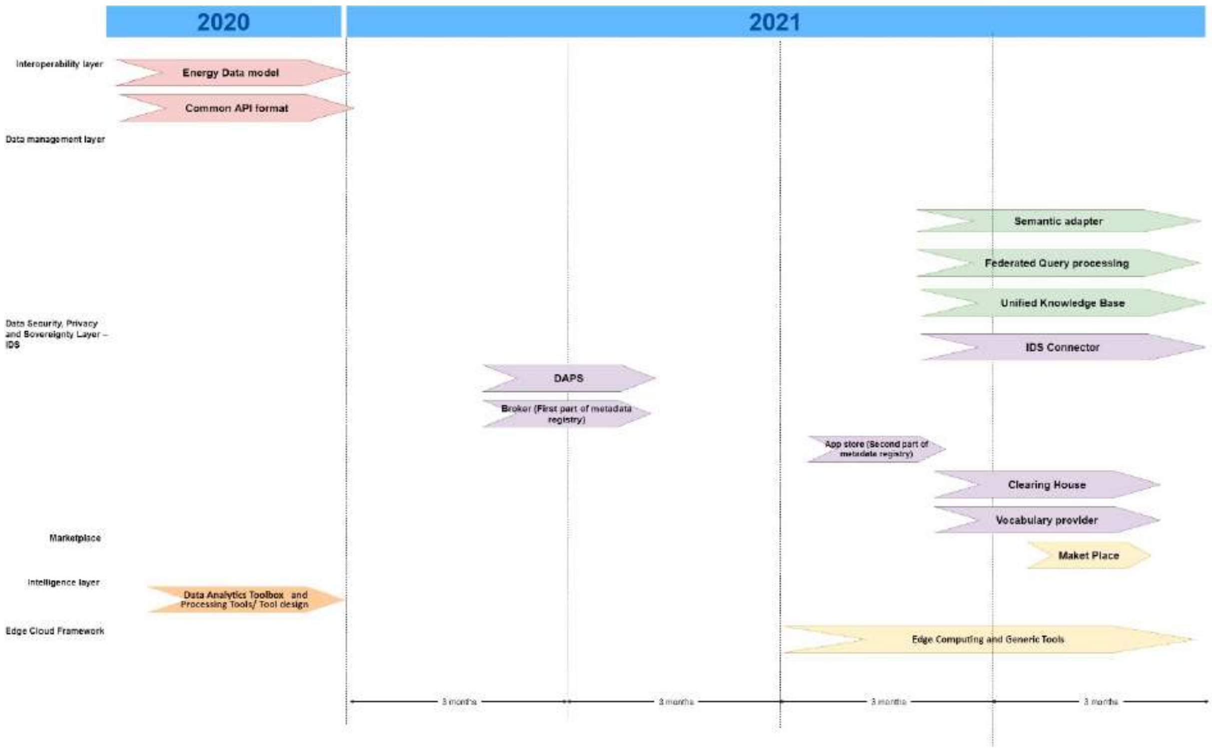


Figure 49: PLATOON Common Component Implementation Plan

Part II : Validation Plan

5. Introduction

Part II of this document covers the validation plan. The purpose of this part of the deliverable D6.1, is to ensure that the demonstration results will be in future stage measurable and fitting the expected from PLATOON project outcomes. Furthermore, the validation plan will help the pilots' owners and the project partners to minimize the risks involved in the implementation in their pilot-compliant component and to assure a correct functionality and operability. To comply with this objective, this second chapter will develop a validation and monitoring plan regarding each one of the low-level use Cases KPIs that the pilot owners intend to measure for each component to be implemented in the project's demo sites.

Moreover, this section also serves as a basis for the pilot's services design and development of the different analytical tools since it contains the performance metrics and the required criteria to reach the complying product for each pilots' component at the end of the experimentations phase.

The validation plan is described for the KPIs to be used to validate each one of the functions developed within the low-level use cases of the PLATOON pilots. In principle, the scope covered is defined by the following details:

a. Description of the software module developed within the pilots, its main functionalities, explaining the main PLATOON architectural components involved in each function and the role of each of them in the tool's flow.
b. A high-level testing approach that defines the validation method to be used. These could be unit tests, simulation, or any other test types.
c. The final part characterizes how the results of a specific function are evaluated, it explains the test steps and pass/fail criteria.

6. Pilot-Specific Validation Plan

6.1. Pilot 1a Predictive Maintenance of Wind Farm

6.1.1. Description

The goal of this pilot is the development of an integrated monitoring strategy for predictive maintenance of electrical drivetrain components, more specifically the generator and the power converter of wind turbines. The other subcomponents of the wind turbine are not in scope. Focus is on the combination of data-driven models with physical models of the generator and power converter into an integrated digital twin strategy. High frequency (kHz range) detailed measurements will be used in a first step. In a later stage the focus of the analysis will shift towards fleet-wide analytics. At this stage lower frequency SCADA data (10-min) and status logs are used. In addition to the anomaly detection for problem identification, also load history of the electrical components is identified. The potential for edge computations of the models is explored. More specifically, the optimization of the computational load for anomaly detection is investigated.

The main objectives of this pilot are:

- Develop, implement, and validate accurate physical and data-driven digital twins and models of the wind turbine electrical drivetrain components: generator and power converter.
- Develop anomaly detection methods for identification of unhealthy behaviour of the components in scope.
- Develop an approach to convert the identified anomalies towards health indicators to create a diagnostic tool.
- Extract the relevant events that the electrical drivetrain components are exposed to and have a potential negative effect on the lifetime of the electrical components.
- Develop an approach to generate synthetic failure data for the electro-generator using the developed digital twin.

Using data-driven and physical models, healthy system behaviour is modelled to serve as baseline for the anomaly detection. The anomaly detection tools developed in the use case will consequently allow the end user to accurately detect failures in the electrical components of wind turbines. The results will be fused into health indicators that form the basis for maintenance decisions. The end user will be responsible for the interpretation of the health indicators and the actual decision taking. The health indicators are specifically linked to the different failure modes that are targeted. The focus is on the detection of failures in the generator and the converter.

The following generator failures are in scope:
1. Generator winding short circuit fault
2. Generator bearing damage
3. Generator looseness and imbalance
4. Generator overtemperature

The following converter failures are in scope:
a. Open switch fault
b. IGBT short-circuit

In addition to the diagnostic capabilities also the identification of the historical loading of the machine is assessed to allow the user to gain insights in the loading that potentially led to the failure. Focus is on the loading that is relevant for the electrical components. As such turbine power production, rpm, current, voltage and local or ambient temperature and humidity values are in focus.

6.1.2. Main Functions

The predictive maintenance services are composed of the following tools:

- **Wind Turbine Digital Twin**: The app will mimic the behaviour of the wind turbine drive train of a double fed induction generator (DFIG) based on a hybrid model (physical model and data driven) trained with real operational SCADA data.
- **Wind Turbine Digital Twin, Anomaly/Failure Detection**: The app will detect anomalies/failures as differences between the values estimated by the digital twin and the values in de SCADA data. Once detected, anomalies/failures are grouped according to their similarity in magnitude, operating conditions, and temporal characteristics.
- **Wind Turbine Digital Twin, Anomaly/Failure Simulation**: The app will insert and label simulated failures of the wind turbine drive train using the developed digital twin.
- **Wind Turbine Health Tracker**: The goal of the app is to accurately diagnose failures in the electric components of a wind turbine with focus on the doubly fed induction generator and the power converter. The app focusses on the detection of changes in the behaviour of these components by means of AI methods processing timeseries data (e.g., SCADA data). In this sense it can be used to automatically process data of entire fleets of wind turbines. Moreover, the progression of the damage is tracked, and a potential root cause indicated. The app can condense this information in health indicators that are shareable through the API. Furthermore, it allows for a coupling with existing dashboards. This app is the top-level orchestration app that integrates the complete turbine health processing pipeline. This app needs the following sub-apps to be available to provide full functionality.
- **Wind turbine Health Tracker, Anomaly Detection**: This app is a standalone app that models timeseries data and performs anomaly detection using data-driven models.
- **Wind turbine Health Tracker, Failure Diagnosis**: This app targets the translation of anomaly health scores that represent the chance that a component will fail.

- **Wind turbine Health Tracker, Root Cause Identifier**: This sub-app transforms the information from the health scores and the wind turbine ontology, which represents the subcomponents of the wind turbine and their failure modes, into a suggestion of the failure type and its potential cause.
- **Wind turbine Health Tracker, Dashboard Preparation**: This sub-app collects all data from the Wind turbine health tracker pipelines and prepares the data in a structured way to actionable graphs (backend timeseries, not figure itself) and messages.
- **Wind turbine Health Tracker, SCADA Data Cleaner**: This sub-app is a standalone app that can be used to clean and aggregate SCADA timeseries and status log data to a consistent dataset sampled at either 1-second, 1-minute, or 10-minute interval. Different data-cleaning methods are available: unrealistic value removal, extreme values, missing data… and the data quality is assessed. Status logs active at discrete periods in time are converted from text data to timeseries data.

6.1.3. Tool Process View

This section is dedicated to describing the tool system process including: the different layers, the data sources, the data flows and the runtime mode.

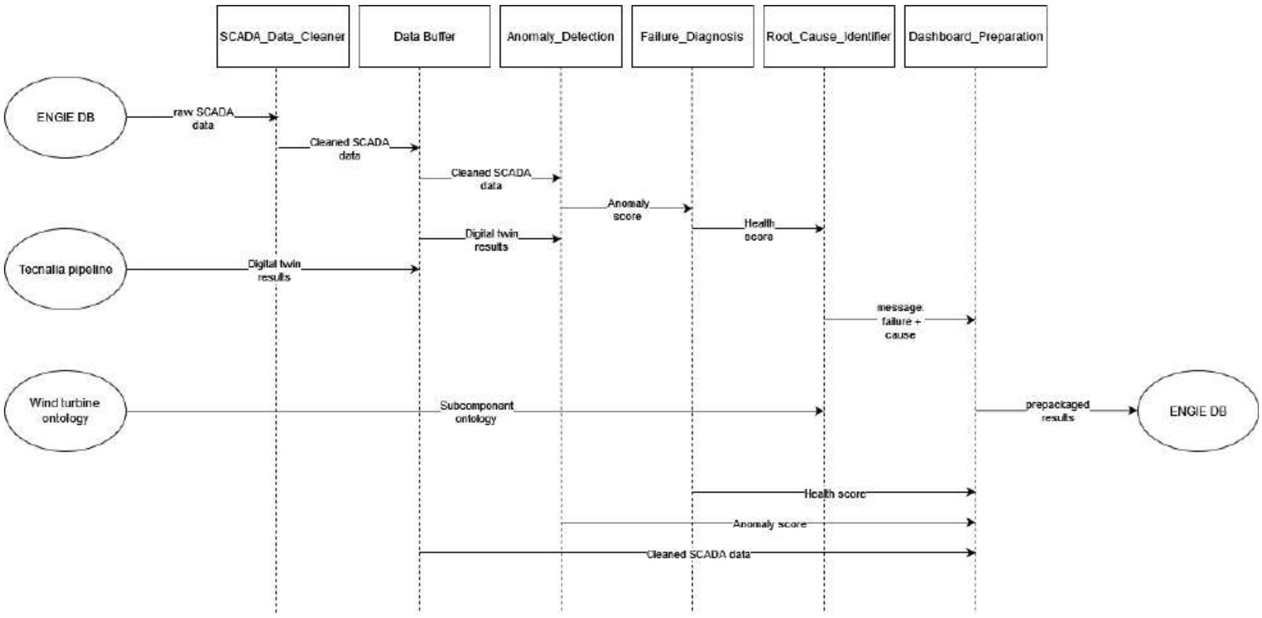


Figure 50: Schematic Overview of Health Tracker Pipeline and the Data Flows between the Individual Steps

The table below explains PLATOON architectural components involved in the tool flow and the role of each one of them.

PLATOON Component	Interfaces	role
Data Connector (IDS connector)	HTTP Protocol	Connect the ENGIE database with data analytics tools services from VUB and TECN.

IOT Connector	API Integration	Connects Edge Computing from VUB with the Platform from ENGIE
Data Curation	HTTP Protocol, Flow Files	Data Formatting, Data Aggregation and Data Enrichment in Data Pipelines
Semantic Adapter	HTTP Protocol, Flow Files	Converts Raw Data to Semantic Data according to Semantic Data Models in Real-Time Pipelines
Energy Data Model	//	Raw Data Converted to Semantic Data according to these models
Vocabulary Manager	HTTP Protocol	Used to Maintain Ontologies
IDS Metadata Registry	HTTP Protocol	Registers metadata of all the IDS connectors and apps
Marketplace	HTTP Protocol	Shows metadata of all apps and datasets
DAPS	HTTP Protocol	Authenticates all IDS components and partners.
Clearing House	HTTP Protocol	Registers all data/service transactions
Unified Knowledge Base	HTTP Protocol	Consists of two data bases: Static context data is put in sematic database and timeseries data is put in no SQL database.
Data Analytics Toolbox	HTTP Protocol, API Integration	Detection of anomalies and identification of root causes
Data Analytics Toolbox – Visualization Dashboard	API Integration	Used for the visualization of the output of the tools

Table 46: PLATOON Components involved in Predictive Maintenance tool - Pilot 1A

6.1.4. Validation Metrics

To ensure the performance, the quality and the results of the various tools developed in this pilot, it is important to perform a set of tests to measure the use case requirements and the targets defined in the description of the pilot's low level use case. The validation process should make sure that the use case requirements meet the KPI's which are defined for this pilot. The validation tests are important to provide feedback for further improvement of the tools used within this pilot. The KPIs for this pilot are the following:

6.1.4.1. KPI 01: Modelling Quality

This KPI measures whether the modelling approach is capable to fit healthy component data.

Testing approach
The modelling quality will be measured using several model quality statistics, such as RMS.

Test steps

- As a first step, different summary statistics will be calculated, such as the RMS of the error.
- As a second step, the predicted value of the parameter calculated in the previous step will be compared with the true value of that parameter and divided by 100 to determine the percentage error.

Pass/fail criteria

The performance of the model must be sufficient to realize the criteria in KPI 03: Fault detection.

6.1.4.2. KPI 02: Integration

This KPI measures whether all the components in this pilot are able to work together:

- Data Connector (IDS connector)
- IOT Connector
- Data Curation
- Semantic Adapter
- Energy Data Model
- Vocabulary Manager
- IDS Metadata Registry
- Marketplace
- DAPS
- Clearing House
- Unified Knowledge Base
- Data Analytics Toolbox
- Data Analytics Toolbox – Visualization Dashboard.

Testing approach

The success of this KPI is fully dependent on the ability of the pilot data analytics tools to interact with and send data to each other.

Test steps

- The input and output of each pipeline will be validated.
- Afterwards, test data will be exchanged between the pilot analytics blocks.

Pass/fail criteria

The complete pipeline needs to pass the integration test.

6.1.4.3. KPI 03: Fault Detection

This KPI measures the anomaly detection speed and its accuracy (false vs true positives).

Testing approach
To determine the anomaly detection speed, the time to catastrophic failure will be calculated. To determine the anomaly detection accuracy, a confusion matrix will be defined.

Test steps
- Step 1: The number of true positives, false positives, true negatives and false negatives will be calculated.
- Step 2: The confusion matrix will be completed with these values.

Pass/fail criteria
Predict equal or more failures compared to current techniques. Generate less false positives than current techniques.

6.1.4.4. KPI 04: Load Characterization

This KPI measures whether the automated tools can capture important historical loading events.

Testing approach
Testing whether this KPI is fulfilled will be done on the ENGIE Senvion data. The dataset contains 10-minute SCADA data. A file containing the replacements and failures is also available. The relative number of replacements and failures that are correctly predicted by the tool are used as an indicator for how well the tool can capture the important historical loading events.

Test steps
- Step 1: Run the tool on the ENGIE Senvion data.
- Step 2: Calculating the relative number of replacements/failures the tool correctly predicts.

Pass/fail criteria
At least 80% of the important historical loading events should be detected.

6.1.4.5. KPI 05: Processing Reach

This KPI measures the size of the fleet datasets that can be analyzed automatically (e.g. amount of wind turbines, amount of channels…).

Testing approach
Testing whether this KPI is fulfilled will be done by feeding the tool datasets of different sizes. By starting with a small dataset (small fleet) and gradually increasing the size of the dataset (size of the fleet), it should be possible to get an idea of how much data the tool can process on standard server equipment in an acceptable time frame.

Test steps

- Step 1: Monitoring CPU time + RAM consumption used by the tool to process the data of small, medium and large fleet of turbines.
- Step 2: Monitoring CPU time + RAM consumption used by the tool to process SCADA data with small, medium, and large number of signals.

Pass/fail criteria
The PLATOON pipeline should be able to process the data from windfarms that are comparable in size to the ENGIE Senvion fleet.

6.1.4.6. KPI 06: Processing Speed

This KPI measures the speed at which one complete data analysis of the complete pipeline can be done.

Testing approach
The testing approach for this KPI is like the testing approach for KPI 05. Testing whether KPI 06 is fulfilled will be done by feeding the pipeline datasets of different sizes. By starting with a small dataset (small fleet/small number of signals) and gradually increasing the size of the dataset (larger fleets/larger number of signals), it should be possible to get an idea of how much data the pipeline can process on standard server equipment in an acceptable time.

Test steps
- Step 1: Monitoring CPU time + RAM consumption used by the tool to process the data of a small, medium, and large fleet of turbines.
- Step 2: Monitoring CPU time + RAM consumption used by the tool to process SCADA data with small, medium, and large number of signals.

Pass/fail criteria
The application of the methodology on data comparable in size to that generated by the ENGIE Senvion fleet should be feasible with costs not exceeding the acceptable level.

6.1.4.7. KPI 07: Maintenance Costs

This KPI measures the reduction in the maintenance cost of the wind turbine due to early fault detection.
Testing approach
The maintenance costs will be estimated by comparing cost of component replacement at detection with cost of component replacement at catastrophic failure. Revenues during additional time that the machine was able to run are subtracted from the maintenance costs.

Test steps
- Step 1: Calculating maintenance cost in the situation as it is now (before implementation health tracker).
- Step 2: Calculating maintenance cost when the health tracker is used. This is done by considering how often the health tracker can detect a catastrophic failure a useful time in advance. Useful time in advance is defined as the time the wind turbine operator

normally needs to include the replacement in the normal maintenance schedule of the turbine.

- Step 3: Calculating the extra revenues that can be made by including the replacements in the normal maintenance schedule. This can be determined by estimating the difference in the loss of revenues due to catastrophic failures before and after the implementation of the health tracker. When the health tracker is implemented, downtime due to catastrophic losses that are predicted correctly (sufficiently in advance) by the tracker, are excluded from the loss of revenues.

Pass/fail criteria

Minimizing the maintenance costs by keeping a high false positive and low false negative rate as defined in KPI 03.

6.1.4.8. KPI 08: Availability

This KPI measures an increase of the wind turbine availability due to taking faster remedial actions triggered by better predictive maintenance.

Testing approach

The availability increase will be estimated by comparing the current, as-is availability with the new availability after usage of the PLATOON data analytics tools.

Test steps

- Step 1: Estimating the availability of wind turbines without the health tracker by calculating the ratio of up-time versus down-time.
- Step 2: Estimating the availability of wind turbines with the implementation of the health tracker by calculating the ratio of up-time (= up-time before the usage of the health tracker + extra up-time due to the usage of the health tracker) versus down-time (= down-time before usage of the health tracker – down-time avoided by using the health tracker).
- Step 3: Calculating the difference between the estimate in step 1 and the estimate in step 2.

Pass/fail criteria

Predict failures 50% earlier compared to current techniques. This allows for a faster identification of problems and should facilitate a more optimized maintenance planning. This should result in a decrease of the downtime of the turbines.

6.2. Pilot 2a Electricity Balance and Predictive Maintenance

6.2.1. Description

The overall goal of the PLATOON Pilot #2a is to integrate and deploy different PLATOON analytical and edge services with the Institute Mihajlo Pupin (IMP), proprietary VIEW4 Supervisory Control And Data Acquisition (SCADA) system. After the prioritization of scenarios, LLUC 03, LLUC 04, LLUC 05 and LLUC 07 were selected for implementation in Pilot #2a:

- **LLUC 03 Load Energy Forecaster:** hybrid solution for day-ahead country-level load forecast. The developed approach is a combination of the k-nearest-neighbour and convolutional neural network approach which provides estimated energy demand day ahead with the 24-hour time resolution depending on the previous load. More details regarding the model, corresponding training process and offline test results can be found in Deliverable *D4.4*. Along with the production forecasting services, this solution is intended for grid stability, energy planning and dispatch. The service is deployed at the PLATOON central server, at the IMP premises in Belgrade, Serbia.
- **LLUC 04 Wind Energy Production Forecaster:** hybrid neural network approach which combines the layers LSTM, convolutional, dense and dropout. The specific architecture has been optimized to achieve the highest performance; more details are presented in Deliverable *D4.4*. This service is intended to support grid stability, as it provides forecasted wind production depending on the weather condition. Core models used for this purpose are data-driven. The service is deployed at the PLATOON central server, at the IMP premises in Belgrade, Serbia.
- **LLUC 05 RES effect calculation:** service for analysis of unexpected variations (e.g., voltage profile of the power system), before and after RES integration to the power system. Since the PV plant is already installed, the analytics' functionality is to also estimate the condition on the grid without a PV plant. Since the services need real-time data with high reporting rates of the grid status, the PMU is deployed at the edge, being also the main source of the data. To assure the quality of the service (QoS), the analytics are also deployed at the edge. Furthermore, the live-streamed data is pre-processed to be sent to the central computer database, which is then used for long term evaluation. The service is deployed at the edge computer provided by CS and integrated with the IMP infrastructure, at the IMP premises in Belgrade, Serbia.
- **LLUC 07 PV panels Predictive maintenance:** service for predictive analytics and continuous monitoring of asset performance, providing early warnings of the component/object failures (e.g., RES plant/component). Identifying problems before they occur helps to reduce unscheduled downtime, improves plant maintenance, and optimizes asset performance. The long-term historical data (>1 year) is used to estimate the degradation of PV modules and to estimate when, how many and which PV modules should be replaced with new ones. Additionally, the service can estimate the failure of the DC string or any other abnormal behaviour of the PV plant by triggering different flags and notifying the end-user of the issues. The service is

deployed at the edge computer provided by CS and integrated with IMP infrastructure, at IMP premises in Belgrade, Serbia.

6.2.2. Main Functions

The previously presented scenarios have each the following main functions:

- **LLUC03 Load Energy Forecaster, Data connector**: extracts data from the IMP SCADA system.

- **LLUC03 Load Energy Forecaster, Data-driven Machine Learning (ML) model:** the developed load forecasting model is a day ahead hourly load estimation. Possibly to plan usage and maintain grid stability, which could be compromised by the increased penetration of renewable energy sources.
- **LLUC04 Wind Energy Production Forecaster, Data connector**: extracts data from the IMP SCADA system.
- **LLUC04 Wind Energy Production Forecaster, Hybrid ML model**: the developed production forecaster is a day ahead hourly wind production forecast. Possibly for energy dispatch, usage planning and maintaining a stable grid when renewable sources are available on the production side.
- **LLUC05 RES effect calculation**, **PMU concentrator:** capable of connecting to one or more PMUs and collects phasor data and discrete event data from PMUs and transmits data to other applications. The PMU concentrator utilizes ethernet to collect the data and needs to be compliant with the IEEE C37.118 protocol. The concentrator can efficiently collect data from different sources and align them according to GPS time. At the same time, the aligned data can be streamed to other applications for additional processing. In addition, data can be locally stored in a time-series database for subsequent processing.
- **LLUC05 RES effect calculation**, **Monitoring:** a function that monitors the main parameters of the grid, that can filter out the one-time events related to the abnormal status of the grid (e.g., flickering, short circuit, etc.). It has as main inputs the GPS aligned data of voltages and currents from PMU (Synchrophasors).
- **LLUC05 RES effect calculation**, **Estimation of RES integration:** from the continuous monitoring data, the grid behaviour is estimated without RES for a specific edge point. Additionally, the insertion capacity estimation is calculated for the connection point from the PV power plant production data and PV plant production data. The necessary input data are as follows:
    1. Filtered and GPS aligned data of voltages and currents from PMU (Synchrophasors).
    2. PV production.
    3. Historical weather data.
- **LLUC05 RES effect calculation**, **Edge Visualization:** provides the grid status visually, it can be used for easier deployment and connection of the PMUs to the grid from the perspective of different sites. Furthermore, it enables the analysis of the grid in the case of unexpected behaviour, since it has direct access to the raw data and influxDB of the data concentrator.

- **LLUC07 PV panels Predictive maintenance, Data connector:** connects to a central computer (IMP database) to collect the historical data about the PV plant performance and weather forecast, while also performing data cleaning. The main inputs for this function are:
    1. Historical PV performance.
    2. Weather forecast and historical weather.
- **LLUC07 PV panels Predictive maintenance, Event detector:** constantly monitoring of the PV plant production while comparing with the PV forecasting. If an anomaly is detected in the PV plant production, a notification is sent to the central computer. It can detect power drop, non-symmetrical power generation (e.g., failure of the inverter), lower production (e.g., shading, module/string failure). In addition, it can predict from the correction factor the degradation of the PV modules.
- **LLUC07 PV panels Predictive maintenance, PV predictive maintenance service:** From the continuous monitoring data, the PV performance factor is calculated from which the degradation of the modules is estimated. Additionally, the PV power plant is continuously monitored to detect a possible defect on the PV power plant (failure of the inverter, additional shading, low voltage or current).

6.2.3. Tools Process View

6.2.3.1. Analytical Service for Load Energy Forecast

As the main input to the load forecasting model, the previous 24-hour load was applied. This load is obtained via the SCADA system and is accessible through the PLATOON platform. Additionally, time and date related parameters are used. After all the required inputs are collected from the PLATOON platform, estimation of the hybrid load forecaster model is stored in a MySQL database, so it could be used and/or be validated by other services. A sequence diagram is shown in Figure 51, while the explanation of the role of each component is summarized in Table 47.

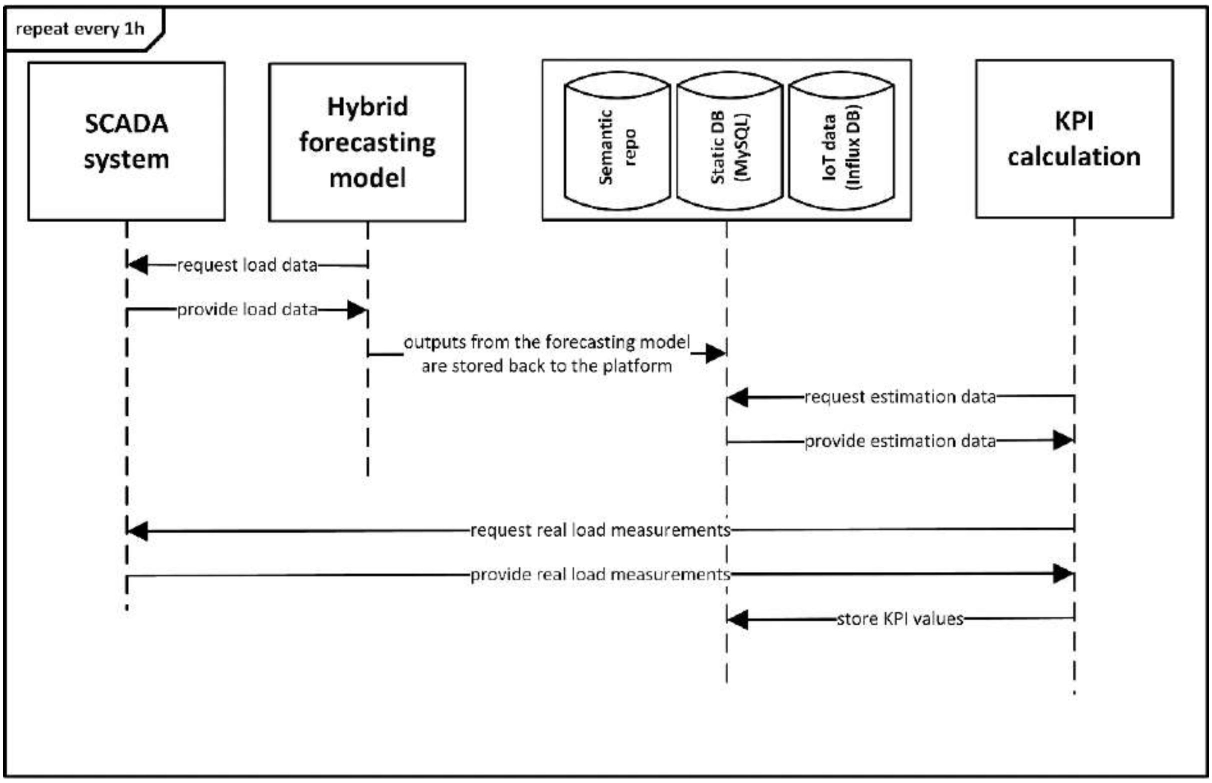


Figure 51: Sequence Diagram of the Validation Process for Load Energy Forecaster of Pilot 2a

PLATOON Component	Interfaces	Role
SCADA system	MySQL queries	Obtain real-world load measurements.
PLATOON MySQL database	MySQL queries	Stores historical and real-time measurements that are not time series by their nature (e.g., forecasts weather, production, and load, since they have multiple values for each timestamp).
Hybrid forecasting model		Estimates load forecast day ahead with 24-hour time resolution in accordance with the obtained inputs from the PLATOON platform.
KPI calculation		Obtains the relevant measurements and estimations and calculates predefined KPI. Finally, stores them in PLATOON MySQL

Table 47: PLATOON Components involved in the Service for Load Energy Forecast of Pilot 2a

6.2.3.2. Analytical Service for Wind Energy Production Forecast

To provide the forecast, it was necessary to obtain forecasted weather parameters, and these are collected from the *WeatherBit* weather service. This data was used as input for the production estimation by the neural network-based model. It is collected from the service and stored within the PLATOON Pilot #2a platform, so relevant inputs are obtained from the corresponding MySQL database. Finally, when the production is estimated, it is stored back to the same database within PLATOON platform, so that it can be used and/or validated. The sequence diagram is shown in Figure 52, while the explanation of the role of each component is summarized in Table 48.

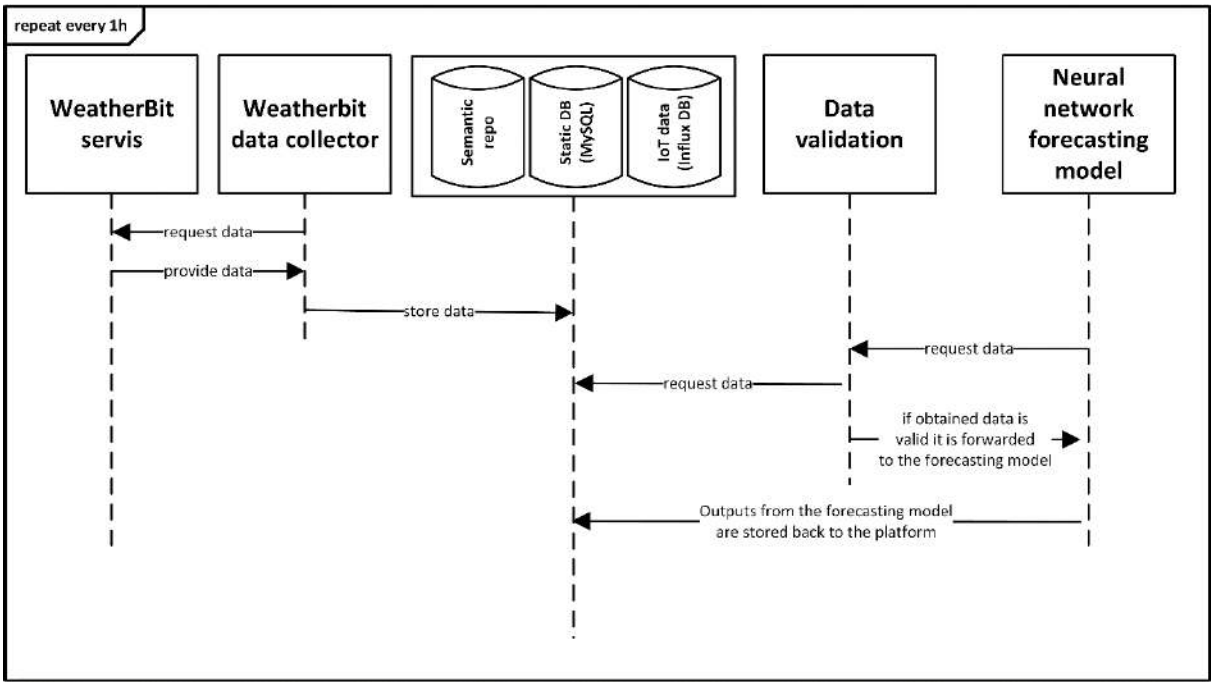


Figure 52: Sequence diagram of the validation process for wind energy production forecaster of Pilot 2a

PLATOON Component	Interfaces	Role
WeatherBit data collector	API	Collects meteorological data from the *Weatherbit* service each hour and stores them within MySQL database, so they can be used by other services.
PLATOON MySQL database	API	Stores historical and real-time measurements that are not time series by their nature (e.g., forecasts weather, production and load, since they have multiple values for each timestamp).

Neural network-based wind production forecasting model		Estimates wind production forecast day ahead with 24-hour time resolution in accordance with the obtained inputs from the PLATOON platform.

Table 48: PLATOON Components involved in Service for Wind Energy Production Forecast of Pilot 2a

6.2.3.3. RES Effects Calculation Process View

The main input for this process is the PMU data collected from the PMU, and it is stored in influxDB by the PMUs data concentrator service. Afterwards, the RES effect calculation service accesses this data concentrated in the influxDB. Furthermore, the solar insolation for the site is obtained from the PLATOON MySQL database, to which also the output from RES effective service is saved. Finally, the RES effect calculation is executed periodically once per day. The sequence diagram is shown in **Error! Reference source not found.**, while the explanation of the role of each component is summarized in **Error! Reference source not found.**.

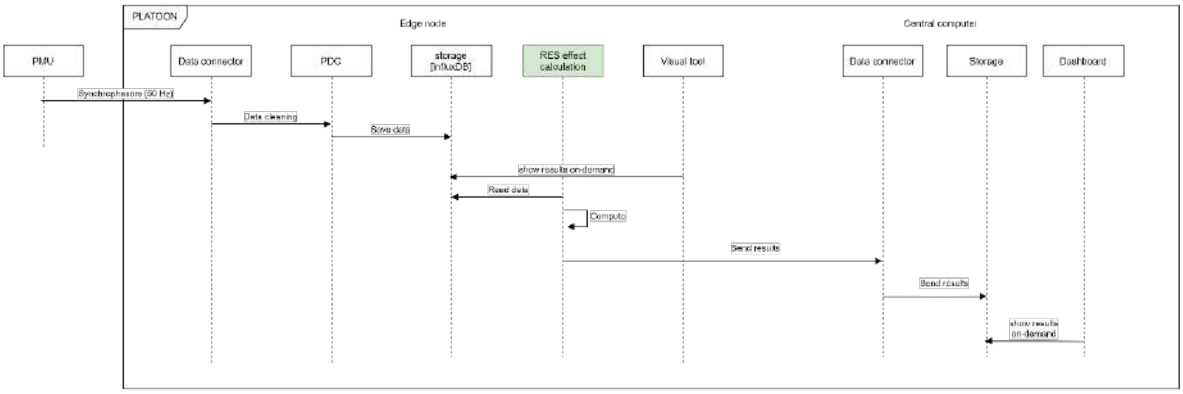


Figure 53: RES Effect Calculation Tool Process View of Pilot 2a

PLATOON Component	Interfaces	Role
InfluxDB (part of PDC)	influxQL	Collects the synchrophasor data from the PMU and stores it into the influxDB, so other services can use it.
PLATOON MySQL data base	API	Stores historical and real-time measurements which are not time series by their nature (e.g., forecasts weather, production, and load, since they have multiple values for each timestamp).
RES effect calculation		The main RES effective analytical service.

Table 49: PLATOON Components involved in RES Effect Calculation Tool of Pilot 2a

6.2.3.4. PV Predictive Maintenance Process View

The main input to the PV predictive Maintenance model is the historical data obtained from the PLATOON MySQL database together with the solar insolation. Additionally, as the PMU data is needed, it is collected from influxDB. The PMU data concentrator service collects the data from PMU with a frequency of 50Hz and stores it into influxDB. PV predictive maintenance service is executed once per day. Furthermore, in the case of anomaly detection in the PV performance, a message is asynchronously sent to the PLATOON MySQL database and can be used to trigger external actions. The sequence diagram is shown in Figure 54, while the explanation of the role of each component is summarized in Table 50.

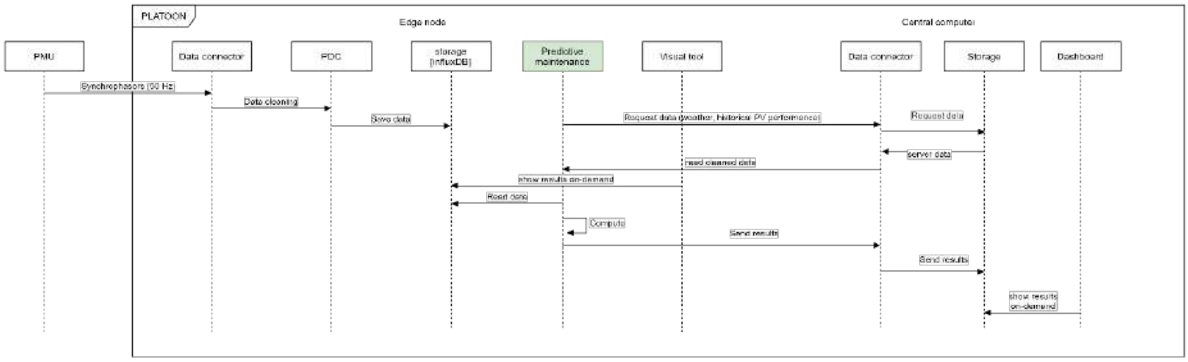


Figure 54: PV Predictive Maintenance Process View of Pilot 2a

PLATOON Component	Interfaces	Role
InfluxDB (part of PDC)	influxQL	Collects the synchrophasor data from the PMU and stores it into the influxDB, so other services can utilize them
PLATOON MySQL database	API	Stores historical and real-time measurements which are not time series by their nature (e.g., forecasts weather, production, and load, since they have multiple values for each timestamp).
PV predictive maintenance calculation		The core Predictive maintenance analytical service.

Table 50: PLATOON Components involved in PV Predictive Maintenance Tool of Pilot 2a

6.2.4. Validation metrics

6.2.4.1. LLUC 03 (Load Forecasting Performance Evaluation) KPIs

As a part of the KPI list for Pilot #2a, a list of load forecasting performance evaluation KPIs is suggested. All these KPIs are related to the accuracy estimation, and therefore, will be presented together. These KPIs will cover the following metrics:

- Production Forecasting Mean Absolute Error
- Production Forecasting Mean Absolute Percentage Error
- Production Forecasting Root Mean Square Error
- Production Forecasting Root Mean Square Error Percentage

All will be calculated by comparing real and estimated energy demand, as follows:

Testing approach

Two main data points are required to be able to evaluate the KPIs – the real and the estimated load. As previously mentioned, real load measurements will be obtained from the SCADA system, whilst the estimated ones are stored in the MySQL database, as a part of the PLATOON platform. Consequently, the considered KPIs will be calculated by the following definitions:

i. Production Forecasting Mean Absolute $= \frac{1}{n}\sum_{i=1}^{n}|e_i|$

ii. Production Forecasting Mean Absolute Percentage Error $= \frac{1}{n}\sum_{i=1}^{n}\frac{|e_i|}{d_i}$

iii. Production Forecasting Root Mean Square Error $= \sqrt{\frac{1}{n}\sum_{i=1}^{n}e_i^2}$

iv. Production Forecasting Root Mean Square Error Percentage $= \frac{\sqrt{\frac{1}{n}\sum_{i=1}^{n}e_i^2}}{\frac{\sum_{i=1}^{n}d_i}{n}}$

where e_i is the difference between estimated and real load (d_i), and n is the number of samples for each calculated KPI.

Test steps

With the goal of providing KPI estimation, as presented in Figure 51: Sequence Diagram of the Validation Process for Load Energy Forecaster Figure 51, the following steps will be implemented:

i. Obtain real load measurement from the SCADA system.
ii. Obtain estimated production from MySQL database.
iii. KPI calculation for each metric (using shown definitions).
iv. Store KPI values in MySQL.

Apart from the definition of the testing steps, the frequency of their execution must be defined. Since the load forecast will be updated hourly, the KPI calculation should not occur more than on an hourly frequency.

Pass/fail criteria

The expected results/outputs to confirm that the test, once the test steps are executed, can be considered successful and the requirement of the evaluation are verified.

6.2.4.2. LLUC 04 (Production Forecasting Performance Evaluation) KPIs

As a part of the KPI list for Pilot #2a, a list of production forecasting performance evaluation KPIs is suggested. All KPIs that follow are related to the estimation accuracy, and therefore, similarly to LLUC 03, these will be presented together, as a part of this subsection. These KPIs cover the following metrics:

- Production Forecasting Mean Absolute Error
- Production Forecasting Mean Absolute Percentage Error
- Production Forecasting Root Mean Square Error
- Production Forecasting Root Mean Square Error Percentage

All will be calculated by comparing real and estimated energy demand.

Testing approach

To evaluate the KPIs, estimated and real production measurements will be necessary. As previously explained, estimations are stored within the PLATOON platform, i.e., in the MySQL database. As for the real production measurements, these will be obtained from the SCADA system. Hence, production measurement and estimation will be collected from the described sources and KPIs will be calculated with the following definitions:

i. Production Forecasting Mean Absolute Error $= \frac{1}{n}\sum_{i=1}^{n}|e_i|$
ii. Production Forecasting Mean Absolute Percentage Error $= \frac{1}{n}\sum_{i=1}^{n}\frac{|e_i|}{p_i}$
iii. Production Forecasting Root Mean Square Error $= \sqrt{\frac{1}{n}\sum_{i=1}^{n} e_i^2}$
iv. Production Forecasting Root Mean Square Error Percentage $= \frac{\sqrt{\frac{1}{n}\sum_{i=1}^{n} e_i^2}}{\frac{\sum_{i=1}^{n} p_i}{n}}$

where e_i is the difference between estimated and real production (p_i), and n is the number of samples for which KPI is calculated.

Test steps

To providee the KPI estimation, the following steps will be implemented:

i. Obtain real production measurement from the SCADA system.
ii. Obtain estimated production from MySQL database.
iii. KPI calculation for each metric (using shown definitions).
iv. Store KPI values in MySQL.

Since the forecast is updated each hour, the KPI should not be updated more frequently. In addition, it is important that for the performance evaluation, the last predictions are used since they will be the most reliable and precise.

Pass/fail criteria

The expected results/outputs to confirm that the test, once the test steps are executed, can be considered successful and the requirement of the evaluation are verified.

6.2.4.3. LLUC 05 (RES Effect Calculation Evaluation) KPIs

Testing approach

For calculating the KPI of the Increase in PV insertion capacity, the PMU/InfluxDB installed at the Edge will be used:

$$\frac{\max\,(U_{with\_PV}) - U_n}{\max\,(U_{w/o\_PV}) - U_n} P_{PV\_installed} \frac{1.1U_n - U_n}{\max\,(U_{w/o\_PV}) - U_n}$$

Test steps

To provide the KPI estimation, the following steps are used:

i. Obtain the maximum daily grid voltage from the PMU.
ii. Estimate maximum daily grid voltage without PV.
iii. For certain periods, and the estimated worst-case scenario, estimate maximum grid voltage.
iv. Calculate the capacity.

Pass/fail criteria

The expected results/outputs to confirm that the test, once the test steps are executed, can be considered successful and the requirement of the evaluation are verified.

6.2.4.4. LLUC 07 (PV Panels Predictive Maintenance Evaluation) KPIs

Testing approach

The algorithm detects abnormal behaviour (e.g., failures) and predicts the degradation constant, consequently, the maintenance costs are reduced. The KPI is calculated with the following definitions.

i. **Binary 0 1,** Triggers detection of failure, immediate replacement:

$$\left(N_{days\ estimate} - N_{days\ after\ detecting failure}\right) * E_{daily} * price_{of\ electricity}$$

ii. **Prediction of failure,** Reduction of Asset Investment costs by minimizing the number of elements to be replaced (PV modules):

$$\left(\sum_{i=0}^{N_{total}} i - \sum_{i=0}^{N_{string}} i\right) * cost\_of\_module$$

Test steps

To provide the KPI estimation, the following steps will be used:

i. Obtain correction factor for PV.
ii. Obtain historical degradation parameters.
iii. Check the values for PV plant/string or inverter level.
iv. Compare to the predefined threshold (e.g., 75% for the efficiency module), 0 or 1 for the inverters.

Pass/fail criteria

The expected results/outputs to confirm that the test, once the test steps are executed, can be considered successful and the requirement of the evaluation are verified.

6.3. Pilot 2b Electricity Grid Stability, Connectivity and Life Cycle

6.3.1. LLUC-01-2B: Predictive maintenance

6.3.1.1. Description

Maintenance actions in small transformers are very often not sufficient or inefficient due to the low price of the transformers compared to the maintenance costs, therefore on the one hand many maintenance actions are taken only when a failure occurs with the consequent expenses, on the other hand many maintenance actions are taken too early in time, replacing components that could work for a longer time. How to plan maintenance actions in small transformers is something DSO struggles with because of their low budget and the uncertainty of failures. The tools developed in this UC can be an opportunity for maintenance companies to plan their actions more efficiently. To be economically feasible, the developed tool must minimize the required monitoring equipment costs (sensors, gateways…) and labour costs while ensuring a high accuracy and maintaining the quality of the service.

6.3.1.2. Main Functions

The following tools will be developed within UC1 in Predictive Maintenance:

- **Variable estimation:** Virtual sensors will be developed to estimate some variables associated with the operation of the transformer. These variables can be measured by installing extra physical sensors and their associated monitoring infrastructure. However, distribution transformers are equipment of which the cost is very low, so it makes no sense to try to optimize their maintenance with a new methodology that requires the utilization of new sensor devices which are not cost effective. The aim is to develop virtual sensors associated for instance to magnitudes like the top oil temperature. This variable has a high correlation with the hot spot temperature, which is the key factor in insulation aging, and with the load factor, which could be profiled with measurements coming from the AMI infrastructure of the connection points downstream the transformer.
- **Health monitoring:** The Remaining Useful Life (RUL), and its associated health index, of the transformer critical components will be calculated based on the standards that are currently applied (as the IEEE C57.19.100 and IEC 60076-7). The health index of these components will be used to calculate the health index of the transformer, for different failure modes, due to aging in working conditions.
- **Maintenance planning**: The information derived from the health monitoring functionality will be used to optimize the default maintenance plan provided by the transformer manufacturer based on preventive maintenance, so that the real aging of the transformer depending on its utilization will be used to tailor its maintenance plan to both minimize the cost and the probability of a failure. Furthermore, considering the maintenance costs and the health index, maintenance actions will be suggested.
- **Asset operation optimization:** A model which simulates the effect of different operational actions in the grid O&M cost will be developed. This model will provide support to the investment plan, based on the simulation of the effect of new

distribution conditions on the transformer operation costs, being able to assess for instance if it is more convenient to add an extra transformer in a congested feeder with an expected rise of demand or to replace it once its decreased useful life has ended thus to the accelerated aging process on overload conditions.

- **Predictive analysis:** To detect transformer failures, from historical data (oil temperature, load, performance…), it will be determined patterns and link among parameters defining its normal values. and triggering an alarm if they are out of the ordinary values.

6.3.1.3. Tools Process View

The following data sources are required to perform the Predictive Maintenance for MV/LV Transformers system:

- **Load measurements:**
  - o Historical data of the transformer low voltage energy output and the energy consumption of the prosumers connected to each power transformer.
  - o the power transformer input energy.
- **Temperature data, historical data of the temperature registered by:**
  - o the sensors installed at the transformer centre.
  - o the power transformer case.
  - o the top oil temperature sensor.

To obtain the MV power and the temperature sensors, we have an FTP that gets the actual values each minute.

The input data required for both Predictive Maintenance for MV/LV Transformers system and the non-technical loss detection in Smart Grids tools, data process, execution modes and pipelines are presented below.

<u>Tool 01 – UC1: Oil Temperature Estimation</u>

Using a sensor on a distribution transformer is always a dilemma in terms of cost-benefit. Oil temperature is the most representative value in terms of estimating the transformer aging. Within UC1 a tool will be developed which analyses the best approach to install temperature sensors in a transformer to optimize the transformer maintenance plan.

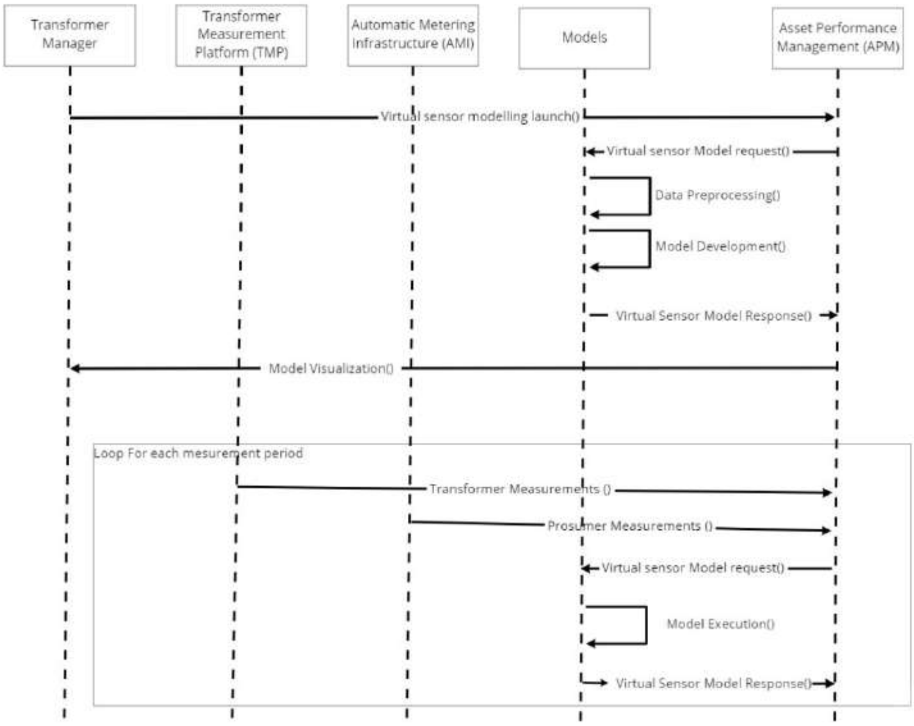


Figure 55: Oil Temperature Estimation Process View

PLATOON Component	Interfaces	Role
MYSQL database	Python API	This data base stores the data registered by all the sensors installed in the field. On top of that it includes all the valuable data that is registered by the smart meters.
MYSQL weather database	Python API	This data base stores the data registered by a meteorological centre installed at UIB (University of Balearic Islands) located at just 2km of the pilot installations.
Data Connector	HTTPS/REST	IDS Connector Between Onesait Platform and TECN server.
Top Oil temperature virtual sensor.	-	The core virtual sensor that simulates the temperature registered by the immersion sensor minimizing the installation of sensors cost.
Hot spot temperature virtual sensor	-	Physical model that uses load and the result from top oil temperature virtual sensor to estimate the hottest temperature inside the power transformer.

Table 51: PLATOON Components involved in Oil Temperature Estimation Tool - Pilot 2b

Tool 02 – UC1: Health Monitoring

The present tool will monitor the transformer health, the Remaining Useful Life (RUL). To obtain the RUL, the health index of the transformer critical components will be calculated based on the standards that are currently applied (as the IEEE C57.19.100 and IEC 60076-7). The health index of these components will be used to calculate the health index of the transformer, for different failure modes, due to aging in working conditions.

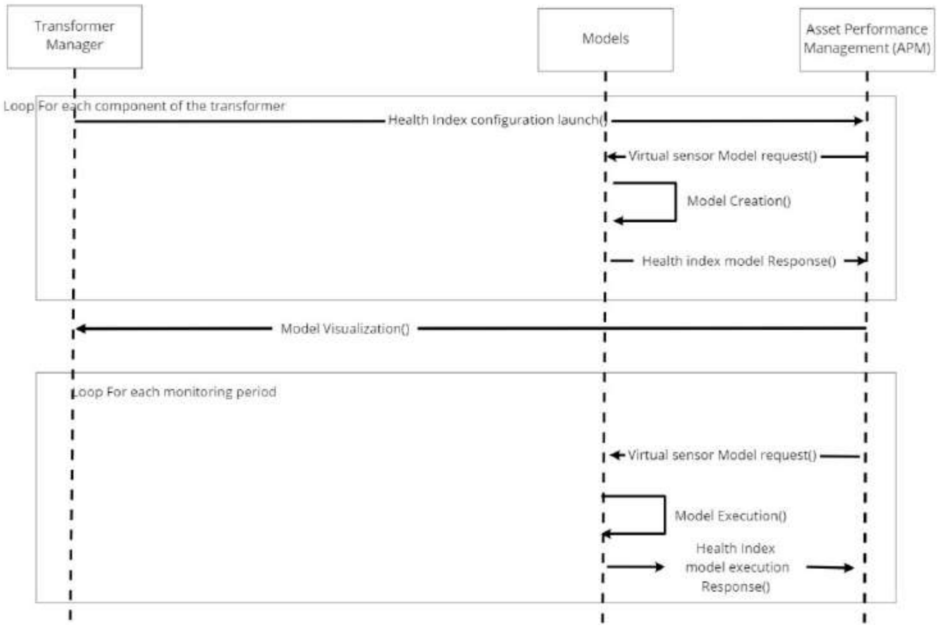


Figure 56: Health Monitoring Process View

PLATOON Component	Interfaces	Role
MYSQL database	Python API	This data base stores the data registered by all the sensors installed in the field. On top of that it includes all the valuable data that is registered by the smart meters.
Top Oil temperature virtual sensor.	-	The core virtual sensor that simulates the temperature registered by the immersion sensor minimizing the installation of sensors cost.
Hot spot temperature virtual sensor	-	Physical model that uses load and the result from top oil temperature virtual sensor to estimate the hottest temperature inside the power transformer.
Remaining useful life calculation	-	Physical model that uses the result from top oil temperature and hot spot temperature virtual sensors to estimate the loss of life of the power

		transformer, and with that the remaining useful life.

Table 52: PLATOON Components involved in Health Monitoring Tool - Pilot 2b

Tool 03 – UC1: Maintenance Planning

A maintenance planning tool will be developed using the information derived from the health monitoring functionality providing preventive maintenance, so that the real aging of the transformer depending on its utilization will be used to tailor its maintenance plan to both minimize the cost and the probability of a failure. Furthermore, considering the maintenance costs and the health index, maintenance actions will be suggested.

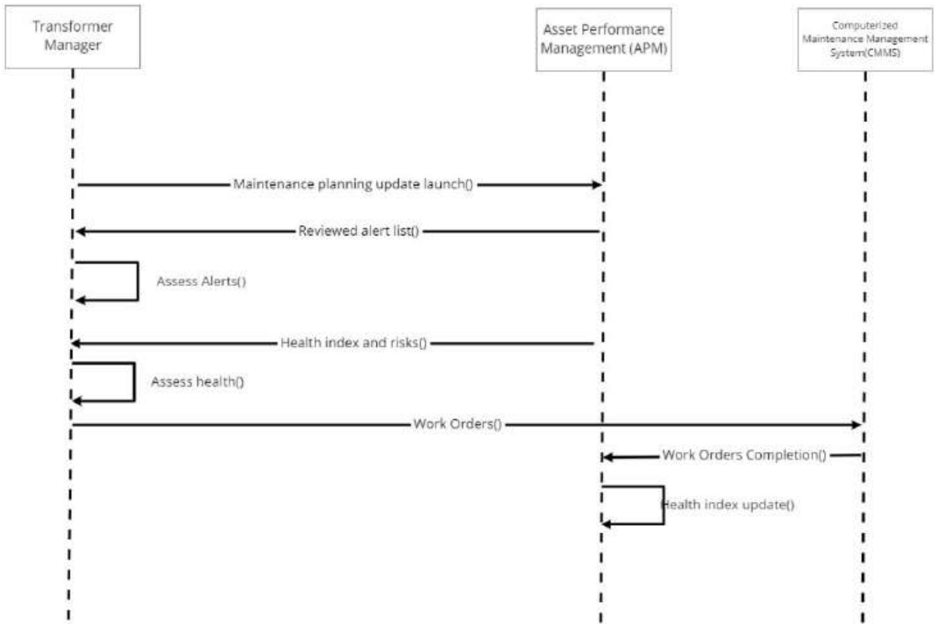


Figure 57: Maintenance Planning Process View

PLATOON Component	Interfaces	Role
MYSQL database	Python API	This data base stores the data registered by all the sensors installed in the field. On top of that it includes all the valuable data that is registered by the smart meters.
Remaining useful life calculation	-	Physical model that uses the result from top oil temperature and hot spot temperature virtual sensors to estimate the loss of life from the power transformer, and with that the remaining useful life.

Table 53: PLATOON Components involved in Maintenance Planning Tool - Pilot 2b

Tool 04 – UC1: Asset Operation Optimization

This tool simulates the effect of different operational actions in the grid O&M cost, providing support to the investment plan, based on the simulation of the effect of new distribution conditions on the transformer operation costs, being able to assess for instance if it is more convenient to add an extra transformer in a congested feeder with an expected rise of demand or to replace it once its decreased useful life has ended.

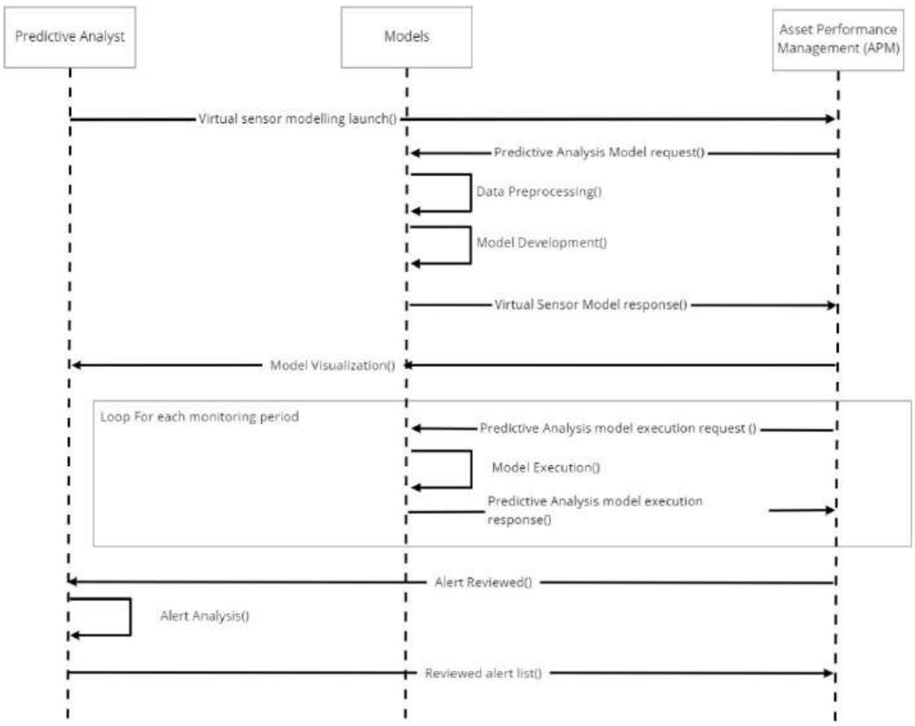


Figure 58: Asset Operation Optimization process view

PLATOON Component	Interfaces	Role
MYSQL database	Python API	This data base stores the data registered by all the sensors installed in the field. On top of that it includes all the valuable data that is registered by the smart meters.
Remaining useful life calculation	-	Physical model that uses the result from top oil temperature and hot spot temperature virtual sensors to estimate the loss of life of the power transformer, and with that the remaining useful life.

Table 54: PLATOON Components involved in Asset Operation Optimization Tool - Pilot 2b

Tool 05 – UC1: Predictive Analysis

To detect transformer failures, from historical data (oil temperature, load, performance…), it will be determined patterns and link among parameters defining its normal values. and triggering an alarm if they are out of the ordinary values.

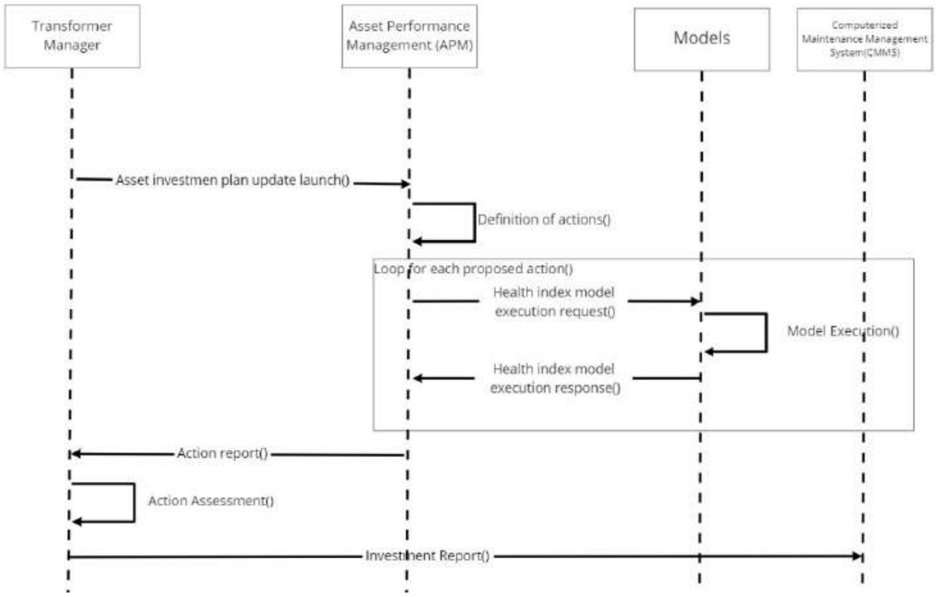


Figure 59: Asset Predictive Analysis Process View

PLATOON Component	Interfaces	Role
MYSQL database	Python API	This data base stores the data registered by all the sensors installed in the field. On top of that it includes all the valuable data that is registered by the smart meters.
Top Oil temperature virtual sensor.	-	The core virtual sensor that simulates the temperature registered by the immersion sensor minimizing the installation of sensors cost.
Hot spot temperature virtual sensor	-	Physical model that uses load and the result from top oil temperature virtual sensor to estimate the hottest temperature inside the power transformer.
Remaining useful life calculation	-	Physical model that uses the result from top oil temperature and hot spot temperature virtual sensors to estimate the loss of life of the power transformer, and with that the remaining useful life.

Table 55: PLATOON Components involved in Asset Predictive Analysis tool - Pilot 2b

6.3.2. LLUC-02-2B: NTL Detection

6.3.2.1. Description

NTL in the electric system is one of the biggest fraud factors, generally due to smart meter and/or connection to the grid (bypass of certain consumer loads) manipulation. NTL can be attributed to i) administrative losses due to accounting errors and record keeping, ii) customer theft, iii) customer non-payment and iv) theft by non-customers.

For instance, in the last years, losses in the Spanish electric system have been about the 8% and almost half of that amount could be due to NTL. NTL detection is a complex task as DSOs do not have the appropriate tools and resources to avoid fraud techniques, and the only effective way to fight against NTL is to detect it once it has been committed, and to establish legal actions in that case.

Many theorical studies in detecting NTL using different techniques have been conducted in the last years. One of these techniques is data science, very popular in academia.
The main output of this UC is to develop a solution for NTL detection using data analytics, which just requires measurement data available from the Automatic Metering Infrastructure-AMI, and optionally information on the grid topology.

6.3.2.2. Main Functions

Five different activities are envisaged, which are defined in five main scenarios (Prosumer Segmentation, Grid Topology Identification, Technical Losses Model, Global Losses Assessment and NTL identification):

- **Grid Topology Identification:** The topology of the distribution grid to which it will be applied the assessment of NTL has to be known. It can be either entered by the NTL manager or it can be inferred through the analysis of historical data. Grid topology includes the list of which substations and transformation centres compose the part of the distribution grid that will be analysed, which connection points are located at the MV or LV branches, what is the distance (or the resistance of the wires) of those connection points to the corresponding CT or substation, to which phase are LV 1-phase consumers connected to. In this case the Grid Topology is already known by the DSO, so, no specific identification tool has been developed.
- **Prosumer Segmentation:** The historical prosumer smart meter data available will be cleaned and processed for the prosumer segmentation process, where prosumers will be clustered depending on their consumption behaviour. If historic NTL is known, based on evidence of fraud, the dataset will be labelled accordingly.
- **Technical Losses Model**: A study of global energy losses will be carried out, based on measurements of the energy consumed at the prosumer connection points and the energy fed by the substation and CTs. Global losses are a combination of technical

losses (due to power dissipation in lines and transformers) and NTL. The outcome of this scenario is to define a model that estimates the expected value of energy fed by a MV substation if global losses are just due to technical losses, i.e., no NTL occurs. This granularity of the estimation will be provided on a PTU basis, which is the standard time unit in which the smart meters are configured to provide values on accumulated energy consumption. Although the development of this model will be based on data analytics, the information on grid topology (impedance of lines, efficiency of transformers, location of CTs and prosumer connection points…) will enhance the accuracy of the model, as this information is related to the coefficient that could be applied to each prosumer to calculate the energy needed to be disposed at the substation bar (which represents the borderline between the transmission and the distribution grid) to provide a certain consumption at its connection point.

- **Global Losses Assessment:** The Technical Losses model will be used in a procedure that will be defined to assess if NTL has occurred for a certain PTU range, typically in monthly periods. If both the real and the expected energy at the distribution grid borderline differ more than a defined threshold, it would indicate the existence of NTL losses. In the case that this threshold has been exceeded for a significative period within the analysed time range, it could be determined the profile of the energy that has been theft, calculated at the substation bars.
- **NTL identification:** Once NTL is supposed to have happened, the prosumer segmentation model will be applied to determine the set of prosumers that would be the authors of NTL, based on the variation of its expected behaviour (it is also considered the possibility of a verdict including fraud due to non-customers). The combination of the real energy profiles of the customers that have not committed fraud to the expected and the expected profile of those prosumers who are supposed to have committed fraud should fit with the energy profile measured at the control points in which the DSO have measurement capability, i.e. the substation and the CTs. The fulfilment of this condition will be used to define feasible sets of NTL authors, and the persistence in consecutive analysis periods of a certain prosumer in feasible solutions will potentially nominate that prosumer as an NTL author.

6.3.2.3. Tools Process View

The following data sources are required to perform the Predictive Maintenance for MV/LV Transformers system and the non-technical loss detection in Smart Grids Validation:

- **Load measurements:**
  - Historical data of the transformer low voltage energy output and the energy consumption of the prosumers connected to each power transformer.
  - the power transformer input energy.

To obtain the temperature sensors, we have an FTP that gets the actual values each minute.

The input data required for the non-technical loss detection in Smart Grids tools, data process, execution modes and pipelines are presented below.

Tool 06 – UC2 Technical Losses Model

A tool that calculates the expected technical loses of the grid based on the grid topology and load.

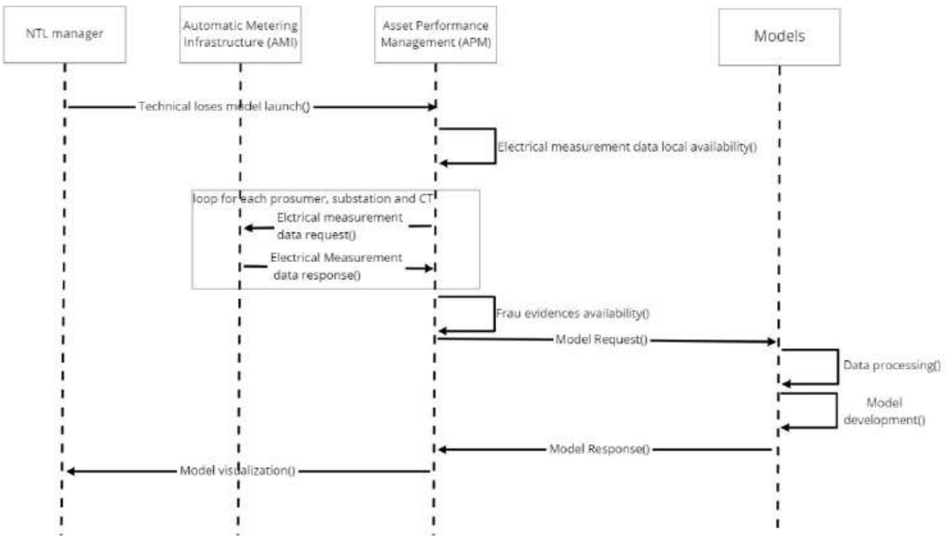


Figure 60: Technical Losses Process View

PLATOON Component	Interfaces	Role
MYSQL database	Python API	This data base stores the data registered by all the sensors installed in the field. On top of that it includes all the valuable data that is registered by the smart meters.
Data Connector	HTTPS/REST	IDS Connector Between Onesait Platform and TECN server.
Technical loses model	-	Model that calculates the expected technical loses of the grid based on the grid topology and load.

Table 56: PLATOON Components involved in Technical Losses Model Tool - Pilot 2b

Tool 08 – UC2 Global Losses Assessment

A tool that studies of global energy losses, based on measurements of the energy consumed at the prosumer connection points and the energy fed by the substation and CTs. Global losses are a combination of technical losses (due to power dissipation in lines and transformers) and NTL. The tool estimates the expected value of energy fed by a MV substation if global losses are just due to technical losses, i.e., no NTL occurs.

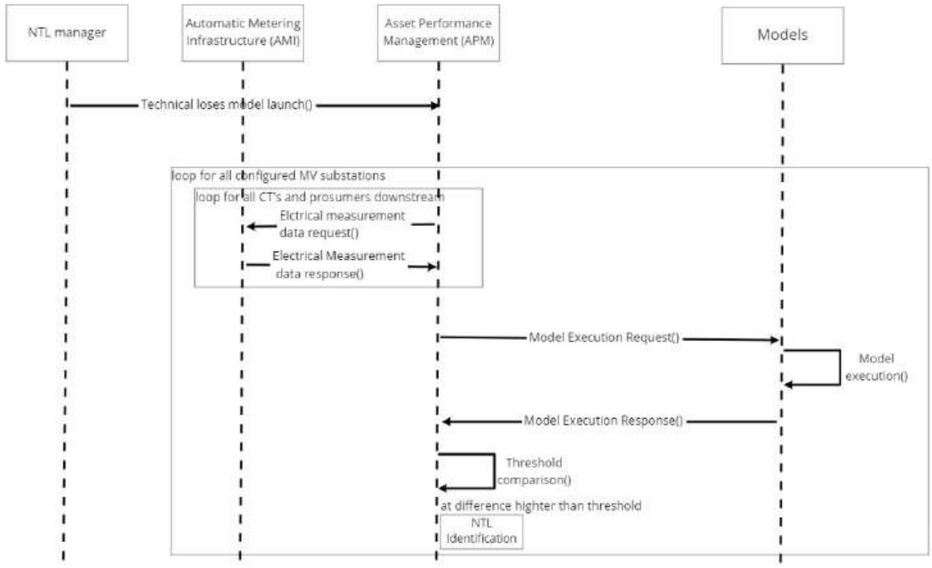


Figure 61: Global Losses Assessment Process View

PLATOON Component	Interfaces	role
MYSQL database	Python API	This data base stores the data registered by all the sensors installed in the field. On top of that it includes all the valuable data that is registered by the smart meters.
Technical loses model	-	Model that calculates the expected global loses of the grid based on the grid topology and load.

Table 57: PLATOON Components involved in Global Loses Assessment Tool - Pilot 2b

Tool 9 – UC2: NTL Identification

A tool for the quantification of losses in the distribution grid of a DSO and the detection of non-technical losses (NTL), using prosumer segmentation and their demand baseline. The fulfilment of this condition will be used to define feasible sets of NTL authors, and the persistence in consecutive analysis periods of a certain prosumer in feasible solutions will potentially nominate that prosumer as an NTL author.

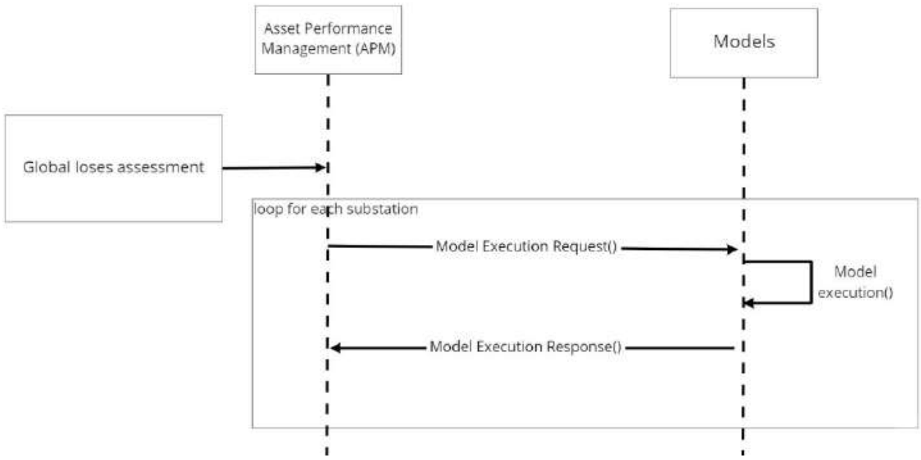


Figure 62: NTL Identification Process View

PLATOON Component	Interfaces	role
MYSQL database	Python API	This data base stores the data registered by all the sensors installed in the field. On top of that it includes all the valuable data that is registered by the smart meters.
Technical loses model	-	Model that calculates the expected global loses of the grid based on the grid topology and load.
Non-technical loses identification tool	-	Model that uses the results from technical loses and global loses assessment to detect if a threshold is surpassed and then assigns the anomaly type and possible cause.

Table 58: PLATOON Components involved in NTL Identification Tool - Pilot 2b

6.3.3. Validation Metrics

Within the project different KPIs have been defined to evaluate the performance of the tools developed. In the present section are presented the KPI defined and their description.

6.3.3.1. KPI -01 – UC1 Temperature Estimation Accuracy (%)

Tool KPI estimation: Variable estimation

Hourly temperature accuracy estimation based on estimated temperature (ET) and actual (measured) temperature (AT) for top oil.

Testing approach

Real data in different periods of time retrieved from the pilot sensors will be used to test the Temperature accuracy of the virtual sensor.
Validation data: Real, selected randomly from the available data.

Test steps

01- Model the top oil temperature using machine learning/deep learning.
02-Compare the prediction obtained using our model with the real values obtained from the sensor.

Pass/fail criteria

The expected accuracy for the virtual parameter is less than 5%.

6.3.3.2. KPI -02 – UC1 True Positives (TP)

Tool KPI estimation: Predictive analysis

Number of anomalies detected with early warnings confirmed with a corrective work order or agreed to reveal abnormal behaviour.

Testing approach

Anomalies detected by the model will be compared with real anomalies occurred in the pilot for a period.
Validation data: Based on predictive warnings and real anomalies

Test steps

01- Compute the warnings of needed corrective order given by the model.
02- Calculate the number of corrective orders that are predicted and applied, or abnormal behaviour has been detected.

Pass/fail criteria

The expected TP rate is higher than 90%.

6.3.3.3. KPI -03 – UC1 False Positives (FP)

Tool KPI estimation: Predictive analysis

Early warnings with no associated corrective work order or agreed not to reveal any abnormal behaviour

Testing approach

Early warnings with no confirmed anomalies will be computed as false positives.

Validation data: Based on predictive warnings and real anomalies

Test steps

01- Compute the warnings of needed corrective order given by the model.
02- Calculate the number of corrective orders that are predicted but not applied.

Pass/fail criteria

The expected FP rate is lower than 10%.

6.3.3.4. KPI -04 – UC1 False Negatives (FN)

Tool KPI estimation: Predictive analysis

Corrective work order without a previous early warning.

Testing approach

Anomalies detected by the model will be compared with real anomalies occurred in the pilot for a period.
Validation data: Based on predictive warnings and real anomalies

Test steps

01- Obtain the warnings of needed corrective order given by the model.
02- Calculate the number of corrective orders that are not predicted and applied.

Pass/fail criteria

The expected FN rate is under 10%.

6.3.3.5. KPI -05 – UC1 True negatives (TN)

Tool KPI estimation: Predictive analysis

No early warning and no work order.

Testing approach

Anomalies detected by the model will be compared with real anomalies occurred in the pilot for a period.
Validation data: Based on predictive warnings and real anomalies

Test steps

01- Obtain the warnings of needed corrective order given by the model.
02- Calculate the number of corrective orders that are not predicted and not applied.

Pass/fail criteria

The expected FP rate is over 90%.

6.3.3.6. KPI -06 – UC1 Specify (%)

Tool KPI estimation: Predictive analysis

Proportion of true negatives relative to all real negative cases.

$$Specificity\ (\%) = \frac{TN}{TN + FP}$$

Testing approach

Anomalies detected by the model will be compared with real anomalies occurred in the pilot for a period.
Validation data: Based on predictive warnings and real anomalies

Test steps

Use True Negatives (TN) and False Positives (FP) to compute the Specificity.

Pass/fail criteria

The expected Specificity is higher than 90%.

6.3.3.7. KPI -07 – UC1 Sensitivity (%)

Tool KPI estimation: Predictive analysis

Proportion of true positives relative to all real positive cases.

$$Sensitivity(\%) = \frac{TP}{TP + FN}$$

Testing approach

Anomalies detected by the model will be compared with real anomalies occurred in the pilot for a period.
Validation data: Based on predictive warnings and real anomalies

Test steps

Use True Positives (TP) and False Negatives (FN) to calculate the Sensitivity.

Pass/fail criteria

The expected Sensitivity is higher than 90%.

6.3.3.8. KPI-08–UC1 Cohen's Kappa (%)

Tool KPI estimation: Maintenance Planning

Measurement of matches in the predictive tool discounting the probability of random matching.

$$\kappa\ (Cohen'sKappa) = \frac{2 \cdot (TP \cdot TN - FN * FP)}{(TP + FP) \cdot (FP + TN) + (TP + FN) \cdot (FN + TN)}$$

Testing approach

Anomalies detected by the model will be compared with real anomalies occurred in the pilot for a period.
Validation data: Based on predictive warnings and real anomalies

Test steps

01- Calculate the TP, TN, FP, FN.
02- Apply the formula to obtain the needed value.

Pass/fail criteria

Not applicable.

6.3.3.9. KPI-09– UC1 Savings (€)

Tool KPI estimation: Asset Operation Optimization/Maintenance Planning

Cumulative measurement of savings associated to True Positives considering a) Avoided breakdown consequences + b) Downtime cost.

Testing approach

Anomalies detected by the model will be compared with real anomalies occurred in the pilot for a period.
Validation data: Simulated costs/savings of each asset operation optimization recommendation and maintenance planning scheduled.

Test steps

01- Calculate the breakdown caused by the failure that has been predicted and corrected and the downtime that it should have caused.
02- Obtain the monetary compensation that this downtime and breakdown should have caused.

Pass/fail criteria

Not applicable.

6.3.3.10. KPI-10 – UC1 Additional Costs (€)

Tool KPI estimation: Asset Operation Optimization/Maintenance Planning

Increased costs due to maintenance activities associated to False Positives. They should be subtracted from Savings to get the net value.

Testing approach

Anomalies detected by the model will be compared with real anomalies occurred in the pilot for a period.
Validation data: Simulated costs by Asset Operation Optimization and Maintenance Planning recommendations.

Test steps

Obtain the cost of maintenance caused due to false positives.

Pass/fail criteria

Not applicable.

6.3.3.11. KPI-11 – UC1 Anticipation time (days)

Tool KPI estimation: Predictive analysis

For each True Positive it represents the delta Time between the moment of detection and the (estimated) time of failure.

Testing approach

Anomalies detected by the model will be compared with real anomalies occurred in the pilot for a period.
Validation data: Based on predictive warnings and estimations of the time to failure.

Test steps

Predict the failure dates of the transformers and obtain the difference between the predicted date and the (estimated) real failure dates. In the case of real-time data, estimated failure date will be necessary since the transformer will not be run to failure.

Pass/fail criteria

Not applicable.

6.3.3.12. KPI-12– UC1 Risk decrease (€)

Tool KPI estimation: Asset operation optimization

Risk decrease comparing risk-based maintenance supported by the tool to the ordinary preventive maintenance (equal maintenance expenditure is assumed in both cases).

Testing approach

Anomalies detected by the model will be compared with real anomalies occurred in the pilot for a period.
Validation data: Fake data comparing the cost of an operation against the cost of a transformer breakdown.

Test steps

01- Calculate the ordinary risk of failure and predicted risk of failure. Multiply this by the cost of maintenance.
02- Obtain the difference between the cost * risk between the tool and the current maintenance strategy.

Pass/fail criteria

Not applicable.

6.3.3.13. KPI-13– UC1 Maintenance cost savings (€)

Tool KPI estimation: Asset Operation Optimization

Maintenance cost savings comparing risk-based maintenance supported by the tool to the ordinary preventive maintenance (equal risk level is assumed in both cases).

Testing approach

Anomalies detected by the model will be compared with real anomalies occurred in the pilot for a period.
Validation data: Fake data, simulation of future maintenance actions cost, comparing the regular maintenance costs against the recommended maintenance by the tool.

Test steps

01- Calculate the costs of ordinary maintenance and predicted maintenance.
02- Obtain the difference between predicted maintenance cost and ordinary maintenance cost.

Pass/fail criteria

Not applicable.

6.3.3.14. KPI-14– UC1 Useful Life Extension (years)

Based on the estimation of the RUL (Remaining Useful Time) it indicates the achievable extension of life relative to that indicated by the manufacturer.

Testing approach

Anomalies detected by the model will be compared with real anomalies occurred in the pilot for a period.

Test steps

01- Apply the standards to obtain the HST from the TOT
02- Apply the standards to calculate the useful life decrease from the TOT.

Pass/fail criteria

Not applicable.

6.3.3.15. KPI-15– UC2 Global Losses Energy Percentage

Tool KPI estimation: Global Loses Assessment

Percentage of the energy that is provided from a MV substation or LV CT that is not settle to any consumer and is therefore lost. To be averaged in long periods (at least months).

Testing approach

Test validation against database.
Validation data: Fake, data generated randomly multiplying random prosumers and periods combinations by a factor < 1.

Test steps

01- Calculate the total consumption of all customers.
02- Calculate the percentage of the customers consumptions over the energy provided by the power transformer.

Pass/fail criteria

Range falls between [0-4%].

6.3.3.16. KPI-16– UC2 NTL Energy Percentage

Tool KPI estimation: Global Loses Assessment

Percentage of the energy that is provided from a MV substation or LV CT that is lost due to NTL.

Testing approach

Test validation against database.
Validation data: Synthetic data generated randomly multiplying random prosumers and periods combinations by a factor < 1.

Test steps

01- Calculate the total consumption of all customers.
02- Calculate the percentage of the customers consumptions over the energy provided by the power transformer.

Pass/fail criteria

Range falls between [0-4%].

6.3.3.17. KPI-17– UC2 TL Energy Percentage

Tool KPI estimation: Technical Loses Model

Percentage of the energy that is provided from a MV substation or LV CT that is lost due to TL.

Testing approach

Test validation against database.

Test steps

01- Obtain the characteristics of the distribution grid.
02- Calculate the expected technical loses.

Pass/fail criteria

Range falls between [0-4%].

6.3.3.18. KPI-18– UC2 Customer NTL Energy Percentage

Tool KPI estimation: Global Loses Assessment

Percentage of the energy that is provided from a MV substation or LV CT that is lost due to fraud executed by customers. This portion of NTL is more likely to be avoided after it is detected, as legal actions can be taken against the connection point contractors.

Testing approach

Test validation simulating distinct NTL patterns in the data base.
Validation data: Synthetic data generated randomly multiplying random prosumers and periods combinations by a factor < 1.

Test steps

01- Obtain the characteristics of the distribution grid.
02- Calculate the expected technical loses.

Pass/fail criteria

Range falls between [0-4%].

6.3.3.19. KPI-19– UC2 Non-Customer NTL Energy Percentage

Tool KPI estimation: NTL Identification

Percentage of the energy that is provided from a MV substation or LV CT that is lost due to fraud executed by non-customers. This energy is stolen by non-permitted connections to the grid, which are difficult to be located physically.

Testing approach

Test validation simulating distinct NTL patterns in the data base.
Validation data: Synthetic data generated randomly multiplying random prosumers and periods combinations by a factor < 1.

Test steps

01-Subtract the technical loses to the total loses.
02-Obtain the part of the result that cannot be imputed to customers.

Pass/fail criteria

Range falls between [0-4%].

6.3.3.20. KPI-20– UC2 True positives (TP)

Tool KPI estimation: NTL identification

Number of customers identified as fraud authors in the NTL identification scenario which are verified to be committing fraud.

Testing approach

Anomalies detected by the model will be compared with real anomalies occurred in the pilot for a period.
Validation data: Fake, data generated randomly multiplying random prosumers and periods combinations by a factor < 1.

Test steps

01-Obtain the customers that can be causing NTL using the developed models and identify if they are really causing NTL
02-Calculate the number of customers that are predicted as causing NTL and are really causing NTL.

Pass/fail criteria

The expected TP rate is higher than 95%.

6.3.3.21. KP-21– UC2. False positives (FP)

Tool KPI estimation: NTL identification

Number of customers identified as fraud authors in the NTL identification scenario which are not committing fraud, as result of a verification action.

Testing approach

Test validation simulating distinct NTL patterns in the data base.
Validation data: Synthetic data generated randomly multiplying random prosumers and periods combinations by a factor < 1.

Test steps

01-Obtain the customers that can be causing NTL using the developed models and identify if they are really causing NTL
02-Calculate the number of customers that are predicted as causing NTL and are not causing NTL.

Pass/fail criteria

The expected FP rate is lower than 5%.

6.3.3.22. KPI-22– UC2. False negatives (FN)

Tool KPI estimation: NTL identification

Number of customers which are not identified as fraud authors in the NTL identification scenario but are really committing fraud.

Testing approach

Test validation simulating distinct NTL patterns in the data base.
Validation data: Synthetic data generated randomly multiplying random prosumers and periods combinations by a factor < 1.

Test steps

01-Obtain the customers that can be causing NTL using the developed models and identify if they are really causing NTL
02-Calculate the number of customers that are predicted as not causing NTL and are really causing NTL.

Pass/fail criteria

The expected FP rate is higher than 95%.

6.3.3.23. KPI-23– UC2 True Negatives (TN)

Tool KPI estimation: NTL identification

Number of customers which are not identified as fraud authors in the NTL identification scenario and are not really committing fraud.

Testing approach

Test validation simulating distinct NTL patterns in the data base.
Validation data: Synthetic data generated randomly multiplying random prosumers and periods combinations by a factor < 1.

Test steps

01-Obtain the customers that can be causing NTL using the developed models and identify if they are really causing NTL
02-Calculate the number of customers that are predicted as not causing NTL and are not causing NTL.

Pass/fail criteria

The expected FP rate is lower than 5%.

6.3.3.24. KPI-24– UC2 Specificity (%)

Tool KPI estimation: NTL identification

Proportion of true negatives relative to all negative cases.

Testing approach

Test validation simulating distinct NTL patterns in the data base.
Validation data: Synthetic data generated randomly multiplying random prosumers and periods combinations by a factor < 1.

Test steps

01-Obtain the proportion of negative cases of NTL that are correctly identified.

Pass/fail criteria

The expected Specificity is higher than 95%.

6.3.3.25. KPI-25– UC2 Sensitivity (%)

Tool KPI estimation: NTL identification

Proportion of actual positives cases of NTL correctly identified.

Testing approach

Test validation simulating distinct NTL patterns in the data base.
Validation data: Synthetic data generated randomly multiplying random prosumers and periods combinations by a factor < 1.

Test steps

01-Obtain the proportion of positives that are correctly identified.

Pass/fail criteria

The expected Sensitivity is higher than 95%.

6.3.3.26. KPI-26– UC2 Cohen's Kappa (%)

Tool KPI estimation: NTL identification

Measurement of matches in the NTL identification scenario discounting the probability of randomly matching.

Testing approach

Test validation simulating distinct NTL patterns in the data base.
Validation data: Synthetic data generated randomly multiplying random prosumers and periods combinations by a factor < 1.

Test steps

01- Calculate the TP, TN, FP, FN.
02- Apply the formula to obtain the NTL identifications not well predicted randomly.

Pass/fail criteria

Not applicable.

6.3.3.27. KPI-27– UC2 Savings (€)

Tool KPI estimation: NTL identification

Economic savings due to detected non-technical losses.

Testing approach

Test validation simulating distinct NTL patterns in the data base.
Validation data: Synthetic data generated randomly multiplying random prosumers and periods combinations by a factor < 1.

Test steps

Obtain the costs of energy production and impute the percentage of NTL to these costs.

Pass/fail criteria

Not applicable.

6.4. Pilot 3a Office Building: Operation Performance Thanks to Physical Models and IA Algorithms

6.4.1. LLUC 01-3A - Optimizing HVAC Control regarding Occupancy

6.4.1.1. Description

The HVAC optimization developed within the scope of pilot #3A provides an optimized operation schedule for each day of the week for an office building and its different zones, based on the presence in the building and the comfort level required by the occupants. The description of the two main functions of the module is below:

The first function predicts the global building occupancy, and the second function predicts the pre-heating and pre-cooling setpoints in the different zones of the building based on the outputs on the first function and the building consumption behaviour.
The HVAC optimization and control targets the following:

- Optimize the building energy consumption,
- Maximize the comfort of occupants with the best energy efficiency,
- Automate HVAC system control and reduce manual intervention on system controls.

This use case presents a set of functionalities to collect, transform, and process data (generate forecasts, estimations, and schedules), using data from the building data sources (Building management system, IT network) and sent by external providers through API interface (weather forecasts).

6.4.1.2. Main Functions

The optimization service can be divided into two core functions.

- **Occupancy prediction in the building zones**

The occupancy prediction in the building and zones is responsible for generating the forecast of each building zone's occupancy status (occupied or unoccupied) for the next seven days with an hourly time step. These forecasts are updated daily based on real-time occupancy calculations.
First, the forecast of the occupancy probability of each zone for the next seven days at an hourly time step is computed. Second, above a threshold probability defined by the user, a zone is considered occupied.
The data input required for this function is:

    - Real-time IT data for both WIFI and LAN in the building to estimate occupancy for each relevant zone of the building,
    - Historical IT data for both WIFI and LAN in the building,
    - Calendar data (public holidays, other) that could impact the building occupancy,
    - Occupancy edge devices that count people present in a specific area at any time.

- **Preheating and precooling time estimation**

This function predicts the possible pre-heating or pre-cooling time of the different zones of the building before a zone is occupied from occupancy forecast, weather forecast, and real-time air temperature of the different zones.
The data input required for this function is:

    - The building consumption data during the occupancy periods,
    - The building zones occupancy status predictions,
    - The real-time building occupancy status,
    - The weather forecasts: external temperature and the solar radiation received by the building,
    - The real-time air temperature measurements in the different zones of the building.

6.4.1.3. Tool Process View

The following data sources are required to perform the optimization and the control of the HVAC system on the office building functions models:

- Load measurements:
    - Historical data for the building energy consumption.
    - 10 min updates of the real-time consumption
- IT connection Data:
    - Real-time LAN connections with the location in the building zone
    - Real-time Wi-Fi connection data with the location in the building zone
- Weather forecasts: API to collect
- Real-time weather data: air temperature and solar irradiation
- Weather forecast: air temperature and solar irradiation
- The real-time air temperature in the building

To obtain the weather measurements and forecasts, we include a web API based using REST architecture.
The input data required for occupancy prediction and pre-heating and pre-cooling time estimation tools, data process, execution modes, and pipelines are presented below.

- **Tool 01: Occupancy prediction in the building zones**

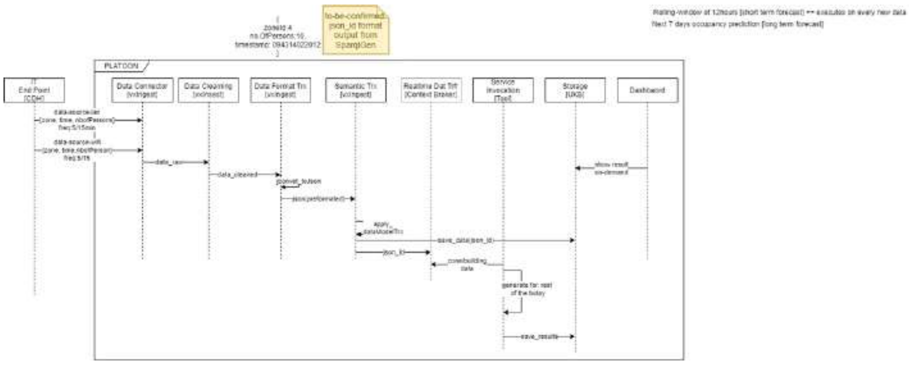


Figure 63: Pilot 3A- Occupancy Prediction in the Building Zone - Tool Process View

The table below explains PLATOON architectural components involved in Tool01 flow and the role of each one of them.

PLATOON Component	Interfaces	role
Data connector	HTTP protocol, integration with CDH (AWS-S3)	Connects the batch data sources
Semantic adapter	HTTP protocol, flow files	Converts raw data to semantic data according to sematic data models in Realtime pipelines
Data curation engine (Vx ingest)	HTTP protocol, flow files	Data formatting, data aggregation and data enrichment in data pipelines.
Context broker (KAFKA)	HTTP protocol, Kafka events	When tool execute at real time mode context broker is used for events communication for input and output data pipelines.
Unified knowledge base (semantic and time series data base)	HTTP protocol, API integration	Consists of two data bases, Static context data is put in sematic database and timeseries data is put in no SQL database.
Energy data models	//	Output of 2.3, raw data converted to semantic data according to these data models.
Vocabulary manager	//	Used to maintain ontologies.
Data analytics toolbox (Realtime and Batch)	HTTP protocol, API integration	Used for the tool's execution.
Data analytics dashboard	API integration	Used to show the results of the tool's output.
Batch and Realtime mode of the tool	//	The tools execute in two modes batch mode executes once in 24 hours and produces results for next

		24 hours. The Realtime mode executes every 5minutes when new data is available and produces results for next 24hours.
Federated query processing (batch mode)	API integration	When the tool execute in the batch mode queries are done through FQP

Table 59: PLATOON Components involved in Occupancy Prediction Tool - Pilot 3a

- **Tool 02 pre-heating and pre-cooling time estimation**

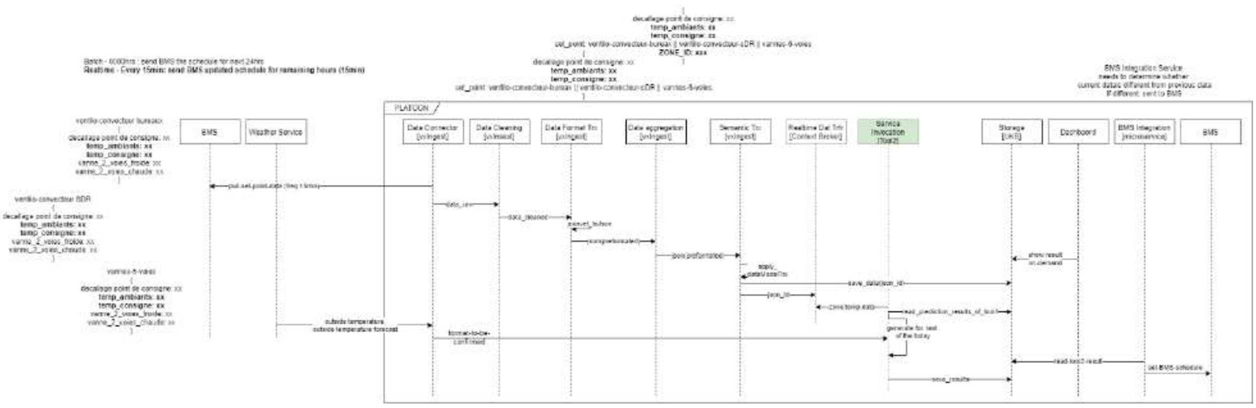


Figure 64: Pilot 3a Pre-Heating and Pre-Cooling Time Estimation - Tool Process View

The table below explains PLATOON architectural components involved in Tool02 flow and the role of each one of them.

PLATOON Component	Interfaces	role
Data connector	HTTP protocol, integration with CDH (AWS-S3)	Connects the batch data sources
Semantic adapter	HTTP protocol, flow files	Converts raw data to semantic data according to sematic data models in Realtime pipelines
Data curation engine (Vx ingest)	HTTP protocol, flow files	Data formatting, data aggregation and data enrichment in data pipelines.
Context broker (KAFKA)	HTTP protocol, Kafka events	When tool executes its results are published on KAFKA where the data pipeline is applied, and results are stored.
Unified knowledge base	HTTP protocol	Consists of two data bases,

(semantic and time series data base)		Static context data is put in sematic database and timeseries data is put in no SQL database.
Energy data models	//	Output of 2.3, raw data converted to semantic data according to these data models.
Vocabulary manager	//	Used to maintain ontologies.
Data analytics toolbox (Realtime and Batch)	HTTP protocol, API integration	Used for the tool's execution.
Data analytics dashboard	API integration	Used to show the results of the tool's output.
Batch mode of the tool	//	The tool executes in batch mode once in 48 hours and produces results for next 48 hours.

Table 60: PLATOON Components involved in Pre-heating and Pre-cooling Time Estimation Tool - Pilot 3a

6.4.2. LLUC 02-3A - Provide Demand Response Services through Building Inertia and HVAC Controls

6.4.2.1. Description

The demand response service developed within the scope of pilot #3A provides a smart module to supervise the implementation of Demand Response services in an office Building using HVAC load predictions, load control, and building inertia.
The demand response smart module targets the following:

- Provide flexibility services to contribute to the grid
- Provide accurate predictions of the flexibility available for the next day to help the aggregator value the Demand Response service provided on the market
- Generate income by contracting with an aggregator

6.4.2.2. Main Functions

The demand response services can be divided into three core functions.

- **Prediction of HVAC LOAD**

The HVAC load forecast is responsible for generating predicted time series of the electrical HVAC consumption at the 48h horizon with 30-min time steps for the different technical systems ("cooling" and "Ventilation"). These forecasts are calculated based on the tools' outputs from the previous use case, the outside temperature data, and historical HVAC energy consumption data.
The data input required for this function is:

- Occupancy prediction data (from tool 1).
- preheating/cooling time estimation (from tool2).
- Outside temperature weather forecasting.
- Energy Consumption data from BMS.

- **Prediction of potential load interruption**

This function predicts the maximum number of time steps of the HVAC load interruption to maintain the comfort of the occupants of the building. The forecasts are generated for the next day to offer an aggregator a Demand Response (Flexibility) service.
The data input required for this function is:

- Prediction of HVAC load from tool 3.
- Outside temperature weather forecasting.
- Current temperatures and setpoints from BMS.

- **Simulation of HVAC load for load shifting program**

This function simulates HVAC load at 48h horizon with 30 min time step.
The data input required for this function is:

- Outside temperature weather forecasting
- HVAC energy Consumption data from BMS
- Prediction of ambient temperature (tool 4) Preheating/precooling time estimation (tool

6.4.2.3. Tool Process View

- **Tool 03: Prediction of HVAC LOAD**

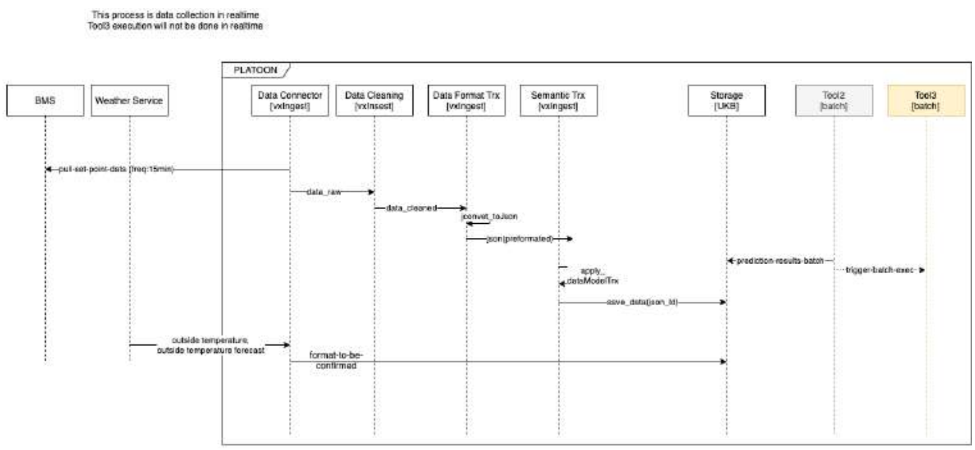


Table 61: Pilot 3a Prediction of HVAC LOAD Tool Process View

PLATOON Component	Interfaces	role
Data connector	HTTP protocol, integration with CDH (AWS-S3)	Connects the batch data sources
Semantic adapter	HTTP protocol, flow files	Converts raw data to semantic data according to sematic data models in Realtime pipelines
Data curation engine (Vx ingest)	HTTP protocol, flow files	Data formatting, data aggregation and data enrichment in data pipelines.
Context broker (KAFKA)	HTTP protocol, Kafka events	When tool executes its results are published on KAFKA where the data pipeline is applied, and final results are stored.
Unified knowledge base (semantic and time series data base)	HTTP protocol	Consists of two data bases, Static context data is put in sematic database and timeseries data is put in no SQL database.
Energy data models	//	Output of 2.3, raw data converted to semantic data according to these data models.
Vocabulary manager	//	Used to maintain ontologies.
Data analytics toolbox (Realtime and Batch)	HTTP protocol, API integration	Used for the tool's execution.
Data analytics dashboard	API integration	Used to show the results of the tool's output.
Batch mode of the tool	//	The tool executes in batch mode once in 24 hours and produces results for next 24 hours

Table 62: PLATOON Components involved in Prediction of HVAC LOAD - Pilot 3a

- **Tool 04: Prediction of potential load interruption**

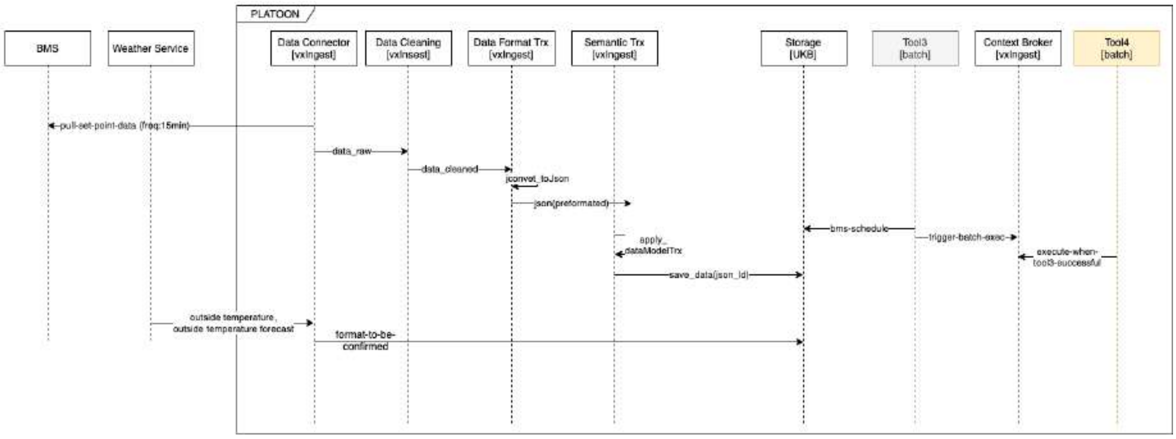


Figure 65: Prediction of Potential Load Interruption Tool Process View

PLATOON Component	Interfaces	role
Data connector	HTTP protocol, integration with CDH (AWS-S3)	Connects the batch data sources
Semantic adapter	HTTP protocol, flow files	Converts raw data to semantic data according to sematic data models in Realtime pipelines
Data curation engine (Vx ingest)	HTTP protocol, flow files	Data formatting, data aggregation and data enrichment in data pipelines.
Context broker (KAFKA)	HTTP protocol, Kafka events	When tool executes its results are published on KAFKA where the data pipeline is applied and final results are stored.
Unified knowledge base (semantic and time series data base)	HTTP protocol	Consists of two data bases, Static context data is put in sematic database and timeseries data is put in no SQL database.
Energy data models	//	Output of 2.3, raw data converted to semantic data according to these data models.
Vocabulary manager	//	Used to maintain ontologies.
Data analytics toolbox (Batch)	HTTP protocol, API integration	Used for the tool's execution.
Data analytics dashboard	API integration	Used to show the results of the tool's output.
Batch mode of the tool	//	

Table 63: PLATOON Components involved in Prediction of Potential Load Interruption - Pilot 3a

- **Tool 05: Simulation of HVAC load for implementation of a load shifting program**

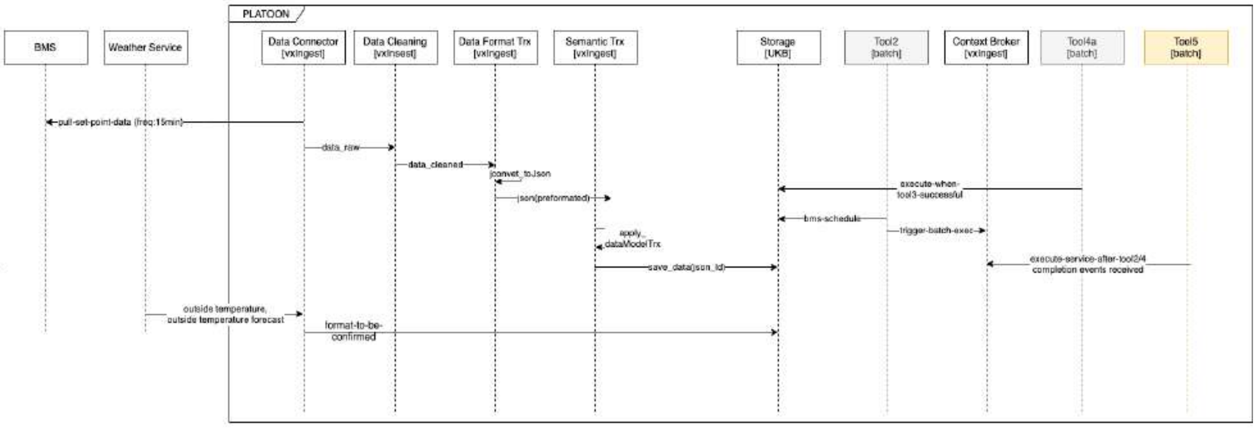


Figure 66: Pilot 3a Simulation of HVAC Load for Load Shifting Program Tool Process View

PLATOON Component	Interfaces	role
Data connector	HTTP protocol, integration with CDH (AWS-S3)	Connects the batch data sources
Semantic adapter	HTTP protocol, flow files	Converts raw data to semantic data according to sematic data models in Realtime pipelines
Data curation engine (Vx ingest)	HTTP protocol, flow files	Data formatting, data aggregation and data enrichment in data pipelines.
Context broker (KAFKA)	HTTP protocol, Kafka events	When tool executes its results are published on KAFKA where the data pipeline is applied, and final results are stored.
Unified knowledge base (semantic and time series data base)	HTTP protocol	Consists of two data bases, Static context data is put in sematic database and timeseries data is put in no SQL database.
Energy data models	//	Output of 2.3, raw data converted to semantic data according to these data models.
Vocabulary manager	//	Used to maintain ontologies.
Data analytics toolbox	HTTP protocol, API integration	Used for the tool's execution.

(Realtime and Batch)		
Data analytics dashboard	API integration	Used to show the results of the tool's output.
Batch mode of the tool	//	

Table 64: PLATOON Components involved in Simulation of HVAC Load for Load Shifting Program - Pilot 3a

6.4.3. Validation Metrics

To ensure the performance, the quality of Pilot 3A service's results, and measure the efficiency of the process, it is important to perform a set of tests for this module, including the requirements and the targets defined in the description of the pilot's low level use case.
The validation process should ensure that the key performance indicators KPIS defined for this module meet the use case requirements. The validation tests are also important to provide feedback for improvement of the optimization of the building consumption. The KPIs covering the tests for the HVAC optimization module and the demand response module, including the PLATOON components listed in the previous section occupancy prediction in the building zone, preheating and pre-cooling time estimation, HVAC load prediction, preheating and pre-cooling time estimation, and simulation of HVAC load for load shifting program functions are described below. The details regarding the mathematical formula, the data description, and the details of the KPIS are defined in Annex II.

6.4.3.1. LLUC-01-KPI 01: Deviation to target comfort during occupancy time

Testing approach

The thermal comfort in the building is evaluated in terms of air temperature. The objective is to be within the range of comfort defined by the building manager.
The deviations to this range will be monitored during occupancy periods, and the heating and cooling forecasted schedule in the building will be evaluated.

Test steps

This KPI is calculated according to the need of the evaluation on daily, weekly, or monthly basis following the steps below.

- Choice of a period, or calculation for default periods (days, weeks, months, years)
- For the given period considered (week, month, year), identification of the occupancy periods for the different zones defined in the building.
- Request of the temperature for the different occupancy periods of the different zones and apply the formula specified on the KPI template.

Pass/fail criteria

The pass criteria for this scenario is to check that the measured air temperature of the building deviation doesn't exceed 2°C during the test period under the condition's setup up by the optimization module and for all the measurements cycles.

6.4.3.2. LLUC-01-KPI 02: Unnecessary HVAC heating emission

Testing approach

Unnecessary HVAC heating emission is calculated to evaluate the amount of energy emission (heating or cooling) that could be considered as unnecessary regarding the actual building occupancy, especially when:

- Preheating or precooling time over-anticipation.
- Heating/cooling but no one present for the rest of the day.

The percentage of valve opening attributed to a specific weight will be considered as the measure of the unnecessary heating or cooling emission.

Test steps

This KPI is calculated according to the need of the evaluation on daily, weekly, or monthly basis following the steps below.

- Choice of a period, or calculation for default periods (days, weeks, months, years).
- Identification of time periods for each valve where:
  - Last period is at the end of the day when the zone is unoccupied, but heating is still happening (over anticipation).
  - The first period of the day when the zone is unoccupied, heating is happening, but preheating period is finished (Tzone-Tsetpoint<Tref_lim).
- For the different periods identified, and for the different zones and valves considered, the formula specified on the KPI template can be calculated.

Pass/fail criteria

The pass criteria for this scenario is to check that the energy emissions of the building do not exceed 10% during the test period under the condition's setup up by the optimization module and for all the measurements cycles.

6.4.3.3. LLUC-01-KPI 03: Unnecessary HVAC cooling emission

Testing approach

Unnecessary HVAC cooling emission is calculated to evaluate the amount of energy emission (heating or cooling) that could be considered as unnecessary regarding the actual building occupancy, especially when:

- Preheating or precooling time over-anticipation.
- Heating/cooling but no one present for the rest of the day.

The percentage of valve opening attributed to a specific weight will be considered as the measure of the unnecessary heating or cooling emission.

Test steps

This KPI is calculated according to the need of the evaluation on daily, weekly, or monthly basis following the steps below.

- Choice of a period, or calculation for default periods (days, weeks, months, years).
- Identification of time periods for each valve where:
  - Last period is at the end of the day when the zone is unoccupied, but cooling is still happening (over anticipation).
  - The first period of the day when the zone is unoccupied, is happening, but the cooling period is finished (Tzone-Tsetpoint<Tref_lim).
- For the different periods identified, and for the different zones and valves considered, the formula specified on the KPI template can be calculated.

Pass/fail criteria

The pass criteria for this scenario is to check that the energy emissions of the building do not exceed 10% during the test period under the condition's setup up by the optimization module and for all the measurements cycles.

6.4.3.4. LLUC-01-KPI 04: Gain on heating consumption

Testing approach

Climate corrected gain on heating energy consumption is evaluated in comparison with the consumption of the building in the previous year.

Test steps

- Choice of a period, or calculation for default periods (days, weeks, months, years)
- Data of the previous year over the same period must be available.
- Application of the formula specified on the KPI template.

Pass/fail criteria

The gain of heating consumption of the building should be more than 10% during the test period and compared to the reference year.

6.4.3.5. LLUC-01-KPI 05: Gain on cooling consumption

Testing approach

Climate corrected gain on cooling energy consumption is evaluated in comparison with the consumption of the building in the previous year.

Test steps

- Choice of a period or calculation for default periods (days, weeks, months, years). Data of the previous year over the same period must be available.
- Application of the formula specified on the KPI template.

Pass/fail criteria

The gain of cooling consumption of the building should be more than 10% during the test period and compared to the reference year.

6.4.3.6. LLUC-02-KPI 01: Mean error on heating load prediction Testing approach

Testing approach

Mean error (%) on the HVAC heating load prediction is calculated every 30min as the errors between the predicted and the actual energy consumption , divided by the predicted one (when HVAC is operating).

Test steps

This KPI is calculated according to the need of the evaluation on daily, weekly, or monthly basis following the steps below.

- Choice of a period, or calculation for default periods.
- Application of the mathematical formula listed on the KIP template in annex II.

Pass/fail criteria

The mean error (%) on the HVAC heating load prediction building should be less than 20% during the test period.

6.4.3.7. LLUC-02-KPI 02: Mean error on cooling load prediction

Testing approach

Mean error (%) on the HVAC cooling load prediction is calculated every 30min as the errors between the predicted and the realized energy consumption , divided by the predicted one (when HVAC is operating).

Test steps

This KPI is calculated according to the need of the evaluation on daily, weekly, or monthly basis following the steps below.

- Choice of a period, or calculation for default periods.
- Application of the mathematical formula listed on the KIP template in annex II.

Pass/fail criteria

Mean error (%) on the HVAC cooling load prediction building should be less than 20% during the test period.

6.4.3.8. LLUC-02-KPI 03: 95-percentile error on heating load prediction Testing approach

Testing approach

95-percentile error on the HVAC heating load prediction calculated every 30min as the errors between the predicted and the actual energy consumption , divided by the predicted one (when HVAC is operating).

Test steps

This KPI is calculated according to the need of the evaluation on daily, weekly, or monthly basis following the steps below.

- Choice of a period, or calculation for default periods.
- Application of the mathematical formula listed on the KIP template.

Pass/fail criteria

95-percentile error on the HVAC heating load prediction should be less than 30% during the test period.

6.4.3.9. LLUC-02-KPI 04: 95-percentile error on cooling load prediction

Testing approach

Error (%) on the HVAC cooling load prediction is calculated every 30min as the errors between the predicted and the realized energy consumption, divided by the predicted one (when HVAC is operating). The error can be characterized over the period: mean, standard deviations, daily distribution, seasonal distribution.

Test steps

This KPI is calculated according to the need of the evaluation on daily, weekly, or monthly basis following the steps below.

- Choice of a period, or calculation for default periods.
- Application of the mathematical formula listed on the KIP template.

Pass/fail criteria

Error (%) on the HVAC cooling load prediction should be less than 30% during the test period.

6.4.3.10. LLUC-02-KPI 05: Error on the flexibility prediction

- **Testing approach**

Error (%) on the prediction of "flexibility available" on the building, in terms of time of interruption of heating or cooling in the building, during flexibility events implemented in the building. This parameter will be calculated manually. No need for a routine.

- **Test steps**

For the evaluation of this parameter, it is enough to use the mathematical formula defined of the KPI template on annex II.

- **Pass/fail criteria**

Error (%) on the prediction of "flexibility available" on the building should be less than 20% during the test period

6.4.3.11. LLUC-02-KPI 06: Mean error on HVAC load prediction for days with load shifting programs

Testing approach

Mean error (%) on the HVAC load prediction calculated every 30min as the errors between the predicted and the realized energy consumption divided by the predicted one (when HVAC is operating), in case of the implementation of a load shifting program (not the usual building operation).

Test steps

For the evaluation of this parameter, it is enough to use the mathematical formula defined by the KPI template in annex II.

Pass/fail criteria

The mean error (%) on the HVAC load prediction should be less than 20% during the test period.

6.5. Pilot 3b-PI Advanced Energy Management System and Spatial (Multi-Scale) Predictive Models in the Smart City

6.5.1. LLUC01-3B_PI Building Heating & Cooling consumption Analysis and Forecast

6.5.1.1. Description

Efficiently forecasting energy consumption can reduce costs and emissions. Improving the comfort of the working environments can positively affect the productivity of working human resources and quality of customer interactions in retail offices. The correlation with occupancy of employees and clients, together with benchmark with similar building, represent an area of optimization for both cooling and heating systems.
The tools developed in this Use Case can help the Company Building and Energy managers to better address their action in planning energy consumption and asset maintenance in order to ensure energy saving and costs reduction. The benefits of these tools can impact on:

a. Energy plans management (heating, cooling)
b. Energy consumption forecast analysis
c. Building energy usage benchmark
d. Reduction of emissions (CO2 / TOE correlation)

6.5.1.2. Main Functions

The following services will be developed within the UC01_PI:

- **Heating & Cooling consumption benchmarking:** The service will be developed in order to compare buildings heating and cooling consumption in a cluster of buildings or the performances of the same building in different time windows. The model will take into account the information on building characteristics, energy consumption, weather.
- **Heating & Cooling consumption forecast:** Basing analysis on historical data and trends of consumption, but also on the building characteristics and external weather information the service will predict energy consumption based on heating and cooling consumptions of a building or more buildings in a given time range.
- **Consumptions and Occupancy Profile Correlator:** The service will assess if heating and cooling consumptions of a building or more building are correlated with the average number of people inside the building(s). Correlation index will be calculated in order to support the Energy Expert to choose the better configuration policies to guarantee both comfort to the people in the building but also optimizing energy consumption. This service is also applicable to the UC03 (below tool process view) on Lighting plants.
- **Weather Data:** To provide historical weather data (temperature and humidity), an additional service is included. The service takes advantage of the Copernicus E-OBS data access chunks dataset1 to retrieve historical weather data. The needed portion

[1] https://surfobs.climate.copernicus.eu/dataaccess/access_eobs_chunks.php

of the dataset related to Rome is extracted by using climate data operator (cdo)2 utility and stored in a database for further use. Moreover, two REST APIs are provided allowing to query such weather data by coordinate pair or by PI building identifier in a time window.

6.5.1.3. Tool Process View

- **Data Sources:** The following data sources are required to perform the Pilot #3b_PI UC01:
  - **General Buildings Data:**
    - Building Data: Information about building characteristics and general (ID Office, destination use, smq, climate zone, etc.).
    - Calendar: Office opening hours and shifts.
    - Occupancy: daily customers and employees in the building.
  - **Measurements**:
    - Buildings Energy Consumption: aggregated historical consumption of all systems in the building (lighting, heating, cooling, computers, etc.).
    - Systems Energy Consumption: real consumption data collected from heating and cooling plants.
  - **Weather Data:** Information on external environmental temperature and humidity.

To have the information required related to the measurement datasource we have sensors and meters in the buildings that get the actual value at least daily.

[2] https://code.mpimet.mpg.de/projects/cdo

Tool 01: Heating & Cooling Consumption Benchmarking

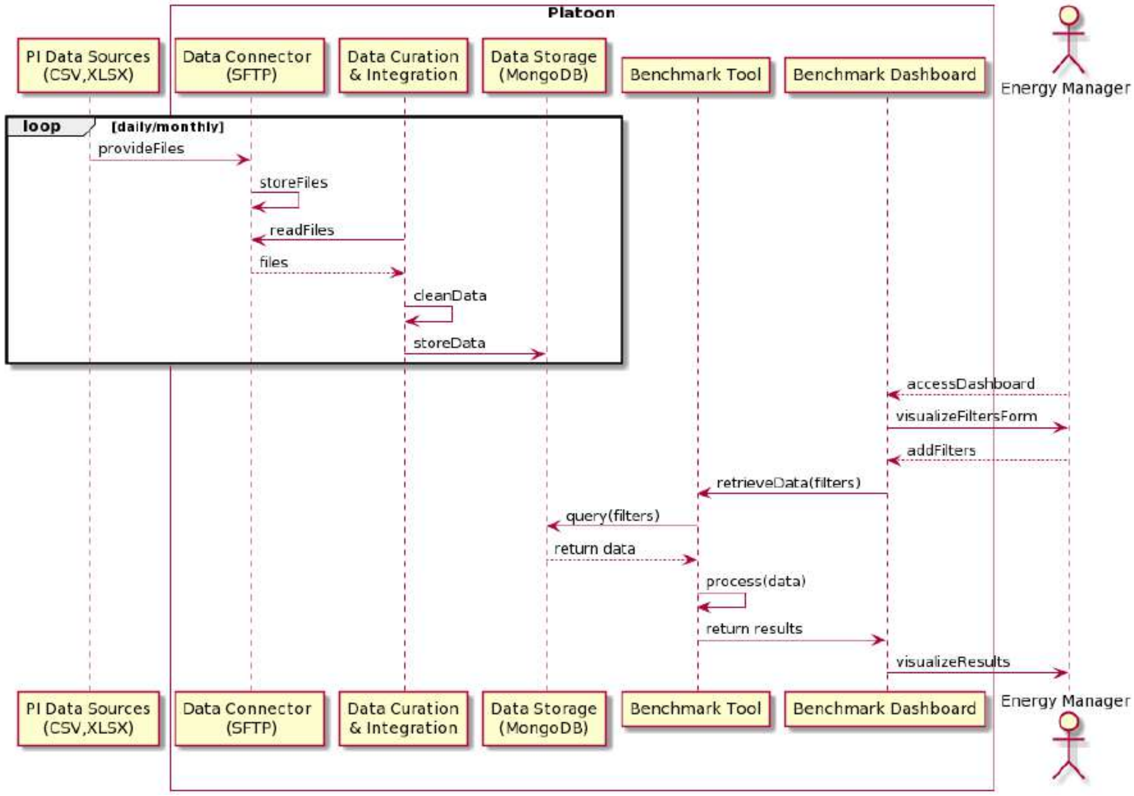


Figure 67: Pilot 3b – PI Heating and Cooling Consumption Benchmark tool Overview

PLATOON Component	Interfaces	role
Data Connector	SFTP protocol	This component allows the provisioning of the data sources used by the tool
Data Curation and Integration	File flows, PyMongo	This component reads the provided files, formats, and cleans the data and sends the data to the Storage component
Data Storage		This component is a NoSQL database (MongoDB) used to store the cleaned data
Data Analytics Toolbox (Benchmark Tool)	PyMongo, APIs exposed	This component exposes a set of REST APIs. Each time a new request is provided, it queries the storage component, aggregates and processes the data and provides the results. For the buildings where heating and cooling real measures are not available, they are evaluated from the aggregated consumption and

		specific monthly percentages contained in the Building master data.
Data Analytics Dashboard (Benchmark Dashboard)	HTTP protocol, API integration	This component is used by the energy manager to interact with the Data Analytics Toolbox to access the results and visualize them.

Table 65: PLATOON components involved in Heating and Cooling Consumption Benchmark Tool - Pilot 3b-PI

Tool 02: Heating & Cooling Consumption Forecast

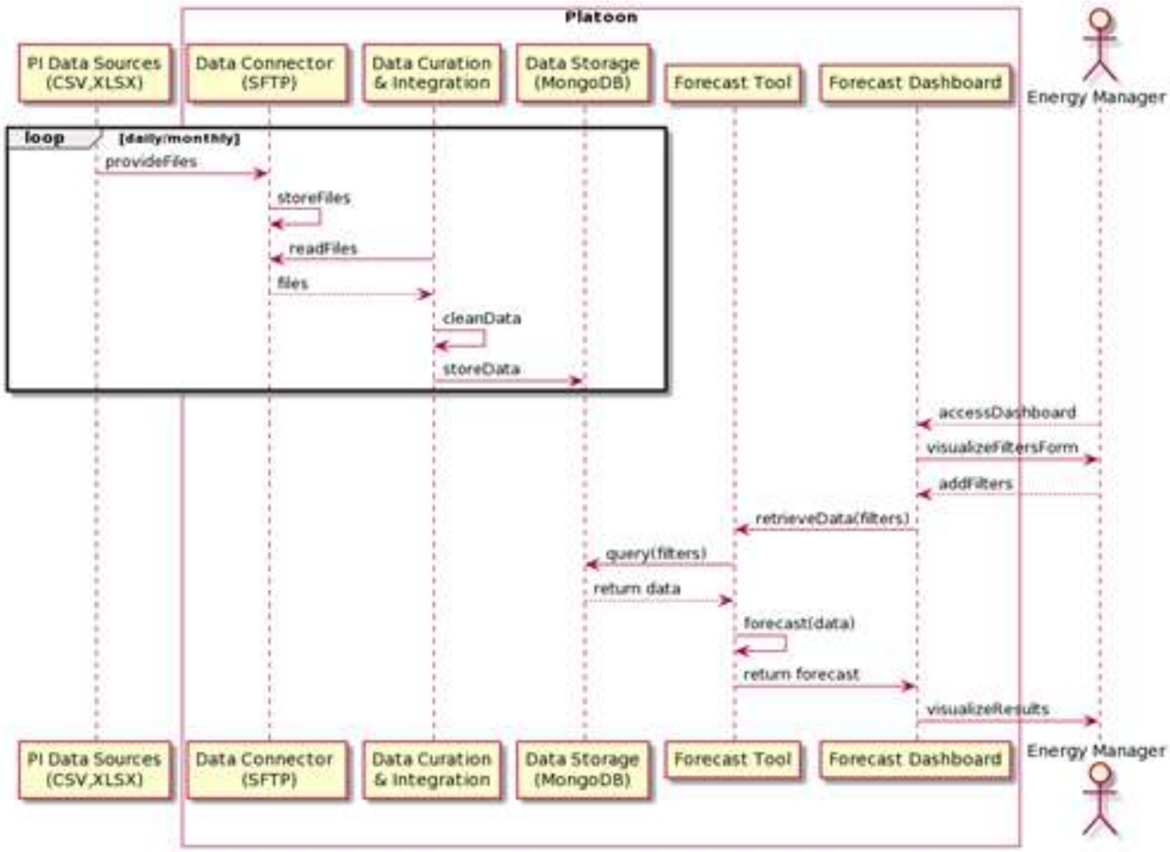


Figure 68: Pilot 3b – PI Heating and Cooling Consumption Forecast Tool Overview

PLATOON Component	Interfaces	role
Data Connector	SFTP protocol	This component allows the provisioning of the data sources used by the tool
Data Curation and Integration	File flows, PyMongo	This component reads the provided files, formats, and cleans the data and sends the data to the Storage component

Data Storage		This component is a NoSQL database (MongoDB) used to store the cleaned data
Data Analytics Toolbox (Forecast Tool)	PyMongo, APIs exposed	This component exposes a set of REST APIs. Each time a new request is provided, it queries the storage component, aggregates and processes the data and provides the results. The forecasting process is performed through Prophet[3] library.
Data Analytics Dashboard (Forecast Dashboard)	HTTP protocol, API integration	This component is used by the energy manager to interact with the Data Analytics Toolbox to access the forecasted results and visualize them.

Table 66: PLATOON components involved in Heating and Cooling Consumption Forecast Tool - Pilot 3b-PI

Tool 03: Occupancy Impact on Energy Consumption of Heating & Cooling Plants

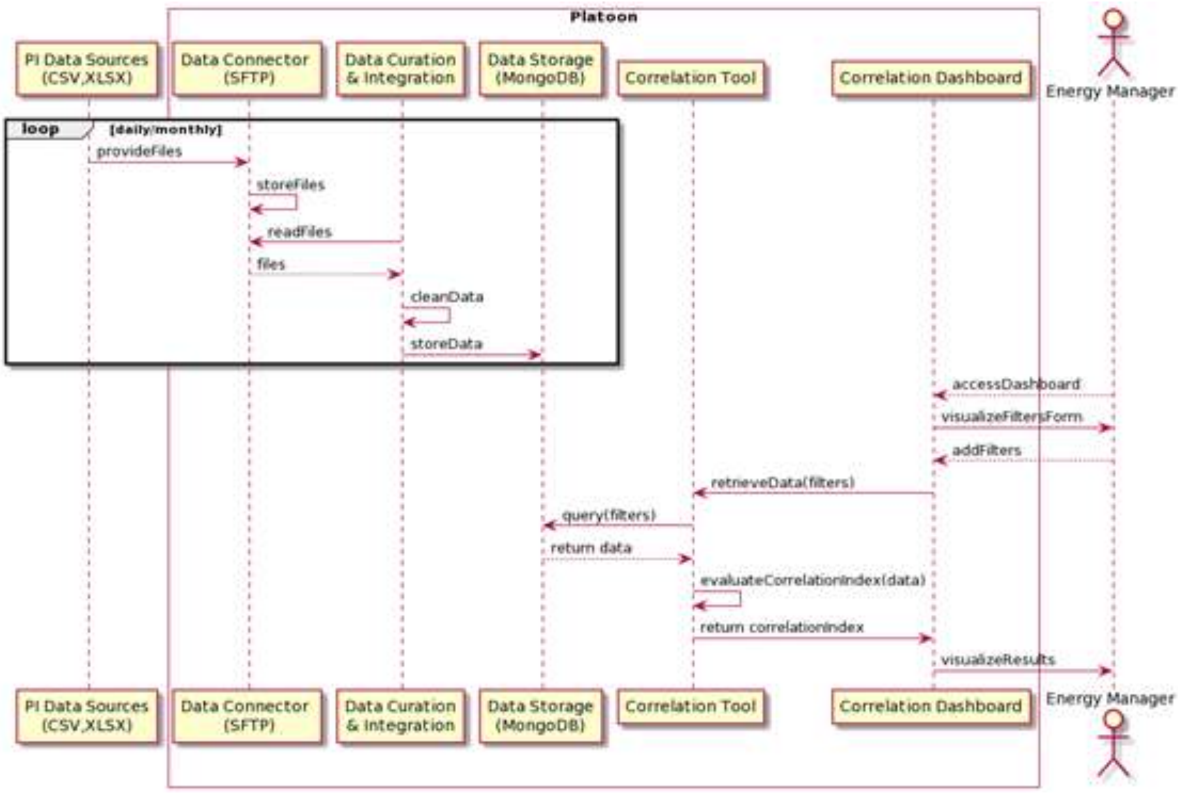


Figure 69: Pilot 3b – PI Occupancy Impact on Energy Consumption of Heating & Cooling Plants Tool Overview

[3] https://facebook.github.io/prophet/

PLATOON Component	Interfaces	role
Data Connector	SFTP protocol	This component allows the provisioning of the data sources used by the tool
Data Curation and Integration	File flows, PyMongo	This component reads the provided files, formats, and cleans the data and sends the data to the Storage component
Data Storage		This component is a NoSQL database (MongoDB) used to store the cleaned data
Data Analytics Toolbox (Correlation Tool)	PyMongo, APIs exposed	This component exposes a set of REST APIs. Each time a new request is provided, it queries the storage component, aggregates and processes the data and provides the correlation indexes.
Data Analytics Dashboard (Correlation Dashboard)	HTTP protocol, API integration	This component is used by the energy manager to interact with the Data Analytics Toolbox to access the forecasted results and visualize them.

Table 67: PLATOON components involved in Occupancy Impact on Energy Consumption of Heating & Cooling Plants Tool - Pilot 3b-PI

6.5.2. LLUC02-3B_PI Predictive maintenance (anomaly detection) of cooling and heating plants

The tool identified for this use case will be managed in the context of the 1st PLATOON Open Call - Technology Transfer Programme. The company Atlantis Engineering SA will develop the solution according with the LLUC02 requirements and will produce the required deliverable according with the Individual Mentoring Plan (IMP).
The choice to involve Atlantis Engineering in the development of this tool, already defined as original pilot UC, has been driven by the expertise of the company in this field and their project proposal, submitted for the open call selection, very related to this topic. Anyway, it should be clarified that the development of the whole service and integration with PLATOON compliant platform (i.e. Digital Enabler) will be done in strict collaboration with Engineering Ingegneria Informatica as technical partner of Poste Italiane.
In the following sections a brief description of the tool is provided.

6.5.2.1. Description

Nowadays plants maintenance is carried out according to fixed schedules with planned actions with specific timing related to plants complexity and building dimension and through on demand tickets to solve plants failures or fixing issues (change temperature for better comfort). The possibility to have information that shows evidence of deviation from standard

system behaviours is very important for the Energy Expert to take decision for any corrective action. Through alerts sent when anomaly is detected, the Energy Expert will be always aligned on the systems health status.
The expected benefits are an improvement of monitoring of plant performance and a useful support to identify behaviours not in line with energy objectives and company policies.

6.5.2.2. Main Functions

The following services will be developed within the UC02_PI:

- **Anomaly Detection:** The service will analyze and identify any malfunctions in the Heating and Cooling systems.
- **Performances Benchmarking Service:** The service is finalized to evaluate Heating and Cooling performance comparing a single building with itself or with different buildings during the time window selected. The methodology of analysis is described in KPI-09_PI.

6.5.2.3. Tool Process View

- **Data Sources:** The following data sources are required to perform the Pilot #3b_PI UC02:
    - **General Buildings Data:**
        - Building Data: Information about building characteristics and general (ID Office, destination use, smq, climate zone, etc.).
        - Calendar: Office opening hours and shifts.
    - **Measurements:**
        - System Alarms generated by the sensors installed in the buildings.
        - Systems Energy Consumption: data collected from heating and cooling plants.
        - Sensors number.
        - Internal temperature
    - **Weather Data:** Information on external environmental temperature and humidity.

Tool 04: Anomaly Detection

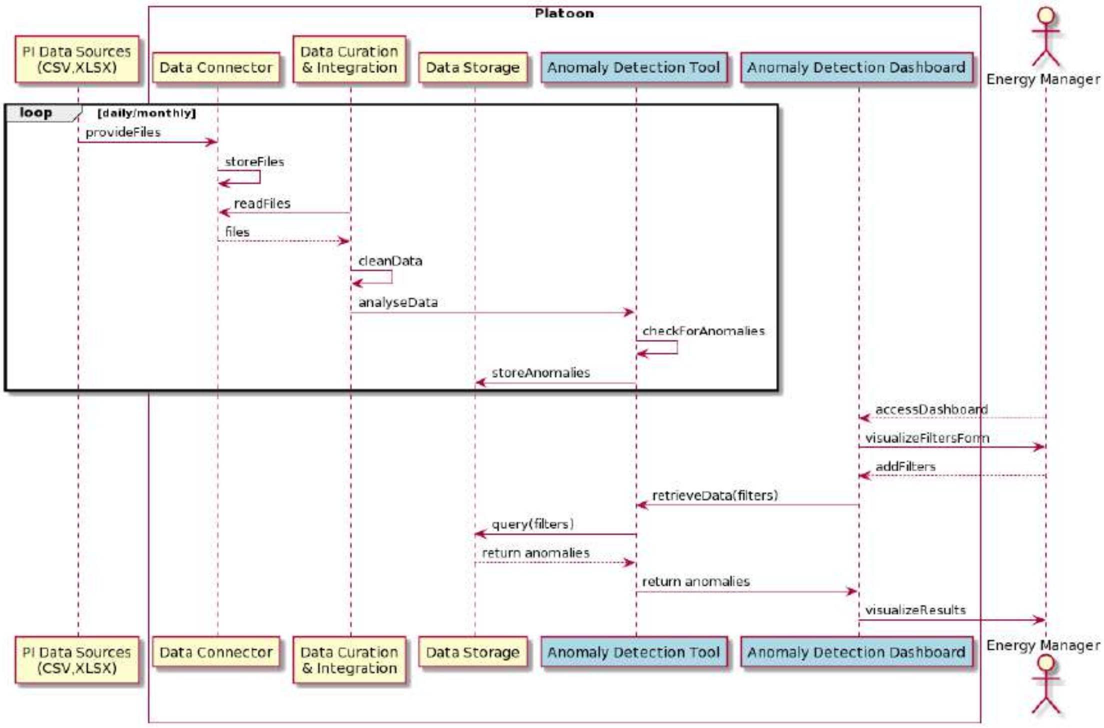


Figure 70: Pilot 3b – PI Predictive Maintenance (Anomaly Detection) of Cooling and Heating Plants

PLATOON Component	Interfaces	role
Data Connector	SFTP protocol	This component allows the provisioning of the data sources used by the tool
Data Curation and Integration	File flows, PyMongo	This component reads the provided files, formats, and cleans the data and sends the data to the Storage component
Data Storage		This component is used to store the cleaned data and the detected anomalies.
Data Analytics Toolbox (Anomaly Detection Tool)	APIs exposed	This component receives the cleaned data and check for anomalies in the stream using three approaches: Rule-based, Trend-based and Outlier-based. The detected anomalies are stored in the Data Storage component.
Data Analytics Dashboard (Anomaly	HTTP protocol, API integration	This component is used by the energy manager to interact with the Data Analytics Toolbox to access the

Detection Dashboard)		detected anomalies and visualize them.

Table 68: PLATOON Components involved in Predictive Maintenance (Anomaly Detection) of Cooling and Heating Plants - Pilot 3b-PI

6.5.3. LLUC03-3B_PI lighting consumption estimation &benchmarking

6.5.3.1. Description

It's very important knowing lighting consumptions as accurately as possible; on the other hand, the consumption is often aggregated so that the specific consumption is often estimated with not an accurate approach.
Knowing other consumption usage data (such as heating and cooling...), total consumption of the building, lighting installations number and type and other building characteristics (such as category, square meters, generic occupancy profiles...) it's possible to estimate the specific building lighting consumption, to benchmark, plan optimization actions and detect anomalies and outliers. The benefit expected should impact on the optimisation of lighting consumption and consequently on GHG emissions.

6.5.3.2. Main Functions

In thi use caes the following services are implemented and validated:

- **Building Lighting Evaluator:** The information on building Lighting consumption is almost never available. The knowledge of the total energy consumption of a building and that of some systems in it is not sufficient to have an estimate of lighting consumption. The app will calculate this value starting from information on consumption but analysing also other information and will produce the value required. The end user shall select the perimeter and the criteria on which to base the analysis.
- **Lighting consumption benchmarking**: The service shall produce a report to allow a comparison of lighting consumption due to lighting between buildings or lighting solutions. In this way the Energy Expert will be supported to make decision in planning optimisation.
- **Lighting consumption Correlation**: The service shall allow the Energy Expert to evaluate if lighting consumption of a building or more buildings are correlated with the average number of people inside the building(s). The service is included in the tool developed for the UC01 - Consumptions and Occupancy Profile Correlator.

6.5.3.3. Tools Process View

- **Data Sources:** The following data sources are required to perform the Pilot #3b_PI UC03:
  - **General Buildings Data:**
    - Building Data: Information about building characteristics and general (ID Office, destination use, smq, climate zone, etc.).
    - Calendar: Office opening hours and shifts.
    - Occupancy: daily customers and employees in the building
  - **Measurements**:
    - Buildings Energy Consumption: aggregated historical consumption of all systems in the building (lighting, heating, cooling, computers, etc.).
    - Systems Energy Consumption: real lighting consumption data.

Tool 05: Lighting Consumption Estimation & Benchmarking

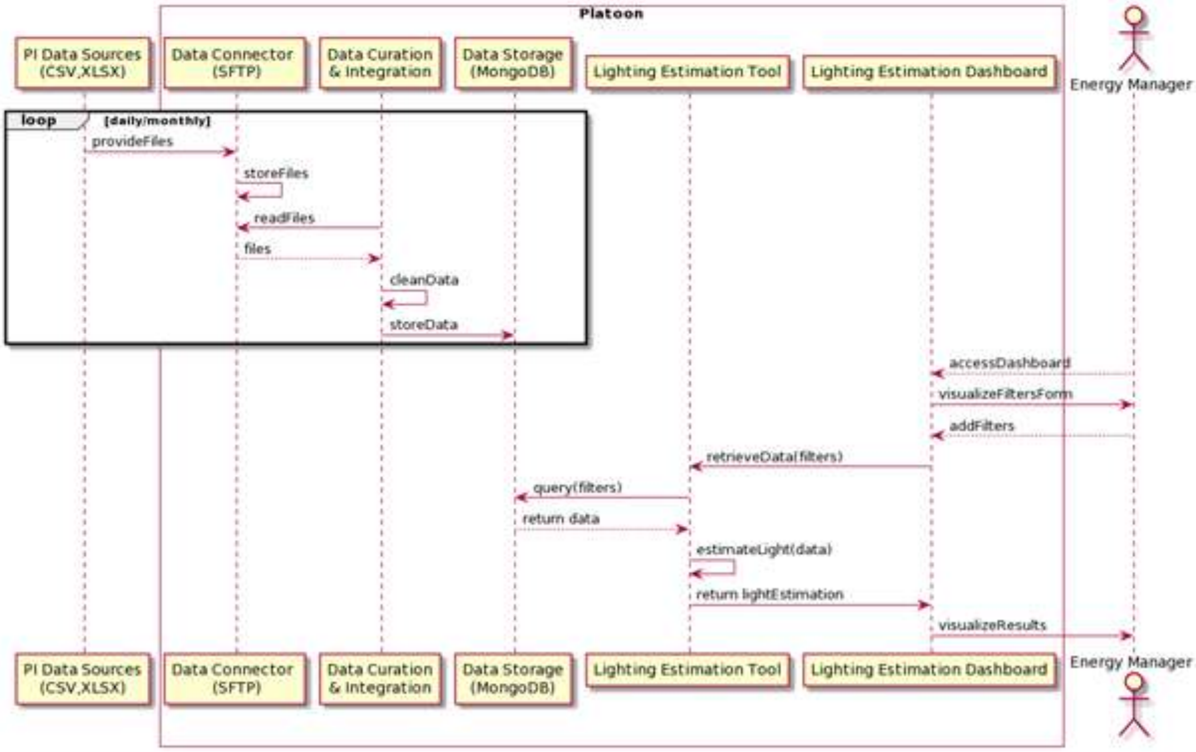


Figure 71: Pilot 3b – PI Lighting Consumption Estimation Tool Overview

PLATOON Component	Interfaces	role
Data Connector	SFTP protocol	This component allows the provisioning of the data sources used by the tool
Data Curation and Integration	File flows, PyMongo	This component reads the provided files, formats, and cleans the data and

		sends the data to the Storage component
Data Storage		This component is a NoSQL database (MongoDB) used to store the cleaned data
Data Analytics Toolbox (Benchmark Tool)	PyMongo, APIs exposed	This component exposes a set of REST APIs. Each time a new request is provided, it queries the storage component, aggregates and processes the data and provides the results. Lighting estimation is performed over a model built thanks to the real lighting consumptions data of a specific type of building (Smart Buildings).
Data Analytics Dashboard (Benchmark Dashboard)	HTTP protocol, API integration	This component is used by the energy manager to interact with the Data Analytics Toolbox to access the results and visualize them.

Table 69: PLATOON Components involved in Lighting Consumption Estimation Tool Overview - Pilot 3b-PI

6.5.4. Validation Metrics

To ensure the performance, the quality and the results of the tools developed in the pilot, it is important to perform a set of tests in order to measure the use case requirements and the targets defined in the description of the pilot's low level use case. The validation process should make sure that the use case requirements meet the KPI's which are defined for this pilot. The validation tests are important to provide feedback for further improvement of the tools used within this pilot.

The KPIs for the Pilot #3b_PI are the following:

USE CASE	ID	Name
LLUC-01	PI_KPI01	Forecast Error
	PI_KPI02	Building Benchmarking BtI_LY
	PI_KPI03	Building Benchmarking BtI_LWs
	PI_KPI04	Building Benchmarking BtB
	PI_KPI05	CO2 emission reduction
LLUC-02	PI_KPI06	Recall
	PI_KPI07	Precision
	PI_KPI08	F1-Score
	PI_KPI09	Performances Analysis
LLUC-03	PI_KPI10	Lighting Estimation

Table 70: Pilot 3b-PI- KPIs

6.5.4.1. KPI -01 Forecast Error

The KPI calculates the % of deviation between the energy consumption forecast and the actual consumption in the building. The scope is to measure the effectiveness of the predictive model.

Testing approach
The KPI-01 is evaluated as the Mean absolute percentage error (MAPE) between the real consumption data and the forecasted one. The following general formula is applied to evaluate the error:

$$\frac{1}{n}\sum_{i=1}^{n}\frac{|e_i|}{d_i}$$

Each value represents the error between the real value and the estimated one, and is averaged by the number of considered samples.

Test steps
To evaluate this KPI the following steps are necessary which are performed offline to check the forecasting model performances:

1. Select a building or a group of buildings
2. Select a specific system (total, heating, cooling or lighting)
3. Select the aggregation level (daily, monthly or yearly) for the measures

4. Extract and aggregate the data from the historical data considering the chosen aggregation level
5. Divide the measures in a training set and test set
6. Apply the forecast procedure for the training set
7. Evaluate the KPI using the predicted values and the test set

Pass/fail criteria
The obtained MAPE is within +/- 20% range.

6.5.4.2. KPI –02 Building Benchmarking BtI_LY

This KPI calculates, in % value, the difference in Energy consumption of a building with itself. The comparison will be made with the previous year consumption. The purpose is to verify any degradation in energy performances or the effectiveness of any interventions/new policies applied to the interested building during the analyzed period.

Testing approach
The calculation of the KPI-02 BtI_LY will be performed against the available historical consumption data of each building. The consumption data might have different time frequency depending on the specific type of the building (hourly for all of the buildings and quarter hour for the Smart Buildings). These data are aggregated to provide yearly consumption data about the total, heating, cooling or lighting systems. The aggregated data is then used to evaluate the KPI considering current and past year measures.

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Test steps
To evaluate this KPI the following steps are necessary:

1. Select a building or a group of buildings
2. Select a specific system (total, heating, cooling or lighting)
3. Extract consumption data of the current and last year from the available historical data for each building
4. For each building, aggregate the data to evaluate the total year consumption
5. For each building apply the following formula, that evaluates, in % value, the difference of energy consumption (EC) for two years:

$$\mathbf{B}_{\mathrm{BTI}_{\mathrm{LY}},\mathrm{i}} = \frac{(\mathrm{EC}_{\mathrm{y,i}} - \mathrm{EC}_{\mathrm{y-1,i}})}{\mathrm{EC}_{\mathrm{y-1,i}}} * 100$$

6. Finally, if more than one building is selected, apply the following formula, that extracts the average difference, in %, among the selected buildings (N):

$$\mathbf{B}_{\mathrm{BTI}_{\mathrm{LY}},\mathrm{M}} = \frac{1}{\mathrm{N}} \sum_{\mathrm{i}} \mathrm{B}_{\mathrm{BTI}_{\mathrm{LY}},\mathrm{i}}$$

Pass/fail criteria
The expected result is a value included in +/- 20%. This value will be included in the Benchmark dashboard.

6.5.4.3. KPI –03 Building Benchmarking BtI_LWs

This KPI calculates, in % value, the difference in Energy consumption of a building with itself during the time. The comparison will be made with the previous two weeks consumption. The purpose is to verify any degradation in energy performances or the effectiveness of any interventions/new policies applied to the interested building, during the analyzed period.

Testing approach
The calculation of the KPI-03 Btl_LWs will be performed against the available historical consumption data of each building. The consumption data might have different time frequency depending on the specific type of the building (hourly for all of the buildings and quarter hour for the Smart Buildings). These data are aggregated to provide weekly consumption data about the heating, cooling or lighting systems. The aggregated data is then used to evaluate the KPI considering the current and previous two weeks.

Test steps
To evaluate this KPI the following steps are necessary:

1. Select a building or a group of buildings.
2. Select a specific system (total, heating, cooling or lighting).
3. Extract consumption data of the current and previous two weeks from the available historical data for each building.
4. For each building, aggregate the data to evaluate the total weekly consumption.
5. For each building apply the following formula, that evaluates, in % value, the difference of energy consumption (EC) for the three weeks:

$$\mathbf{B}_{\mathbf{BTI}_{\mathbf{LW},\mathbf{i}}} = \frac{EC_{W,i} - [\frac{EC_{W-1,i} + EC_{W-2,i}}{2}]}{(EC_{W-1,i} + EC_{W-2,i})/2} * 100$$

6. If more than one building is selected, apply the following formula to have an average % value for the group of buildings (N):

$$\mathbf{B}_{\mathbf{BTI}_{\mathbf{LW},\mathbf{M}}} = \frac{1}{N}\sum_{i} B_{BTI_{LW},i}$$

Pass/fail criteria
The expected result is included in +/- 20% range. The KPI will be included in the benchmarking dashboard.

6.5.4.4. KPI –04 Building Benchmarking BtB

This KPI calculates, in % value, the difference in Energy consumption between a cluster of buildings in a certain time range. The purpose is to verify any degradation in energy performances or the effectiveness of any interventions/new policies applied during the analyzed period.

Testing approach

The calculation of the KPI-04 BtB will be performed against the available historical consumption data of each cluster of buildings. The consumption data might have different time frequency depending on the specific type of the building (hourly for all of the buildings and quarter hour for the Smart Buildings). These data are aggregated to provide consumption data about the heating, cooling or lighting systems in a selected time range. The aggregated data is then used to evaluate the KPI.

Test steps

To evaluate this KPI the following steps are necessary:

1. Select a cluster of buildings by their category and destination of use
2. Select from the cluster one or more buildings
3. Select a time window
4. Select a specific system (total, heating, cooling or lighting)
5. Extract consumption data from the available historical data for each building in the selected time window
6. For each building, aggregate the data and normalize the measure by the volume of the specific building
7. For each building in the cluster apply the following formula that evaluates in %, the difference in Energy consumption between a building with the other building of its cluster:

$$\mathbf{B}_{\mathbf{BTB,i}} = \frac{\frac{B_i}{m_i^3} - \left(\sum_j \frac{B_j}{m_j^3}\right)/(n-1)}{\left(\sum_j \frac{B_j}{m_j^3}\right)/(n-1)} * 100$$

8. If more than one building is selected, apply the following formula to have an average % value for the group of buildings (N):

$$\mathbf{B}_{\mathbf{BTB,M}} = \frac{1}{N}\sum_i \mathbf{B}_{\mathbf{BTB,i}}$$

Pass/fail criteria

The expected result is value included in +/- 20% range. The KPI will be included in the benchmarking dashboard.

6.5.4.5. KPI –05 CO2 emission reduction

This KPI calculates in % value, the impact of energy consumption reduction on CO2 emissions in a certain time range. The purpose is to evaluate the effectiveness of actions implemented for environmental sustainability.

Testing approach
The calculation of the KPI-05 CO2 emission reduction will be performed against the available historical consumption data of each cluster of buildings. The consumption data might have different time frequency depending on the specific type of the building (hourly for all of the buildings and quarter hour for the Smart Buildings). These data are aggregated to provide consumption data about the heating, cooling or lighting systems in a year. The aggregated data is then used to evaluate the KPI.

Test steps
To evaluate this KPI the following steps are necessary:

1. Select a building or a group of buildings.
2. Select a specific system (total, heating, cooling or lighting).
3. Extract consumption data from the available historical data for each building for the last year.
4. Extract from the building master data the available consumption budget (kWh).
5. For each building apply the following formula that gives the % value of the CO2 saving for each building:

$$\Delta(\mathbf{CO_2})_{y,i} = \frac{\text{Budget (Kwh)}_{y,i} - \text{Consumption (Kwh)}_{y,i}}{\text{Consumption (Kwh)}_{y,i}} * 100$$

6. If more than one building is selected, apply the following formula to have an average % value for the group of buildings (M):

$$\Delta(\mathbf{CO_2})_{y,M} = \frac{1}{M}\sum_{i}\Delta(\mathrm{CO_2})_{y,i}$$

Pass/fail criteria
The expected result is a value between 0 and 10%. The KPI will be included in the benchmarking dashboard.

6.5.4.6. KPI -06 Recall

The KPI calculates which is the number of cases in the Heating and Cooling system, that were correctly identified as problematic (True Positives) by the algorithm, divided by the number of those cases that were wrongly identified as non-problematic (False Negatives) plus the number of the True Positives. The scope is to measure the effectiveness of anomaly detection algorithm.

Testing approach

The ratio of instances accurately predicted as problematic (True Positives) to the summation of those predicted as non-problematic (False Negatives) and to those correctly classified (True Positives). The following provided formula, evaluates the Recall:

$$Recall = \frac{True\ Positives}{True\ Positives + False\ Negatives}$$

Test steps

The following actions are required to evaluate this KPI, and they are conducted to check the performance of the Fault Detection model:

1. Pick a building or a collection of buildings to work with.
2. Pick the Heating and Cooling system of a specific building to work with
3. Choose the specific time interval for the measures (daily, monthly, or yearly).
4. Using the chosen time period, extract and aggregate data from historical data.
5. Separate the measurements into a training and a test set.
6. Apply the Anomaly Detection approaches on the training set
7. Use actual values of each instance of the test set against the values estimated by the Anomaly Detection model on the test data set, to evaluate the KPI

Pass/fail criteria

The expected result is a value around 80% and ideally around 85%.

6.5.4.7. KPI -07 Precision

The KPI calculates which is the number of the cases in the Heating and Cooling System that were correctly classified (True Positives) as malfunctions by the Anomaly Detection approaches, divided by the number of those cases that were wrongly identified as malfunctions (False Positives) plus the number of the True Positives. The scope is to measure the effectiveness of anomaly detection algorithm.

Testing approach

Precision is defined as the proportion of accurately classified faulty instances to all instances classified as faults. The following provided formula, evaluates the Precision:

$$Precision = \frac{True\ Positives}{True\ Positives + False\ Positives}$$

Test steps

The following actions are required to evaluate this KPI, and they are conducted to check the performance of the Fault Detection model:

1. Pick a building or a collection of buildings to work with.
2. Pick the Heating and Cooling system of a specific building to work with
3. Choose the specific time interval for the measures (daily, monthly, or yearly).
4. Using the chosen time period, extract and aggregate data from historical data.
5. Separate the measurements into a training and a test set.
6. Apply the Fault Detection approaches on the training set
7. Use actual values of each instance of the test set against the values estimated by the Fault Detection model on the test data set, to evaluate the KPI

Pass/fail criteria
The expected result is a value around 80% and ideally around 85%.

6.5.4.8. KPI -08 F1-Score

F1 score is calculated as the weighted average of Precision and Recall. As, a result F1 score considers both False Negatives and False Positives. F1 score is very useful in case the data set has an uneven class distribution. This KPI is used to check the performance of the Anomaly Detection model

Testing approach
Precision and Recall are required to be calculated first, to calculate the F1 score. Therefore, the F1 score is calculated by using the provided formula below:

$$F1 = 2 * \frac{Precision * Recall}{Precision + Recall}$$

Test steps
The following actions are required to evaluate this KPI:

1. Pick a building or a collection of buildings to work with.
2. Pick the Heating and Cooling system of a specific building to work with
3. Choose the specific time interval for the measures (daily, monthly, or yearly).
4. Using the chosen time period, extract and aggregate data from historical data.
5. Separate the measurements into a training and a test set.
6. Apply the Fault Detection approaches on the training set
7. Use actual values of each instance of the test set against the values estimated by the Fault Detection model on the test data set, to evaluate the KPI.

Pass/fail criteria
The expected result is a value around 80% and ideally around 85%.

6.5.4.9. KPI -09 Performances Analysis

This KPI measures the energy consumed by the air conditioning systems for returning to optimal internal temperature, normalized by the temperature recover range. The aim is to identify any degradation in the performance of the Heating and Cooling plants.

Testing approach

This KPI evaluates the energy consumed by heating and cooling plants to recover optimal internal temperature.

Every time temperature detected by one of the building sensors will go out of range (below 19° or beyond 27°) we will have a 'Temperature Violation'. Returning to temperature optimal range will require an extra energetic effort devoted by heating and cooling systems and this energetic effort.

This energetic effort is influenced by the range of Celsius degrees to recover, the mean energy consumed by systems to preserve constant the temperature and by the volume of the building.

Normalizing by these factors we will evaluate the capacity of the systems to recover one Celsius degree.

Evaluate all the 'Temperature Violation' average for a specific month and building will allow to monitor cooling/heating plants performance trends and compare them between different buildings.

Test steps

To evaluate this KPI it is important to underline that the model is built against a specific set of buildings (Smart Buildings) that provides detailed consumption data. Moreover, the tests are performed offline to check the model performances. The following steps are needed:

1. Select a month and building among the so-called Smart Buildings.
2. Calculate the normalized energy consumption to recover one Celsius degree, for the temperature violation 'k',
$$\mathbf{E_{cond,k}} = \frac{1}{\mathrm{M - N + 1}} \sum_{\mathrm{j=N}}^{M} \frac{(\overline{\mathrm{E}}_{\mathrm{cons,k,j}} - \mathrm{E_{bias,k}})}{\left|\mathrm{T_{thr}} - \mathrm{T_{int,k}}\right| \times \mathrm{volume} \times \mathrm{p_j}}$$
3. Calculate the mean normalized energy consumption for the building 'i' and the month 'm' (It's a mean of all 'K' Temperature Violation of that month for that building)
$$\mathbf{E_{cond,i\_m}} = \frac{1}{\mathrm{K}} \sum_{\mathrm{k}} \mathbf{E_{cond,k,i\_m}}$$
4. Make the same calculation for every month and every building for which we have data
5. Make comparisons month by month (same building) or for a specific month/range of time (between different buildings)

Pass/fail criteria

The expected result is a value <= 5%. If the Threshold is greater, it could indicate a problem (performance decay of the building systems, or limited performance of a building systems vs another building systems).

6.5.4.10. KPI -10 Lighting Estimation

The KPI calculates the % of deviation between the actual and the estimated lighting consumption. The weight of consumption due to lighting is estimated to be greater than 20% of the overall electrical consumption of buildings. A deeper understanding of the lighting optimization levels and correlation (hours of artificial lighting use, number of users, sqm, …) can be useful to reduce lighting consumption.

Testing approach
As for the KPI-01, the KPI-08 takes advantage of the Mean absolute percentage error (MAPE) to estimate the performances of the lighting estimation model. The following general formula is applied to evaluate the error:

$$\frac{1}{n}\sum_{i=1}^{n}\frac{|e_i|}{d_i}$$

where each e_i represents the error between the real value and the estimated one, and n is the number of considered samples.

Test steps
To evaluate this KPI it is important to underline that the model is built against a specific set of buildings (Smart Buildings) that provides real lighting consumption data. Moreover, the tests are performed offline to check the model performances. The following steps are needed:

1. Select a building or a group of buildings among the so-called Smart Buildings.
2. Select the aggregation level (daily, monthly or yearly) for the measures.
3. Extract and aggregate the lighting data from the historical data considering the chosen aggregation level.
4. Divide the measures in a training set and test set.
5. Apply the estimation algorithm for the training set.
6. Evaluate the KPI using the predicted values and the test set.

Pass/fail criteria
The expected result is a value included in +/- 10%.

6.6. Pilot 3b ROM Advanced Energy Management System and Spatial (Multi-Scale) Predictive Models in the Smart City

6.6.1. Description

The LLUC 3B-04 focuses on building an integrated monitoring and analytical system for data coming from the meters of the different buildings of Rome Municipality that can increase the awareness on the energy consumption profiles, anomalies, forecasting and efficiency measures potentialities. The system monitors and analyses the data coming from more than 2000 buildings and complexes of buildings together with around 9135 energy meters (6685 electric meters and 2450 gas meters) managed by the Public Works and Infrastructure Department of Roma Capitale (SIMU Department).

6.6.2. Main Functions

The following tools and services will be developed within the use case:

- **Spatial Reporting:** The tool takes advantage of the GeoJSON representations of the buildings to create a report visualizing the consumption data over the entire Rome Municipality area or, by performing spatial queries over the underlying repository, on specific areas of the municipality (e.g., a single district).
- **Benchmarking Analysis:** The tool allows to measure energy consumptions and performances of a set of buildings in a specified time range or the same building in different time ranges.
- **Forecast on energy consumption:** The tool predicts the energy consumptions based on historical consumption trends for electric (in and out if PV plant is present) and natural gas meters consumptions of a building or a set of buildings
- **RES Potentialities:** The tool aims at identifying potentialities in terms of PV plants production: efficiency of existing plants, max peak power installable on the buildings, ideal storage capacity to maximize self-consumption and max energy PV production that could be shared with the local Energy Community.

6.6.3. Tool Process View

The following data sources are required to perform the pilot:

- Buildings Data: which contains the information of the buildings, such as the name, the address, the destination of use, its surface (m2) and volume (m3). Moreover, this data source provides the number of floors and rooms of each floor with the detailed information of the surface of each room and its height (m).
- Electrical Consumption: which gives the consumptions of each pod.
- Gas Consumption: which gives the gas consumption (m3) of each pdr.
- PV Meters Data: which reports the daily production measures (kWh) of a set of buildings.
- GeoJSON Polygons: which contains the GeoJSON representation of the buildings and the polygon of Rome districts.

- External Weather Data: which contains the historical weather.

Tool 01: Spatial Reporting

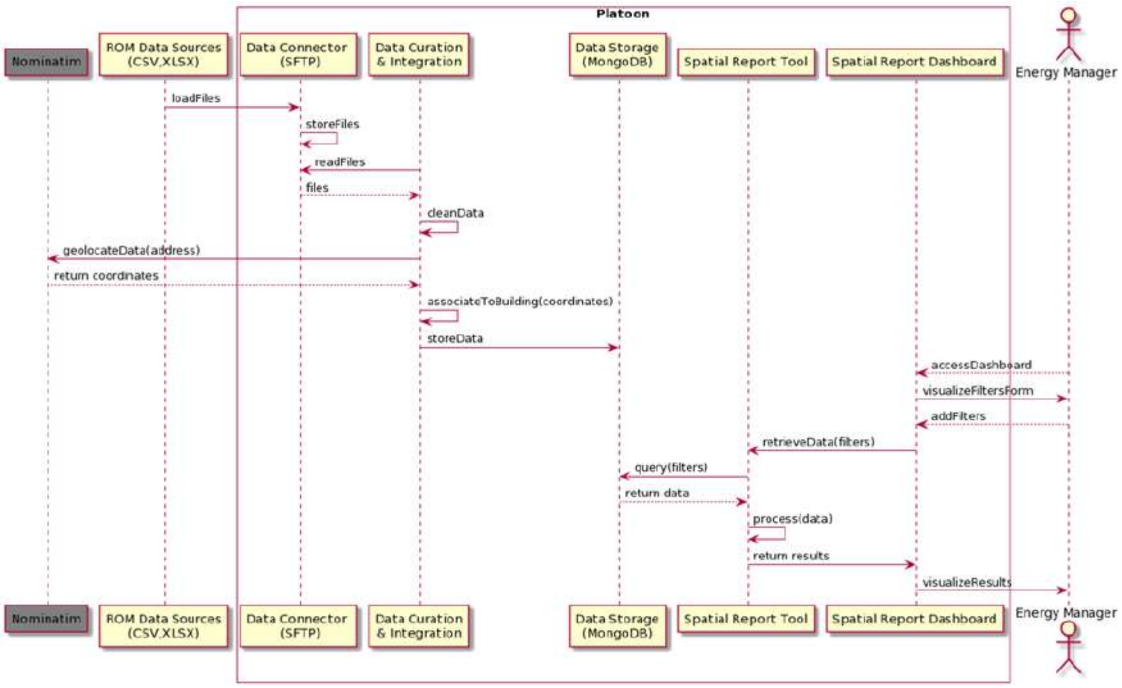


Figure 72: Pilot 3b-ROM – Spatial Reporting Tool Overview

PLATOON Component	Interfaces	role
Data Connector	SFTP protocol	This component allows the provisioning of the data sources used by the tool
Data Curation and Integration	File flows, PyMongo	This component reads the provided files, formats, and cleans the data and sends the data to the Storage component. Moreover, it is in charge of geocode the meters, where a direct connection with the building is not available, and create an association with the building itself.
Data Storage		This component is a NoSQL database (MongoDB) used to store the data
Data Analytics Toolbox (Spatial Reporting Tool)	PyMongo, APIs exposed	This component exposes a set of REST APIs. Each time a new request is provided, it queries the storage component, aggregates and processes the data and provides the results.
Data Analytics Dashboard (Spatial	HTTP protocol, API integration	This component is used by the energy manager to interact with the Data

Reporting Dashboard)		Analytics Toolbox to access the results and visualize them.

Table 71: PLATOON Components involved in Spatial Reporting Tool - Pilot 3b-ROM

Tool 02: Benchmarking Analysis

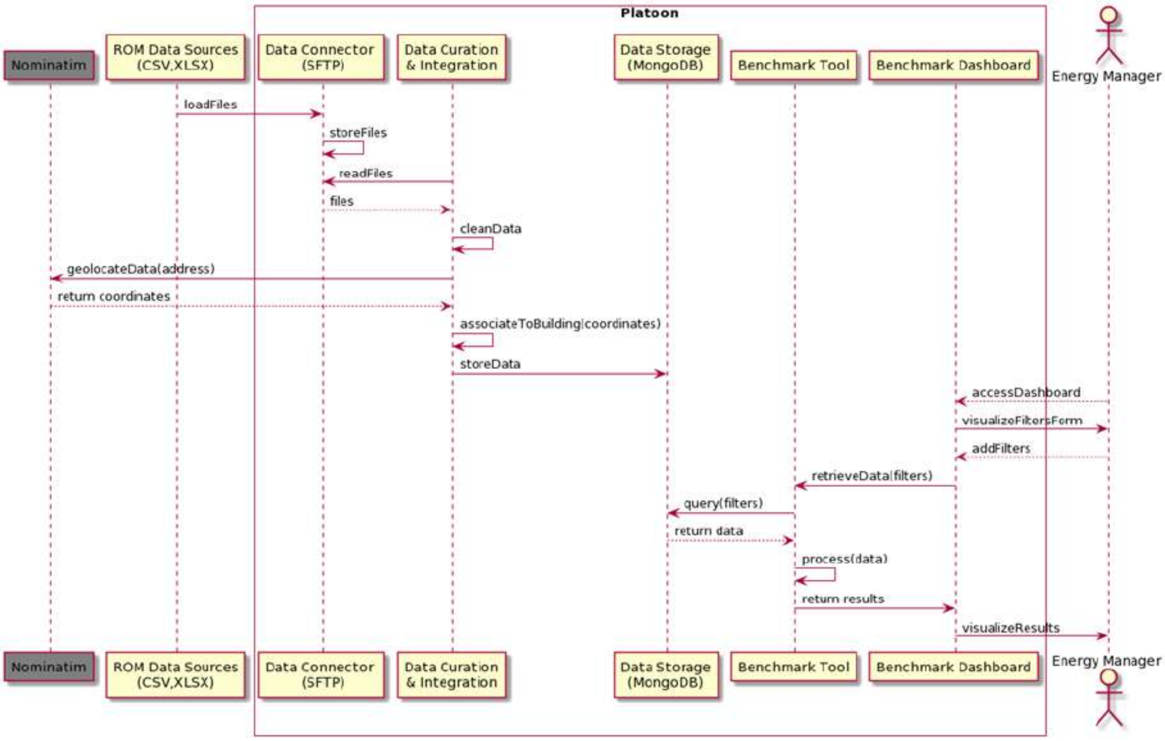


Figure 73: Pilot 3b-ROM – Benchmarking Analysis Tool Overview

PLATOON Component	Interfaces	role
Data Connector	SFTP protocol	This component allows the provisioning of the data sources used by the tool
Data Curation and Integration	File flows, PyMongo	This component reads the provided files, formats, and cleans the data and sends the data to the Storage component. Moreover, it is in charge of geocode the meters, where a direct connection with the building is not available, and create an association with the building itself.
Data Storage		This component is a NoSQL database (MongoDB) used to store the data
Data Analytics Toolbox (Benchmark Tool)	PyMongo, APIs exposed	This component exposes a set of REST APIs. Each time a new request is provided, it queries the storage component, aggregates and

		processes the data and provides the results.
Data Analytics Dashboard (Benchmark Dashboard)	HTTP protocol, API integration	This component is used by the energy manager to interact with the Data Analytics Toolbox to access the results and visualize them.

Table 72: PLATOON Components involved in Benchmarking Analysis Tool - Pilot 3b-ROM

Tool 03: Forecast on energy consumption

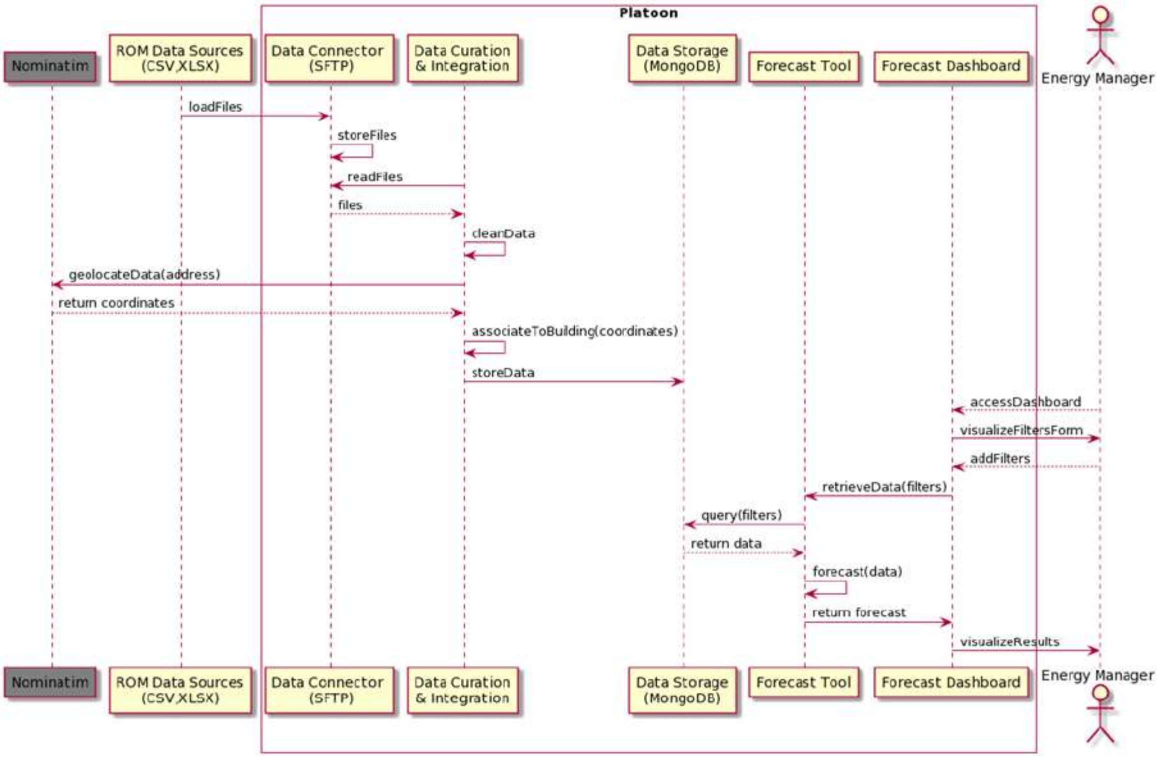


Figure 74: Pilot 3b-ROM – Forecast on Energy Consumption Tool Overview

PLATOON Component	Interfaces	role
Data Connector	SFTP protocol	This component allows the provisioning of the data sources used by the tool
Data Curation and Integration	File flows, PyMongo	This component reads the provided files, formats, and cleans the data and sends the data to the Storage component. Moreover, it is in charge of geocode the meters, where a direct connection with the building is not available and create an association with the building itself.

Data Storage		This component is a NoSQL database (MongoDB) used to store the data
Data Analytics Toolbox (Forecast Tool)	PyMongo, APIs exposed	This component exposes a set of REST APIs. Each time a new request is provided, it queries the storage component, aggregates and processes the data and provides the results.
Data Analytics Dashboard (Forecast Dashboard)	HTTP protocol, API integration	This component is used by the energy manager to interact with the Data Analytics Toolbox to access the results and visualize them.

Table 73: PLATOON Components involved in Forecast on Energy Consumption Tool - Pilot 3b-ROM

Tool 04: RES Potentialities

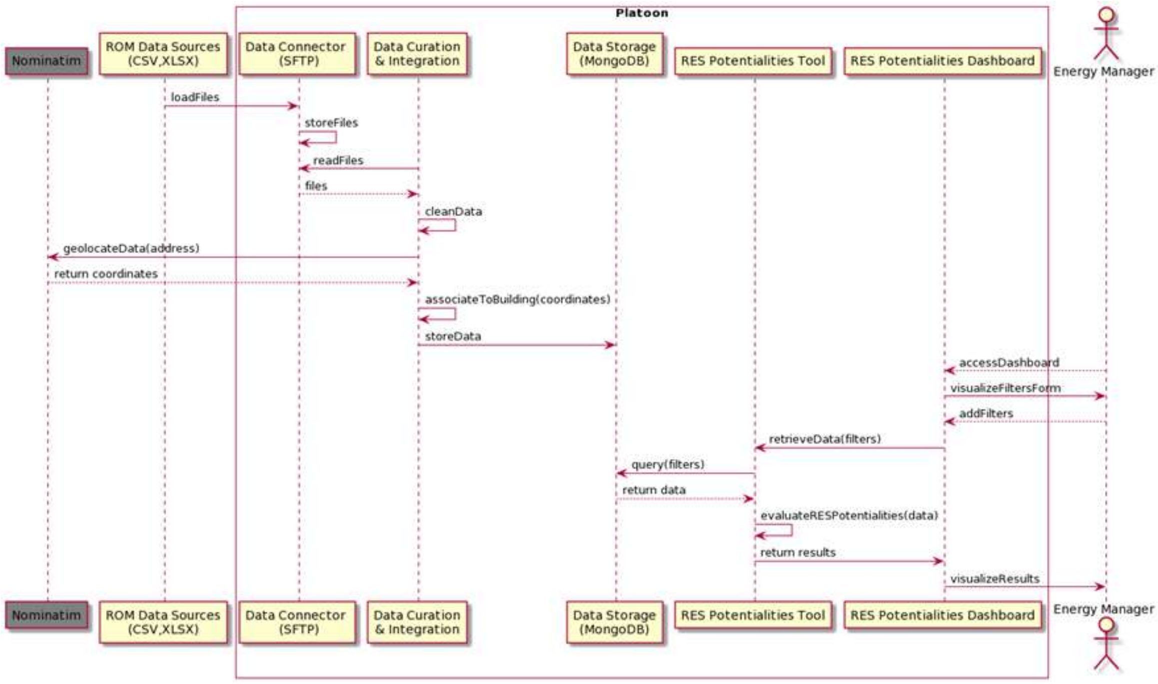


Figure 75: Pilot 3b-ROM – RES Potentialities Tool Overview

PLATOON Component	Interfaces	role
Data Connector	SFTP protocol	This component allows the provisioning of the data sources used by the tool
Data Curation and Integration	File flows, PyMongo	This component reads the provided files, formats, and cleans the data and sends the data to the Storage component. Moreover, it oversees

		geocode the meters, where a direct connection with the building is not available and create an association with the building itself.
Data Storage		This component is a NoSQL database (MongoDB) used to store the data
Data Analytics Toolbox (RES Potentialities Tool)	PyMongo, APIs exposed	This component exposes a set of REST APIs. Each time a new request is provided, it queries the storage component, aggregates and processes the data and provides the results.
Data Analytics Dashboard (RES Potentialities Dashboard)	HTTP protocol, API integration	This component is used by the energy manager to interact with the Data Analytics Toolbox to access the results and visualize them.

Table 74: PLATOON components involved in RES Potentialities Tool - Pilot 3b-ROM

6.6.4. Validation Metrics

Within Pilot 3B – ROM different KPIs have been defined to evaluate the performance of the developed tools. The following KPIs are provided:

ID	Name
ROM_KPI01	Total Energy Savings
ROM_KPI02	Saving Personnel Costs
ROM_KPI03	Number of Energy Saving/Efficiency Actions Results
ROM_KPI04	Number of Anomalies detected
ROM_KPI05	CO2 emission reduction
ROM_KPI06	Number of Tools Outputs
ROM_KPI07	Efficiency of PV plants, compared to expected production
ROM_KPI08	RES suggested self-consumption
ROM_KPI09	Forecast Error
ROM_KPI10	Building Benchmarking BtI_LY
ROM_KPI11	Building Benchmarking BtI_LWs
ROM_KPI12	Building Benchmarking BtB

Table 75: Pilot 3B-ROM-KPIs

To access the details of ROM_KPI05, ROM_KPI09, ROM_KPI10, ROM_KPI11 and ROM_KPI12, the reader is referred to the discussion of validation metrics of “Pilot 3b-PI Advanced Energy Management System and Spatial (Multi-Scale) Predictive Models in the Smart City”, since the same approach is used.

6.6.4.1. KPI 01: Total Energy Savings

This KPI measures the impact of PLATOON’s services in terms of the interventions that should reduce the yearly total consumptions, such as the dismission of meters, the maintenance actions and contractual re-definition resulting from the analysis.

Testing approach
This KPI is evaluated as the total energy saved by exploiting PLATOON services in a reference year (kWh / Y). To retrieve such value, it is important to underline that to understand which are the meters where maintenance have been performed is crucial to validate the tools during WP6. Since direct feedbacks of the users are needed by monitoring the output of the analytical tools.

Test steps
To evaluate the KPI value the yearly consumptions of the meters, belonging to a selected building or a group of buildings, where action have been performed should be retrieved and aggregated considering a reference period. These values are then used to evaluate the KPI.

Pass/fail criteria
Not applicable

6.6.4.2. KPI 02: Saving Personnel Costs

This KPI measure the difference of the saved personnel cost (per year) and the depreciation of the data monitoring system. It measures the percentage of € per year saved thanks to the installation of a monitoring system. At the time this document is written, information about personnel costs are not available, thus additional details will be provided once this data is available.

6.6.4.3. KPI 03: Number of Energy Saving/Efficiency Actions Results

This KPI counts the number of energy meters for which PLATOON services produce actions resulting in energy saving during the year.

Testing approach
This KPI gives the number of meters where maintenance actions have been performed over a reference period. To retrieve such value, it is important to underline that to understand which are the meters where maintenance have been performed is crucial to validate the tools during WP6. Since direct feedbacks of the users are needed by monitoring the output of the analytical tools

Test steps
To evaluate the KPI value the number of meters, belonging to a selected building or a group of buildings, where action have been performed should be retrieved and aggregated considering a reference period. The aggregated value represents the KPI itself.

Pass/fall criteria
Not applicable

6.6.4.4. KPI 04: Number of Anomalies Detected

This KPI measure the number of anomalies detected by PLATOON services during a reference period.

Testing approach
From the analysis of the load curves of the different meters, if the consumptions diverged from the expected value, an anomaly is created and stored to be used for schedule maintenance actions.

Test steps
To evaluate this KPI a building or a group of buildings need to be selected together with a reference period. The number of anomalies occurred in the meters belonging to the selected buildings are aggregated and provided. The aggregation level can be monthly or yearly. The result value is the KPI itself.

Pass/fail criteria
Not applicable

6.7. Pilot 3c Energy Efficiency and Predictive Maintenance in the Smart Tertiary Building Hub Grade

6.7.1. LLUC-01-3C-Advanced EMS

6.7.1.1. Description

This use case focuses on the development, implementation and validation of an Advanced EMS system that aims to optimise the use of PV panel generation and HVAC operation in order to maximise RES usage and minimise the energy bill.

6.7.1.2. Main Functions

The main functions that will be validated in this use case are the following:

- **Tool 1: PV energy generation Forecaster:** Forecasts the PV generation based on weather forecast data.
- **Tool 2: Base Energy Forecaster:** Forecasts the base energy (all energy except HVAC) based on historical energy consumption data and weather data.
- **Tool 3: HVAC Digital Twin:** Simulates HVAC operation based on HVAC data, weather data and historical energy consumption data.
- **Tool 4: Energy Bill and RES Usage Optimiser:** Optimises HVAC and RES usage to minimise energy bill based on the outputs from the previous tools combined with the forecasted energy price data.

6.7.1.3. Tool Process View

In this use case GIROA will act as data provider and Tecnalia as data user. All the data will be stored in Giroa´s consolidated database. The following data sources will be used:

1. **RES data:** Includes the data regarding the design and operational constraints of the local installed PV panels (e.g., installed power).
2. **Weather Data:** Includes measured and forecasted weather parameters such as outside air temperature and solar irradiance.
3. **Energy Consumption data:** Includes the measured energy consumption values from all the equipment in the building including the HVAC system.
4. **HVAC data:** Includes data related to the HVAC design and operation constraints as well as the user preferences (e.g., comfort range and set points).
5. **Energy Prices Data:** Includes the forecasted sell and buy energy prices.

The data from Giroa´s consolidated database will be sent to Tecnalia through IDS connectors. Tecnalia will process the data and send it back to Giroa through the same IDS connectors. Processed data will be stored in the consolidated database and visualised in their infrastructure.

The figures below show the UML diagram with the interactions for the different tools:

Tool 1: PV Energy Generation Forecaster

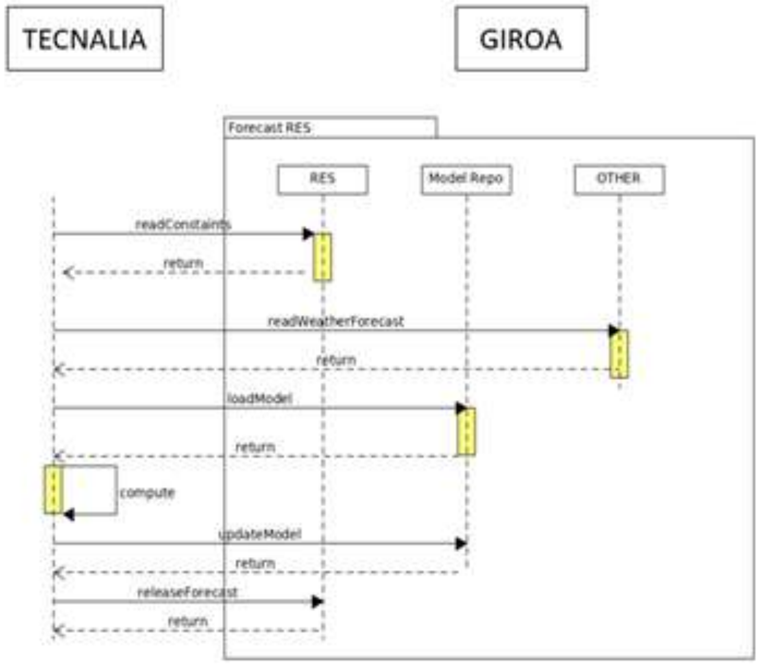


Figure 76: LLUC01-3C: Tools Process View – Tool 1

Tool 2: Base Energy Forecaster

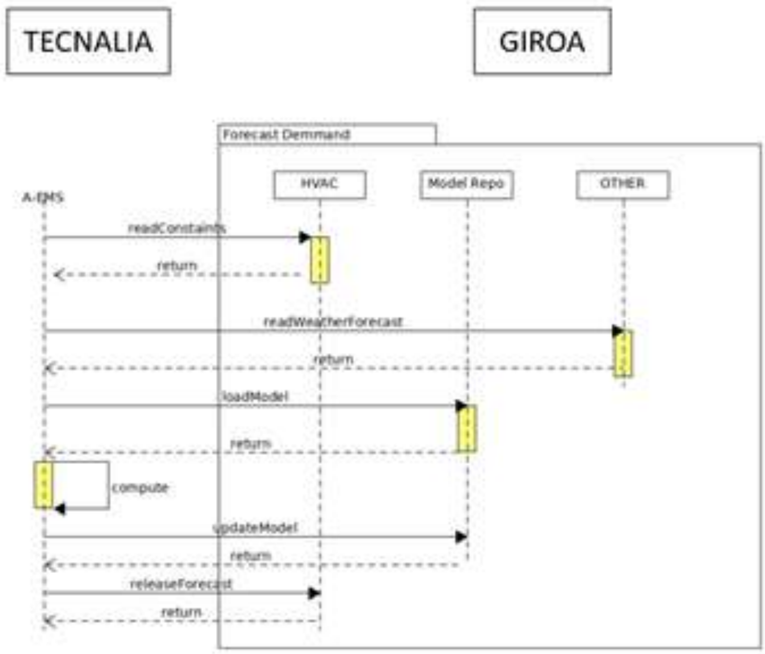


Figure 77: LLUC01-3C: Tools Process View – Tool 2

Tool 3 and 4: HVAC Digital Twin and Energy Bill and RES usage Optimisers

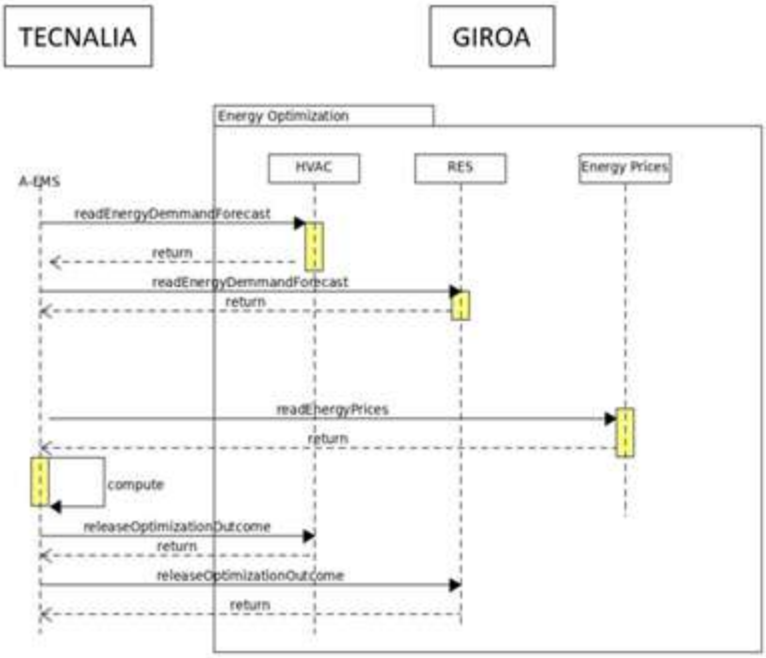


Figure 78: LLUC01-3C: Tools Process View – Tool 3 and 4

The table below explains PLATOON architectural components involved in all the four tools.

PLATOON Component	Interfaces	role
Consolidated Database	MYSQL / REST API	Data storage and integration
Semantic Adapter	REST API	Addapts the data models from GIROA´s database to the common PLATOON data models.
DAPS,	Multipart/REST API	Authenticates both IDS components and actors.
Metadata Registry	Multipart/REST API	Shows available resources (datasets/tools), stores metadata and shws corresponding IDS connector information.
Clearing House	Multipart/REST API	Register all the data transactions between IDS connectors.
Marketplace	Multipart/REST API	Contains the metadata of datsets/tools.
Vocabulary provider	Multipart/REST API	Manages the PLATOON common data models.
Data connector	IDS connector	Connects the data from the consolidated database from Giroa

		with the data analytics tools hosted in Tecnalia´s infrastructure.
Data Analytics Toolbox	REST API	Processes the raw data from Giroa and provides valuable recommendations.
Visualisation Dashboard	REST API	Raw and processed data visualisation

Table 76: PLATOON components involved in Pilot 3c Tools

6.7.2. Validation Metrics

6.7.2.1. KPI 01: Data Connector Integration

Validation of the data connector including the following functionalities:

- Semantic adaptation: PLATOON data models mapping
- IDS connector between Giroa and Tecnalia and data usage policies.
- Integration with PLATOON Central Components Metadata Registry, Vocabulary Provider, DAPS and Clearing House.

Testing approach
After implementing the IDS connector data will be sent from Giroa to Tecnalia and viceversa.

Test steps

- Step 1: Send test data from Giroa to Tecnalia and vice versa and validate that the data has been correctly received.
- Step 2: Validate that the data is in line with the PLATOON Common Data Models.
- Step 3: Validate two different data usage scenarios: one where the data usage policy has been met, and another where it has not been met. Check that in the first case the data is being sent, but not in the second case.
- Step 4: Register the connector in the Metadata Registry and validate that it has been successfully registered and can be seen in the Marketplace.
- Step 5: Send a query through the IDS Vocabulary provider and validate that the received response is correct.
- Step 6: Validate that the data transactions are being registered in the Clearing House.

Pass/fail criteria
All the test steps described above must be successful.

6.7.2.2. KPI 02: Energy Bill reduction

This KPI evaluates the energy bill reduction achieved.

Testing approach
Run Advanced EMS with online data from Giroa and compare current energy bill prices and the simulated energy bill prices if they had applied the recommendations from the Advanced EMS system.

Test steps
- Step 1: Run online data through the Advanced EMS system for one day.
- Step 2: Calculate the energy bill for the same day as if they had applied the recommendations from the Advanced EMS system.
- Step 3: Get the actual energy bill for the same day.
- Step 4: Compare the actual and calculated values according to the formula shown in Appendix II.
- Step 5: Validate different days.
- Step 6: Validate different configuration scenarios.
- Step 7: Show summary statistics.

Pass/fail criteria
Energy Bill is reduced at least by 10%.

6.7.2.3. KPI 03: RES usage ratio

At the moment all the generated PV energy is directly sold to the grid. This KPI evaluates the potential RES usage (self-consumption) vs the total energy consumption ratio.

Testing approach
Run Advanced EMS with online data from Giroa and calculate the potential RES self-consumption that could be achieved.

Test steps
- Step 1: Run online data through the Advanced EMS system for one day.
- Step 2: Calculate the potential RES usage that could be achieved.
- Step 3: Compare it with the total energy consumption for the same day using the formula defined in Appendix II.
- Step 4: Validate different days.
- Step 5: Validate different configuration scenarios.
- Step 6: Show summary statistics.

Pass/fail criteria
Potential RES usage should be at least 20%.

6.7.3. LLUC-02-3C Predictive maintenance for smart tertiary buildings

6.7.3.1. Description

This use case focuses on the predictive maintenance of air conditioning equipment, specifically on chiller machines and hydraulic pumps.

GIROA currently has a Siemens Desigo system that monitors a large amount of information coming through multiple sensors for each machine. This data is integrated with other sensors, such as electric and thermal meters, into a central database.

On the one hand, SISTEPLANT will implement their Promind platform into GIROA´s infrastructure connected to its database. SISTEPLANT will generate and implement in Promind digital twins for chillers which will replicate the operation under normal conditions and will be used to generate different indicators that will be grouped into a structure called Process Mastery Level (PML). The purpose of this structure is to show in a simple, non-technical way the Health Status of the chiller machine.

On the other hand Tecnalia will develop and implement predictive maintenance data analytic tools for hydraulic pumps on an edge computing device installed in the pilot site of Giroa. The output of these data analytic tools will be stored in Giroa´s datatabse and will be shown in the dashboard in Promind.

In order to develop the tools, the following health indicators are considered*:

1. Energy Variator
2. Starter
3. Phase imbalance
4. Power Supply
5. Communications
6. Flow Meter
7. Temp Out of range
8. Evaporator Return
9. Temp Increase
10. Power consumption increase
11. Evaporator Outlet Temp
12. Thermic Power
13. CoP
14. Rotational Speed

*If the correlation of the model is not good enough, some of them could be discarded.

Finally, the developed failure detection system is complemented through the integration with a Computer aided Maintenance Management System (CMMS). The application will be able to integrate with Giroa-Veolia’s CMMS and generate Work Order Requests based on the results of the analytical models.

The CMMS will manage the Work Orders and will generate a series of KPIs related to the chillers and hydraulic pumps (maintenance costs, mean time between failures, availability, etc.).

A dashboard will centralise all the information so that the supervision technicians can quickly and easily understand the health status of the machines and related KPI's.

6.7.3.2. Main functions

a. **Tool 01: Integration with CMMS:** Integration with the CMMS system will be developed with two main objectives: to generate work requests when the models determine that a machine requires preventive or corrective maintenance, and to generate and retrieve maintenance indicators related to the CMMS.
b. **Tool 02: Process Mastery Level (PML):** Analytical tool to calculate Health status of the chillers based on defined rules. Within this tool multiple analytical models are developed, at least one digital twin for each identified failure mode. The digital twins will be able to correlate with the real time operation values of the machine and will be able to predict and identify malfunctions of the chiller. In addition, a hierarchical structure of the machine and machine sub-elements will be created, so that the health status of each machine sub-element as well as the overall machine status can be easily identified.
c. **Tool 03: Edge Computing – Predictive Maintenance tools for Hydraulic Pumps:** This tool will be implemented in an edge computing device (Jetson Nano) which is installed in the pilot site of Giroa. This tool will ingest high frequency vibration data directly from the sensor and some other lower frequency parameters such as flow and rotational speed from Giroa´s consolidated database. The outputs will be stored back in Giroa´s consolidated database and shown in the visualisation dashboard in Promind.
d. **Tool 04: Visualization Dashboard:** Hierarchical visualization of the PML components and general KPIs from tools 2 and 3. A visualisation tool will be created to show the hierarchical structure of the PML, as well as the different indicators obtained from the CMMS and other auxiliary analytical models.

6.7.3.3. Tool Process View

The diagram below shows the complete information flow for each of the tools described in the previous section:

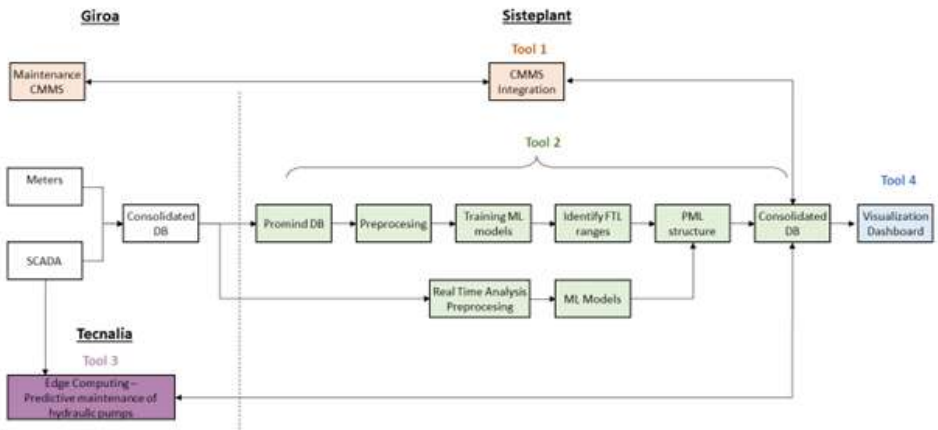


Figure 79: LLUC-02-3C-Tool Process View

Tool 01: Integration with CMMS

Data Sources from Giroa-Veolia's CMMS:

1. Calculated Maintenance cost
2. Mean Time Between Failures
3. Availability

We collect this information on demand.

Data Sources from PML tool to CMMS: Work Request. We send this information when required by the definition.
The table below explains PLATOON architectural components involved in Tool 01 flow and the role of each one of them.

PLATOON Component	Interfaces	role
Data connector	Secured API Rest	Connects the batch data sources
CMMS data		Output from CMMS, raw data converted to semantic data according to these data models
Vocabulary manager		Used to maintain ontologies.

Table 77: PLATOON components involved in Integration with CMMS Tool - Pilot 3c

Tool 02: Process Mastery Level (PML)

Data Sources from Giroa-Veolia's to PML:
The following data sources are required to perform Pilot 3C LLUC02:

1. Chiller Machine
   a. Power consumption related signals
   b. Process output variables

    c. Process input variables
    d. Set-points signals
2. Building Cooling circuit
    a. Pump related variables
    b. Flow meters
    c. Temperature meters
3. External variables
    a. Temperature variables
    b. Humidity variables

To have the information required related to the measurement data source we have sensors and meters in the buildings as well as in some machine sub-elements. We collect all the information from the sensors in five-minute periods.

Failure modes to detect:
As main element of this development, we are going to analyse and generate the following digital twin models. They are related with the following machine Failure Modes:

a. Energy Variator
b. Starter
c. Phase imbalance
d. Power Supply
e. Communications
f. Flow Meter
g. Temp Out of range
h. Evaporator Return
i. Temp Increase
j. Power consumption increase

In addition, we are going to generate additional digital twin for some of the output process variables:

k. Evaporator Outlet Temp
l. Thermic Power
m. CoP

For each of the digital twins, we are going to correlate the real time data with the models and we are going to represent the correlation through a FTL approach. This means we are selecting a range from the model statistics where the representation should be close to 1 and when should be close to 0.

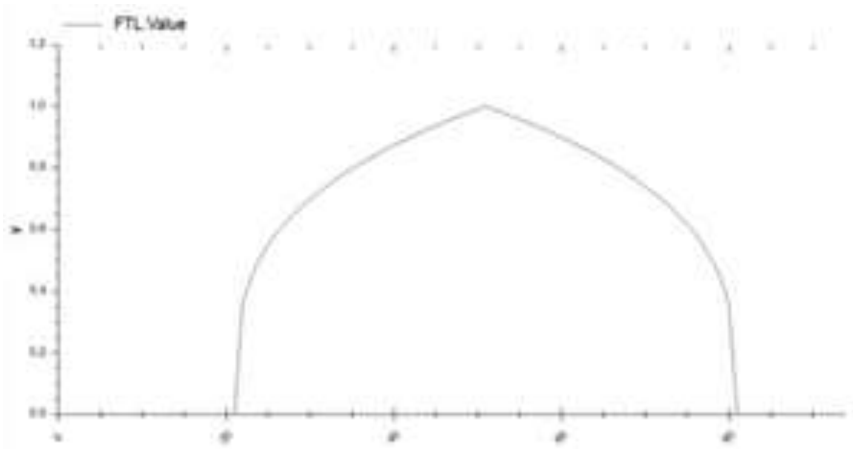


Figure 80: FTL Representation. Model statistics output [x] vs FTL representation [y]

This way, we are going to have a very intuitive view (0-1) of the Health Status of each part of the chiller, by analysing the failure modes.

A hierarchical structure of the chiller elements / failure modes will be done, from the main chiller level to the elements of the chillers. The consolidation of all FTL information will be represented by the Process Mastery Level (PML).

The table below explains PLATOON architectural components involved in Tool 02 flow and the role of each one of them.

PLATOON Component	Interfaces	role
Data connector	Secured API Rest	Connects the batch data sources with the CMMS, both for input and output
Data connector	Windows Communication Foundation (WCF)	Connects the output data with the dashboard
Data curation engine		Data formatting, data aggregation and data enrichment in data pipelines
Vocabulary manager		Used to maintain ontologies.
Data analytics toolbox (Realtime and Batch)		Used for the tool's execution.
Batch mode of the tool		The tool executes in batch mode data batchs of every 8 hours for historical analysis
Real Time mode of the tool		The tool executes in real time for the current data analysis

Table 78: PLATOON components involved in Process Mastery Level (PML) Tool - Pilot 3c

Tool 03: Edge Computing – Predictive Maintenance tools for Hydraulic Pumps

Data Sources from SCADA to Edge Computing device:

1. X axes vibration.
2. Y axes vibration.

Data Sources from Consolidated Database to Edge Computing device:
1. Volumetric Flow
2. Rotational Speed of the pump
3. Power consumption of the pump

Data Sources from Edge Computing to Consolidated Database/Dashboard:
1. Hydraulic Pump Status

The table below explains the PLATOON architectural components involved in Tool 03 flow and the role of each one of them.

PLATOON Component	Interfaces	role
IOT connector	Modbus or similar protocol with SCADA	Connects the data from the SCADA to the edge computing device
Data connector	REST API	Connects the data from the consolidated database with the edge computing device.
Data Analytics Toolbox	The tools will be implemented dockerized into the Edge computing device.	There will be two tools: -Real time tool for vibration data analysis. -Batch tool for data analysis of the rest of the parameters.

Table 79: PLATOON Components involved in Edge Computing Tool - Pilot 3c

Tool 04: Visualization Dashboard

Data Sources from PML to Dashboard:
1. Energy Variator
2. Starter
3. Phase imbalance
4. Power Supply
5. Communications
6. Flow Meter
7. Temp Out of range
8. Evaporator Return
9. Temp Increase
10. Power consumption increase
11. Evaporator Outlet Temp
12. Thermic Power
13. CoP
14. Pump Rotational Speed

Data Sources from CMMS to Dashboard:
1. Availability

2. Mean Time Between Failures (MTBF)
3. Maintenance Costs

Data Sources from Edge Computing to Dashboard:

1. Hydraulic Pump Status

The dashboard will show consolidated information coming from the ML models and the CMMS. The main purpose will be to represent the hierarchical structure of the PML, showing the Health status of the machine. It will have one page at machine level with information consolidated for all failure modes, and it will also have a detailed page for each one.

The table below explains PLATOON architectural components involved in Tool 04 flow and the role of each one of them.

PLATOON Component	Interfaces	role
Data connector	Windows Communication Foundation (WCF)	Connects the data from the PMLs
Vocabulary manager		Used to maintain ontologies.
Data analytics dashboard		Used to show the results of the tool's output
Batch and Realtime mode of the tool		The tools execute in two modes: showing historical data and, being able to refresh on screen information

Table 80: PLATOON Components involved in Visualization Dashboard - Pilot 3c

6.7.4. Validation Metrics

6.7.4.1. KPI 01: Health Monitoring

This KPI measures the accuracy of the developed data analytics tools for Chillers and Hydraulic Pumps.

Testing approach

First, offline data coming from Giroa's data base will be used for training the models with information of normal working conditions. Once the models are trained then they will be validated with online data from Giroa.

The approach is to compare the models normal working situation versus the abnormal working situation where the sensors are reading abnormal information.

This way, we will verify if the corresponding component is working properly or not, showing us the health status of the machine.

For testing purposes, it is not possible to break down the machine to generate abnormal working situations. To overcome this problem, we will generate modified dummy data , e.g. by applying x1,2 and x0,8 multipliers for the testing time slots.

Test steps

- Step 1: Train the model with offline normality data. Where necessary, convert the information into PML structure.
- Step 2: Generate time slots of 8 hours for the incoming sensor information.
- Step 3: Generate dummy failure data that simulates the failure of the chiller, modify some information with x1,2 and x0,8 multipliers.
- Step 4: Integrate real online data with simulated dummy data.
- Step 5: Validate analytical tools using the corresponding metrics: R2, MAE and Balanced Accuracy.
- Step 6: Verify the obtained results.

Pass/fail criteria

The expected result will be the followings:

When unaltered data is analyzed: the analytical models should correlate. In this scenario, tools should determine that the machine is operating normally.

When altered data is analyzed: the analytical models should not correlate. In this scenario, the tools should determine that the machine is not operating in normal conditions.

6.7.4.2. KPI 02: Availability

This KPI is coming from the Tool 1 CMMS Integration. The Availability of the machine in a concrete period will be calculated for both chillers and hydraulic pumps.

Testing approach

The availability of an asset is calculated as followed:

We will generate some simulated Work Orders into the CMMS system so the real Operation time will be reduced. Once the KPI is calculated it will travel to Promind Server and it will be displayed consolidated information into the Dashboard.

Test steps

- Step 1: Create simulated Work Order into the CMMS system.
- Step 2: Calculate the KPI.
- Step 3: Use the integration to send the information to Promind Server.
- Step 4: Display the information into the consolidated Dashboard.

Pass/fail criteria

- The calculated KPI will be correctly calculated according to the test data.
- The information will be displayed into the consolidated Dashboard.

6.7.4.3. KPI 03: Mean Time Between Failures

This KPI is coming from the Tool 1 CMMS Integration. The Mean Time Between Failures (MTBF) of the machine in a concrete period will be calculated

Testing approach
The MTBF of an asset is calculated as followed:

$$MTBF = (\text{Total Working Time} - \text{Total Breakdown Time}) / \text{Number of Breakdowns}$$
$$MTBF = \text{Total Operational time} / \text{Number of Breakdowns}$$

We will generate some simulated Work Orders into the CMMS system so operational time losses will be created. Once the KPI is calculated it will travel to Promind Server and it will be displayed as chiller consolidated information into the Dashboard.

Test steps
- Create simulated Work Order into the CMMS system.
- Calculate the KPI.
- Use the integration to send the information to Promind Server.
- Display the information into the consolidated Dashboard.

Pass/fail criteria
- The calculated KPI will be correctly calculated according to the test data.
- The information will be displayed into the consolidated Dashboard.

6.7.4.4. KPI 04: Maintenance Cost

This KPI is coming from the Tool 1 CMMS Integration. The total cost associated to the Ciller asset will be calculated

Testing approach
During the maintenance operations on the chiller and hydraulic pumps, different cost categories are to be associated with the asset, like for example, the labour time or spare parts used during the corrective works.

Test steps
- Create simulated Work Order into the CMMS system.
- Incorporate cost categories to the WO.
- Calculate the Maintenance cost of the asset KPI.
- Use the integration to send the information to Promind Server.
- Display the information on the consolidated Dashboard.

Pass/fail criteria
- The calculated KPI will be correctly calculated according to the test data.
- The information will be displayed on the consolidated Dashboard.

6.8. Pilot #4a Energy Management of Microgrids

6.8.1. Description

Pilot 4a takes place at the Multi-Good Microgrid Laboratory (MG2lab) in Politecnico di Milano, Italy. MG2lab is an experimental facility for real-life scale research, simulation, and test purposes; in particular, the use case developed in Pilot 4a applies to a micro-grid test-bench, aimed at providing an analysis facility for real-life scale research, simulation, and test purposes: the goal of the functionality addressed in the current use case is to study data-driven energy management able to deal with the increased complexity of the energy systems and to assess the advantages of innovative strategies: EMS with real-time processing and optimization for small-scale/renewable electricity generation, generation, and load forecast, smart storage/generation. Indeed, the aim of Energy Management Systems (EMS) is essential for the optimal exploitation of distributed and renewable energy resources in a micro-grid. The EMS is hereby intended as the algorithm that manages the forecasting modules for load and renewable profile prediction and the real-time management of all the energy assets. The aim is the optimization of unit commitment and scheduling of the energy resources on the basis of asset precise characterization and input predicted profiles.

6.8.2. Main Functions

The energy management of the microgrid can be divided into four core functions provided by the following analytics tools:

a. **Tool #1: day-ahead renewable energy generation forecasting**

   PV power production forecast is a data-driven service that predicts renewable energy production from photovoltaic plants, based on current weather forecasts.

   This prediction is required by the EMS for the optimal exploitation of distributed and renewable energy resources, and to improve grid stability and balancing, which could be affected by the intermittent and stochastic nature of renewable energy sources, which highly depend on meteorological conditions.

   The prediction modules are data-driven, trained on (historical) experimental measurements of energy production in-situ, and related weather forecasts, coupled with the solar radiation under clear-sky condition (CSRM).

b. **Tool #2: day-ahead load consumption forecasting**

   Load forecast is a data-driven service that predicts renewable energy consumption from loads in the microgrid, mainly based on scheduled use of devices and current weather condition.

   As for the RES generation, knowing in advance the future energy load can provide an advantage in the management of the grid.

   In fact, short-term load forecasting is fundamental in the day-to-day operations, unit commitment and the scheduling functions of the EMS for the optimal exploitation of distributed energy resources, and to improve grid stability and balancing.

   The loads forecast, performed by means of computational intelligence techniques (autoregressive) is a key point for estimating the expected baseline in the microgrid.

c. **Tool #3: nowcasting of renewable energy production**

The ability to forecast intermittent energy sources is critical for grid optimization and power regulation, in smart-grid and micro-grid contexts. A smart persistence algorithm can be used to refine day-ahead forecast with respect to current weather conditions. Additionally, total sky imagery can be employed for forecasting solar energy availability on short time horizons, by means of ground observations with full-sky pictures that can be used to forecast from real-time up to 10-30 minutes ahead both energy production and loads.

d. **Tool #4: robust optimization for EMS**

Power Dispatch Optimizer optimizes the microgrid behaviour implemented in the EMS, by exploiting an Optimal Power Flow algorithm, able to consider the fluctuation of Renewable Energy Resources (RES) and to optimize the economic unit dispatch. A MILP-based algorithm that includes a precise characterization of the electrical grid is addressed. This solution will guarantee global optimum, fast convergence, and precise network modelling, by developing and testing advanced optimization methods to consider every possible uncertain outcome in the microgrid, contemplate adaptive optimal dispatch policies instead of fixed control structures, allow the best exploitation of renewable resources, and, finally, guarantee reliable and efficient operations of the microgrid.

6.8.3. Tools Process View

The following data sources are required to perform the forecasting of energy production and consumption profiles, respectively, and to perform the optimization required by the energy management system:

- Power measurements:
  - 1 min updates of the real-time power production by renewable sources
  - 1 min updates of the real-time power consumption
  - 1 min updates of energy storage systems status (SoC)
- Weather parameters:
  - Real time weather data: air temperature and solar irradiation
  - Daily weather forecast on hourly basis: environmental temperature, solar irradiation, wind, pressure, rain, cloud coverage
  - Full sky pictures for solar radiation nowcasting

Weather forecasts are collected daily from a commercial weather provider (external service). The process flow with the components required to perform the abovementioned functionalities are presented in the following figures

Tool 01: Day-ahead PV power forecasting

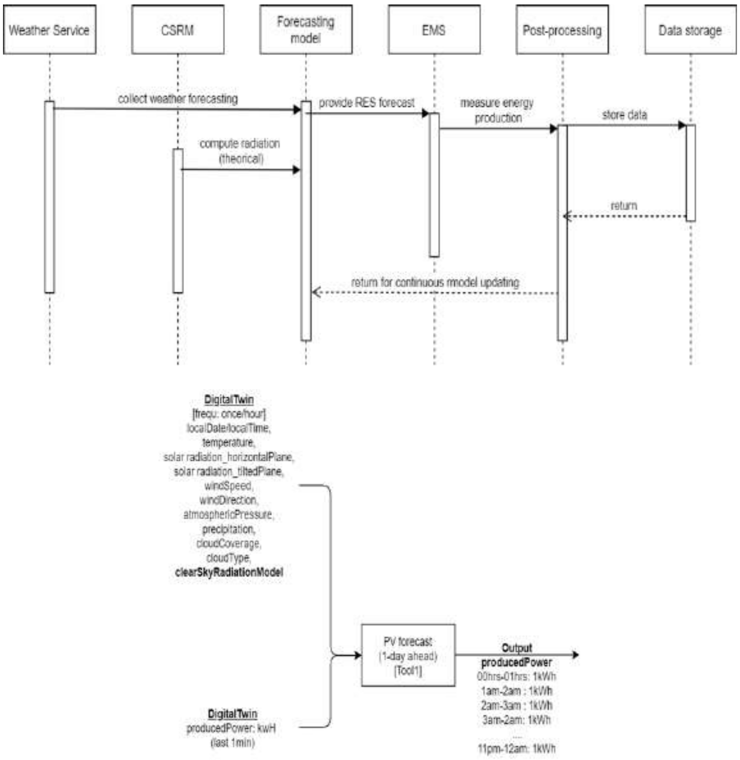


Figure 81: Pilot 4A Day-Ahead Renewable Energy Generation Forecasting - Tool Process View

The table below explains PLATOON architectural components involved in Tool 01 (PV forecast) and the role of each one of them.

PLATOON Component	Interfaces	Role
Data connector	HTTP protocol, integration with CDH (AWS-S3)	Connects the batch data sources
Data curation engine (Vx ingest)	HTTP protocol, flow files (JSON)	Data formatting, data aggregation and data enrichment in data pipelines.
Unified knowledge base (semantic and time series data base)	HTTP protocol, API integration	Consists of two data bases, Static context data is put in sematic database and timeseries data is put in no SQL database.
Energy data models	//	Output of 2.3, raw data converted to semantic data according to these data models.
Data analytics toolbox (Realtime and Batch)	HTTP protocol, API integration	Used for the tool's execution.
Data analytics dashboard	API integration	Used to show the results of the tool's output.

Batch and Realtime mode of the tool	//	The tool executes in batch mode once in 24 hours and produces results for next 24 hours.

Table 81: PLATOON components involved in Day-Ahead Renewable Energy Generation Forecasting Tool Pilot 4a

Tool 02: Day-Ahead Renewable Energy Load Forecasting

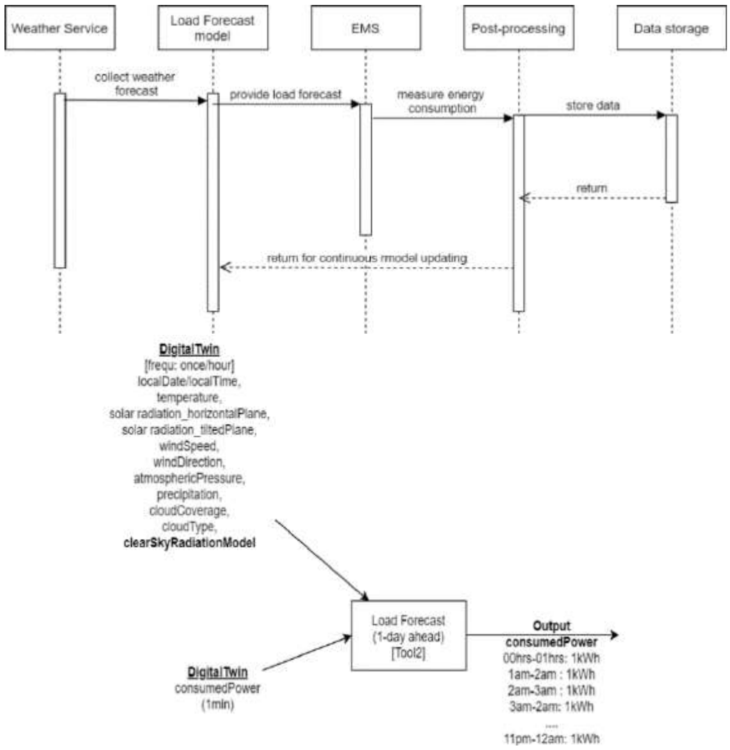


Figure 82: Pilot 4a Day-Ahead Load Forecasting - Tool Process View

The table below explains PLATOON architectural components involved in Tool 02 (Load forecast) and the role of each one of them.

PLATOON Component	Interfaces	Role
Data connector	HTTP protocol, integration with CDH (AWS-S3)	Connects the batch data sources
Data curation engine (Vx ingest)	HTTP protocol, flow files (JSON)	Data formatting, data aggregation and data enrichment in data pipelines.
Unified knowledge base (semantic and time series data base)	HTTP protocol, API integration	Consists of two data bases, Static context data is put in sematic database and timeseries data is put in no SQL database.
Energy data models	//	Output of 2.3, raw data converted to semantic data according to these data models.

Data analytics toolbox (Realtime and Batch)	HTTP protocol, API integration	Used for the tool's execution.
Data analytics dashboard	API integration	Used to show the results of the tool's output.
Batch and Realtime mode of the tool	//	The tool executes in batch mode once in 24 hours and produces results for next 24 hours.

Table 82: PLATOON Components involved in Day-Ahead Load Forecasting Tool - Pilot 4a

Tool 03: PV Power Nowcasting

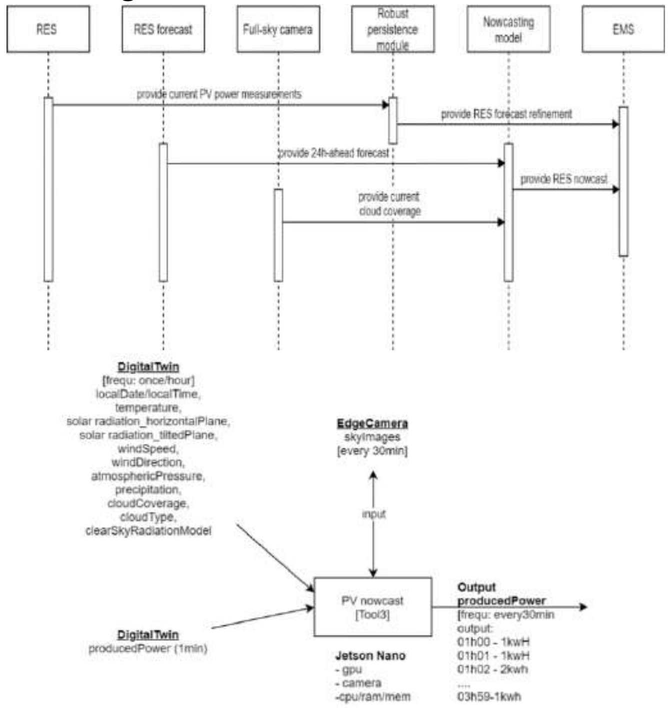


Figure 83: Pilot 4a Renewable Energy Generation Nowcasting - Tool Process View

The table below explains PLATOON architectural components involved in Tool 03 (PV power nowcast) and the role of each one of them.

PLATOON Component	Interfaces	Role
Data connector	HTTP protocol, integration with CDH (AWS-S3)	Connects the batch data sources
Data curation engine (Vx ingest)	HTTP protocol, flow files (JSON)	Data formatting, data aggregation and data enrichment in data pipelines.
Unified knowledge base (semantic and time series data base)	HTTP protocol, API integration	Consists of two data bases, Static context data is put in sematic database and timeseries data is put in no SQL database.
Energy data models	//	Output of 2.3, raw data converted to semantic data according to these data models.
Data analytics toolbox (Realtime and Batch)	HTTP protocol, API integration	Used for the tool’s execution.

Data analytics dashboard	API integration	Used to show the results of the tool's output.
Batch and Realtime mode of the tool	//	The tool executes in real-time mode every 10 minutes when new data is available and produces results for next 3 hours.

Table 83: PLATOON Components involved in Renewable Energy Generation Nowcasting Tool - Pilot 4a

Tool 04: EMS Robust Optimization

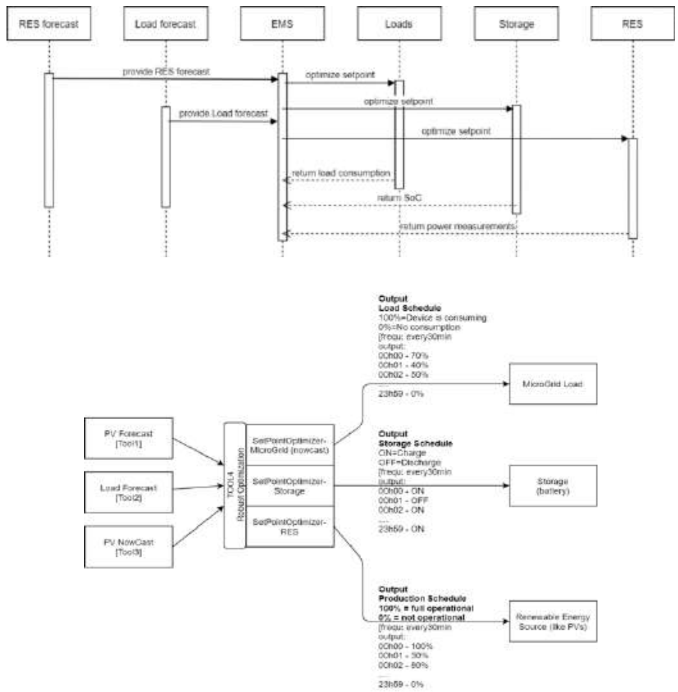


Figure 84: Pilot 4a EMS Robust Optimization - Tool Process View

The table below explains PLATOON architectural components involved in Tool 04 (EMS robust optimization) and the role of each one of them.

PLATOON Component	Interfaces	Role
Data connector	HTTP protocol, integration with CDH (AWS-S3)	Connects the batch data sources
Data curation engine (Vx ingest)	HTTP protocol, flow files (JSON)	Data formatting, data aggregation and data enrichment in data pipelines.
Unified knowledge base (semantic and time series data base)	HTTP protocol, API integration	Consists of two data bases, Static context data is put in sematic database and timeseries data is put in no SQL database.
Energy data models	//	Output of 2.3, raw data converted to semantic data according to these data models.
Data analytics toolbox (Realtime and Batch)	HTTP protocol, API integration	Used for the tool's execution.

Data analytics dashboard	API integration	Used to show the results of the tool's output.
Batch and Realtime mode of the tool	//	The tools execute in two modes: batch mode executes once in 24 hours and produces results for next 24 hours. The Realtime mode executes every 10 minutes when new data is available and produces results for next 3 hours.

Table 84: PLATOON Components involved in EMS Robust Optimization Tool - Pilot 4a

6.8.4. Validation metrics

To ensure the performance of the microgrid energy management, optimization and control, and to measure its efficiency, suitable key performance indicators have been defined to assess the fulfilment of the requirements and the targets defined in the description of the pilot's low level use case. These validation tests are also important to provide feedback for improvement of the optimization of the energy management system.
The KPIs covering the tests for the EMS optimization module, including the forecasting and nowcasting components listed in the previous section for both power production and consumption, are defined as the follows:

6.8.4.1. KPI-01 Energy availability

This indicator measures the percentage of energy provided by renewable sources with respect to the measured energy consumption when the optimization for renewable electricity generation is performed considering smart storage and generation.

Testing approach
The KPI related to energy availability is measured considering the daily energy production with respect to the daily energy consumption; hence, the KPIs will be evaluated in accordance with the following definition:

$$\mathrm{KPI}_{01}(\%) = \frac{\sum_{t=1}^{24} P_{PV,t}}{\max\left(\sum_{t=1}^{24} P_{PV,t}, \sum_{t=1}^{24} P_{load,t}\right)} \cdot 100$$

where $P_{PV,t}$ is the produced power at time t from renewable sources, while $P_{load,t}$ is the measured power consumption at the same instant, and the considered time range is $t = 1{:}N$ (e.g. 24 hours).

Test steps
In order to be able to evaluate this KPI, real power production ($P_{PV,t}$) and consumption ($P_{load,t}$) measurements will be needed. These measurements are stored within PLATOON platform data storage, obtained in real-time at each considered time step t from the micro-grid monitoring system. The testing period is over 24 hours, thus this KPI will be computed with daily frequency by summing up the measured power values listed above over the last 24 hours.

Pass/fail criteria
Once the steps described above have been executed, in order to confirm that the test can be considered successful and the requirement of the evaluation verified, this KPI has to be correctly calculated according to the measured test data, and the related results (in percentage) displayed into the consolidated dashboard. Higher percentage values will correspond to a successful result in terms of energy availability, with an ideal target of 100% for this indicator.

6.8.4.2. KPI-02 - the reduction of maintenance effort and costs

This indicator measures the reduction of maintenance effort and costs in terms of percentage of energy from the electrical grid with respect to the total energy consumption when the optimization for renewable electricity generation is performed considering smart storage and generation.

Testing approach

The KPI related to energy availability is measured considering the daily energy production with respect to the daily energy consumption; hence, the KPIs will be evaluated in accordance with the following definition:

$$\mathrm{KPI}_{02}(\%) = \frac{\sum_{t=1}^{24}\left(P_{load,t} - P_{PV,t}\right)}{\sum_{t=1}^{24} P_{load,t}} \cdot 100$$

where $P_{PV,t}$ is the produced power at time t from renewable sources, while $P_{load,t}$ is the measured power consumption at the same instant, and the considered time range is $t = 1{:}N$ (e.g. 24 hours).

Test steps

In order to be able to evaluate this KPI, real power production ($P_{PV,t}$) and consumption ($P_{load,t}$) measurements will be needed. These measurements are stored within PLATOON platform data storage, obtained in real time at each considered time step t from the micro-grid monitoring system. The testing period is over 24 hours, thus this KPI will be computed with daily frequency by summing up the measured power values listed above over the last 24 hours.

Pass/fail criteria

Once the steps described above have been executed, in order to confirm that the test can be considered successful and the requirement of the evaluation verified, this KPI has to be correctly calculated according to the measured test data, and the related results (in percentage) displayed into the consolidated dashboard. Lower percentage values will correspond to a successful result in terms of energy cost, with an ideal target of 0% for this indicator.

6.8.4.3. KPI-03 Forecast accuracy

This indicator measures the accuracy of forecasting in terms of percentage error with respect to the daily measured energy, both for production and consumption, in particular considering the well-known normalized Root Mean Square Error indicator (nRMSE).

Testing approach

The KPI related to forecasting accuracy is measured considering the daily power forecast with respect to its daily measurement; hence, the KPIs will be evaluated in accordance with the following definition:

$$\mathrm{KPI}_{03}(\%) = \frac{1}{\max\,(P_{m,t})} \sqrt{\frac{\sum_{t=1}^{24}\left(P_{f,t} - P_{m,t}\right)^2}{N}} \cdot 100$$

where $P_{f,t}$ is the forecasted power at time t, $P_{m,t}$ is the measured power at the same instant, and $\max\,(P_{m,t})$ is the maximum power value measured in the considered time range $t = 1{:}\,24$ (e.g. 24 hours).

Test steps

In order to be able to evaluate this KPI, power forecast ($P_{f,t}$) and real measurements ($P_{m,t}$) will be needed. These data and measurements are stored within PLATOON platform data storage, obtained in real time at each considered time step t from the micro-grid monitoring system. The testing period is over 24 hours, thus this KPI will be computed with daily frequency by summing up the power values listed above over the last 24 hours.

Pass/fail criteria

Once the steps described above have been executed, in order to confirm that the test can be considered successful and the requirement of the evaluation verified, this KPI has to be correctly calculated according to the measured test data, and the related results (in percentage) displayed into the consolidated dashboard. Lower percentage values will correspond to a successful result in terms of forecasting accuracy, with an ideal target of 0% for this indicator.

6.8.4.4. KPI-04 (Realtime)

This indicator measures the ability of the system to monitor, analyze and optimize data at real time rate, when the optimization for renewable electricity generation is performed considering smart storage and generation.

Testing approach

The KPI related to real-time capability is measured considering the forecast skill of the nowcasting feature with respect to day-ahead forecasts; hence, the KPIs will be evaluated in accordance with the following definition:

$$\mathrm{KPI}_{04}(\%) = \frac{\sum_{t=1}^{24}\left(P_{m,t} - P_{f,t}\right)^2 - \sum_{t=1}^{24}\left(P_{m,t} - P_{n,t}\right)^2}{\sum_{t=1}^{24}\left(P_{m,t} - P_{f,t}\right)^2} \cdot 100$$

where $P_{f,t}$ is the day-ahead forecasted power at time t, $P_{m,t}$ is the power forecast adjusted in real time by the nowcasting tool, $P_{m,t}$ is the measured power at the same instant, and the considered time range is $t = 1{:}\,24$ (e.g. 24 hours).

Test steps

In order to be able to evaluate this KPI, day-ahead power forecast ($P_{f,t}$) the most updated nowcast values ($P_{n,t}$) and the corresponding real measurements ($P_{m,t}$) will be needed. These data and measurements are stored within PLATOON platform data storage, obtained in real time at each considered time step t from the micro-grid monitoring system. The testing period is over 24 hours, thus this KPI will be computed with daily frequency by summing up the power values listed above over the last 24 hours.

Pass/fail criteria

Once the steps described above have been executed, in order to confirm that the test can be considered successful and the requirement of the evaluation verified, this KPI has to be correctly calculated according to the measured test data, and the related results (in percentage) displayed into the consolidated dashboard. Higher percentage values will correspond to a successful result in terms of real-time forecast skill, with an ideal target of 100% for this indicator.

7. PLATOON Common Components Validation Plan

This section covers the validation plan for the PLATOON Common Components that have been developed in the project and that will be integrated and validated with the pilot specific components explained in the previous section.

7.1. Marketplace - IDS Metadata Registry (Broker/Appstore), Clearing House and DAPS

7.1.1. Description

The Metadata Registry is the main component of the Marketplace. It can be used to register, update, or unregister the Connector or Resource (Resource or AppResource) metadata. Self-description of the Metadata Registry is also available in the Marketplace, and one can query for any information provided in it.

7.1.2. Main Functions

The following list shows the main functions of the Metadata Registry:

- **Description Request**: Gets the self-description of the Metadata Registry.
- **Register/Update Connector**: Registers the Connector if it doesn't exist in the Metadata Registry or update the Connector if it exists. Users can also include Resources (metadata of the data) while registering a Connector.
- **Unregister Connector**: Unregisters the Connector from the Metadata Registry.
- **Update Resource**: Updates the information of a particular Resource of a Connector.
- **Unregister Resource**: Removes a particular Resource from a Connector.
- **Register App**: Registers metadata of an App in the Resource Catalog of the Connector.
- **Unregister App**: Unregisters metadata of an App from the Resource Catalog of the Connector.
- **Query**: Queries the SPARQL triples in Fuseki triple store.

7.1.3. Tool Process View

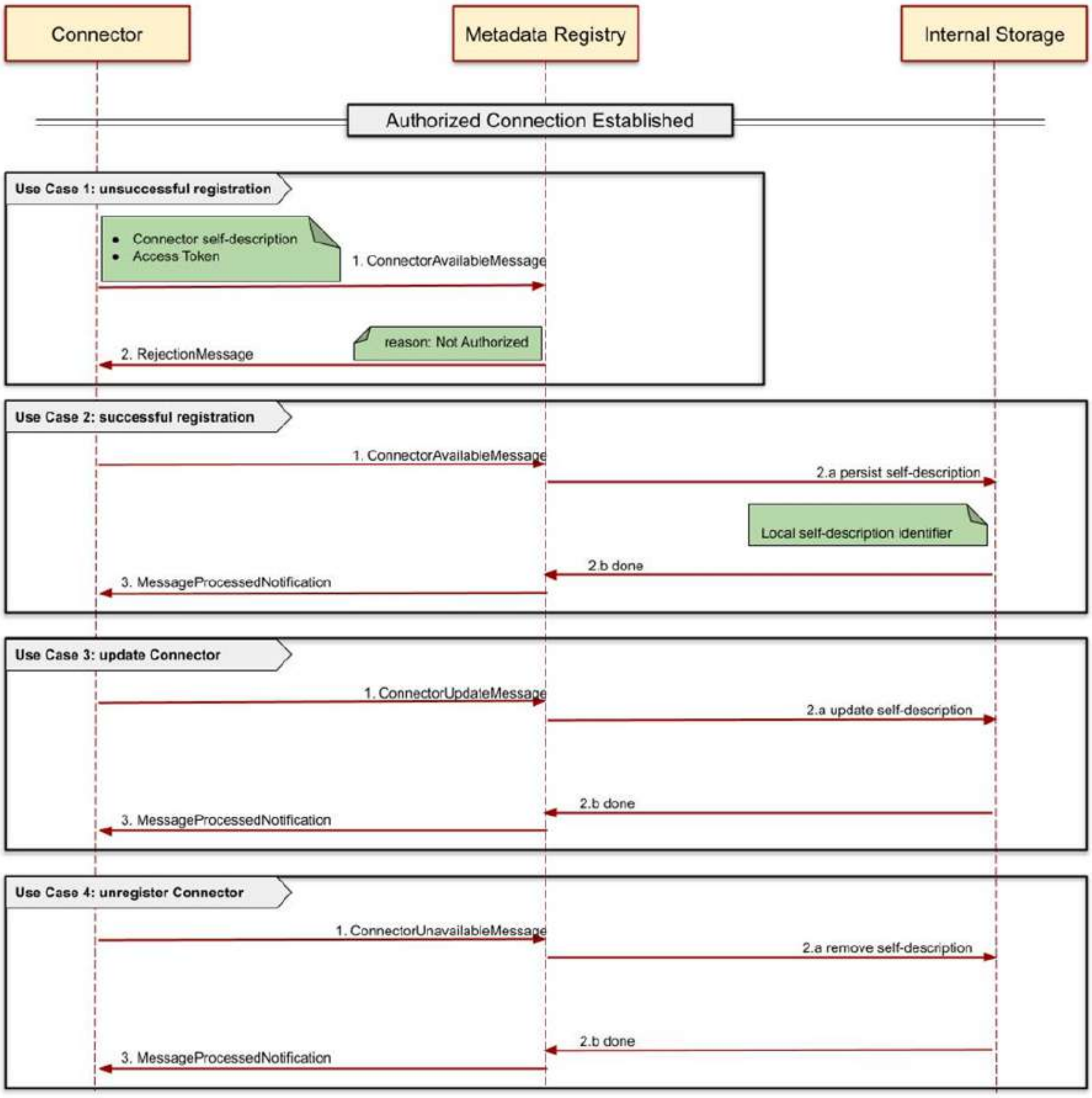


Figure 85: IDS Metadata Registry - Tool Process View

PLATOON Component	Interfaces	Role
IDS Connector	HTTP protocol, REST/MULTIPART API	Data consumer/provider. Metadata consumer.
Metadata Registry	HTTP protocol, REST/MULTIPART API	Metadata provider.

Table 85: IDS Metadata Registry Components

7.1.4. Validation Metrics

7.1.4.1. KPI 01 Metadata Registry (Broker Functionality)

The IDS Connectors from the different pilot partners must be able to register and be visible to the Metadata Registry.

Testing approach
Validate the corresponding IDS messages through Postman or other similar methods.
Validate in all pilots with IDS connectors.

Test steps
- Register the pilot partner connectors.
- Get the list of registered connectors and confirm that all the connectors have been successfully registered.
- Each pilot gets the information from the other partner connector through the Metadata Registry.

Pass/fail criteria
The IDS Connectors from the different pilot partners are registered and be visible in the Metadata Registry.

7.1.4.2. KPI 02 Metadata Registry (App Functionality)

Metadata of the Apps should be registered into the Metadata Registry so that the pilot partner can be redirected to the platform to download and implement the Apps into an IDS connector.

Testing approach
Validate the corresponding IDS messages through Postman or other similar methods.
Validate that the App is correctly working on the IDS connector. Validate it in at least one Pilot.

Test steps
- Register an IDS app into the App Store.
- Check that the IDS app has been successfully registered.
- Download and implement the IDS app into an IDS connector through the App Store.

Pass/fail criteria
Metadata of IDS Apps are registered into the Metadata Registry and can be downloaded and implemented into an IDS connector through the Metadata Registry.

7.1.4.3. KPI - 03 Integration with Clearing House

All the transactions from the Metadata Registry should be integrated with the Clearing House. The Clearing House is responsible for registering all data transactions. In PLATOON, we are not developing a Clearing House, but we are using an already existing one developed by

Fraunhofer AISEC. Nevertheless, the integration of the developed Metadata Registry with the AISEC Clearing House should be tested.

Testing approach
Validate the corresponding IDS messages through Postman or other similar methods. Validate that the data transactions are registered in the Clearing House.

Test steps
- Send data through an IDS connector.
- Check that the transaction has been successfully registered in the Clearing House.

Pass/fail criteria
Data transaction is successfully registered in the Clearing House.

7.1.4.4. KPI - 04 Integration with DAPS

All the IDS components should be authenticated through the DAPS. In PLATOON we are not developing a DAPS but we are using an already existing one developed by Fraunhofer AISEC. Nevertheless, the integration of the developed Metadata Registry with the AISEC DAPS should be tested.

Testing approach
Validate the corresponding IDS messages through Postman or other similar methods. Validate that the Metadata Registry, Connectors and Vocabulary Provider are authenticated through the AISEC DAPS.

Test steps
- Send authentication message to the DAPS.
- Check that the DAPS sends a Token back for authentication.

Pass/fail criteria
Authentication is correctly executed through the DAPS.

7.1.4.5. KPI – 05: GUI

Testing approach
Validate the different functionalities of the Marketplace GUI.

Test steps
Check the following functionalities:

- Visualize complete catalogue of registered datasets/tools.
- Search for a dataset/data analytics tool.
- Visualize metadata of dataset/data analytics tools.

Pass/fail criteria

All the functionalities above are working properly.

7.2. IDS Vocabulary Provider

7.2.1. Description

IDS Vocabulary Provider is a central IDS component that manages all the vocabularies (ontologies, reference data models, metadata elements) which can be used to annotate and describe datasets and data analytics tools. This includes the IDS information model and domain specific vocabularies.

The IDS Vocabulary Provider enhances the capabilities of the PLATOON Marketplace regarding interoperability. In fact, it allows the data/data analytics tools consumers to better understand the data and data analytics tools published in the Marketplace which facilitates the implementation and integration of these datasets and data analytics tools within the user's system.

7.2.2. Main Functions

The vocabulary provider provides direct Machine to Machine communication allowing to query and exchange metadata according to the PLATOON Data Models defined in D2.3 through pilot partners IDS connectors.

In addition, the Vocabulary Provider has a Graphical User Interface (GUI), where users can manage vocabularies (upload/upgrade/delete), search for specific terms, visualize the vocabularies in a network graph and execute SparkQL queries.

7.2.3. Tool Process View

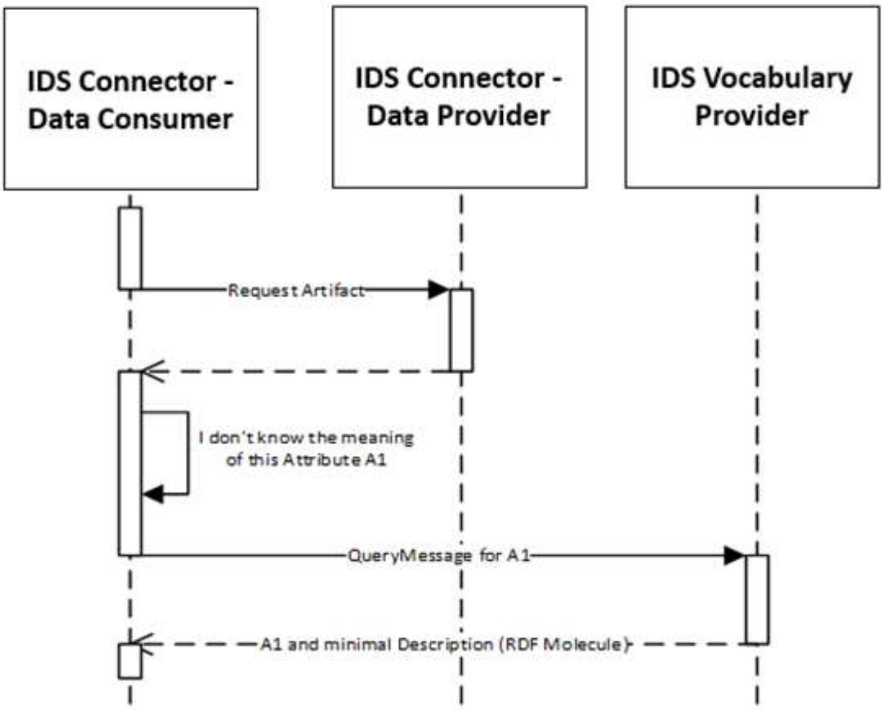


Figure 86: IDS Vocabulary Provider – Tool Process View

PLATOON Component	Interfaces	Role
IDS Connector	HTTP protocol, REST/MULTIPART API	Data consumer/provider. Metadata consumer.
IDS Vocabulary Provider	HTTP protocol, REST/MULTIPART API	Metadata provider.

Table 86: IDS Vocabulary Provider Components

7.2.4. Validation Metrics

7.2.4.1. KPI – 01: PLATOON Data Models Upload

Testing approach

Validate that the PLATOON data model is visible through the Vocabulary Provider. Check in the back end in the database Apache Jena Fuseki.

Test steps

- Step 1: Upload the PLATOON Data Models (link to the GIT Repository).

- Step 2: Check if all the terms and properties are stored in the database Apache Jena Fuseki.

Pass/fail criteria
All terms and properties are stored in the database.

7.2.4.2. KPI –02: Integration with IDS Connectors

Testing approach
Validate the communication between IDS connectors and Vocabulary Provider. Validate the corresponding messages using Postman.

Test steps
- Step 1: Send a test SparkQL query through a QueryMessage and check the result is successful.
- Step 2: Try two types of messages with each of the fields *ontologyName* and searchTerm.

Pass/fail criteria
The resulting messages received by the IDS connector are correct.

7.2.4.3. KPI – 03: Integration with IDS Broker

Testing approach
Validate the communication between IDS Broker and Vocabulary Provider. Validate the corresponding messages using Postman.

Test steps
- Step 1: Register the IDS Vocabulary provider and check if the result is successful.
- Step 2: Unregister the IDS Vocabulary provider and check if the result is successful.

Pass/fail criteria
The IDS vocabulary provider is successfully registered/unregistered in the Broker.

7.2.4.4. KPI – 04: GUI

Testing approach
Validate the different functionalities of the GUI.

Test steps
Check the following functionalities:

- Select ontology.
- Search a term.
- In the documentation tab check, all the metadata for the selected ontology is properly shown.

- In the visualization tab check, all the classes and properties for the selected ontology are displayed.
- In the query tab check that it can execute queries for the selected ontology.
- In the configuration tab check if it can upload/remove ontologies.

Pass/fail criteria

All the functionalities above are working properly.

8. Conclusions

This deliverable summarises the implementation and validation plan defined in task T6.1. This implementation and validation plan contains the description, a discussion of the main functions, a schematic overview of the different tools that are being developed and a description of the validation metrics both for pilots and PLATOON Common Components.

We can state that the implementation plan for the different pilots and PLATOON common components are in line with the requirements defined in the Grant Agreement and in the deliverable in D1.1. Nevertheless, there have been some minor deviations for some pilots. On the one hand, for Pilot 2A, not all the low-level use cases have been covered due to insufficient resources/data. Instead, 4 low use cases have been prioritised. On the other hand, Pilot 3B-PI has adapted the scope of the second low level usecase from Predictive Maintenance to Anomaly detection due to the lack of sufficient failure data. Similarly, Pilot 3B-ROM has not been able to develop the RES potentialities low level usecase due to insuficcient PV data. However, for the later ROM is working to get enough data and it is planned to be developed in the beginning of 2022 so it can be validated as part of WP6. Finally, in Pilot 3C GIR had some issues when installing the vibration sensor. As a workaround TECN has used some open source data to develop the functionalities. GIR is currently working in the sensor installation and should be installed before the end of 2021 so the developed tools can be trained with real pilot data and validated as part of WP6.

Regarding the validation plan, the defined KPIs are in line with what it was defined in the Grant Agreement Impact section and in deliverable D1.1. Equally the defined validation methodology explains with enough detail how to perform the validation. This will be one of the main input for final validation performed in task T6.2-6.4.

Regarding the next steps and risks for next year, it is crucial that all the abovementioned deviations are solved and the implementation of all components is completed for the beginning of 2022, so there is sufficient time for validation. In this sense, a technical workshop is planned for end of January to solve the last minute issues and make final decisions according to the defined contingency plans. Also, it is crucial to have a clear workplan coordinating all the pilot specific tasks T6.2-T6.4 and global validation reporting task T6.5. In this sense WP6 leader together with corresponding task leader needs to present a clear validation workplan in the beginning of 2022. This workplan should include feedback loops for the corresponding technical WPs (WP2-4) to improve the components after validation.

9. Annexes

9.1. Pilot 1a Predictive Maintenance of Wind Farms

Use Case Title :	Predictive maintenance of wind farm
Pilote-ID :	1A
Use Case-ID:	01

Interoperability layer

Component /service	Provider	Demonstration requirements	Supply	Installation / Configuration	Validation	commissioning	Risks	Required input from Tech Partners
Feature exchange service to share simulated failure data of Tecnalia digital twin model with VUB analytics block	Tecnalia/VUB		Definition of exchange formats. Target date: 30.08.2021	Unit test to validate tool correct functioning	Exchange of a reference dataset for testing the complete exchange pipeline to validate correct functioning	Testing of several challenging scenarios to stress test the connection (e.g. incorrect formats, dropping connections,…)	Biggest risk is in the clear definition of exchange formats	IDS responsible: IDS connector tutorial + code implementation
Results pushing service from Tecnalia and VUB tools to ENGIE database/dashboard	VUB/Tecnalia/ENGIE		Definition of exchange formats. Target date:30.09.2021	Unit test to validate tool correct functioning	Exchange of a reference dataset for testing the complete exchange pipeline to validate correct functioning	Testing of several challenging scenarios to stress test the connection (e.g. incorrect formats, dropping connections,)	Biggest risk is in the clear definition of exchange formats	IDS responsible: IDS connector tutorial + code implementation

Data Management Layer

Component /service	Provider	Demonstration requirements	Supply	Installation / Configuration	Validation	commissioning	Risks	Required input from Tech Partners
Data query tool to extract data from ENGIE database	ENGIE		Query and data extraction tool definition	Unit test to validate tool correct functioning	Extraction of a reference dataset for	Validation that tool responds as expected: e.g., response on incorrect	Making sure that all queries necessa	IDS responsible: IDS connector tutorial + code

			. Target date: 01.06.2021		testing the complete data query pipeline to validate correct functioning	query, not providing data where access is not allowed,	ry for analytics tools are possible	implementation

Data Security, Privacy and Sovereignty Layer

Component /service	Provider	Demonstration requirements	Supply	Installation / Configuration	Validation	commissioning	Risks	Required input from Tech Partners
IDS connector architecture to communicate between ENGIE database and analytics blocks	ENGIE		Data exchange format definition . 30.08.2021	Unit testing of the software code	Exchange of a reference dataset for testing the complete secure data exchange pipeline to validate correct functioning	Validation of security by e.g. providing incorrect token,…	Technical risks linked to integration of IDS tools in pipelines	IDS responsible: IDS connector tutorial + code implementation
IDS connector architecture to communicate between Tecnalia digital twin pipeline and VUB models	VUB		Data exchange format definition . Target date: 30.09.2021	Unit testing of the software code	Exchange of a reference dataset for testing the complete secure data exchange pipeline to validate correct functioning	Validation of security by e.g. providing incorrect token,…	Technical risks linked to integration of IDS tools in pipelines	IDS responsible: IDS connector tutorial + code implementation
IDS connector architecture to communicate between EDGE device and VUB analytics block	VUB		Data exchange format definition . Target date 30.10.2021	Unit testing of the software code	Exchange of a reference dataset for testing the complete secure data exchange pipeline to validate correct	Validation of security by e.g. providing incorrect token,…	Technical risks linked to integration of IDS tools in pipelines	IDS responsible: IDS connector tutorial + code implementation

					functioning			
IDS connector architecture to send processed data from analytics blocks back to ENGIE database/dashboard	VUB/Tecnalia		Data exchange format definition. Target date: 30.10.2021	Unit testing of the software code	Exchange of a reference dataset for testing the complete secure data exchange pipeline to validate correct functioning	Validation of security by e.g. providing incorrect token,…	Technical risks linked to integration of IDS tools in pipelines	IDS responsible: IDS connector tutorial + code implementation

Intelligence Layer

Component /service	Provider	Demonstration requirements	Supply	Installation / Configuration	Validation	commissioning	Risks	Required input from Tech Partners
Tecnalia digital twin pipeline	Tecnalia		Dedicated software tool programming targeting the SCADA data of the wind pilot. Target date: 1.10.2021	Unit testing of the analytics code blocks and integrated pipeline	Validation dataset (e.g. La Haute Lys or SCADA data) used for validation of analytics capabilities	Validation of analytics pipeline using SCADA fleet data that was not used in model construction/training	Methodological risks linked to tool effectiveness and software risks linked to tool implementation	
VUB healthy behaviour modelling pipeline	VUB		Dedicated software tool programming targeting the SCADA data of the wind pilot. Target date: 1.10.2021	Unit testing of the analytics code blocks and integrated pipeline	Validation dataset (e.g. La Haute Lys or SCADA data) used for validation of analytics capabilities	Validation of analytics pipeline using SCADA fleet data that was not used in model construction/training	Methodological risks linked to tool effectiveness and software risks linked to tool implementation	
VUB semantic reasoning for failure mode classification pipeline	VUB		Dedicated software tool programming targeting the SCADA data of the wind	Unit testing of the analytics code blocks and integrated pipeline	Validation dataset (e.g. La Haute Lys or SCADA data) used for validation of analytics	Validation of analytics pipeline using SCADA fleet data that was not used in model construction/training	Methodological risks linked to tool effectiveness and software risks	UBO semantic reasoning tool support

			pilot. Target date: 1.11.2021		capabilities		linked to tool implementation	

Edge Computing

Component /service	Provider	Demonstration requirements	Supply	Installation / Configuration	Validation	commissioning	Risks	Required input from Tech Partners
Edge algorithm to calculate DQ currents from current data	VUB	Show correct calculation of DQ currents on current signals sampled at least at 20kHz.	Lab test set-up using NXP dev board that can be artificially fed with measurement data. Target date: 15.10.2021	Unit test of algorithm	Processing of La Haute Lys high frequency current data	Fully autonomous processing measurements collected during several 10-min runs. Dealing with outliers, bad quality measurements and other real-life challenges.	Technical risks only (necessary data available)	none
Local edge storage database	VUB	Should be able to store data during buffer period such that calculations can run on the data	Lab test set-up using NXP dev board that can be artificially fed with measurement data. 15.10.2021	Test by storing testing dataset to validate correct functioning	Processing of La Haute Lys high frequency current data	Fully autonomous storage of measurements collected during several 10-min runs. Validation to deal with NaNs, empty records and other real-life challenges	Technical risks only (necessary data available)	Support in choosing the right technology + if available a POC implementation

9.2. Pilot 2a Pilot Electricity Balance and Predictive Maintenance

Interoperability Layer

Use Case Title :	Electricity Balance and Predictive Maintenance
Pilot ID:	2A
Use-case ID:	01

Component /service	Provider	Demonstration requirements	Supply	Installation / Configuration	Validation	commissioning	Risks	Required input from Tech Partners
Data Connectors	IMP	Required to connect to IMP SCADA data	Scripts for automating the retrieval of SCADA data by August 2021	Unit test of data connectivity with IMP SCADA by August 2021	Extraction of a reference datasets in real time by September 2021	Commissioning of scripts on PLATOON server by September 2021	Making sure that all necessary data is stored in Influx and MySQL (Platoon platform)	
Data Connectors	CS	Required to connect CS edge computer to IMP SCADA	Scripts for storing messages in IMP databases by August 2021	Unit test to validate tool correct functioning by August 2021	Extraction of a reference dataset datasets in real time by September 2021	Commissioning of PMU and data scripts by September 2021	Making sure that all necessary data is stored in Influx and MySQL (Platoon platform)	CS

Data Management Layer

Component /service	Provider	Demonstration requirements	Supply	Installation / Configuration	Validation	commissioning	Risks	Required input from Tech Partners
Semantic Adpter, SDM-RDFizer	TIB	Webinar by end of June 2021	Composed docker image by June 2021	July 2021	Extraction of example data from MySQL database, part of the Platoon platform by September 2021	Commissioning of the final version of transformation scripts by October 2021	Making sure that all transformations needed to answer business questions have been defined	TIB
MySQL Data model for LLUC-04	IMP	Installation at the IMP PLATOON server by April 2021	Updated Data model supplied by April 2021	Configuring the link with WeatherBit by April 2021	Validation of data model by June 2021	Commissioning of a data model that covers all aspects	Making sure that all queries necessary for	

						needed by August 2021	analytics tools are possible	
MySQL Data model for LLUC-03	IMP	Installation at the IMP PLATOON server by August 2021	Updated Data model supplied by September 2021	Configuring the link with IMP SCADA by September 2021	Validation of data model by September 2021	Validation that model covers all aspects needed by September 2021	Making sure that all queries necessary for analytics tools are possible	
Influx Data Model- LLUC-05, LLUC-07	IMP, CS	Installation at the IMP PLATOON server by April 2021	Updated Data model supplied byJune 2021	Configuring the link with IMP SCADA by July 2021	Storing an example message coming from CS edge computer via MQTT broker by August 2021	Validation that model covers all aspects needed by August 2021	Making sure that all queries necessary for analytics tools are possible	CS
Federated Query Processing	TIB	Webinar by end of June 2021	Composed docker image by June 2021	Composed docker image installed by July 2021	Validated by IMP within LLUC-03 and LLUC-04 by September 2021 (IMP)	Commissioning of a tool that responds as expected: e.g. response on incorrect query, not providing data where access is not allowed,… by September 2021 (IMP)	Making sure that all queries necessary for analytics tools are possible	TIB
Unified Knowledge Base	TIB	Webinar by end of June 2021 Demonstration with business questions by September 2021 (IMP)	Composed docker image by June 2021	Composed docker image installed by July 2021	Validated by IMP within LLUC-03 and LLUC-04 by September 2021 (IMP)	SPARQL endpoint up and running. by September 2021 (IMP)	Making sure that business questions are answered	TIB

Data Security, Privacy and Sovereignty Layer

Component /service	Provider	Demonstration requirements	Supply	Installation/ Configuration	Validation	commissioning	Risks	Required input from Tech Partners
IDS connector for RES Forecaster	IMP	Adoption of IDS connector for Pilot 2a	Installation at the IMP PLATOON server by October 2021	Unit testing of the software code by October 2021	Exchange of a reference dataset for testing the complete secure data exchange	Validation of security by e.g. providing incorrect token,… by November 2021 (IMP)	Related to provision of IDS components and Market place	IAIS

					pipeline to validate correct functioning by November 2021			
IDS connector for Load Forecaster	IMP	Adoption of IDS connector for Pilot 2a	Installation at the IMP PLATOON server by October 2021	Unit testing of the software code by October 2021	Exchange of a reference dataset for testing the complete secure data exchange pipeline to validate correct functioning by November 2021	Validation of security by e.g. providing incorrect token,… by November 2021 (IMP)	Related to provision of IDS components and Market place	IAIS

Intelligence Layer

Component /service	Provider	Demonstration requirements	Supply	Installation / Configuration	Validation	commissioning	Risks	Required input from Tech Partners
RES Wind Forecaster	IMP	Yes, Scientific paper	ML Models and dockerized service by June 2021	Unit testing of the analytics code blocks and integrated pipeline by September 2021	Validation dataset, first results by October 2021	Validation of analytics pipeline using SCADA fleet data that was not used in model construction/training by October 2021 (IMP)		no
Load Forecaster	IMP	Yes, Scientific paper	ML Models and dockerized service by September 2021	Unit testing of the analytics code blocks and integrated pipeline by October 2021	Validation dataset, first results by November 2021	Validation of analytics pipeline using SCADA fleet data that was not used in model construction/training by November 2021 (IMP)		no
UI component	IMP	UI should be able to visualize data from the PLATOON KGs	KGs and components for the ESTA-LD tool by October 2021	Unit testing of the integration with KGs store by October 2021	Validation dataset, first results October 2021	Validation of integration with the semantic pipeline for IMP scenarios by November 2021 (IMP)		no

Edge Computing

Componen t /service	Provider	Demonstrati on requirement s	Supply	Installation / Configurati on	Validati on	commissioni ng	Risks	Required input from Tech Partners
Edge computer and 2 PMU units	CS	Edge computer should be able to store high-resolution data and send data to IMP MQQT Broker	To be ready for installatio n at PUPIN premises by Septembe r 2021	It should be configured on site in IMP premises. Test by storing testing dataset in Influx database to validate correct functioning	Validation on premises by IMP by Septembe r 2021	Fully autonomous storage of collected measurements by October 2021		CS
RES effects calculation service	CS	The service should be able to calculate the effects and control/adjust infrastructure parameters	In progress, Interfaces implemen ted by Septembe r 2021	Service should run on edge computer and communicat e with IMP SCADA ? (Platoon platform)	Validation on premises by IMP by Septembe r 2021	The first version validated by IMP by end of October 2021		CS
Predictive maintenanc e service	CS	The service should be able to forecast distortion of quality and predict failures	In progress, Interfaces implemen ted by Septembe r 2021	Service should run on edge computer and communicat e with IMP Platoon Platform	Validation on premises by IMP by Septembe r 2021	The first version validated by IMP by end of October 2021		CS

9.3. Pilot 2b Electricity Grid Stability, Connectivity and Life Cycle

Use Case Title :	Electricity grid stability, connectivity and life cycle
Pilot ID :	2B
Use-case ID :	01, 02

Interoperability Layer

Component /service	Provider	Demonstration requirements	Supply	Installation / Configuration	Validation	commissioning	Risks	Required input from Tech Partners
Component/ service to implement Service 01: Data analytics tools, Semantic Adapter, IDS connector	(Partner)	Identified in D1.1	First action taken to bring the service/component into the scope of the LLUC.	System customization before putting the system to roll-out on pilot premises.	Any kind of pre-check before installation (ex: reception protocol)	Field test to assure that the system/process was correctly installed and configured.		
Data Connector	Indra/Tecnalia	On Onesait side an IDS compliant connector will have to be implemented to exchange data with Tecnalia. Data model translation from internal Onesait structure will also be a requirement	31/08/2021	30/09/2021	30/09/2021	31/12/2021	No documentation available at the moment.	
IoT Connector	Indra	Onesait gateway will most probably used to upload field data. There is a simpler scenario with direct connection to Sampol's database but will not be the ultimate solution	30/06/2021	30/06/2021	30/09/2021	31/12/2021		

Data Curation and Integration	Indra	Data will be consolidated in Onesait storage, mainly time series data	30/09/2021	31/12/2021	31/06/2022	31/10/2022	Data quality issues	
Semantic Adapter	Indra	Semantic translations between Indra/Tecnalia and the Platoon data model will be implemented.	30/06/2021	30/06/2021	30/09/2021	31/12/2021	No documentation available at the moment.	

Data Management Layer

Component /service	Provider	Demonstration requirements	Supply	Installation/ Configuration	Validation	commissioning	Risks	Required Input from Tech Partners
Context Data Broker	Sampol + Indra	Needed (Sampol data acquisition + gateway + Digital broker)).	30/06/2021	30/06/2021	30/09/2021	31/12/2021		
Unified Knowledge Base	Indra	Onesait Platform DB	30/06/2021	30/06/2021	30/09/2021	31/12/2021		

Data Security, Privacy and Sovereignty Layer – IDS

Component /service	Provider	Demonstration requirements	Supply	Installation/ Configuration	Validation	commissioning	Risks	Required Input from Tech Partners
IDS connector	Indra, Tecnalia	IDS connector between Indra´s Onesait Platform and Tecnalias servers.	31/08/2021	30/09/2021	30/09/2021	31/12/2021	No documentation available at the moment.	Code and Training from WP3

Intelligence Layer

Component /service	Provider	Demonstration requirements	Supply	Installation/ Configuration	Validation	commissioning	Risks	Required Input from Tech Partners
Data Analytics Tools	Indra, Tecnalia, Sampol	Implemented each in their servers and offered as a service through APIs	30/09/2021	31/12/2021	31/06/2022	31/10/2022	Some pending questions on how to dockerize tools. Data quality issues	Training from WP4 on tool dockerization.

Data Analytics Dashboard – Visualization	Indra	Based on Onesait platform capabilites	30/09/2021	31/12/2021	31/06/2022	31/10/2022	Data quality issues	-

Edge Computing

Component /service	Provider	Demonstration requirements	Supply	Installation/ Configuration	Validation	commissioning	Risks	Required Input from Tech Partners
Edge Computing – NTL detection	Indra,	Implemented in Indra´s virutalised environment.	30/09/2021	31/12/2021	31/06/2022	31/10/2022	Data quality issues	

9.4. Pilot 3a Office Building: Operation Performance Thanks to Physical Models and IA Algorithms

Use Case Title:	Office building: operation performance thanks to physical models and IA algorithms
Pilote-ID :	3A
Use Case-ID:	01, 02

Interoperability Layer

Component /service	Provider	Demonstration requirements	Supply	Installation/ Configuration	Validation	commissioning	Risks	Required input from Tech Partners
Data Connector	ENGIE	There are 2 data connectors. Batch: data coming from BMS 5 NO HISTORICAL DAT Realtime: Data coming from BMS, and Weather	**01/2021**	05/2021	06/2021	. 07/2021	Delays for data collection from BMS/Occupancy	
Semantic Adapter	ENGIE	Semantic data model adaptation is needed for all data coming from data/IoT connectors	**17/03/21**	31/05/2021	30/06/2021	15/07/2021		

Data Management Layer

Component /service	Provider	Demonstration requirements	Supply	Installation/ Configuration	Validation	commissioning	Risks	Required input from Tech Partners
Context Data Broker	Engineering	Service specific context information retrieval, update of context information and realtime data transmission to Services from IoT connectors	30/06/2021	08/2021			Documents not available and unknow necessary time to implement this component	
Federated Query Processing	TIB	Services querying data from semantic store + historical raw data from Unified KB	30/06/2021	08/2021			Documents not available and unknow necessary time to implement this component	

Intelligence Layer

Component /service	Provider	Demonstration requirements	Supply	Installation/ Configuration	Validation	commissioning	Risks	Required input from Tech Partners
Data Analytics Toolbox and Processing Tools/ Tool design	TCN	<refer: Pilot-3a services document>	**04/2021**	06/2021	07/2021	11/2021		
Data Analytics Dashboard – Visualization	Engie		07/2021	08/2021	10/2021	11/2021	Depends on the analytical tool's readiness	

Edge Computing

Component /service	Provider	Demonstration requirements	Supply	Installation/ Configuration	Validation	commissioning	Risks	Required input from Tech Partners
Edge Computing and Generic Tools	CS	Image Processing: deep learning models with CUDA or TensorRT	08/2021				If delivered after 08/2021 this component will not be a part of the platform	Edge computing framework from CS Documentation on this framework

9.5. Pilot 3b – PI Advanced Energy Management System and Spatial (Multi-Scale) Predictive Models in the Smart City

Use Case Title :	Advanced Energy Management System and Spatial (multi-scale) Predictive Models in the Smart City
Pilot-ID :	3B (PI)
Use Case-ID:	01, 02, 03

Interoperability Layer

Component /service	Provider	Demonstration requirements	Supply	Installation/ Configuration	Validation	commissioning	Risks	Required input from Tech Partners
Data Connector	ENG	Data will be exchange with the pilot through a file exchange protocol (e.g. SFTP) provided by AXWAY gateway	By January 2021	By February 2021	By January 2021	By March 2021	Delay in the identification of the specific protocols and file types (low)	
IoT Connector		Not required. Only historical data will be managed						
Data Curation and Integration	ENG/TIB	Could be necessary for the data integration of the pilot		By June 2021	By June 2021	By July 2021		
Semantic Adapter	ENG/TIB/ENGIE	Yes, to adapt pilot data to the data model	Include provisioning of the specific components in relation with the PLATOON developments By April 2021	By June 2021	By July 2021	By July 2021	Possible delay in other tasks related to the semantic activities (low) Possible delay due to the identification of	

							the right data exchanged in the pilot (low)	
Energy Data model (PLATOON Data models from T2.3)		Yes Includes Data mapping activities	Ongoing By June 2021					
Vocabulary manager		Not needed in the initial pilot scenario						

Data Management Layer

Component /service	Provider	Demonstration requirements	Supply	Installation/ Configuration	Validation	commissioning	Risks	Required input from Tech Partners
Context Data Broker	ENG	Not needed due to the fact that we will not deal with real-time data						
Federated Query Processing	TIB	Not needed in this initial phase of the pilot development, but it will be included in the deployment for future use.	By July 2021	By September 2021	By September 2021	By September 2021		
Unified Knowledge Base	ENG/TIB	Yes, Required for the pilot data	By September 2021	By October 2021	By October 2021	By October 2021		
Context Event Processing		Not needed						

Data Security, Privacy and Sovereignty Layer – IDS

Component /service	Provider	Demonstration requirements	Supply	Installation/ Configuration	Validation	commissioning	Risks	Required input from Tech Partners
Connector	ENG	Not needed in the initial pilot scenario						

Intelligence Layer (see detailed table Data Analytics tool)

Component /service	Provider	Demonstration requirements	Supply	Installation/ Configuration	Validation	commissioning	Risks	Required input from Tech Partners
Data Analytics Toolbox and Processing Tools	ENG	Yes, needed to analyse data based on pilot requirements	By July 2021	By September 2021	By October 2021	By December 2021		
Data Analytics Dashboard Visualization	ENG	Yes, needed to analyse data based on pilot requirements	By July 2021	By September 2021	By October 2021	By December 2021		

Data Analytics Tools

Component /service	Provider	Demonstration requirements	Supply	Installation/ Configuration	Validation	commissioning	Risks	Required input from Tech Partners
Energy Consumption Forecaster			June 2021	September 2021	September 2021	By the end of 2021	None	
Anomaly Detection			October 2021	By the end of 2021	November 2021	By the end of March 2022	None	
Energy Consumption Benchmarking			July 2021	October 2021	September 2021	By the end of 2021	None	
Lighting Consumption Evaluator			September 2021	By the end of 2021	By October 2021	By the end of 2021	None	
Consumptions and Occupancy Profile Correlator			June 2021	By September 2021	By September 2021	By the end of 2021	None	

9.6. Pilot 3b – ROM Advanced Energy Management System and Spatial (Multi-Scale) Predictive Models in Smart City

Use Case Title :	Monitoring and Analysis of energy meters data of ROM large asset
Pilot-ID :	3B - ROM
Use Case-ID:	01. 02. 03. 04

Interoperability Layer

Component /service	Provider	Demonstration requirements	Supply	Installation/ Configuration	Validation	commissioning	Risks	Required input from Tech Partners
Energy Data model (PLATOON Data models from T2.3)	TBD	Yes Includes Data mapping activities	Ongoing By July 2021					
Data Connector	ENG	Data will be exchanged through files exchanges within dedicated repository (service and protocol provided by ENG)	By JULY 2021	By JULY 2021	September 2021	September 2021	Delay in the identification of the specific service, protocols and file types (low)	
IoT Connector		Not required. Only historical data will be managed						
Data Curation and Integration	ENG/TIB	Not necessary in the first iteration of the pilot. Basic data integration capabilities will be implemented by the DE platform						
Semantic Adapter	ENG/TIB/ENGIE	Yes, to adapt pilot data to the data model	By JULY 2021	By JULY 2021	September 2021	September 2021	Possible delay in other tasks related to the semantic	

							activities (low)	

Data Management Layer

Component /service	Provider	Demonstration requirements	Supply	Installation/ Configuration	Validation	commissioning	Risks	Required input from Tech Partners
Context Data Broker	ENG	Not needed due to the fact that we will not deal with real-time data						
Federated Query Processing	TIB	Not needed in this initial phase of the pilot development						
Unified Knowledge Base	ENG/TIB	Yes, Required for the pilot data	September 2021	October 2021	October 2021	By the end of 2021		
Context Event Processing		Not needed						

Data Security, Privacy and Sovereignty Layer

Component /service	Provider	Demonstration requirements	Supply	Installation/ Configuration	Validation	commissioning	Risks	Required input from Tech Partners
Component/ service to implement.	(Partner)	Identified in implementation table	First action taken to bring the service/component into the scope of the LLUC.	System customization before putting the system to roll-out on pilot premises.	Any kind of pre-check before installation (ex: reception protocol)	Field test to assure that the system/process was correctly installed and configured.		
Connector	ENG	Not needed in the initial pilot scenario						
DAPS	IAIS	Not needed in the initial pilot scenario						
Broker/App store (metadata registry)	IAIS	Not needed in the initial pilot scenario						
Clearing House	IAIS	Not needed in the initial pilot scenario						

Vocabulary provider	TECN - IAIS	Not needed in the initial pilot scenario						

Intelligence Layer

Component /service	Provider	Demonstration requirements	Supply	Installation/ Configuration	Validation	commissioning	Risks	Required input from Tech Partners
Data Analytics Toolbox and Processing Tools	ENG	Yes, needed to analyse data based on pilot requirements	By September 2021	By September 2021	By October 2021	By December 2021		
Data Analytics Dashboard Visualization	ENG	Yes, needed to analyse data based on pilot requirements	By September 2021	By September 2021	By October 2021	By December 2021		

Data Analytics Tools

Component /service	Provider	Demonstration requirements	Supply	Installation/ Configuration	Validation	commissioning	Risks	Required input from Tech Partners
LLUC 3B_ROM_01 Spatial Reporting	ENG		September 2021	September 2021	September 2021	By the end of 2021	None	
LLUC 3B_ROM_02 Benchmarking Analysis	ENG		September 2021	October 2021	October 2021	By the end of 2021	Lackness in Master data on buildings characteristics	
LLUC 3B_ROM_03 Forecast on energy consumptions	ENG		September 2021	October 2021	October 2021	By the end of 2021	None	
LLUC 3B_ROM_04 RES potentialities	ENG-ENGIE	PV PRODUCTION Prediction tool (external)	September 2021 *	december 2021	december 2021	By the end of 2021	* Late access to data related to PV plants	

9.7. Pilot 3c Energy Efficiency and Predictive Maintenance in the Smart Tertiary Building Hubgrade

Use Case Title :	Energy efficiency and predictive maintenance in the smart tertiary building hubgrade
Pilot ID :	3C
Use-case ID :	01, 02

Interoperability Layer

Component /service	Provider	Demonstration requirements	Supply	Installation/ Configuration	Validation	commissioning	Risks	Required input from Tech Partners
Data Connector	GIR	Non-semantic data. It will be just simple time series data stored in SQL server of Giroa.	01/02/2021	28/02/2021	30/03/2021	30/04/2021	Pendding vibration sensor commissioning Linux VPN client license	
IoT Connector	GIR	Non-semantic data. It will be just simple time series data stored in SQL server of Giroa.	30/03/2021	30/03/2021	30/04/2021	07/05/2021	Issues to get access to the final point in the local network	

Data Management Layer

Component /service	Provider	Demonstration requirements	Supply	Installation/ Configuration	Validation	commissioning	Risks	Required input from Tech Partners
N/A								

Data Security, Privacy and Sovereignty Layer

Component /service	Provider	Demonstration requirements	Supply	Installation/ Configuration	Validation	commissioning	Risks	Required input from Tech Partners
IDS Connector	ENG/TECN	Data usage. Between GIR and TECN. Potentially between TECN and SIS (still tbd).	30/08/2021	30/09/2021	01/12/2021	31/12/2021	IDS Connector	ENG/TECN

Intelligence Layer

Component /service	Provider	Demonstration requirements	Supply	Installation/ Configuration	Validation	commissioning	Risks	Required input from Tech Partners
Data Analytics Toolbox and Processing Tools	TECN and SIS	For sure implemented as a service but might consider as well to do a test on the infrastructure using dummy code.	01/12/2021	31/12/2021	30/06/2022	31/12/2022	Insufficient vibration historical data storage,	
Data Analytics Dashboard – Visualization	SIS	Use Promind capabilities - Visualization Dashnobard to show outputs from data analytics tools from SIS and TECN. Also GIR want to show some results in another dashboard that they use internally in Giroa.	01/01/2021	31/07/2021	30/06/2022	31/12/2022	Insufficient historical data from some data variables	

Edge Computing

Component /service	Provider	Demonstration requirements	Supply	Installation/ Configuration	Validation	commissioning	Risks	Required input from Tech Partners
Vibration data analisys/preprocesing	TECN	Preprocessing of vibration data from hydraulic pumps	30/03/2021	30/03/2021	30/07/2021	01/12/2021	Issues to get access to the final point in the local network	

9.8. Pilot 4a Energy Management of Microgrids

Use Case Title :	Energy management of microgrids
Pilot ID :	4A
Use-case ID :	01

Interoperability Layer

Component /service	Provider	Demonstration requirements	Supply	Installation/ Configuration	Validation	commissioning	Risks	Required input from Tech Partners
Data Connector	ENGIE / PDM	There are 2 data connectors. 3. Realtime: data coming from digit twin 4. Batch: Data coming from external service	**01/2021**	05/2021	06/2021	07/2021	Delays for infrastructure activation + data communication from digital twin	
Semantic Adapter	ENGIE	Semantic data model adaptation is needed for all data coming from data/IoT connectors	**17/03/21**	31/05/2021	30/06/2021	15/07/2021		

Data Management Layer

Component /service	Provider	Demonstration requirements	Supply	Installation/ Configuration	Validation	commissioning	Risks	Required input from Tech Partners
Context Data Broker	Engineering	Service specific context information retrieval, update of context information and realtime data transmission to Services from IoT connectors (raw + semantic) to services	30/06/201	08/2021			Documents not available and unknow necessary time to implement this component	
Federated Query Processing	TIB	Services querying data from semantic store + historical raw data from Unified KB	30/06/2021	08/2021			Documents not available and unknow necessary time to implement this component	
Unified Knowledge Base	TIB	Store raw data (non-semantic) as well as semantic data and results	30/06/2021	08/2021			Documents not available and unknow necessary time	

		of services forecasting					to implement this component	

Intelligence Layer

Component /service	Provider	Demonstration requirements	Supply	Installation/ Configuration	Validation	commissioning	Risks	Required input from Tech Partners
Data Analytics Toolbox and Processing Tools/ Tool design	PDM	<refer: Pilot-4a services document>	04/2021	06/2021	09/2021	12/2021		Inputs from WP4.1 training
Data Analytics Dashboard – Visualization	Engie / PDM		06/2021	07/2021	10/2021	11/2021	Depends on the analytical tools readiness	

Edge Computing

Component /service	Provider	Demonstration requirements	Supply	Installation/ Configuration	Validation	commissioning	Risks	Required input from Tech Partners
Edge Computing and Generic Tools	CS	Image Processing: deep learning models with CUDA or TensorRT (GPU pr	08/2021	07/2021	10/2021	11/2021	If delivered after 08/2021 this component will not be a part of the platform	Edge computing framework from CS Documentation on this framework

10. Annex II – KPI Templates

10.1. Pilot 1a Predictive Maintenance of Wind Farms

<table>
<tr><th colspan="5">KPI N°1</th></tr>
<tr><td>KPI-Name</td><td colspan="2">Modeling quality</td><td>KPI-ID</td><td>1</td></tr>
<tr><td>KPI-Type</td><td colspan="4">Technical (specific to the pilot use case) or business (refer to D8.1/ PLATOON KPIs)
Technical</td></tr>
<tr><td>Description</td><td colspan="4">Modelling approach capable to fit healthy component data. Several model quality statistics can be calculated: e.g. rms</td></tr>
<tr><td>Target Value</td><td>Target value:
After data cleaning the model fit should be above 97% for healthy steady state data</td><td>Threshold Value

97% for healthy steady state data after data cleaning</td><td colspan="2">The value used to assess the effectiveness/efficiency performance of the monitored process.
RMS error</td></tr>
<tr><td>Rounding</td><td colspan="4">Round to 1%</td></tr>
<tr><td>Unit</td><td colspan="4">Percentage error</td></tr>
<tr><td>Formula</td><td colspan="4">((predicted value of modeled parameter – true value)/true value) * 100</td></tr>
<tr><td>Calculating frequency</td><td colspan="4">Upon retraining of the model</td></tr>
<tr><th colspan="5">Calculation Methodology</th></tr>
<tr><td>Step</td><td colspan="4">Description</td></tr>
<tr><td>01-</td><td colspan="4">Different summary statistics can be calculated: e.g. rms of the error.</td></tr>
<tr><td>02</td><td colspan="4"></td></tr>
<tr><th colspan="5">Data Source</th></tr>
<tr><td>Data description</td><td>Data source</td><td>Data collection frequency</td><td>Data collection time range</td><td>Data Owner</td></tr>
<tr><td>Signals used as input for the models</td><td>SCADA data</td><td>10 min</td><td>Data corresponding to training range for the model.</td><td>ENGIE</td></tr>
</table>

KPI N°2				
KPI-Name	Integration		**KPI-ID**	2
KPI-Type	Technical			
Description	Metric targeted at the validation of the fact that the tools of this pilot are able to work together.			
Target Value	1	**Threshold Value**	1	
Rounding	Not applicable			
Unit	Binary 1 or 0			
Formula	If all tools to complete the pilot data analysis can interact and send data to each other than this KPI is 1. Otherwise, it is 0.			
Calculating frequency	At each pipeline release			
Calculation Methodology				
Step	**Description**			
01-	based on unit tests the input-output functioning of each pipeline is validated.			
02	Test data is exchanged between the pilot analytics blocks			
Data Source				
Data description	**Data source**	Data collection frequency	Data collection time range	Data Owner
Test data	Predefined set of validation data.			Each pilot party involved with specific tools

KPI N°3				
KPI-Name	Fault detection		**KPI-ID**	3
KPI-Type	Technical			
Description	Anomaly detection speed + accuracy (false vs true positive). The accuracy is expressed using a confusion matrix. For the speed this is expressed in time to catastrophic failure.			
Target Value	Compared to the current failure detection the speed should improve with at least 25%, while keeping false positives below 10%	**Threshold Value**	All improvement compared to current situation is already useful.	
Rounding	Not applicable for accuracy. Each element in the confusion matrix is binary. For the speed rounded to the next day.			

Unit	time			
Formula	Confusion matrix for each day block in time			
Calculating frequency	Once per day			
Calculation Methodology				
Step	**Description**			
01-				
02				
Data Source				
Data description	**Data source**	Data collection frequency	Data collection time range	Data Owner
E.G. energy consumption	E.g. BMS	E.g. 15 min	E.g. Monthly	

KPI N°4			
KPI-Name	Processing capability	**KPI-ID**	4
KPI-Type	Technical		
Description	There are two aspects being tested in this KPI. The first is the speed at which one complete data analysis of the complete pipeline can be done. The second is the number of turbines that are feasible to be analysed using the approach.		
Target Value	Full processing chain for a farm should be able to run on a standard server.	**Threshold Value**	Full processing chain for a farm should be able to run on a standard server.
Rounding	Rounding up of CPU and RAM to next unit		
Unit	Nbr of s on CPU of type X with X Gb RAM for 1 turbine		
Formula	Cores and Gb		
Calculating frequency	Upon changes in the pipelines		
Calculation Methodology			
Step	**Description**		
01-			

02				
Data Source				
Data description	**Data source**	Data collection frequency	Data collection time range	Data Owner
Input data sources for the analytics methods	Input data sources for the analytics methods	Same as inputs for the analytics methods		

KPI N°5			
KPI-Name	Maintenance costs reduction	**KPI-ID**	5
KPI-Type	Business		
Description	The reduction in the maintenance cost of the wind turbine due to early fault detection. Less consequent damages are present and maintenance actions are clustered. Costs will be estimated by comparing cost of component replacement at detection to catastrophic failure. Revenues during additional time that the machine was able to run are subtracted from the maintenance costs.		
Target Value	10-20%	**Threshold Value**	10%
Rounding	Round to 0.01%		
Unit	%		
Formula	Euro maintenance cost with early detection/Euro maintenance cost run to failure		
Calculating frequency	yearly		
Calculation Methodology			
Step	**Description**		
01-			
02			

Data Source				
Data description	**Data source**	Data collection frequency	Data collection time range	Data Owner
Maintenance records containing the maintenance actions	Maintenance records	continuously	yearly	ENGIE

performed on the wind turbines under investigation				

KPI N°6			
KPI-Name	Availability increase	**KPI-ID**	6
KPI-Type	**Technical (specific to the pilot use case) or business (refer to D8.1/ PLATOON KPIs)**		
Description	The increase of the turbine availability due to faster actions triggered by better predictive maintenance. We focus on machines with an error.		
Target Value	2-5%	**Threshold Value**	2%
Rounding	Round to 0.01%		
Unit	% of the time		
Formula	Abs(Availability as is situation – Availability after usage of Platoon toolbox)		
Calculating frequency	yearly		

Calculation Methodology	
Step	**Description**
01-	Isolation of the availability reductions linked to the subcomponents within focus in Platoon.
02	Comparison of the estimated availability with and without the fault detection knowledge of platoon analytics tools.

Data Source				
Data description	**Data source**	Data collection frequency	Data collection time range	Data Owner
Annotated stops	Maintenance records	continuously	yearly	ENGIE

10.2. Pilot 2a Electricity Balance and Predictive Maintenance

10.2.1. LLUC P 2a-07

KPI N°1			
KPI-Name	Saving costs	**KPI-ID**	KPI-8
Description	Algorithms detects abnormal behaviour and predicts the degreation constant. Reduces maintainance costs. It also detects failures.		
Unit	€		
Formula	1. Binary 0 1 Trigger's detection of failure, immediate replacement $(N_{days\ estimate} - N_{days\ after\ detecting failure}) * E_{daily} * price_{of\ electricity}$ 2. Prediction of failure Reduction of Asset Investment costs by minimizing the number of elements to be replaced (PV modules). $\left(\sum_{i=0}^{N_{total}} i - \sum_{i=0}^{N_{string}} i\right) * cost\_of\_module$		
Calculating frequency	daily		

Calculation Methodology	
Step	**Description**
01-	Obtain correction factor for PV from the service
02	Obtain historical degradation parameter from the service
03	Check the values for PV plant/string or inverter level
04	Compared to the predefined threshold (eg. 75% for module efficiency), 0 or 1 for the inverters

Data Source				
Data description	**Data source**	Data collection frequency	Data collection time range	Data Owner
E.G., energy consumption	E.g., EMS	daily	daily	

10.2.2. LLUC P 2a-05

KPI N°1				
KPI-Name	Increase in PV insertion capacity		**KPI-ID**	KPI-8
Description	Estimate how many PVs can be integrated into LV grid (and where) before a grid limitation is reached (e.g., overvoltage limit). Increase is compared to actual installed PV capacity on LV grid.			
Unit	%			
Formula	$\frac{P_{max}(Vmax)}{P_{installedPV}} * 100\%$ V_{max} according to EN-50160			
Calculating frequency	Once per installation			
Calculation Methodology				
Step	**Description**			
01-	Obtain the maximal daily grid voltage from PMU			
02	For certain period and for estimated worst case scenario condition estimate max grid Voltage.			
03	Calculate the capacity			
Data Source				
Data description	**Data source**	Data collection frequency	Data collection time range	Data Owner
Grid voltage	EMS / PMU	50 Hz	months	

10.2.3. LLUC P 2a-03

KPI N°1a			
KPI-Name	Load Forecasting Mean Absolute Error	**KPI-ID**	LLUC 2a-03 KPI 1a
Description	This KPI is supposed to provide precision performance estimation for Load Forecasting models.		
Unit	[W]		
Formula	$= \frac{1}{n}\sum_{i=1}^{n}\lvert e_i \rvert$		

	where e_i is difference between estimated and real load and n is number of samples for which KPI is calculated.			
Calculating frequency	This KPI should be evaluated daily or monthly			
Calculation Methodology				
Step	**Description**			
01-	Estimated and real load from the PLATOON platform should be obtained and KPI should be calculated according to the formula above.			
Data Source				
Data description	**Data source**	Data collection frequency	Data collection time range	Data Owner
Energy consumption	MySQL	hourly	daily, monthly, yearly	IMP

KPI N°1b			
KPI-Name	Load Forecasting Mean Absolute Percentage Error	**KPI-ID**	LLUC 2a-03 KPI 1b
Description	This KPI is supposed to provide precision performance estimation for Load Forecasting models, similarly to the previous one, but normalized.		
Unit	[%]		
Formula	$$= \frac{1}{n}\sum_{i=1}^{n}\frac{\lvert e_i\rvert}{d_i}$$ where e_i is difference between estimated and real load d_i, and n is number of samples for which KPI is calculated.		
Calculating frequency	This KPI should be evaluated daily or monthly		
Calculation Methodology			
Step	**Description**		
01-	Estimated and real load from the PLATOON platform should be obtained and KPI should be calculated according to the formula above.		
Data Source			

Data description	**Data source**	Data collection frequency	Data collection time range	Data Owner
Energy consumption	MySQL	hourly	daily, monthly, yearly	IMP

KPI N°2a				
KPI-Name	Load Forecasting Root Mean Square Error		**KPI-ID**	LLUC 2a-03 KPI 2a
Description	This KPI is supposed to provide precision performance estimation for Load Forecasting models.			
Unit	[W]			
Formula	$= \sqrt{\frac{1}{n}\sum_{i=1}^{n} e_i^2}$ where e_i is difference between estimated and real load, and n is number of samples for which KPI is calculated.			
Calculating frequency	This KPI should be evaluated daily or monthly			
Calculation Methodology				
Step	**Description**			
01-	Estimated and real load from the PLATOON platform should be obtained and KPI should be calculated according to the formula above.			
Data Source				
Data description	**Data source**	Data collection frequency	Data collection time range	Data Owner
Energy consumption	MySQL	hourly	daily, monthly, yearly	IMP

KPI N°2b			
KPI-Name	Load Forecasting Root Mean Square Error Percentage	**KPI-ID**	LLUC 2a-03 KPI 2b
Description	This KPI is supposed to provide precision performance estimation for Load Forecasting models, similarly to the previous one, but normalized.		
Unit	[%]		
Formula	$= \frac{\sqrt{\frac{1}{n}\sum_{i=1}^{n} e_i^2}}{\frac{\sum_{i=1}^{n} d_i}{n}}$ where e_i is difference between estimated and real load (d_i), and n is number of samples for which KPI is calculated.		
Calculating frequency	This KPI should be evaluated daily or monthly		
Calculation Methodology			

Step	Description			
01-	Estimated and real load from the PLATOON platform should be obtained and KPI should be calculated according to the formula above.			
Data Source				
Data description	**Data source**	Data collection frequency	Data collection time range	Data Owner
Energy consumption	MySQL	hourly	daily, monthly, yearly	IMP

10.2.4. LLUC P 2a-04

KPI N°1a			
KPI-Name	Production Forecasting Mean Absolute Error	**KPI-ID**	LLUC 2a-04 KPI 1a
Description	This KPI is supposed to provide precision performance estimation for Production Forecasting models.		
Unit	[W]		
Formula	$$= \frac{1}{n}\sum_{i=1}^{n}\lvert e_i \rvert$$ where e_i is difference between estimated and real production and n is number of samples for which KPI is calculated.		
Calculating frequency	This KPI should be evaluated daily or monthly		

Calculation Methodology				
Step	**Description**			
01-	Estimated and real production from the PLATOON platform should be obtained and KPI should be calculated according to the formula above.			
Data Source				
Data description	**Data source**	Data collection frequency	Data collection time range	Data Owner
Energy production	MySQL	hourly	daily, monthly, yearly	IMP

KPI N°1b				
KPI-Name	Production Forecasting Mean Absolute Percentage Error		**KPI-ID**	LLUC 2a-04 KPI 1b
Description	This KPI is supposed to provide precision performance estimation for Production Forecasting models, similarly to the previous one, but normalized.			
Unit	[%]			
Formula	$$=\frac{1}{n}\sum_{i=1}^{n}\frac{\lvert e_i\rvert}{p_i}$$ where e_i is difference between estimated and real production p_i, and n is number of samples for which KPI is calculated.			
Calculating frequency	This KPI should be evaluated daily or monthly			
Calculation Methodology				
Step	**Description**			
01-	Estimated and real production from the PLATOON platform should be obtained and KPI should be calculated according to the formula above.			
Data Source				
Data description	**Data source**	Data collection frequency	Data collection time range	Data Owner
Energy consumption	MySQL	hourly	daily, monthly, yearly	IMP

KPI N°2a			
KPI-Name	Production Forecasting Root Mean Square Error	**KPI-ID**	LLUC 2a-04 KPI 2a
Description	This KPI is supposed to provide precision performance estimation for Production Forecasting models.		
Unit	[W]		
Formula	$$=\sqrt{\frac{1}{n}\sum_{i=1}^{n}e_i^2}$$ where e_i is difference between estimated and real production, and n is number of samples for which KPI is calculated.		
Calculating frequency	This KPI should be evaluated daily or monthly		
Calculation Methodology			
Step	**Description**		

01-	Estimated and real production from the PLATOON platform should be obtained and KPI should be calculated according to the formula above.			
Data Source				
Data description	**Data source**	Data collection frequency	Data collection time range	Data Owner
Energy consumption	MySQL	hourly	daily, monthly, yearly	IMP

KPI N°2b			
KPI-Name	Production Forecasting Root Mean Square Error Percentage	**KPI-ID**	LLUC 2a-04 KPI 2b
Description	This KPI is supposed to provide precision performance estimation for Production Forecasting models, similarly to the previous one, but normalized.		
Unit	[%]		
Formula	$$= \frac{\sqrt{\frac{1}{n}\sum_{i=1}^{n} e_i^2}}{\frac{\sum_{i=1}^{n} p_i}{n}}$$ where e_i is difference between estimated and real production (p_i), and n is number of samples for which KPI is calculated.		
Calculating frequency	This KPI should be evaluated daily or monthly		
Calculation Methodology			
Step	**Description**		
01-	Estimated and real production from the PLATOON platform should be obtained and KPI should be calculated according to the formula above.		

Data Source				
Data description	**Data source**	Data collection frequency	Data collection time range	Data Owner
Energy consumption	MySQL	hourly	daily, monthly, yearly	IMP

10.3. Pilot 2b Electricity Grid Stability, Connectivity and Life cycle

10.3.1. LLUC P 2b-01

KPI N°1				
KPI-Name	Temperature estimation accuracy (%)		**KPI-ID**	01
Description	Hourly temperature accuracy estimation based on estimated temperature (ET) and actual (measured) temperature (AT) for top oil.			
Unit	None			
Formula	(ET-AT)/AT (%)			
Calculating frequency	Hourly			
Calculation Methodology				
Step	**Description**			
01-	Model the top oil temperature using machine learning/deep learning.			
02	Compare the prediction obtained using our model with the real values obtained from the sensor.			
Data Source				
Data description	**Data source**	Data collection frequency	Data collection time range	Data Owner
Transformer Temperature and load	Transformer Temperature sensors database S02	15 min	unknown	SAMPOL

KPI N°2			
KPI-Name	True positives (TP)	**KPI-ID**	02
Description	Number of anomalies detected with early warnings and confirmed with a corrective work order		
Unit	None		
Formula			
Calculating frequency	Hourly		

Calculation Methodology				
Step	**Description**			
01-	Obtain the warnings of needed corrective order given by the model.			
02	Calculate the number of corrective orders that are predicted and applied.			
Data Source				
Data description	**Data source**	Data collection frequency	Data collection time range	Data Owner
Transformer Temperature and load	Transformer Temperature sensors database S02	15 min	unknown	SAMPOL

KPI N°3			
KPI-Name	False positives (FP)	**KPI-ID**	03
Description	Early warnings with no associated corrective work order		
Unit	None		
Formula			
Calculating frequency	Hourly		

Calculation Methodology				
Step	**Description**			
01-	Obtain the warnings of needed corrective order given by the model.			
02	Calculate the number of corrective orders that are predicted but not applied.			
Data Source				
Data description	**Data source**	Data collection frequency	Data collection time range	Data Owner
Transformer Temperature and load	Transformer Temperature sensors database S02	15 min	unknown	SAMPOL

KPI N°4				
KPI-Name	False negatives (FN)		**KPI-ID**	04
Description	Corrective work order without a previous early warning.			
Unit	None			
Formula				
Calculating frequency	Hourly			
Calculation Methodology				
Step	**Description**			
01-	Obtain the warnings of needed corrective order given by the model.			
02	Calculate the number of corrective orders that are not predicted and applied.			
Data Source				
Data description	**Data source**	Data collection frequency	Data collection time range	Data Owner
Transformer Temperature and load	Transformer Temperature sensors database S02	15 min	unknown	SAMPOL

KPI N°5			
KPI-Name	True Negatives (TN)	**KPI-ID**	05
Description	No early warning and no work order		
Unit	None		
Formula			
Calculating frequency	Hourly		
Calculation Methodology			
Step	**Description**		
01-	Obtain the warnings of needed corrective order given by the model.		
02	Calculate the number of corrective orders that are not predicted and not applied.		

Data Source				
Data description	**Data source**	Data collection frequency	Data collection time range	Data Owner
Transformer Temperature and load	Transformer Temperature sensors database S02	15 min	unknown	SAMPOL

KPI N°6					
KPI-Name	Specificity (%)		**KPI-ID**	06	
Description	Proportion of true negatives relative to all negative cases.				
Unit					
Formula	(TN/(TN+FP))				
Calculating frequency	Hourly				
Calculation Methodology					
Step	**Description**				
01-	Obtain the proportion of transformers that does not need a corrective order that are correctly identified.				
Data Source					
Data description	**Data source**	Data collection frequency	Data collection time range	Data Owner	
Transformer Temperature and load	Transformer Temperature sensors database S02	15 min	unknown	SAMPOL	

KPI N°7			
KPI-Name	Sensitivity (%)	**KPI-ID**	07
Description	Proportion of actual needed corrective order correctly identified		
Unit	None		
Formula	(TP/(TP+FN))		
Calculating frequency	Hourly		
Calculation Methodology			

Step	**Description**			
01-	Obtain the proportion of transformers that need a corrective order that are correctly identified.			
Data Source				
Data description	**Data source**	Data collection frequency	Data collection time range	Data Owner
Transformer Temperature and load	Transformer Temperature sensors database S02	15 min	unknown	SAMPOL

KPI N°8					
KPI-Name	Cohen's Kappa (%)		**KPI-ID**	08	
Description	Measurement of matches in the predictive tool discounting the probability of randomly matching				
Unit	None				
Formula	$K = \frac{p_0 - p_e}{1-p_e}$, where $p_0 = \frac{TP+TN}{TP+TN+FP+FN}$ and $p_e = p_{Yes} + p_{No} = \frac{TP+FP}{TP+TN+FP+FN} \frac{TP+FN}{TP+TN+FP+FN} + \frac{FP+TN}{TP+TN+FP+FN} \frac{FN+TN}{TP+TN+FP+FN}$				
Calculating frequency	Hourly				
Calculation Methodology					
Step	**Description**				
01-	Calculate the TP,TN,FP,FN.				
02	Apply the formula to obtain the needed corrective orders not well predicted randomly.				
Data Source					
Data description	**Data source**	Data collection frequency	Data collection time range	Data Owner	
Transformer Temperature and load	Transformer Temperature sensors database S02	15 min	unknown	SAMPOL	

KPI N°9			
KPI-Name	Savings (€)	**KPI-ID**	09

Description	Cumulative measurement of savings associated to True Positives considering: a) Avoided breakdown consequences + b) Downtime cost			
Unit	€			
Formula				
Calculating frequency	Hourly			
Calculation Methodology				
Step	**Description**			
01-	Calculate the breakdown caused by the failure that has been predicted and corrected and the downtime that it should have caused.			
02	Obtain the monetary compensation that this downtime and breakdown should have caused.			
Data Source				
Data description	**Data source**	Data collection frequency	Data collection time range	Data Owner
Transformer Temperature and load	Transformer Temperature sensors database S02	15 min	unknown	SAMPOL

KPI N°10				
KPI-Name	Additional Costs (€)		**KPI-ID**	10
Description	Increased costs due to maintenance activities associated to False Positives. They should be subtracted from Savings to get the net value.			
Unit	€			
Formula				
Calculating frequency	Hourly			
Calculation Methodology				
Step	**Description**			
01-	Obtain the cost of maintenance caused due to false positives.			
Data Source				
Data description	**Data source**	Data collection frequency	Data collection time range	Data Owner

Transformer Temperature and load	Transformer Temperature sensors database S02	15 min	unknown	SAMPOL

KPI N°11				
KPI-Name	Anticipation time (days)		**KPI-ID**	11
Description	For each True Positive it represents the delta Time between the moment of detection and the time of failure.			
Unit	Seconds|Minutes|Days			
Formula				
Calculating frequency	Hourly			
Calculation Methodology				
Step	**Description**			
01-	Predict the failure dates of the transformers and obtain the difference between the predicted date and the real failure dates.			
Data Source				
Data description	**Data source**	Data collection frequency	Data collection time range	Data Owner
Transformer Temperature and load	Transformer Temperature sensors database S02	15 min	unknown	SAMPOL

KPI N°12			
KPI-Name	Risk decrease (€)	**KPI-ID**	12
Description	Risk decrease comparing risk-based maintenance supported by the tool to the ordinary preventive maintenance (equal maintenance expenditure is assumed in both cases)		
Unit	€		
Formula			
Calculating frequency	Hourly		
Calculation Methodology			
Step	**Description**		

01-	Calculate the ordinary risk of failure and predicted risk of failure. Multiply this by the cost of maintenance.			
02	Obtain the difference between the cost * risk between the tool and the actual maintenance strategy.			
Data Source				
Data description	**Data source**	Data collection frequency	Data collection time range	Data Owner
Transformer Temperature and load	Transformer Temperature sensors database S02	15 min	unknown	SAMPOL

KPI N°13			
KPI-Name	Maintenance cost savings (€)	**KPI-ID**	13
Description	Maintenance cost savings comparing risk-based maintenance supported by the tool to the ordinary preventive maintenance (equal risk level is assumed in both cases)		
Unit	€		
Formula			
Calculating frequency	Hourly		
Calculation Methodology			
Step	**Description**		
01-	Calculate the costs of ordinary maintenance and predicted maintenance.		
02	Obtain the difference between predicted maintenance cost and ordinary maintenance cost.		

Data Source				
Data description	**Data source**	Data collection frequency	Data collection time range	Data Owner
Transformer Temperature and load	Transformer Temperature sensors database S02	15 min	unknown	SAMPOL

KPI N°14			
KPI-Name	Useful Life Extension (years)	**KPI-ID**	14

Description	Based on the estimation of the RUL (Remaining Useful Time) it indicates the achievable extension of life relative to that indicated by the manufacturer			
Unit	Years/months			
Formula	Previous RUL- loss of life since last RUL calculation			
Calculating frequency	Daily			
Calculation Methodology				
Step	**Description**			
01-	Apply the standards to obtain the HST from the TOT			
02	Apply the standards to calculate the useful life decreasement from the TOT.			
Data Source				
Data description	**Data source**	Data collection frequency	Data collection time range	Data Owner
Transformer Temperature and load	Transformer Temperature sensors database S02	15 min	unknown	SAMPOL

10.3.2. LLUC P 2b-02

KPI N°1			
KPI-Name	Global Losses Energy Percentage	**KPI-ID**	NTL-KPI-01
Description	Percentage of the energy that is provided from a MV substation or LV CT that is not settle to any consumer and is therefore lost. To be averaged in long periods (at least months).		
Unit	None		
Formula	NTL-KPI-01 = NTL-KPI-02 + NTL-KPI-03		
Calculating frequency	Hourly/Daily		
Calculation Methodology			
Step	**Description**		
01-	Calculate the total consumption of all customers.		

02	Calculate the percentage of the customers consumptions over the energy provided by the power transformer.			
Data Source				
Data description	**Data source**	Data collection frequency	Data collection time range	Data Owner
Data obtained from the Parc Bit distribution Grid	S02	1 hour	2016-10-19 00:00:00, 2020-10-16 04:00:00,	SAMPOL

KPI N°2			
KPI-Name	NTL Energy Percentage	**KPI-ID**	NTL-KPI-02
Description	Percentage of the energy that is provided from a MV substation or LV CT that is lost due to NTL		
Unit	None		
Formula	NTL-KPI-02 = NTL-KPI-04 + NTL-KPI-05		
Calculating frequency	Hourly/Daily		
Calculation Methodology			
Step	**Description**		
01-	Calculate the NTL caused by consumers and non-consumers.		
02			

Data Source				
Data description	**Data source**	Data collection frequency	Data collection time range	Data Owner
Data obtained from the Parc Bit distribution Grid	S02	1 hour	2016-10-19 00:00:00, 2020-10-16 04:00:00,	SAMPOL

KPI N°3			
KPI-Name	TL Energy Percentage	**KPI-ID**	NTL-KPI-03
Description	Percentage of the energy that is provided from a MV substation or LV CT that is lost due to TL		

Unit	None			
Formula	None			
Calculating frequency	Hourly/Daily			
Calculation Methodology				
Step	**Description**			
01-	Obtain the characteristics of the distribution grid.			
02	Calculate the expected technical loses.			
Data Source				
Data description	**Data source**	Data collection frequency	Data collection time range	Data Owner
Data obtained from the Parc Bit distribution Grid	S02	1 hour	2016-10-19 00:00:00, 2020-10-16 04:00:00,	SAMPOL

KPI N°4			
KPI-Name	Customer NTL Energy Percentage	**KPI-ID**	NTL-KPI-04
Description	Percentage of the energy that is provided from a MV substation or LV CT that is lost due to fraud executed by customers. This portion of NTL is more likely to be avoided after it is detected, as legal actions can be taken against the connection point contractors.		
Unit	None		
Formula	None		
Calculating frequency	Hourly/Daily		
Calculation Methodology			
Step	**Description**		
01-	Subtract the technical loses to the total loses.		
02	Obtain the part of the result that can be imputed to customers.		
Data Source			

Data description	**Data source**	Data collection frequency	Data collection time range	Data Owner
Data obtained from the Parc Bit distribution Grid	S02	1 hour	2016-10-19 00:00:00, 2020-10-16 04:00:00,	SAMPOL

KPI N°5			
KPI-Name	Non-Customer NTL Energy Percentage	**KPI-ID**	NTL-KPI-05
Description	Percentage of the energy that is provided from a MV substation or LV CT that is lost due to fraud executed by non-customers. This energy is stolen by non-permitted connections to the grid, which are difficult to be located physically.		
Unit	None		
Formula	None		
Calculating frequency	Hourly/Daily		
Calculation Methodology			
Step	**Description**		
01-	Subtract the technical loses to the total loses.		
02	Obtain the part of the result that can not be imputed to customers.		
Data Source			

Data description	**Data source**	Data collection frequency	Data collection time range	Data Owner
Data obtained from the Parc Bit distribution Grid	S02	1 hour	2016-10-19 00:00:00, 2020-10-16 04:00:00,	SAMPOL

KPI N°6			
KPI-Name	True positives (TP)	**KPI-ID**	NTL-KPI-06
Description	Number of customers identified as fraud authors in the NTL identification scenario which are verified to be committing fraud		
Unit	None		
Formula	None		

Calculating frequency	Hourly/Daily			
Calculation Methodology				
Step	**Description**			
01-	Obtain the customers that can be causing NTL using the developed models and identify if they are really causing NTL			
02	Calculate the number of customers that are predicted as causing NTL and are really causing NTL.			
Data Source				
Data description	**Data source**	Data collection frequency	Data collection time range	Data Owner
Data obtained from the Parc Bit distribution Grid	S02	1 hour	2016-10-19 00:00:00, 2020-10-16 04:00:00,	SAMPOL

KPI N°7			
KPI-Name	False positives (FP)	**KPI-ID**	NTL-KPI-07
Description	Number of customers identified as fraud authors in the NTL identification scenario which are not committing fraud, as result of a verification action		
Unit	None		
Formula	None		
Calculating frequency	Hourly/Daily		

Calculation Methodology				
Step	**Description**			
01-	Obtain the customers that can be causing NTL using the developed models and identify if they are really causing NTL			
02	Calculate the number of customers that are predicted as causing NTL and are not causing NTL.			
Data Source				
Data description	**Data source**	Data collection frequency	Data collection time range	Data Owner
Data obtained from the Parc Bit distribution Grid	S02	1 hour	2016-10-19 00:00:00, 2020-10-16 04:00:00,	SAMPOL

KPI N°8				
KPI-Name	False negatives (FN)		**KPI-ID**	NTL-KPI-08
Description	Number of customers which are not identified as fraud authors in the NTL identification scenario but are really committing fraud			
Unit	None			
Formula	None			
Calculating frequency	Hourly/Daily			
Calculation Methodology				
Step	**Description**			
01-	Obtain the customers that can be causing NTL using the developed models and identify if they are really causing NTL			
02	Calculate the number of customers that are predicted as not causing NTL and are really causing NTL.			
Data Source				
Data description	**Data source**	Data collection frequency	Data collection time range	Data Owner
Data obtained from the Parc Bit distribution Grid	S02	1 hour	2016-10-19 00:00:00, 2020-10-16 04:00:00,	SAMPOL

KPI N°9			
KPI-Name	True negatives (TN)	**KPI-ID**	NTL-KPI-09
Description	Number of customers which are not identified as fraud authors in the NTL identification scenario, and are not really committing fraud.		
Unit	None		
Formula	None		
Calculating frequency	Hourly/Daily		
Calculation Methodology			
Step	**Description**		

01-	Obtain the customers that can be causing NTL using the developed models and identify if they are really causing NTL			
02	Calculate the number of customers that are predicted as not causing NTL and are really not causing NTL.			
Data Source				
Data description	**Data source**	Data collection frequency	Data collection time range	Data Owner
Data obtained from the Parc Bit distribution Grid	S02	1 hour	2016-10-19 00:00:00, 2020-10-16 04:00:00,	SAMPOL

KPI N°10					
KPI-Name	Specificity (%)		**KPI-ID**	NTL-KPI-10	
Description	Proportion of true negatives relative to all negative cases.				
Unit	None				
Formula	(TN/(TN+FP))				
Calculating frequency	Hourly/Daily				
Calculation Methodology					
Step	**Description**				
01-	Obtain the proportion of negative cases of NTL that are correctly identified.				
02					
Data Source					
Data description	**Data source**	Data collection frequency	Data collection time range	Data Owner	
Data obtained from the Parc Bit distribution Grid	S02	1 hour	2016-10-19 00:00:00, 2020-10-16 04:00:00,	SAMPOL	

KPI N°11			
KPI-Name	Sensitivity (%)	**KPI-ID**	NTL-KPI-11

Description	Proportion of actual positives cases of NTL correctly identified.			
Unit	None			
Formula	(TP/(TP+FN))			
Calculating frequency	Hourly/Daily			
Calculation Methodology				
Step	**Description**			
01-	Obtain the proportion of positives that are correctly identified.			
02				
Data Source				
Data description	**Data source**	Data collection frequency	Data collection time range	Data Owner
Data obtained from the Parc Bit distribution Grid	S02	1 hour	2016-10-19 00:00:00, 2020-10-16 04:00:00,	SAMPOL

KPI N°12			
KPI-Name	Cohen's Kappa (%)	**KPI-ID**	NTL-KPI-12
Description	Measurement of matches in the NTL identification scenario discounting the probability of randomly matching.		
Unit	None		
Formula	$K = \frac{p_0 - p_e}{1 - p_e}$, where $p_0 = \frac{TP+TN}{TP+TN+FP+FN}$ and $p_e = p_{Yes} + p_{No} = \frac{TP+FP}{TP+TN+FP+FN} \frac{TP+FN}{TP+TN+FP+FN} + \frac{FP+TN}{TP+TN+FP+FN} \frac{FN+TN}{TP+TN+FP+FN}$		
Calculating frequency	Hourly/Daily		
Calculation Methodology			
Step	**Description**		
01-	Calculate the TP,TN,FP,FN.		

02	Apply the formula to obtain the NTL identifications not well predicted randomly.			
Data Source				
Data description	**Data source**	Data collection frequency	Data collection time range	Data Owner
Data obtained from the Parc Bit distribution Grid	S02	1 hour	2016-10-19 00:00:00, 2020-10-16 04:00:00,	SAMPOL

KPI N°13				
KPI-Name	Economic Savings		**KPI-ID**	NTL-KPI-13
Description	Economic savings due to detected non-technical losses.			
Unit	None			
Formula	None			
Calculating frequency	Hourly/Daily			
Calculation Methodology				
Step	**Description**			
01-	Obtain the costs of energy production and impute the percentage of NTL to this costs.			
02				
Data Source				
Data description	**Data source**	Data collection frequency	Data collection time range	Data Owner
Data obtained from the Parc Bit distribution Grid	S02	1 hour	2016-10-19 00:00:00, 2020-10-16 04:00:00,	SAMPOL

10.4. Pilot # 3a Office building: operation performance thanks to physical models and IA algorithms

10.4.1. LLUC P-3a-01

KPI N°1			
KPI-Name	Deviation to target comfort during occupancy time	**KPI-ID**	KPI-1
KPI-Type	Technical/Business		
Description	The thermal comfort in the building is evaluated thanks to air temperature. During occupancy time, the objective is to be within the range of comfort defined by the building manager. The deviations to this range will be monitored during occupancy periods.		
Target Value	0.5°C to comfort range	**Threshold Value**	2°C to comfort range
Rounding	Rounding to 0.01		
Unit	°C		
Formula	During occupancy periods : $$\sum_{t=0}^{nb_{timestep}} \sum_{p=0}^{nb_{point}} \frac{error\big(T(t,p), Target_{range}\big) * w(p)}{nb_{timestep} * nb_{point} * \sum_{p=0}^{nb_{point}} w(p)}$$ T(t,p): temperature of the point p at the timestep t (during occupancy period) w(p) : weight of the point p (if any, default 0) Target_range : Interval of room temperature defined by the building manager that is considered as “acceptable”. Typically : [20°C-25°C] nb_timestep : number of regular timestep (hourly or less) in the period analyzed. nb_point : number of temperature sensor points		
Calculating frequency	According to need : daily, weekly, monthly …		
Calculation Methodology			
Step	**Description**		
01	Choice of a period, or calculation for default periods (days, weeks, months, years)		
02	For the given period considered (week, month, year), identification of the occupancy periods for the different zones defined in the building.		
03	Request of the temperature for the different occupancy periods of the different zones and application of the formula		

Data Source				
Data description	**Data source**	**Data collection frequency**	**Data collection time range**	**Data Owner**
Occupancy in the different zones	ENGIE IT – data occupancy	15 min	Ongoing in real time	ENGIE
Temperature in the different zones	BMS	15 min ?	Ongoing in real time	ENGIE
Config pilot	config	-	-	ENGIE

KPI N°2			
KPI-Name	Unnecessary HVAC heating emission	**KPI-ID**	KPI-2
KPI-Type	Technical/Business		
Description	Evaluate the amount of energy emission (heating or cooling) that could be considered as unnecessary regarding the actual building occupancy, especially when : ■ Preheating or precooling time over-anticipation ■ Heating/cooling but no one present for the rest of the day. The percentage of valve opening, attributed to a specific weight will be considered as the measure of the unnecessary heating or cooling emission.		
Target Value	<10%	**Threshold Value**	30%
Rounding	Rounding to 0.1%		
Unit	%		
Formula	$$\frac{\sum_{v=0}^{nb_{nb\_valve}} \sum_{t \in [unecessary\ heating]} Op_h(v,t) * P_{max,h}(v)}{\sum_{v=0}^{nb_{nb_{valve}}} \sum_{t \in [whole\ period]} Op_h\ (v,t) * P_{max,h}(v)}$$ With : [Unnecessary heating] : ▪ Last period at the end of the day when the zone is unoccupied but heating still happening. ▪ First period of the day when the zone is unoccupied, heating is happening, but preheating period is finished (Tzone-Tsetpoint<Tref_lim) Op_h (v,t) : opening of the valve v for heating during the time step t $P_{max,h}$ (v) : Maximum power of the heat emissions behind the valve v		
Calculating frequency	According to need : daily, weekly, monthly …		
Calculation Methodology			

Step	Description			
01-	Choice of a period, or calculation for default periods (days, weeks, months, years)			
02	Identification of time periods for each valve where : - Last period at the end of the day when the zone is unoccupied, but heating still happening (over anticipation) - First period of the day when the zone is unoccupied, heating is happening, but preheating period is finished (Tzone-Tsetpoint<Tref_lim)			
03	For the different periods identified, and for the different zones and valves considered, the above formula can be calculated			
Data Source				
Data description	**Data source**	**Data collection frequency**	**Data collection time range**	**Data Owner**
Temperature in the different zones	BMS	15 min ?	Ongoing in real time	ENGIE
Valve opening in the different zones	BMS	15 min ?	Ongoing in real time	ENGIE
Temperature setpoints in the different zones	BMS	15 min ?	Ongoing in real time	ENGIE
Config pilot	config	-	-	ENGIE

KPI N°3			
KPI-Name	Unnecessary HVAC cooling emission	**KPI-ID**	KPI-2bis
KPI-Type	Technical/Business		
Description	Evaluate the amount of energy emission (heating or cooling) that could be considered as unnecessary regarding the actual building occupancy, especially when : ■ Preheating or precooling time over-anticipation ■ Heating/cooling but no one present for the rest of the day. The percentage of valve opening, attributed to a specific weight will be considered as the measure of the unnecessary heating or cooling emission.		
Target Value	<10%	**Threshold Value**	30%
Rounding	Rounding to 0.1%		
Unit	%		

Formula	$$\frac{\sum_{v=0}^{nb_{nb\_valve}} \sum_{t\,\epsilon\,[necessary\ heating]} Op_c(v,t) * P_{max,c}(v)}{\sum_{v=0}^{nb_{nb_{valve}}} \sum_{t\,\epsilon\,[whole\ period]} Op_c\,(v,t) * P_{max,c}(v)}$$ With : [Unnecessary heating periods] : ▪ Last period at the end of the day when the zone is unoccupied, but heating still happening. ▪ First period of the day when the zone is unoccupied, heating is happening, but preheating period is finished (Tzone-Tsetpoint<Tref_lim) Op_c (v,t) : opening of the valve v for cooling during the time step t $P_{max,c}$ (v) : Maximum power of the cooling emissions behind the valve v
Calculating frequency	According to need : daily, weekly, monthly …
Calculation Methodology	
Step	**Description**
01-	Choice of a period, or calculation for default periods (days, weeks, months, years)
02	Identification of time periods for each valve where : - Last period at the end of the day when the zone is unoccupied, but cooling still happening (over anticipation) - First period of the day when the zone is unoccupied, cooling is happening, but precooling period is finished (Tzone-Tsetpoint<Tref_lim)
03	For the different periods identified, and for the different zones and valves considered, the above formula can be calculated

Data Source

Data description	Data source	Data collection frequency	Data collection time range	Data Owner
Temperature in the different zones	BMS	15 min ?	Ongoing in real time	ENGIE
Valve opening in the different zones	BMS	15 min ?	Ongoing in real time	ENGIE
Temperature setpoints in the different zones	BMS	15 min ?	Ongoing in real time	ENGIE
Config pilot	config	-	-	ENGIE

KPI N°4			
KPI-Name	Gain on heating consumption	**KPI-ID**	KPI-3
KPI-Type	Technical/Business		
Description	Climate corrected gain on heating energy consumption in comparison with the consumption of the previous year		
Target Value	>10%	**Threshold Value**	0%
Rounding	0.1%		
Unit	%		
Formula	For a given period : $$\frac{Cs_{ht,p} * HDD(p,Text(p)) - Cs_{ht,p\_py} * HDD(p\_py,Text(p\_py))}{Cs_{ht,p\_py} * HDD(p\_py,Text(p\_py))}$$ With : $Cs_{ht,p}$: energy consumption for heating during the period p Cs_{ht,p_py} : energy consumption for heating during the period p but the previous year HDD(p,Text(p)) : Heating degree day for the period p and the external temperature over the period HDD(p,Text(p)) : Heating degree day for the period p of the previous year and the external temperature during this period ***à cf. formula of calculation HDD at the end of the document***.		
Calculating frequency	On request		

Calculation Methodology	
Step	**Description**
01-	Choice of a period, or calculation for default periods (days, weeks, months, years) *à Data of the previous year over the same period has to be available*
02	Application of the formula

Data Source				
Data description	**Data source**	**Data collection frequency**	**Data collection time range**	**Data Owner**
Energy consumption for heating	BMS	15 min ?	Ongoing in real time	ENGIE
External temperature setpoint	BMS/	1h or less	Defined periods	ENGIE

KPI N°5			
KPI-Name	Gain on cooling consumption	**KPI-ID**	KPI-4
KPI-Type	Technical/Business		
Description	Climate corrected gain on cooling energy consumption in comparison with the consumption of the previous year		
Target Value	>10%	**Threshold Value**	0%
Rounding	0.1%		
Unit	%		
Formula	For a given period : $$\frac{Cs_{c,p} * CDD\big(p, Text(p)\big) - Cs_{c,p\_py} * CDD\big(p\_py, Text(p\_py)\big)}{Cs_{c,p\_py} * CDD\big(p\_py, Text(p\_py)\big)}$$ With : $Cs_{ht,p}$: energy consumption for cooing during the period p Cs_{ht,p_py} : energy consumption for cooling during the period p but the previous year CDD(p,Text(p)) : cooling degree day for the period p and the external temperature over the period CDD(p,Text(p)) : cooling degree day for the period p of the previous year and the external temperature during this period ***→ cf. formula of calculation CDD at the end of the document***.		
Calculating frequency	On request		

Calculation Methodology	
Step	**Description**
01-	Choice of a period, or calculation for default periods (days, weeks, months, years) *→ Data of the previous year over the same period has to be available*
02	Application of the formula

Data Source				
Data description	**Data source**	**Data collection frequency**	**Data collection time range**	**Data Owner**
Energy consumption for cooling	BMS	15 min ?	Ongoing in real time	ENGIE
External temperature setpoint	BMS/	1h or less	Defined periods	ENGIE

10.4.2. LLUC P-3a-02: Provide Demand Response services through building inertia and HVAC controls

KPI N°1			
KPI-Name	Mean error on heating load prediction	**KPI-ID**	KPI-1
KPI-Type	Technical/Business		
Description	Mean error (%) on the HVAC heating load prediction calculated every 30min as the errors between the predicted and the realized energy consumption and the predicted one (when HVAC is operating).		
Target Value	Error <10%	**Threshold Value**	Mean error above 20%
Rounding	0.1%		
Unit	%		
Formula	$$\sum_{t=0}^{nb_{timetep}} \frac{Cs_{ht,model}(t) - Cs_{ht,real}(t)}{Cs_{ht,real}(t) * nb_{timestep}}$$ With : $Cs_{ht,model}(t)$: heating consumption predicted by the model for the timestep t $Cs_{ht,\ real}(t)$: real heating consumption measured for the timestep t		
Calculating frequency	Once, daily, weekly, monthly …		
Calculation Methodology			
Step	**Description**		
01-	Choice of a period, or calculation for default periods (days, weeks, months, years)		
02	Application of formula		

Data Source				
Data description	**Data source**	**Data collection frequency**	**Data collection time range**	**Data Owner**
Energy consumption for heating	BMS	30 min	Ongoing in real time	ENGIE
Predicted energy consumption	Platoon tool	30 min	-	ENGIE

KPI N°2

KPI-Name	Mean error on cooling load prediction		**KPI-ID**	KPI-1bis
KPI-Type	Technical/Business			
Description	Mean error (%) on the HVAC cooling load prediction calculated every 30min as the errors between the predicted and the realized energy consumption and the predicted one (when HVAC is operating).			
Target Value	Error <10%	**Threshold Value**	Mean error above 20%	
Rounding	0.1%			
Unit	%			
Formula	$$\sum_{t=0}^{nb_{timetep}} \frac{Cs_{c,model}(t) - Cs_{c,real}(t)}{Cs_{c,real}(t) * nb_{timestep}}$$ With : $Cs_{c,model}(t)$: cooling consumption predicted by the model for the timestep t $Cs_{c, real}(t)$: real cooling consumption measured for the timestep t			
Calculating frequency	Once, daily, weekly, monthly …			
Calculation Methodology				
Step	**Description**			
01-	Choice of a period, or calculation for default periods (days, weeks, months, years)			
02	Application of formula			
Data Source				
Data description	**Data source**	**Data collection frequency**	**Data collection time range**	**Data Owner**
Energy consumption for cooling	BMS	30 min	Ongoing in real time	ENGIE
Predicted energy consumption	Platoon tool	30 min	-	ENGIE

KPI N°3			
KPI-Name	95-percentile error on heating load prediction	**KPI-ID**	KPI-2
KPI-Type	Technical/Business		

Description	95-percentile Error on the HVAC heating load prediction calculated every 30min as the errors between the predicted and the realized energy consumption and the predicted one (when HVAC is operating).		
Target Value	Error <20%	**Threshold Value**	Mean error above 40%
Rounding	0.1%		
Unit	%		
Formula	Error on each timestep $$Err(t) = \frac{Cs_{ht,model}(t) - Cs_{ht,real}(t)}{Cs_{ht,real}(t)}$$ Then, identification of the 95-percentile of the Err(t) over the period With : $Cs_{ht,model}(t)$: heating consumption predicted by the model for the timestep t $Cs_{ht, real}(t)$: real heating consumption measured for the timestep t		
Calculating frequency	Once, daily, weekly, monthly …		
Calculation Methodology			
Step	**Description**		
01-	Choice of a period, or calculation for default periods (days, weeks, months, years)		
02	Application of the formula		

Data Source

Data description	**Data source**	**Data collection frequency**	**Data collection time range**	**Data Owner**
Energy consumption for heating	BMS	30 min	Ongoing in real time	ENGIE
Predicted energy consumption	Platoon tool	30 min	-	ENGIE

KPI N°4			
KPI-Name	95-percentile error on cooling load prediction	**KPI-ID**	KPI-2bis
KPI-Type	Technical/Business		
Description	Error (%) on the HVAC cooling load prediction calculated every 30min as the errors between the predicted and the realized energy consumption, divided by the predicted one (when HVAC is operating).		

	The error can be characterized over the period: mean, standard deviations, daily distribution, seasonal distribution.		
Target Value	Error <20%	**Threshold Value**	Mean error above 40%
Rounding	0.1%		
Unit	%		
Formula	Error on each timestep $$Err(t) = \frac{Cs_{c,model}(t) - Cs_{c,real}(t)}{Cs_{c,real}(t)}$$ Then, identification of the 95-percentile of the Err(t) over the period With : $Cs_{c,model}(t)$: cooling consumption predicted by the model for the timestep t $Cs_{c, real}(t)$: real cooling consumption measured or the timestep t		
Calculating frequency	Once, daily, weekly, monthly …		

Calculation Methodology	
Step	**Description**
01-	Choice of a period, or calculation for default periods (days, weeks, months, years)
02	Application of formula

Data Source

Data description	Data source	Data collection frequency	Data collection time range	Data Owner
Energy consumption for cooling	BMS	30 min	Ongoing in real time	ENGIE
Predicted energy consumption	Platoon tool	30 min	-	ENGIE

KPI N°5			
KPI-Name	Error on the flexibility prediction	**KPI-ID**	KPI-4
KPI-Type	Technical/Business		
Description	Error (%) on the prediction of “flexibility available” on the building, in term of time of interruption of heating or cooling in the building, during flexibility event implemented in the building.		

Target Value	Target : 10%		**Threshold Value**	30%
Rounding	0.1%			
Unit	%			
Formula	$$\frac{\mathrm{Time}_{\mathrm{int,model}} - \mathrm{Time}_{\mathrm{int,real}}}{\mathrm{Time}_{\mathrm{int,real}}}$$ Time_(int,model) : time of interruption planned in the model Time_(int, real) : actual time of interruption that was actually implemented in the building.			
Calculating frequency	After interruption event …			
Calculation Methodology				
Step	**Description**			
01-	Application of the formula			
Data Source				
Data description	**Data source**	**Data collection frequency**	**Data collection time range**	**Data Owner**
Predicted time of interruption	Platoon tool	30 min	-	ENGIE
Interruption	BMS	-	-	ENGIE

KPI N°6			
KPI-Name	Mean error on HVAC load prediction for days with load shifting programs	**KPI-ID**	KPI-5
KPI-Type	Technical/Business		
Description	Mean error (%) on the HVAC load prediction calculated every 30min as the errors between the predicted and the realized energy consumption and the predicted one (when HVAC is operating), in case of the implementation of a load shifting program (not the usual building operation)		
Target Value	Error <10%	**Threshold Value**	20%
Rounding	0.1%		
Unit	%		

Formula	$$\sum_{t=0}^{nb_{timetep}} \frac{Cs_{ht,c,model}(t) - Cs_{ht,c,real}(t)}{Cs_{ht,c,real}(t) * nb_{timestep}}$$ With : $Cs_{ht,c,model}$(t) : heating or cooling consumption predicted by the model for the timestep t $Cs_{ht, real}$(t) : real heating or cooling consumption measured for the timestep t			
Calculating frequency	For a day after implementation of load shifting program			
Calculation Methodology				
Step	**Description**			
01	Application of the formula			
Data Source				
Data description	**Data source**	**Data collection frequency**	**Data collection time range**	**Data Owner**
Energy consumption for heating	BMS	30 min	Ongoing in real time	ENGIE
Energy consumption for cooling	BMS	30 min	Ongoing in real time	ENGIE
Predicted energy consumption	Platoon tool	30 min	-	ENGIE

10.5. Pilot 3b - PI Advanced Energy Management System and Spatial (Multi-Scale) Predictive Models in the Smart City

10.5.1. LLUC-01

KPI N°1			
KPI-Name	Forecast Error	**KPI-ID**	PI_KPI01
KPI-Type	Technical		
Description	The KPI calculates the % of deviation between the energy consumption forecast and the actual consumption in the building. The KPI checks how closely the predictive model adheres to reality - Effectiveness		
Target Value	+-5%	**Threshold Value**	+-20%
Rounding	round off to 0% for values between 0.00 and 0.49 and to 1% for values above		
Unit	Kilowatt per hour (KWh)		
Formula	$$\mathbf{FE_i} = \frac{(F_{F,i} - F_{A,i})}{F_{A,i}} * 100$$ $$\mathbf{FE_M} = \frac{1}{N}\sum_i FE_i$$ FE_i= Forecast Error % of building “i” $F_{F,i}$ = Forecasted value of building “i” $F_{A,i}$ = Actual value of building “i” N = number of buildings utilized for the KPI calculation		
Calculating frequency	Weekly (Alert if Threshold Value is exceeded)		
Calculation Methodology			
Step	**Description**		
01	Select the time range and the specific building and the perimeter of calculation: 1. Total energy consumption or 2. Total energy consumption for Specific line (cooling/heating) in the building		
02	Calculate the forecast taking into account: – Real data consumption – Temperature and Humidity (internal and external) – Number of Customers and Employees – Building open hours and shift – Building Climate Zone, m^3		

03	Get the Real consumption data (of the target month) taking into account: - The full month active energy consumption (Total Active Energy) of the selected building or of a specific line (Detailed Energy Consumption)			
04	Apply the formula			
05	The formula will be applied for each one of the selected buildings, then arithmetic mean will be calculated from these selected values.			
Data Source				
Data description	**Data source**	**Data collection frequency**	**Data collection time range**	**Data Owner**
Office Registry	Building Data	At starting up and then occasionally, when changes occur	No Temporal Range	Poste Italiane
Building Calendar	Building Data	Monthly	From 01/01/2018	Poste Italiane
Total Active Energy consumption	Energy Consumption	Monthly		Poste Italiane
Detailed Energy Consumption DL_102	Energy Consumption	Monthly	TBD	Poste Italiane
Detailed Energy Consumption	Energy Consumption	Daily	From 01/01/2018	Poste Italiane
Temperature, Humidity	Weather		From 01/01/2018	External Services
Customers Number	Occupancy	Monthly	From 01/01/2018	Poste Italiane
Employees Number	Occupancy	Monthly	From 01/01/2018	Poste Italiane

KPI N°2				
KPI-Name	Building Benchmarking BtI_LY		**KPI-ID**	PI_KPI02
KPI-Type	Business			
Description	The KPI calculate, in % value, the difference in Energy consumption of a building with itself during the time. The comparison will be made with the previous year consumption			
Target Value	+-10%	**Threshold Value**	+-20%	
Rounding	round off to 0% for values between 0.00 and 0.49 and to 1% for values above			
Unit	Kilowatt per hour (KWh)			
Formula				

	$$\mathbf{B_{BTI_{LY,i}}} = \frac{(\mathrm{EC_{y,i}} - \mathrm{EC_{y-1,i}})}{\mathrm{EC_{y-1,i}}} * 100$$ $$\mathbf{B_{BTI_{LY,M}}} = \frac{1}{\mathrm{N}}\sum_{\mathrm{i}} \mathrm{B_{BTI_{LY,i}}}$$ BBTILY,i = Building "i" last year comparison (with itself) ECy,i = Energy Consumption in the time range for building "i" ECy-1, i= Energy Consumption in the same time range of the previous year for building "i" N = number of buildings utilized for the KPI calculation			
Calculating frequency	Weekly			
Calculation Methodology				
Step	**Description**			
01	The calculation takes into account: a. The time range (reference week) b. The time range for benchmark (the same week of the previous year) c. The building d. The perimeter of the analysis: Total energy consumption, or, where available the energy consumption of heating or cooling, lighting			
02	The formula will be applied for each one of the selected buildings, then arithmetic mean will be calculated from these selected values.			
03	Normalize both the consumptions by the comfort level (where available) Comfort level is a range of internal temperature and humidity that must be complied Comfort level = f (internal temperature, internal humidity) (Internal humidity, internal temperature) = f (external humidity, external temperature)			
Data Source				
Data description	**Data source**	**Data collection frequency**	**Data collection time range**	**Data Owner**
Office Registry	Building Data	At starting up and then occasionally, when changes occur	No Temporal Range	Poste Italiane
Building Calendar	Building Data	Monthly	From 01/01/2018	Poste Italiane
Detailed Energy Consumption	Energy Consumption	Daily	From 01/01/2018	Poste Italiane
Detailed Energy Consumption DL_102	Energy Consumption	Monthly	TBD	Poste Italiane
Total Active Energy consumption	Energy Consumption	Monthly	From 01/01/2018	Poste Italiane
Temperature, Humidity	Weather			External Services

KPI N°3			
KPI-Name	Building Benchmarking BtI_LWs	**KPI-ID**	PI_KPI03
KPI-Type	Business		
Description	The KPI calculate, in % value, the difference in Energy consumption of a building with itself during the time. The comparison will be made with the two previous weeks comsumptions		
Target Value	+-10%	**Threshold Value**	+-20%
Rounding	round off to 0% for values between 0.00 and 0.49 and to 1% for values above		
Unit	Kilowatt per hour (KWh)		
Formula	$$\mathbf{B_{BTI_{LW},i}} = \frac{(\mathrm{EC_{W,i}} - [\frac{\mathrm{EC_{W-1,i}} + \mathrm{EC_{W-2,i}}}{2}]}{(\mathrm{EC_{W-1,i}} + \mathrm{EC_{W-2,i}})/2} * 100$$ $$\mathbf{B_{BTI_{LW},M}} = \frac{1}{\mathrm{N}}\sum_{\mathrm{i}} \mathrm{B_{BTI_{LW},i}}$$ BBTILY,i = Building “i” comparison with two last weeks (with itself) ECw,i = Energy Consumption in the time range for building “i” ECW-1,i , ECW-2,i = Energy Consumption of the two previous weeks for building “i” N = number of buildings utilized for the KPI calculation		
Calculating frequency	Weekly		

Calculation Methodology	
Step	**Description**
01	The calculation takes into account: 2.1.1. The time range (reference week) 2.1.2. The time range for benchmark (the two previous weeks) 2.1.3. The building 2.1.4. The perimeter of the analysis: Total energy consumption, or, where available the energy consumption of heating or cooling, lighting
02	The formula will be applied for each one of the selected buildings, then arithmetic mean will be calculated from these selected values.
03	Normalize both the consumptions by the comfort level (where available) Comfort level is a range of internal temperature and humidity that must be complied Comfort level = f(internal temperature, internal humidity) (Internal humidity, internal temperature) = f (external humidity, external temperature)

Data Source				
Data description	**Data source**	**Data collection frequency**	**Data collection time range**	**Data Owner**

Office Registry	Building Data	At starting up and then occasionally, when changes occur	No Temporal Range	Poste Italiane
Building Calendar	Building Data	Monthly	From 01/01/2018	Poste Italiane
Detailed Energy Consumption	Energy Consumption	Daily	From 01/01/2018	Poste Italiane
Detailed Energy Consumption DL_102	Energy Consumption	Monthly	TBD	Poste Italiane
Total Active Energy consumption	Energy Consumption	Monthly	From 01/01/2018	Poste Italiane
Temperature, Humidity	Weather			External Services

KPI N°4			
KPI-Name	Building Benchmarking BtB	**KPI-ID**	PI_KPI04
KPI-Type	Business		
Description	The KPI calculate, in % value, the difference in Energy consumption between a cluster of buildings.		
Target Value	+-10%	**Threshold Value**	+-20%
Rounding	round off to 0% for values between 0.00 and 0.49 and to 1% for values above		
Unit	Kilowatt per hour (KWh)		
Formula	$$\mathbf{B_{BTB,i}} = \frac{\frac{B_i}{m_i^3} - (\sum_j \frac{B_j}{m_j^3})/(n-1)}{(\sum_j \frac{B_j}{m_j^3})/(n-1)} * 100$$ $$\mathbf{B_{BTB,M}} = \frac{1}{N}\sum_i B_{BTB,i}$$ $B_{BTB,i}$ = Building Energy Consumption comparison with the mean of the same cluster B_i = Energy Consumption of Building “i” B_j = = Energy Consumption of Building “j” (Some cluster of “i”, i.e., some typology and destination use) n = number of buildings in the cluster m^3 = volume of building N = number of buildings utilized for the KPI calculation		

Calculating frequency	Weekly (Alert if Threshold Value is exceeded)
Calculation Methodology	
Step	**Description**
01	The calculation takes into account: 1. The time range (current year last week) 2. The building types 3. The building's destination uses 4. the perimeter of the analysis: Total energy consumption or, where available the energy consumption of heating or cooling, lighting
02	The formula will be applied for each one of the selected buildings, then arithmetic mean will be calculated from these selected values.
03	Normalize the consumptions of both the buildings by the comfort level (where available). Comfort level* is a range of internal temperature and humidity that must be complied. *Comfort level = f(internal temperature, internal humidity) (Internal humidity, internal temperature) = f(external humidity, external temperature)

Data Source				
Data description	**Data source**	**Data collection frequency**	**Data collection time range**	**Data Owner**
Office Registry	Building Data	At starting up and then occasionally, when changes occur	No Temporal Range	Poste Italiane
Building Calendar	Building Data	Monthly	From 01/01/2018	Poste Italiane
Detailed Energy Consumption	Energy Consumption	Daily	From 01/01/2018	Poste Italiane
Detailed Energy Consumption DL_102	Energy Consumption	Monthly	TBD	Poste Italiane
Total Active Energy consumption	Energy Consumption	Monthly	From 01/01/2018	Poste Italiane
Temperature, Humidity	Weather		From 01/01/2018	External Services

KPI N°5			
KPI-Name	CO2 emission reduction	**KPI-ID**	PI_KPI05
KPI-Type	Business		
Description	The KPI calculate the impact of energy consumption reduction on CO2 emissions in a time range		
Target Value	≥ 10%	**Threshold Value**	0≤ $\Delta(\mathbf{CO_2})_{y,M}$ <10%

Rounding	round off to 0 for values between 0.00 and 0.49 and to 1 for values above
Unit	Kg
Formula	$\Delta(\mathbf{KWh})_{y,i} = \frac{\text{Budget (Kwh)}_{y,i} - \text{Consumption (Kwh)}_{y,i}}{\text{Consumption (Kwh)}_{y,i}} * 100$ $\Delta(\mathbf{KWh})_{\mathbf{y,i}} = \Delta(\mathbf{CO_2})_{\mathbf{y,i}}$ Because $C_{O2}\text{ (Kg)} = 0{,}36099 * \text{Energy (KWh)}$ Finally $\Delta(\mathbf{CO_2})_{\mathbf{y,M}} = \frac{1}{M}\sum_{i}\Delta(CO_2)_{y,i}$ Budget (kWh)y,i = yearly budget of building “i” Consumption (kWh)y,I = yearly consumption of building “i” Δ(KWh) y,i = consumption saving percentage of building “i” Δ (CO_2) y,I = CO_2 saving percentage of building “i” M = number of buildings utilized for the KPI calculation
Calculating frequency	Yearly

Calculation Methodology

Step	**Description**
01	Calculate the yearly total consumption of the building
02	The formula will be applied for each one of the selected buildings, then arithmetic mean will be calculated from these selected values.

Data Source

Data description	**Data source**	**Data collection frequency**	**Data collection time range**	**Data Owner**
Office Registry	Building Data	At starting up and then occasionally, when changes occur	Static - No Temporal Range	Poste Italiane
Building Calendar	Building Data	Monthly	From 01/01/2018	Poste Italiane
Total Active Energy consumption	Energy Consumption	Monthly	From 01/01/2018	Poste Italiane

10.5.2. LLUC-02

KPI N°6			
KPI-Name	Recall	**KPI-ID**	PI_KPI06
KPI-Type	Technical		
Description	The KPI measures the number of cases which correctly classified as problematic (True Positives) by the algorithm divided by the sum of the cases that were classified as normal but actually were problematic (False Positives) plus the number of True Positives.		
Target Value	90%	**Threshold Value**	>=80%
Rounding	N/A		
Unit	Adimensional		
Formula	$$Recall = \frac{TruePositives}{TruePositives + FalsePositives}$$		
Calculating frequency	Monthly		

Calculation Methodology	
Step	**Description**
01	The time range comprises the historical data up to the month chosen for the analysis
02	2.5.3. Identify all those cases where correctly identified (TruePositives) as abnormalities in the Heating and Cooling system and those which are classified as normal but are cases with anomalous behaviors (False Negatives).
03	Apply the formula
04	The formula will be applied for each one of the selected buildings.

Data Source				
Data description	**Data source**	**Data collection frequency**	**Data collection time range**	**Data Owner**
Office Registry	Building Data	At starting up and then occasionally, when changes occur	Static - No Temporal Range	Poste Italiane
Building Calendar	Building Data	Monthly	From 01/01/2018	Poste Italiane

Detailed Energy Consumption	Energy Consumption	Daily	From 01/01/2018	Poste Italiane
Alarms of abnormal behaviours of the systems	System Fault	Daily	From June 2021	Poste Italiane
Temperature, Humidity	Weather		From 01/01/2018	External Services
Systems Registry	Building Systems	At starting up and then occasionally, when changes occur	No Temporal Range	Poste Italiane

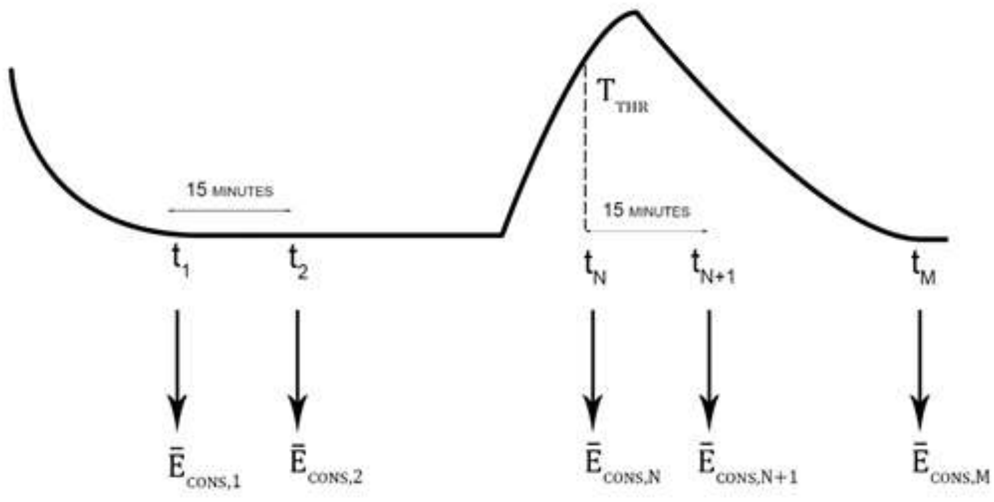
KPI N°7			
KPI-Name	Precision	**KPI-ID**	PI_KPI07
KPI-Type	Technical		
Description	The KPI measures Pre-MATE's performance. Precision, is defined as the ratio of all cases that are correctly identified as problematic (True Positives) to all cases that are identified as problematic, even if they are not, actually (All Positives-True and False).		
Target Value	90%	**Threshold Value**	>=80%
Rounding	N/A		
Unit	Adimensional		
Formula	$$Precision = \frac{TruePositives}{TruePosives + FalsePositives}$$		
Calculating frequency	Monthly		
Calculation Methodology			
Step	**Description**		
01	The time range comprises the historical data up to the month chosen for the analysis		
02	Identify all those cases where correctly identified (True Positives) as abnormalities in the Heating and Cooling system and those which are classified as problematic but are actually normal behaviors (False Negatives)		
03	Apply the formula		
04	The formula will be applied for each one of the selected buildings.		
Data Source			

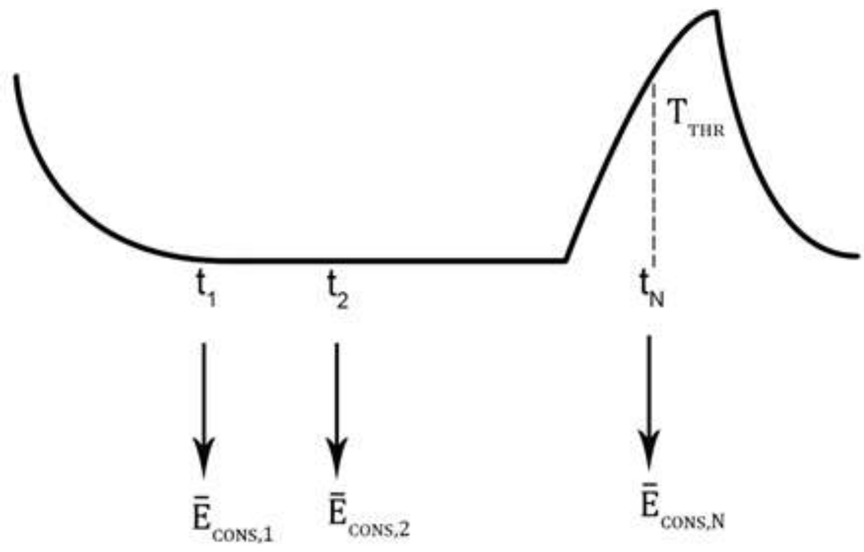
Data description	Data source	Data collection frequency	Data collection time range	Data Owner
Office Registry	Building Data	At starting up and then occasionally, when changes occur	No Temporal Range	Poste Italiane
Building Calendar	Building Data	Monthly	From 01/01/2018	Poste Italiane
Detailed Energy Consumption	Energy Consumption	Daily	From 01/01/2018	Poste Italiane
Alarms of abnormal behaviours of the systems	Systems Fault	Daily	From June 2021	Poste Italiane
Temperature, Humidity	Weather		From 01/01/2018	External Services
Systems Registry	Building Systems	At starting up and then occasionally when changes occur	No Temporal Range	Poste Italiane

KPI N°8			
KPI-Name	F1-Score	**KPI-ID**	PI_KPI08
KPI-Type	Technical		
Description	The KPI is used in cases where the best combination of precision and recall is desired. F_1 score could be used to combine the two criteria. The F_1 score is the harmonic mean of precision and recall, using the formula below to account for both metrics		
Target Value	90%	**Threshold Value**	>=80%
Rounding	N/A		
Unit	Adimensional		
Formula	$$F_1 = 2\frac{Precision \cdot Recall}{Precision + Recall}$$		
Calculating frequency	Bi-Monthly		
Calculation Methodology			
Step	**Description**		

01	The time range comprises the historical data up to the month chosen for the analysis			
02	Calculate Recall and Precision KPIs before			
03	Apply the formula			
04	The formula will be applied for each one of the selected buildings			
Data Source				
Data description	**Data source**	Data collection frequency	Data collection time range	Data Owner
Office Registry	Building Data	At starting up and then occasionally when changes occur	No Temporal Range	Poste Italiane
Building Calendar	Building Data	Monthly	From 01/01/2018	Poste Italiane
Detailed Energy Consumption	Energy Consumption	Daily	From 01/01/2018	Poste Italiane
System Registry	Building Systems	At starting up and then occasionally, when changes occur	No Temporal Range	Poste Italiane
Employees Number	Occupancy	Monthly	From 01/01/2018	Poste Italiane

KPI N°09			
KPI-Name	Performances Analysis	**KPI-ID**	PI_KPI09
KPI-Type	Technical/Business		
Description	This KPI measures the energy consumed by the conditioning systems for returning to optimal internal temperature, normalized for the temperature recover range.		
Target Value	5% (month to month increase)	**Threshold Value**	10% (month to month increase)
Rounding	No		
Unit	KWh		
Formula			

	$$\mathbf{E_{cond,k}} = \frac{1}{M-N+1}\sum_{j=N}^{M}\frac{(\overline{E}_{cons,k,j} - E_{bias,k})}{\lvert T_{thr} - T_{int,k}\rvert \times volume \times p_j}$$ *where* $$\mathbf{E_{bias,k}} = \frac{1}{N}\sum_{n=1}^{N}\overline{E}_{cons,n}$$ $$\mathbf{p_j} = \frac{\#\ of\ sensor\ out\ of\ range, at\ the\ time\ 'j'}{total\ number\ of\ sensors\ in\ the\ building}$$ *finally* $$\mathbf{E_{cond1\_m}} = \frac{1}{K}\sum_{k}\mathbf{E_{cond,k1\_m}}$$ = normalized energy the conditioning systems consume per unit of volume and temperature to bring the internal temperature back to the normal range, for the temperature violation 'k'. (is costituited by M-N+1 fifteen minutes interval see figure below)  = energy consumed for conditioning in the optimal range of temperature (from t_1 to t_2) and till the threshold reached(from t_2 to t_N), when is on range or above (see figure below) (19° or above in the heating tabulated period, 27° or below in the cooling tabulated period), for the temperature violation 'k')

	 when is on range or above (19° or above in the heating tabulated period, 27° or below in the cooling tabulated period), for the temperature violation 'k') = Energy consumption at time 'j' = temperatute threshold : they are tabulated : 19° (in the heating tabulated period) ; 27° (in the cooling tabulated period) = max out of range internal temperature to recover for the temperature violation 'k' volume= building volume = normalized energy the conditioning systems consume per unit of volume and temperature to bring the internal temperature back to the normal range, for the month 'm' and the building 'i' K = number of violations for the month 'm' and the building 'i' = ratio between the number of sensor out of range at the time 'j and the total number of sensors in the building
Calculating frequency	Monthly
Calculation Methodology	
Step	**Description**
01	Data have to be taken on building type = Smart building, in the total time window of availability of data. Data must be considered only for days and hours in which the buildings are open
03	Calculate the plants consumption taking into account, for each temperature violation, the energy consumed for the conditioning, normalized by bias energy, temperature interval, and number of sensors outside range in that moment
04	Apply the formulas. We will have a value for each smart building and for each month, so could be compared the performance of different months of the same building for degradation analysis or could be compared performance of different buildings (in which case will be useful compare the same month)

Data Source

Data description	Data source	Data collection frequency	Data collection time range	Data Owner

Office Registry	Building Data	At starting up and then occasionally, when changes occur	Static - No Temporal Range	Poste Italiane
Building Calendar	Building Data	Monthly	From 01/01/2018	Poste Italiane
Detailed Energy Consumption	Energy Consumption (and internal temperatures)	Daily	From when they are available	Poste Italiane

10.5.3. LLUC-03

KPI N°10			
KPI-Name	Lighting Estimation	**KPI-ID**	PI_KPI10
KPI-Type	Technical		
Description	The KPI calculates the % of deviation between the actual and the estimated lighting consumption.		
Target Value	+/- 5%	**Threshold Value**	+/- 10%
Rounding	round off to 0% for values between 0.00 and 0.49 and to 1% for values above		
Unit	Kilowatt per hour (KWh)		
Formula	$$\mathbf{LE_i} = \frac{L_{e,i} - L_{a,i}}{L_{a,i}} * 100$$ $$\mathbf{LE_M} = \frac{1}{N}\sum_i LE_i$$ LE_i = Lighting Estimation Error % of building "I" L_e = Lighting consumption estimated of building "I" L_a = Lighting consumption actual of building "I" N = number of buildings utilized for the KPI calculation		
Calculating frequency	Weekly		
Calculation Methodology			
Step	**Description**		

01	Select the time range and the building (month)
02	Calculate the estimated consumption considering the following information: 1. Total energy consumption in the rime range 2. Parameter on % of incidence of consumption form Heating and Cooling systems 3. Building open hours and shift
03	Lighting consumption estimation will be compared to the real consumption (where available) and then will be exploited by buildings for which is no available.
03	Calculate the real consumption value
04	Apply the formula
05	The formula will be applied for each one of the selected buildings, then arithmetic mean will be calculated from these selected values.

Data Source

Data description	**Data source**	Data collection frequency	Data collection time range	Data Owner
Office Registry	Building Data	At starting up and then occasionally when changes occur	No Temporal Range	Poste Italiane
Building Calendar	Building Data	Monthly	From 01/01/2018	Poste Italiane
Detailed Energy Consumption	Energy Consumption	Daily	From 01/01/2018	Poste Italiane
Detailed Energy Consumption DL_102	Energy Consumption	Monthly	TBD	Poste Italiane
Total Active Energy consumption	Energy Consumption	Monthly		Poste Italiane
System Registry	Building Systems	At starting up and then occasionally, when changes occur	No Temporal Range	Poste Italiane
Employees Number	Occupancy	Monthly	From 01/01/2018	Poste Italiane

10.6. Pilot 3b – ROM Advanced Energy Management System and Spatial (Multi-Scale) Predictive Models in the Smart City

KPI N°01			
KPI-Name	**Total Energy Savings (TES) [kWh / Y]**	**KPI-ID**	ROM_Kpi_R01
KPI-Type	Technical - Energy Savings		
Description	The analysis and the improved management of the meters data (historical and current) will produce a series of measures and interventions ("EVENTS") that should reduce the yearly total energy consumptions, such as dismission of un-useful meters, maintenance and interventions on buildings following some anomalies detection, contractual re-definition resulting from Platoon analysis, other measures impacting on behaviours. Component indicators are the Total Energy Savings in terms of Gas (TES-G) and in terms of Electricity (TES-E), that gives a better picture of the impact of Platoon services. TeS can be applied also to different reference or analysis period different from Year. This KPI calculates for example the difference between the energy consumption before and after reference EVENTS. It is always necessary to explicit the subset of buildings refereed to an instance calculation. This subset can range from n.1 meter/building to all meters/buildings		
Target Value	--% Target to be defined	**Threshold Value**	--%
Rounding	---% round off to 0% for values between 0.00 and 0.49 and to 1% for values above		
Unit	Kilowatt (KWh) / year		
Formula	$\mathbf{TES_Y = TES_G + TES_E}$ $TES_{AY} = \frac{TES_A}{Ref.period} = \frac{TES_E + TES_G}{Ref.\ period}$ TESY = Total Energy Saving (for one full year) TES_F = Forecasted value (calculated for 1 full year after the event, including future periods) TES_{AY} = Actual value normalized on 1 full year TES_A = Actual value (sum of the measured savings from the EVENT time to last data available, when total period is different from 1 year) EVENT time = the date of the intervention / action / event		
Calculating frequency	On demand … Monthly		
Calculation Methodology			
Step	**Description**		
01	Select the time range = Ref. Period (year) ; default is 1 (year) I.e 1 month = 1/12; 18 months = 18/12 Select/identify/Set the EVENT time, in order to verify which period covered by data is available after this EVENT time. Ref.Period is set to this period		

02	Select the specific building(s) and the perimeter of calculation: Total energy consumption for District / Area buildings or Total energy consumption for Specific building(s)
03	Select the Energy typology: Electric (power meters) or Gas (gas meters or kWh derived from contatermie dataset) Or Both
04	Calculate energy saving for selected typology/building(s) comparing consumption related to one full year before the EVENT (ECb) and consumptions after the EVENT (ECa) (normalized if necessary to one full year) : ECa – ECb = TES repeat for different energy typology if requested

Data Source

Data description	**Data source**	**Data collection frequency**	**Data collection time range**	**Data Owner**
Building Calendar	Building Data	Monthly	TBD	
Total Electric Energy consumption	Energy Consumption	Monthly	TBD	ROM
Total Gas Energy consumption	Energy Consumption	Monthly	TBD	ROM
Detailed Energy Consumption	Energy Consumption (electric or gas)	daily	TBD	ROM
Temperature, Humidity	Weather	Monthly		External Services

KPI N°02			
KPI-Name	Saving Personnel Costs	**KPI-ID**	**ROM_04_Kpi_R02**
KPI-Type	Technical		
Description	The installation of a monitoring system shall reduce the costs for the personnel. This KPI is calculated from the difference of the saved personnel costs (per year) and the depreciation amount of the data monitoring system.		
Target Value	15%	**Threshold Value**	30%

Rounding	0% round off to 0% for values between 0.00 and 0.49 and to 1% for values above			
Unit	% on Euro [per year]			
Formula	$SPC = \frac{(CS - CD)}{C_A} \times 100$ CS= Personnel cost saving, based on the calculation of the avoided yearly worked days CD = depreciation amount of the data monitoring system in the same year C_A = Actual value of the personnel cost for the energy management (before Platoon implementation) Note: the calculation has to be limited to the personnel directly involved or impacted from the toolbox usage.			
Calculating frequency	Monthly			
Calculation Methodology				
Step	**Description**			
01				
02	–			
03	-			
04				
Data Source				
Data description	**Data source**	**Data collection frequency**	**Data collection time range**	**Data Owner**
KPI N°0x				
KPI-Name	Forecast Error		**KPI-ID**	
KPI-Type	Technical			
Description	The KPI calculates the % of deviation between the energy consumption forecast and the actual consumption in the building. This KPI checks how closely the predictive model adheres to reality - Effectiveness			
Target Value	5%	**Threshold Value**	10%	
Rounding	0%			

	round off to 0% for values between 0.00 and 0.49 and to 1% for values above
Unit	Kilowatt (KW)
Formula	$$FE = \frac{(F_F - F_A)}{F_A} \times 100$$ FE= Forecast Error % F_F = Forecasted value F_A = Actual value
Calculating frequency	Monthly
Calculation Methodology	
Step	**Description**
01	Select the time range and the specific building and the perimeter of calculation: 3. Total energy consumption or 4. Total energy consumption for energy typology (electric meter or gas mater) in the building (or set of buildings)
02	Calculate the forecast considering: − Real data consumption − Temperature and Humidity (meteo conditions) − Number of Customers and Employees (when occupancy factors is available) − Building open hours and shift (hen occupancy factors is available) − Building Climate Zone, m^3
03	Calculate the Real consumption data (of the target month) taking into account: - Sum the daily energy consumption over the full month for the selected building or set of building
04	Apply the formula

Data Source				
Data description	**Data source**	**Data collection frequency**	**Data collection time range**	**Data Owner**
Office Registry	Building Data	At starting up and then occasionally, when changes occur	No Temporal Range	ROM
Building Calendar	Building Data	Monthly	From 01/01/2016	ROM
Total Active Energy consumption	Energy Consumption	Monthly		ROM
Detailed Energy Consumption DL_102	Energy Consumption	Monthly	TBD	ROM
Detailed Energy Consumption	Energy Consumption	Daily	From 01/01/2016	ROM

Temperature, Humidity	Weather		From 01/01/2016	External Services
Customers Number	Occupancy	Monthly	From 01/01/2016	ROM if available
Employees Number	Occupancy	Monthly	From 01/01/2016	ROM if available

10.7. Pilot 3C Energy Efficiency and Predictive Maintenance in the Smart Tertiary Building Hub Grade

10.7.1. LLUC-3C-01

KPI N°1			
KPI-Name	Integration	**KPI-ID**	2
KPI-Type	Technical		
Description	Metric targeted at the validation of the fact that the tools of this pilot are able to work together. This includes: -Semantic pipeline: PLATOON data models mapping -Data Connectors with legacy databases, sensors, edge computing devices -IDS connector between Sisteplant and Tecnalia -IDS connector with Broker and Marketplace -Data Analytics Tools		
Target Value	1	**Threshold Value**	1
Rounding	Not applicable		
Unit	Binary 1 or 0		
Formula	If all tools to complete the pilot data analysis are able to interact and send data to each other then this KPI is 1. Otherwise it is 0.		
Calculating frequency	At each pipeline release		
Calculation Methodology			
Step	**Description**		
01-	based on unit tests the input-output functioning of each pipeline is validated.		
02	Test data is exchanged between the pilot analytics blocks		
Data Source			

Data description	**Data source**	Data collection frequency	Data collection time range	Data Owner
Test data	Energy consumption/generation data, energy price data, meteo data and operational parameters.	Mins	2021-2022	Giroa

KPI N°2					
KPI-Name	Energy Bill reduction		**KPI-ID**	2	
KPI-Type	Business				
Description	The KPI will evaluate the energy bill reduction achieved				
Target Value	20% reduction	**Threshold Value**	All improvement compared to current situation is already useful.		
Rounding	first decimal				
Unit	% and euros				
Formula	(Current energy bill (euros)- New energy bill(euros))/ Current energy bill (euros)				
Calculating frequency	Once per day				
Calculation Methodology					
Step	**Description**				
01-	Calculate the energy generation and consumption forecast				
02	Calculate corrected energy price taking into account energy production excess and selling/buying poll pricre				
03	Optimise HVAC on/off				
04	Calculate HVAC energy consumption				
05	Calculate energy bill taking into account outputs from steps 2 and 4.				
Data Source					
Data description	**Data source**	Data collection frequency	Data collection time range	Data Owner	
Test data	Energy consumption/generation data, energy price data,	Mins	2021-2022	Giroa	

	meteo data and operational parameters.			

KPI N°3			
KPI-Name	RES ratio utilization ratio	**KPI-ID**	3
KPI-Type	Technical		
Description	The KPI will evaluate the RES usage versus overall energy consumption.		
Target Value	30% increase	**Threshold Value**	Full processing chain for a farm should be able to run on a standard server.
Rounding	1st decimal		
Unit	Percentage		
Formula	RES production usage/ overall energy consumption		
Calculating frequency	Once per day		
Calculation Methodology			
Step	**Description**		
01-	Calculate the energy generation and consumption forecast		
02	Calculate corrected energy price taking into account energy production excess and selling/buying poll pricre		
03	Optimise HVAC on/off		
04	Calculate HVAC energy consumption		
05	Calculate RES usage taking into account outputs from steps 1 and 4.		

Data Source				
Data description	**Data source**	Data collection frequency	Data collection time range	Data Owner
Test data	Energy consumption/generation data, energy price data, meteo data and operational parameters.	Mins	2021-2022	Giroa

10.7.2. LLUC-3C-02

KPI N°1				
KPI-Name	Health Monitoring		**KPI-ID**	KPI-01
Description	Monitoring the health status of each asset, using the PML (Process Mastery Level) indicator, in a range from 0 (Failure Status) to 1 (Optimal Status).			
Target Value	100 %		**Threshold Value**	0 – 100%
Unit	Percentage indicator, set points, etc.			
Formula	Depending on the asset, each one will have its own formula according to the maintenance experts.			
Calculating frequency	Depending on the asset.			
Calculation Methodology				
Step	**Description**			
01-	Define the PML Formula for each asset			
02-	Monitoring the health status according to the values of the variables and its associated PML Value.			
Data Source				
Data description	**Data source**	Data collection frequency	Data collection time range	Data Owner
Signals used as input for the models	Consolidated Data Base with PLC and SCADA data	Defined default time (every 15 min aprox.)		GIROA

KPI N°2			
KPI-Name	Failure Forecast	**KPI-ID**	KPI-02
Description	Expected failure forecast based on historical data.		
Unit	Hours		
Formula	Expected failure Model based on historical data from inputs. Safety set point for the failure Model Current signal status vs failure Model		
Calculating frequency	Daily		
Calculation Methodology			
Step	**Description**		

01-	Define the PML Formula for the asset			
02-	Forecast failure point over time based on current signal status			
Data Source				
Data description	**Data source**	Data collection frequency	Data collection time range	Data Owner
Signals used as input for the models	Consolidated Data Base with PLC and SCADA data	Defined default time (every 15 min aprox.)		GIROA

KPI N°3				
KPI-Name	Availability		**KPI-ID**	KPI-03
Description	Availability of the asset over a period of time. Availability takes into account Availability Loss, which includes any events that stop planned production for an appreciable length of time (usually several minutes; long enough for an operator to log a reason). Used for OEE calculation.			
Unit	%			
Formula	$\frac{Operation\ Time}{Planned\ Production\ Time} x100$			
Calculating frequency	Daily			
Calculation Methodology				
Step	**Description**			
01-	Register events of unplanned stops.			
02	Calculate the availability for a determined period of time by using the above formula.			
Data Source				
Data description	**Data source**	Data collection frequency	Data collection time range	Data Owner
Signals used as input for the models	Consolidated Data Base with PLC and SCADA data	Defined default time (every 15 min aprox.)		GIROA

KPI N°4			
KPI-Name	Performance	**KPI-ID**	KPI-04
Description	Performance takes into account Performance Loss, which accounts for anything that causes the manufacturing process to run at less than the maximum possible speed or performance indicator when it is running (including both Slow Cycles and Small Stops). Used for OEE calculation.		

Unit	%			
Formula	$\frac{Atual\ Rate}{Standard\ Rate} x100$			
Calculating frequency	Daily			
Calculation Methodology				
Step	**Description**			
01-	Determinate Performance indicator			
02	Calculate the performance of the Asset.			
Data Source				
Data description	**Data source**	Data collection frequency	Data collection time range	Data Owner
Signals used as input for the models	Consolidated Data Base with PLC and SCADA data	Defined default time (every 15 min aprox.)		GIROA

KPI N°5			
KPI-Name	Mean Time Between Failures	**KPI-ID**	KPI-05
Description	Mean time between failures (MTBF) describes the expected time between two failures for a repairable system		
Unit	Hours		
Formula	MTBF = (Total Working Time – Total Breakdown Time) / Number of Breakdowns MTBF = Total Operational time / Number of Breakdowns		
Calculating frequency	Daily		
Calculation Methodology			
Step	**Description**		
01-	Acquire running operational time		
02-	Determine Number of breakdowns. Apply filters as needed to exclude micro stops, mini stops, or other criteria's		
03-	Apply formula		
Data Source			

Data description	Data source	Data collection frequency	Data collection time range	Data Owner
Signals used as input for the models	Consolidated Data Base with PLC and SCADA data	Defined default time (every 15 min aprox.)		GIROA

KPI N°6				
KPI-Name	Integration		**KPI-ID**	6
KPI-Type	Technical			
Description	Metric targeted at the validation of the fact that the tools of this pilot are able to work together. This includes: -Semantic pipeline: PLATOON data models mapping -Data Connectors with legacy databases, sensors, edge computing devices -IDS connector between Sisteplant and Tecnalia -IDS connector with Broker and Marketplace -Data Analytics Tools			
Target Value	1	**Threshold Value**	1	
Rounding	Not applicable			
Unit	Binary 1 or 0			
Formula	If all tools to complete the pilot data analysis are able to interact and send data to each other then this KPI is 1. Otherwise it is 0.			
Calculating frequency	At each pipeline release			
Calculation Methodology				
Step	**Description**			
01-	based on unit tests the input-output functioning of each pipeline is validated.			
02	Test data is exchanged between the pilot analytics blocks			
Data Source				
Data description	**Data source**	Data collection frequency	Data collection time range	Data Owner
Test data	Energy consumption/generation data, energy price data, meteo data and operational parameters.	Mins	2021-2022	Giroa

KPI N°7			
KPI-Name	Useful Time	**KPI-ID**	7
KPI-Type	Technical		

Description	It is important to maximize the useful life of each asset. This is done based on various concepts: • Early detection of possible breakdowns • Correct performance of own maintenance tasks (corrective / preventive) • Working with assets in suitable conditions for them (not forcing work in unsuitable conditions, etc.)			
Target Value	Not applicable	**Threshold Value**	Not applicable	
Rounding	Not applicable			
Unit	Hours			
Formula	The mathematical formula is the total time (in hours) that the asset has operated until it has finally been replaced			
Calculating frequency	Daily			
Calculation Methodology				
Step	**Description**			
01-	Acquire necessary data from integration with Prisma (CMMS) - Asset information - Equipment information			
02	For current equipment: - Calculate the time between the installation of the equipment until today. For replaced equipment: - Calculate the time between the installation of the equipment until the replacement			
03	Provide information of the health of the equipment during lifecycle.			
Data Source				
Data description	**Data source**	Data collection frequency	Data collection time range	Data Owner
Maintenance log data	Prisma	Daily	2021-2022	Giroa
Test data	Energy consumption/generation data, energy price data, meteo data and operational parameters.	Mins	2021-2022	Giroa

KPI N°8			
KPI-Name	Maintenance Costs	**KPI-ID**	8
KPI-Type	Business		
Description	The maintenance cost of an asset is the sum of the costs of the work orders that have been carried out on that asset. It is important to indicate that maintenance costs may be higher in some assets that use predictive maintenance. Therefore, the goal should be achieving the lowest possible cost in the set of assets.		
Target Value	Not applicable	**Threshold Value**	Not applicable
Rounding	Not applicable		

Unit	Euros			
Formula	Sum of the maintenance costs of the equipment selected for the use case.			
Calculating frequency	Daily			
Calculation Methodology				
Step	**Description**			
01-	Acquire necessary data from integration with Prisma (CMMS) - Total cost associated to Work Orders related to the equipment			
02	Create total cost KPI associated to the equipment			
Data Source				
Data description	**Data source**	Data collection frequency	Data collection time range	Data Owner
Test data	Operational parameters.	Mins	2021-2022	Giroa
Maintenance log data	Prisma	Daily	Daily	Giroa

10.8. Pilot 4a Energy Management of Microgrids

10.8.1. LLUC P-4a-01

KPI N°1				
KPI-Name	Energy availability		**KPI-ID**	KPI-1
KPI-Type	Technical (specific to the pilot use case)			
Description	Optimal energy consumption (increase in energy availability) – Optimization for renewable electricity generation Smart storage/generation			
Target Value	Example: amount of daily load covered by renewable generation – Target value:100%	**Threshold Value**	The value used to assess the effectiveness/efficiency performance of the monitored process: 90%	
Rounding	the criteria for rounding the calculated values (Example : For % calculation, round off to 0% for values between 0.00 and 0.49 and to 1% for values above)			
Unit	%			
Formula				
Calculating frequency	Daily			
Calculation Methodology				
Step	**Description**			
01-	Daily measurements of load consumption, renewable energy generation and battery			
02				
Data Source				
Data description	**Data source**	Data collection frequency	Data collection time range	Data Owner
Energy consumption	mySQL db	10 min	daily	PDM
Energy production	mySQL db	10 min	daily	PDM

KPI N°2			
KPI-Name	Cost	**KPI-ID**	KPI-2
KPI-Type	Technical (specific to the pilot use case)		

Description	Reduction of maintenance effort and costs (optimization for renewable electricity generation)			
Target Value	Example: maintenance cost	**Threshold Value**		
Rounding	the criteria for rounding the calculated values (Example : For % calculation, round off to 0% for values between 0.00 and 0.49 and to 1% for values above)			
Unit				
Formula				
Calculating frequency	montly			
Calculation Methodology				
Step	**Description**			
01-	measure of maintenance activity / failure rate			
02				
Data Source				
Data description	**Data source**	Data collection frequency	Data collection time range	Data Owner
Failure rate	mySQL db	10 min	daily	PDM
Maintenance activity	mySQL db	10 min	daily	PDM

KPI N°3			
KPI-Name	Forecast accuracy	**KPI-ID**	KPI-3
KPI-Type	Technical (specific to the pilot use case)		
Description	Reduced forecasting errors (generation and load forecast)		
Target Value	Example: forecating error – Target value:0%	**Threshold Value**	The value used to assess the effectiveness/efficiency performance of the monitored process: tbd
Rounding	None		
Unit	%		
Formula	Standard forecating error indicators, such as nRMSE, WMAE, EMAE, OMAE		

	[S. Leva, M. Mussetta, A. Nespoli and E. Ogliari, "PV power forecasting improvement by means of a selective ensemble approach," 2019 IEEE Milan PowerTech, 2019, pp. 1-5, doi: 10.1109/PTC.2019.8810921.]			
Calculating frequency	Daily, monthly, yearly			
Calculation Methodology				
Step	**Description**			
01-	Daily measurements of load consumption, renewable energy generation and battery			
02	Comparison with related forecating and error measurement			
Data Source				
Data description	**Data source**	Data collection frequency	Data collection time range	Data Owner
Energy consumption	mySQL db	10 min	daily	PDM
Energy production	mySQL db	10 min	daily	PDM
Production forecast	mySQL db	10 min	daily	PDM
Solar nowcast	mySQL db / edge node?	10 min	daily	PDM
Load forecast	mySQL db	10 min	daily	PDM

KPI N°4			
KPI-Name	Realtime	**KPI-ID**	KPI-4
KPI-Type	Technical (specific to the pilot use case)		
Description	Ability to monitoring/analyze/optimize data and the system at real time rate (EMS with real-time processing Smart storage/generation)		
Target Value	Tbd	**Threshold Value**	Tbd
Rounding	the criteria for rounding the calculated values (Example : For % calculation, round off to 0% for values between 0.00 and 0.49 and to 1% for values above)		
Unit			
Formula			

Calculating frequency	Daily			
Calculation Methodology				
Step	**Description**			
01-				
02				
Data Source				
Data description	**Data source**	Data collection frequency	Data collection time range	Data Owner
Nowcast	mySQL db	10 min	daily	PDM
EMS schedule	mySQL db	10 min	daily	PDM

10.9. PLATOON Common Components

KPI N°1			
KPI-Name	IDS Metadata Registry (Boker/Appstore)Integration	**KPI-ID**	1
KPI-Type	Technical		
Description	Metric targeted at the validation of the fact that the IDS Metadata Registry (Broker/Appstore) is able to work together with IDS connectors and Data Analytics Tools Dockers and Marketplace.		
Target Value	1	**Threshold Value**	1
Rounding	Not applicable		
Unit	Binary 1 or 0		
Formula	If all tools to complete the pilot data analysis are able to interact and send data to each other then this KPI is 1. Otherwise it is 0.		
Calculating frequency	At each pipeline release		

Calculation Methodology	
Step	**Description**
01-	based on tests the input-output functioning of each pipeline is validated.
02	Test data is exchanged between the pilot analytics blocks

Data Source				
Data description	**Data source**	Data collection frequency	Data collection time range	Data Owner
Each pilot will have its own dataset connected to IDS connectors.				

KPI N°2			
KPI-Name	DAPS Integration	**KPI-ID**	3
KPI-Type	Technical		
Description	Metric targeted at the validation of the fact that the DAPS provided by Fraunhofer AISEC (not developed in PLATOON) is able to work together with PLATOON IDS connectors, IDS Metadata Registry and IDS Vocabulary Provider.		

Target Value	1	**Threshold Value**	1	
Rounding	Not applicable			
Unit	Binary 1 or 0			
Formula	If all tools to complete the pilot data analysis are able to interact and send data to each other then this KPI is 1. Otherwise it is 0.			
Calculating frequency	At each pipeline release			
Calculation Methodology				
Step	**Description**			
01-	based on tests the input-output functioning of each pipeline is validated.			
02	Test data is exchanged between the pilot analytics blocks			
Data Source				
Data description	**Data source**	Data collection frequency	Data collection time range	Data Owner
Each pilot will have its own dataset connected to IDS connectors.				

KPI N°3			
KPI-Name	Clearing House Integration	**KPI-ID**	4
KPI-Type	Technical		
Description	Metric targeted at the validation of the fact that the Clearing House provided by Fraunhofer (not developed in PLATOON) is able to work together with PLATOON IDS connectors, IDS Metadata registry, DAPS and Marketplace.		
Target Value	1	**Threshold Value**	1
Rounding	Not applicable		
Unit	Binary 1 or 0		
Formula	If all tools to complete the pilot data analysis are able to interact and send data to each other then this KPI is 1. Otherwise it is 0.		
Calculating frequency	At each pipeline release		
Calculation Methodology			
Step	**Description**		

01-	based on tests the input-output functioning of each pipeline is validated.			
02	Test data is exchanged between the pilot analytics blocks			
Data Source				
Data description	**Data source**	Data collection frequency	Data collection time range	Data Owner
Each pilot will have its own dataset connected to IDS connectors.				

KPI N°4			
KPI-Name	PLATOON Marketplace GUI Integration	**KPI-ID**	5
KPI-Type	Technical		
Description	Metric targeted at the validation of the PLATOON Marketplace is able to work together with PLATOON IDS Metadata Registry, DAPs and Clearing House.		
Target Value	1	**Threshold Value**	1
Rounding	Not applicable		
Unit	Binary 1 or 0		
Formula	If all tools to complete the pilot data analysis are able to interact and send data to each other then this KPI is 1. Otherwise it is 0.		
Calculating frequency	At each pipeline release		
Calculation Methodology			
Step	**Description**		
01-	based on tests the input-output functioning of each pipeline is validated.		
02	Test data is exchanged between the pilot analytics blocks		

Data Source				
Data description	**Data source**	Data collection frequency	Data collection time range	Data Owner
Each pilot will have its own dataset connected to IDS connectors.				

<table>
<tr><th colspan="5">KPI N°5</th></tr>
<tr><td>KPI-Name</td><td colspan="2">IDS Vocabulary Provider Integration</td><td>KPI-ID</td><td>2</td></tr>
<tr><td>KPI-Type</td><td colspan="4">Technical</td></tr>
<tr><td>Description</td><td colspan="4">Metric targeted at the validation of the fact that the IDS Vocabulary Provider is able to work together with PLATOON datamodels repository, IDS connectors and DAPs.</td></tr>
<tr><td>Target Value</td><td>1</td><td colspan="2">Threshold Value</td><td>1</td></tr>
<tr><td>Rounding</td><td colspan="4">Not applicable</td></tr>
<tr><td>Unit</td><td colspan="4">Binary 1 or 0</td></tr>
<tr><td>Formula</td><td colspan="4">If all tools to complete the pilot data analysis are able to interact and send data to each other then this KPI is 1. Otherwise it is 0.</td></tr>
<tr><td>Calculating frequency</td><td colspan="4">At each pipeline release</td></tr>
<tr><th colspan="5">Calculation Methodology</th></tr>
<tr><td>Step</td><td colspan="4">Description</td></tr>
<tr><td>01-</td><td colspan="4">based on tests the input-output functioning of each pipeline is validated.</td></tr>
<tr><td>02</td><td colspan="4">Test data is exchanged between the pilot analytics blocks</td></tr>
<tr><th colspan="5">Data Source</th></tr>
<tr><td>Data description</td><td>Data source</td><td>Data collection frequency</td><td>Data collection time range</td><td>Data Owner</td></tr>
<tr><td>Each pilot will have its own dataset connected to IDS connectors.</td><td></td><td></td><td></td><td></td></tr>
</table>