SEEDS

Cost-effective and replicable RES-integrated electrified heating and cooling systems for improved energy efficiency and demand response.

D3.1 - Automation and monitoring specifications

WP3, Task 3.1-3.2

16/12/2024

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LIST OF ACRONYMS/ABBREVIATIONS

Abbreviation	Description
API	Application Programmable Interface
AW	Air-to-Water
BACnet	Building Automation and Control Networks
BMS	Building Management System
CO2	Carbon Dioxide
COV	Change of Value
DHW	Domestic Hot Water
DSO	Distributor System Operator

EE	Electric Energy
EV	Electric Vehicle
ERD	Entity-Relationship Diagram
FCUs	Fan-Coil Units
GMS	Global System for Mobile Communications
HMI	Human-Machine Interface
HVAC	Heating, Ventilation and Air-Conditioning
IoT	Internet of Things
IPC	Industrial PC
LCA	Life Cycle Assessment
LPG	Liquefied Petroleum Gas
MPC	Model Predictive Control
MQTT	Message Queuing Telemetry Transport
NGSI-LD	Next Generation Service Interfaces - Linked Data
REST	Representational State Transfer
RH	Relative Humidity
PLC	Programmable Logic Controller
PoLP	Principle of Least Privilege
PV	Photovoltaic
PVT	Photovoltaic-Thermal
TBS	Technical Building System
SoC	State of Charge

1. INTRODUCTION

1.1. AIMS AND OBJECTIVES

The primary aim of this document is to define the requirements, technical specifications, and architecture necessary for implementing smart automation and monitoring systems across the different pilot sites.

The first objective of this deliverable is to survey and analyse the current smartification and automation situation for each pilot site. Through well-defined questionnaires, online and physical meetings this holistic approach will help to recognize and gather detailed information about the current automation, monitoring and smartification situation, identify the missing technology gaps and define the necessary devices and technical specifications. This involves a collaborative effort between the technology provider partners and pilot owners.

The second objective focuses on establishing the technical architecture and specifications for the integrated automation and monitoring systems. This includes defining parameters such as sampling frequency, communication protocols, security mechanisms, and platform specific requirements tailored to the project's needs and each of the pilot's unique characteristics.

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1.2. RELATION TO OTHER ACTIVITIES IN THE PROJECT

This deliverable lays the guidelines and foundation for all the future tools that will be modelled and developed under the tasks of WP3, as well as the tools under WP4 and WP5. It also serves as a starting point by providing a comprehensive framework of the envisaged technical innovations under WP3 for the D3.2 Deliverable “Holistic SEEDS Evaluation Framework”.

1.3. REPORT STRUCTURE

This document is divided into five main chapters. The first chapter presents the scope and the objectives of this deliverable as well as the relation to other tasks of the projects and the overall document structure. For the second, third and fourth chapters the content is further divided for each pilot case, in order to capture the unique characteristics of each pilot site.

In the second chapter of this document, titled “Pilot Smartification/Automation Surveying and Assessment, a comprehensive overview for each pilot site in terms of the existing conditions of smartification and automation levels is provided.

The third chapter of this document, titled “Technical Specifications Definition”, is structured in a way that outlines all the critical technical parameters and requirements for enabling smartification and automation based on each pilot’s sites unique requirements. In the “Observable Features and Sampling Frequency” section, all the monitored features and the data sampling rates are defined. The “Communication Protocol, Authorization and Security Mechanisms” section details all the protocols and security measures that will be used in order to provide secure data transmission and access control. “Database Schemas and Data Models” describes the necessary data structures that will be used for persistent data collections. Finally, “Hosting Requirements” describes the hosting needs and the infrastructure that is required, for each pilot in order to support the IoT ecosystem.

The fourth chapter of the document, titled “Technical Architecture Definition”, has the objective to summarize and provide a detailed framework for the automation and IoT ecosystem within the pilot sites. The first section “Overview of Technical Architecture for Automation and IoT Ecosystem” provides a comprehensive high-level summary of the overall system architecture, highlighting the integration and interactions between the different IoT components. The second, third and fourth sections which are titled “Hardware Gateways”, “Sensing Devices” and “Control and Actuation Devices” respectively, are focused on the physical devices that will be used throughout the pilots and are detailing all the devices that will facilitate communication between parts of the system, all the sensing devices that will be used in the field as well as all the devices responsible for executing or controlling various system commands. Finally, the section “Software Entities” outlines all the software components that will be used in every part of the IoT architecture.

Lastly, the deliverable ends with the fifth chapter for the conclusions.

2. PILOT SMARTIFICATION/AUTOMATION SURVEYING AND ASSESSMENT.

2.1. DANISH PILOT

2.1.1. Pilot Initial Status Description

Tech House is a cutting-edge commercial office building, offering approximately 300 desk spaces within a 5,000 square meter facility. Located in the business district of Vejle Municipality, within a business park dedicated to innovation and Greentech, Tech House is situated in a rapidly growing business community undergoing significant transformation. The building owner is deeply committed to minimizing environmental impact through sustainable practices.

The development of Tech House will significantly bolster the business district, aligning with Vejle's strategic investments in business development. The building owner, Dandy Business Park, has provided Tech House as a testbed for SEEDS free of charge, demonstrating their commitment to fostering innovation and sustainable growth.

Key demonstrations and innovations include:

1. Life Cycle Assessment (LCA) and circularity assessment during design.
2. Integrative design of battery storage, EV chargers, chiller, and ventilation systems.
3. Management of electricity production, battery charging/discharging, and chiller control to maximize self-consumption of photovoltaic (PV) energy, minimize electricity costs, and optimize thermal comfort.
4. A digital platform for data collection, visualization, and facilitating optimal system operation.
5. Controllers that leverage real-time pricing to deploy energy flexibility.

Figure 1: Danish Pilot Overview

2.1.2. Pilot Assessment Survey

Table 1: Danish Pilot Assessment Survey

DK Pilot:		
Current automation		Indoor Climate, Cooling, Heating, Ventilation
Current Monitoring		Power and District Heating consumption hourly collected from utilities
Technology Gaps	Sensors/Meters	Room sensors on CO2, temperature and RH%. Occupancy. Power meters on PV production, Battery Storage and EV chargers
	Automation	Use of battery storage from weather and energy-prices forecasts.
Bill-of-necessary-devices		*To be concluded*
Data storage and access		Data from CO2, RH%, heat and power meters/sensors will be stored on CDK's data platform and enriched with data on the building (Danish BBR data) energy-prices and weather data for partners to access data to develop a digital twin and optimization models

Since the DK Pilot building is still in the development phase, with the systems and infrastructure being actively constructed, it is not yet possible to provide detailed and concrete descriptions of the specific technologies and their implementation.

2.2. BELGIAN PILOT

2.2.1. Pilot Initial Status Description

Almshouses 'De Schipjes' is a social housing neighbourhood located in the historic city centre of Bruges (Belgium). The buildings were retrofitted between 2014 and 2018, to decrease the heat demand and a low-temperature thermal network (supply temperature 50°C) was designed to meet the heat demands of the twelve households.

The heat in the network is supplied by a centralised ground source heat pump and a centralised solar collector field, which are each connected to their own water storage tank (each 950 l) to introduce some extra flexibility in the thermal network. The space heating in every house is provided by a combination of radiators in every room and a floor heating system on the ground floor. The heat control on demand side is provided through an individual room control (thermostat and valve) in each house, located in the living room. The central heat production is on/ off controlled depending on the heat demand. Domestic hot water (DHW) is produced in each house individually by a booster heat pump which upgrades the low-temperature heat in the houses' thermal network (30-40°C) to the required DHW temperature of 60°C, and stored in a water tank of 100 liter.

There is no cooling provided.

The air flow rate is not controlled: the air flow is supplied continuously for a maximum load of all rooms.

There is no lighting control: all lighting is manually switch on or off.

All heating installations and electricity measurements are linked through Priva (BMS). The BMS allows reporting and monitoring regarding local electricity use (actual values and historical data) as well as the current consumption on building level. The building management system (BMS) also allows a central indication of detected faults and alarms for at least 2 relevant technical building systems (TBS) (the heat pumps and circulators, the solar collector, pressure control).

2.2.2. Pilot Assessment Survey

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Since the pilot case is an upgrade of an existing collective production system for this social housing project and there is no need to differentiate the comfort level in the individual houses (collectively managed by owner and project partner Mintus), no additional questionnaires or dedicated workshop have been organised. The main purpose for the upgrade is to improve seasonal efficiency and guarantee the long-term exploitation of the borefield. The optimal sizing of this new hydronic scheme has been designed and simulated by Sweco Belgium and KUL.

As part of renovations within this project, two air-water heat pumps are added to the existing hydraulic scheme, as well as two extra boreholes to the existing borefield. A new hydronic switch frame enables the possibility to switch between heat sources and different configurations during the year. Construction timeline is 2024 Q4. Construction is supervised by SWECO Belgium. Commissioning 2024- 2026 through MPC (Builtwins) in close collaboration with site owner Mintus.

MPC by Builtwins is currently installed (MPC V0) on the pilot site and controls the district heating. An update of the existing BMS (Priva) and the installation of the hydronic switch scheme will unlock more control options for MPC.

MPC V1 envisions the expansion of the current technology with a calibration method such that the building envelope part of the control model used is calibrated with measurement data, improving the accuracy of the model.

MPC V2 envisions Expansions of the calibrated white-box MPC with:

- Hydraulic switching scheme
- Long-term effects of the borefield, including temperature measurements in the borefield
- Electrical systems (if relevant, e.g., PV+ battery, PVT, ...)
- Implementation of the relevant improvements after virtual evaluation (KUL).
- Through observations in De Schipjes and adjustments in virtual experiments (simulations), aim is to come up with a solid proposal for StijnStreuvels.

Table 2: Belgian Pilot Assessment Survey – De Schipjes

BE Pilot: De Schipjes	
Current automation	Heating automation using centralized priva control system (BACnet) and cloud-based building management system.
Current Monitoring	Electrical meter power: hourly Thermal power of the district heating network Temperature sensor in each district house: sensors have been replaced Hot and cold water use for each district house

Technology Gaps	Sensors/Meters	Temperature sensors at each house thermostat and/or in additional rooms. (LoraWan) Solar irradiation sensors (LoraWan) Measurements of the thermal properties of the walls. (manual on-site measurements) dB sensors to measure noise levels of AW HPs
	Automation	Optimal control using Model Predictive Control. Installation thereof on a local computer. Coupling of this computer to LoraWan sensors.
Bill-of-necessary-devices		*Annex in the tender documents*
Data storage and access		Data from existing BACnet components is collected through the local computer and stored in the cloud database of Builtwins. Furthermore, measurements from the newly installed lorawan sensors will be stored in the same database.

2.3. HUNGARIAN PILOT

2.3.1. Pilot Initial Status Description

The demo building of the Hungarian pilot is located at the XVI. district of Budapest, called “Mátyásföld” at the corner of Újszász street and Prodám street.

The flats owned by the Municipality of the XVI. district of Budapest, which can be rented by tender by residents of the district or by employees for at least 6 months of any institution run by the municipality such as public service, public servants, health service, or public education. The size of each apartment is 22 m2. The building was built in the early 1960s as an unmarried officers' hostel, composed of ground floor + 2 storeys with a flat roof. In the 1990s, the building was converted into a 48-apartment building, a pitched roof was added and the staircase was extended. At present, the apartments are heated individually by one gas-fired convector in each room, there is no permanent heating in the utility rooms, and occasional electric radiators are used in the bathrooms. Domestic hot water (DHW) is provided by electric boilers of approximately 30-40 litres. There is no cooling or mechanical ventilation in the building, and there is not any Renewable Energy System installed either.

2.3.2. Pilot Assessment Survey

Table 3: Hungarian Pilot Assessment Survey

HU Pilot:	
Current automation	No automation system is installed currently. Parapet gas burners are providing heat and AC is not installed in the apartments for cooling purposes.

Current Monitoring		Electricity and gas consumption monthly collected by utilities.
Technology Gaps	Sensors/Meters	No sensors are installed currently in the flats: manual setting is possible only by gas burners. Individual zone controllers of VRV/VRF system need to be installed. Only electricity consumption is measured by utility meters: complete communication architecture needs to be established for connecting Modbus communication capable controllers of PV, Storage, Heat Pump and E-car chargers which components are not specified yet. In order to monitor energy efficiency, it is necessary to collect and archive the following data as well: • outside temperature and relative humidity • electricity consumption of HP • air temperature blown in by indoor units • DHW storage temperature • quantity of cold water used for DHW • consumption of DHW per apartment Sensors and communication system (cable) should be installed.
	Automation	Complete microgrid automation should be established on site with continuous energy management on the cooperating assets. The complete microgrid automation requires clarification of the control conditions and interfaces (data connection) on the basis of an agreement with the energy trader.
Bill-of-necessary-devices		Bill of material is yet to define after the finalization of the general pilot design.
Data storage and access		Data will be stored on local IPC (nanobox PC + HMI) and access will be granted towards IoT gateway for DSO

2.4. GREEK PILOT

2.4.1. Pilot Initial Status Description

Figure 2: Greek Pilot - C1 building

The C1 building is a student dormitory built in 1997 with 68 rooms. It is heated by a central solar/biomass system supported by a central oil boiler occasionally e.g. on periods of prolonged cloud cover; while no cooling system is available. Radiators for space heating and a storage tank for domestic hot water (DHW) supplying individual rooms are also present. Finally, a solar thermal field and a geothermal field are nearby, both of which SEEDS will optimally exploit for C1 building energy needs.

2.4.2. Pilot Assessment Survey

The initial pilot visit took place on April 18th, 2024, in Kimmeria, Xanthi. Three SEEDS partners (CERTH, RENEL, and DUTH) were present on-site. The agenda included a comprehensive tour of the entire pilot site area, an evaluation of the current pilot building C1 status, and an assessment of the pre-existing monitoring and automation systems' capabilities. Additionally, the parties engaged in a broad discussion regarding the necessary equipment to be installed at the pilot site, focusing on defining its functional requirements, the preliminary bill of quantities and determining the dimensions of the various components. Below, an overview table of the evaluation of the Greek Pilot and the outcome of the assessment is presented.

Table 4: Greek Pilot Assessment Survey

EL Pilot:	
Current automation	Currently there are no automation sensors/systems in the pilot building.
Current Monitoring	Some buildings of the student housing complex have a BMS. Building C1, however, does not have a BMS, therefore there is no possibility to record consumption, e.g. electricity and thermal energy or hot water consumption both at building level and at floor/room level. This gap is expected to be filled in the framework of the project. The existing consumptions come from the building's consumption records. The

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		campus is equipped with a central weather station.
Technology Gaps	Sensors/Meters	**For each room (20 rooms (out of 68) to be smartified):** sensors on CO_2, temperature and humidity. Sensors on thermal energy and DHW. Smart thermostats for fan coil control. 1 single-phase energy meter to monitor other electric domestic appliances. **Building Basement:** 1 tri-phase electric energy meter, 1 DHW sensor, 1 thermal energy sensor **A PLC gateway** system that will interconnect all smart IoT devices of each room and the devices of the building's basement in a common local/internal communication network. **2 EV chargers**: Access with an Open API **Bi-facial PV system:** Metering: API provided by smart inverter Control: Access to sun-tracking mechanism **Multi-source Ammonia heat pump:** Control and metering with a Modbus connector
	Automatic	Automatic data collection of all registered room automation sensors/meters into a central PLC gateway, that will be responsible to forward all available information to a cloud data management platform. Use of smart controller on the reflector to maximize energy generation yield. Control the operational modes of the heat pump (modulation). Control the operational mode of the individual fan coils in the rooms (smart thermostats and smart heat meters in each room). Flexible management for the cost-effective charging schedule of the EV chargers.
Bill-of-necessary-devices		*The final/exact Bill-of-necessary-devices to be defined alongside the preparation of the tenders' contest.*

Data storage and access	Data from room-specific CO_2, temperature, humidity, power meters/sensors, DHW and heat energy will be stored on DUTH's energy-database alongside with the data from the other buildings already being stored. These data will be enriched with data from building energy systems (e.g., thermal field measurements, EV charger, smart PV inverter), environmental (e.g., local weather station) and other third-party data repositories (e.g., weather forecasting). Moreover, they will be forwarded to CERTH's central IoT platform.

Network Infrastructure: The C1 building is already equipped with a central network rack. Wireless and stable internet connection throughout each room is provided. There are ethernet ports at each room. Remote access to the building's internal communication network will be available, using a dedicated firewall, allowing for remote off-site management and monitoring, which is essential for maintaining demonstration tests and troubleshooting.

Environmental Monitoring: A meteorological station is present at the site to monitor environmental conditions, which will contribute to the automation IoT platform smart capabilities.

IoT Integration: Each sensor will be connected by using the Modbus RTU protocol into a central programmable logic controller (PLC).

The PLC will forward all communication to the database which will be interfaced with the cloud data platform using MQTT protocol. This IoT ecosystem will be designed to be scalable and secure, catering to the building's needs.

Room Automation: Each of the 20 rooms will be outfitted with a domestic hot water (DHW) sensor, thermal energy meter, a smart thermostat, sensors for indoor temperature, CO_2, and humidity, and an electric smart electric meter at the room supply point. These devices will work in tandem to provide a seamless and intelligent room automation experience.

Climate Control: For temperature regulation, fan coils operating at 230V will be installed, featuring simple ON/OFF control states. Additionally, 3-way valves with sensors will be integrated to ensure precise temperature management. A 70KW heat pump will serve the dual purpose of cooling and heating, adapting to seasonal requirements.

Energy Generation: The building will harness solar energy through bi-facial photovoltaic (PV) panels, which boast two degrees of freedom (x-axis and z-axis) for reflector's orientation control, optimizing sunlight capture. The initial estimate for the installed capacity of the PVs is around 10KW. These panels will be paired with a smart inverter system to efficiently convert and manage the solar energy produced as well as reflector controller mechanism in order to optimize energy yield and efficiency.

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Electric Vehicle Support: EV chargers compliant with the IEC 61851 protocol will be installed. These chargers will have remote control capabilities, allowing for flexible charging schedules according to end-users needs and energy tariffs.

2.5. SLOVENIAN PILOT

To ensure the completeness of this deliverable, this chapter includes content that overlaps with D2.1 as a cross-reference.

2.5.1. Pilot Initial Status Description

Pilot projects are Petrol d.d. gas stations:

- Gas station Izola
- Gas station Bled
- Gas station Čatež
- Gas station Velenje
- Gas station Celje;

Each location has the following energy sources and consumers:

Table 5: Slovenian Pilot – Energy sources and consumers matrix

Location	GS Izola	GS Bled	GS Čatež	GS Velenje	GS Celje
External lighting	Yes	Yes	Yes	Yes	Yes
Internal lighting	Yes	Yes	Yes	Yes	Yes
Heat pump internal heating and cooling	Yes	Yes	Currently no but Planned	Currently no but Planned	Currently no but Planned
HVAC Split-systems	Yes	Yes	Yes	Yes	Yes
Ventilation devices	Yes	Yes	Yes	Yes	Yes
Heat pump – sanitary water	Yes	Yes	Yes	Currently no but Planned	Yes
Photovoltaic power plant	Yes	Yes	Currently no but Planned	Yes	Yes
Car wash	Yes – Manual	Yes – Manual	No	Yes – Automatic	No
Car wash – heated water with a heat pump	Currently no but Planned	Currently no but Planned	-	-	-
Car wash – floor heating	No	Yes	-	Yes	-
Electric heating of gutters	No	Yes	Yes	Yes	Yes
Electric vehicle charging station	No	Yes	Yes	No	Yes
Battery storage	No	No	Currently no but Planned	No	No
Diesel generator	No	No	Yes	Yes	No

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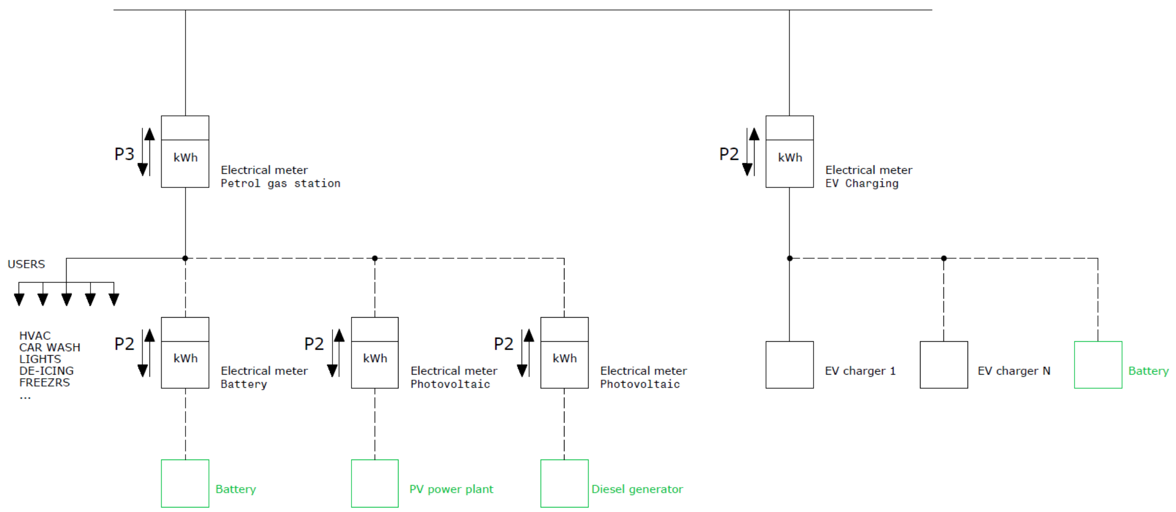

Figure 3: Gas station location schematic – generalized

Gas station "Bled"

Figure 4: Gas station "Bled"

Built in 2019 and with photovoltaic power plant added in 2022 gas station Bled is the newest of the pilot locations. Gas station Bled has a building management system in place. Monitoring and automation for external lighting and HVAC is implemented.

Gas station "Izola"

Figure 5: Gas station "Izola"

Gas station Izola has been built in 2015 and had a photovoltaic power plant added in 2022. It does not have energy monitoring and automation of devices in place. The building has a bar, which is leased out, has a separate metering point, and is not part of the project.

Gas station "Čatež"

Gas station Čatež has been built in 2004 and will have a photovoltaic power plant added in either 2024 or 2025. It does not have energy monitoring and automation of devices in place. The conditioned area is 214 m2. The building has a bar, which is leased out, has a separate metering point, and is not part of the project. Business hours: NON-STOP 24/7.

Figure 6: Gas station "Čatež"

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Gas station "Velenje"

Gas station Velenje has been built in 1997 and had a photovoltaic power plant added in 2023. It does not have energy monitoring and automation of devices in place. The conditioned area is 270 m2. Business hours: Mon – Fri: 6:00 AM – 8:00 PM: Sat: 7:00 AM – 7:00 PM Sun, and holidays: 8:00 AM – 6:00 PM

Figure 7: Gas station "Velenje"

Gas station "Celje"

Gas station Celje has been built in 2007 and had a photovoltaic power plant added in 2023. It does not have energy monitoring and automation of devices in place. The conditioned area is 220 m2. The building has a bar, which is leased out, has a separate metering point, and is not part of the project. Business hours: NON-STOP 24/7.

Figure 8: Gas station "Celje"

2.5.2. Pilot Assessment Survey

Gas station " Bled"

The gas station location consists of the main gas station building, gas pumps under a separate covered area on one side of the building and a manual car wash located across a parking lot on the other side of the main building. Main building contains the shop area, food corner, storage, toilets, communication equipment room, boiler room and a separate bar area which is rented out to a bar business owner.

The bar has it's own electrical meter (kilowatt-hour meter) and a distribution box. The bar is not included in the pilot.

The main gas station building is already partially managed by POL648.80 (PETROL TP09) controller. The equipment that is not fully monitored and automated should be upgraded in a way that enables automated control of energy flows in the building. If POL648.80 (PETROL TP09) controller requires more inputs and outputs it can be upgraded by expansion modules.

Manual car wash uses oil boiler for water heating a will be upgraded with a heat pump that will satisfy the monitoring and automation requirements.

Existing photovoltaic power plant on the roof of the gas station will be included into energy management system.

Table 6: Slovenian Pilot Assessment Survey – Gas station Bled-Seliška

SL Pilot – Gas station Bled:		
Current automation		Indoor Climate, Cooling, Heating, Ventilation, External lighting, Gutter heating.
Current Monitoring		Power and District Heating consumption hourly collected from utilities, External lighting, Water consumption, Solar power production
Technology Gaps	Sensors/Meters	Room sensors on CO2, temperature and RH%. Occupancy. Power meters on PV production.
	Automatic	Integrated monitoring and automation of power sources and loads/users at location for optimal energy management.
Bill-of-necessary-devices		Car wash boiler room, Heat pump 14kW, Socomec W50x EE consumption monitor, communication adapter for heat pump (if needed).
Data storage and access		**Data Collection:**

	The Data Collector collects data over the HTTPS protocol via a TCP/IP interface from a Central SQL database or OPC. **Database Storage:** The collected data are written into its own database within the IoT platform. **Data Integration:** The data integration component sends the data over TCP into a Message Queue. **IJS Side:** The Message Queue on the IJS (Institute Jožef Stefan) side receives the data.

Gas station " Izola"

The gas station location consists of the main gas station building, gas pumps under a separate covered area on one side of the building and a manual car wash located across a parking lot on the other side of the main building. Main building contains the shop area, food corner, storage, toilets, communication equipment room, boiler room and a separate bar area which is rented out to a bar business owner.

The bar has it's own electrical meter (kilowatt-hour meter) and a distribution box. The bar is not included in the pilot.

The main gas station building doesn't have an automated building management system. The equipment should be upgraded in a way that enables automated control of energy flows in the building. If POL648.80 (PETROL TP09) controller with a sufficient number of expansion module will be used for monitoring or automation.

Manual car wash uses oil boiler for water heating a will be upgraded with a heat pump that will satisfy the monitoring and automation requirements.

Existing photovoltaic power plant on the roof of the gas station will be included into the energy management system.

Table 7: Slovenian Pilot Assessment Survey – Gas station Izola-Industrijska

SL Pilot – Gas station Izola:	
Current automation	Indoor Climate, Cooling, Heating, Ventilation, Internal Lighting (partial), External Lighting.
Current Monitoring	Power and Heating consumption hourly collected from

		utilities, Solar power production.
Technology Gaps	Sensors/Meters	Room sensors on CO2, temperature and RH%. Occupancy. Power meters on PV production.
	Automatic	Integrated monitoring and automation of power sources and loads/users at location for optimal energy management.
Bill-of-necessary-devices		Monitoring devices and communication adapters as needed.
Data storage and access		**Data Collection:** The Data Collector collects data over the HTTPS protocol via a TCP/IP interface from a Central SQL database or OPC. **Database Storage:** The collected data are written into its own database within the IoT platform. **Data Integration:** The data integration component sends the data over TCP into a Message Queue. **IJS Side:** The Message Queue on the IJS (Institute Jožef Stefan) side receives the data.

Gas station " Čatež"

Is a gas station on the highway. The gas station location consists of the main gas station building, with a shop area on the left and a restaurant area on the right side of the building. The area of the gas station includes a shop area, storage, toilets, a communication equipment room, a boiler room. S separate restaurant area is rented out.

The restaurant has it's own electrical meter (kilowatt-hour meter) and a distribution box. The restaurant is not included in the pilot.

The location has two electric vehicle charging stations (2 x 50 kW). It is planned to add two more charging stations in the coming years.

The main gas station building doesn't have an automated building management system. The equipment should be upgraded in a way that enables automated control of energy flows in the building. If POL648.80 (PETROL TP09) controller with a sufficient number of expansion module will be used for monitoring or automation.

There is currently no photovoltaic power plant, but one will be added in 2024 or 2025. In addition to photovoltaics, the integration of a battery storage system is planned.

Heating is currently provided by liquefied petroleum gas (LPG), while hot water preparation is primarily done using a heat pump. We want to switch heating to a heat pump. The heating with LPG will remain in place and is intended to operate during colder temperatures and offering flexibility.

Table 8: Slovenian Pilot Assessment Survey – Gas station Čatež

SL Pilot – Gas station Čatež:		
Current automation		Indoor Climate, Cooling, Heating, Ventilation, External lighting, Gutter heating.
Current Monitoring		Power and District Heating consumption hourly collected from utilities, External lighting, Water consumption, Solar power production.
Technology Gaps	Sensors/Meters	Room sensors on CO2, temperature and RH%. Occupancy. Power meters on PV production
	Automatic	Integrated monitoring and automation of power sources and loads/users at location for optimal energy management.
Bill-of-necessary-devices		Boiler room with Heat pump for heating an heat pump for DHW, Socomec W50x EE consumption monitor, communication adapter for heat pump (if needed), Socomec I-35, Socomec TE18, Socomec D50, Socomec U-30, Socomec Power supply P15 100-240 VAC/ 24 VDC 15 W, SOCOMEC RJ12 link kabel x m, Socomec BUS kabel x m RJ45 in Socomec BUS kabel x m RJ45, (Battery storage), PLC PETROL TP09.
Data storage and access		**Data Collection:** The Data Collector collects data over the HTTPS protocol via a TCP/IP interface from a Central SQL database or OPC. **Database Storage:**

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	The collected data are written into its own database within the IoT platform. **Data Integration:** The data integration component sends the data over TCP into a Message Queue. **IJS Side:** The Message Queue on the IJS (Institute Jožef Stefan) side receives the data.

Gas station " Velenje"

Is a gas station on main road between the highway ang Velenje. The gas station location consists of the main gas station building, with an automated manual car wash located near the main building. The area of the gas station includes a shop area, storage, toilets, a communication equipment room, a boiler room.

The main gas station building doesn't have an automated building management system. The equipment should be upgraded in a way that enables automated control of energy flows in the building. If POL648.80 (PETROL TP09) controller with a sufficient number of expansion module will be used for monitoring or automation.

Existing photovoltaic power plant on the roof of the gas station will be included into the energy management system.

Heating is currently provided by heating oil, while hot water preparation is done using electric heaters. We want to switch the heating an the prepration of hot water to a heat pump.

Table 9: Slovenian Pilot Assessment Survey – Gas station Velenje-Celjska

SL Pilot – Gas station Velenje:		
Current automation		Indoor Climate, Cooling, Heating, Ventilation, External lighting, Gutter heating.
Current Monitoring		Power and District Heating consumption hourly collected from utilities, External lighting, Water consumption, Solar power production.
Technology Gaps	Sensors/Meters	Room sensors on CO2, temperature and RH%. Occupancy. Power meters on PV production.
	Automatic	Integrated monitoring and automation of power sources and loads/users at location for optimal energy

	management.
Bill-of-necessary-devices	Boiler room with Heat pump for heating an heat pump for DHW, Heating storage, Socomec W50x EE consumption monitor, communication adapter for heat pump (if needed), Socomec I-35, Socomec TE18, Socomec D50, Socomec U-30, Socomec Power supply P15 100-240 VAC/ 24 VDC 15 W, SOCOMEC RJ12 link kabel x m, Socomec BUS kabel x m RJ45 in Socomec BUS kabel x m RJ45, (Battery storage), PLC PETROL TP09.
Data storage and access	**Data Collection:** The Data Collector collects data over the HTTPS protocol via a TCP/IP interface from a Central SQL database or OPC. **Database Storage:** The collected data are written into its own database within the IoT platform. **Data Integration:** The data integration component sends the data over TCP into a Message Queue. **IJS Side:** The Message Queue on the IJS (Institute Jožef Stefan) side receives the data.

Gas station " Celje"

Is a town gas station. The gas station location consists of the main gas station building, gas pumps under a separate covered area on one side of the building. Main building contains the shop area, food corner, storage, toilets, communication equipment room, boiler room and a separate bar area which is rented out to a bar business owner.

The main gas station building doesn't have an automated building management system. The equipment should be upgraded in a way that enables automated control of energy flows in the building. If POL648.80 (PETROL TP09) controller with a sufficient number of expansion module will be used for monitoring or automation.

Existing photovoltaic power plant on the roof of the gas station will be included into the energy management system.

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Heating is currently provided by a roof-top heating machine on a natural gas., while hot water preparation is done using a heat pump. We want to switch the heating to a heat pump.

Table 10: Slovenian Pilot Assessment Survey – Gas station Celje - Mariborska

SL Pilot – Gas station Celje:		
Current automation		Indoor Climate, Cooling, Heating, Ventilation, External lighting, Gutter heating.
Current Monitoring		Power and District Heating consumption hourly collected from utilities, External lighting, Water consumption, Solar power production.
Technology Gaps	Sensors/Meters	Room sensors on CO2, temperature and RH%. Occupancy. Power meters on PV production.
	Automatic	Integrated monitoring and automation of power sources and loads/users at location for optimal energy management.
Bill-of-necessary-devices		Reversible Heat pump for heating and cooling with storage (if possible), Socomec W50x EE consumption monitor, communication adapter for heat pump (if needed), Socomec I-35, Socomec TE18, Socomec D50, Socomec U-30, Socomec Power supply P15 100-240 VAC/ 24 VDC 15 W, SOCOMEC RJ12 link kabel x m, Socomec BUS kabel x m RJ45 in Socomec BUS kabel x m RJ45, (Battery storage), PLC PETROL TP09
Data storage and access		**Data Collection:** The Data Collector collects data over the HTTPS protocol via a TCP/IP interface from a Central SQL database or OPC. **Database Storage:** The collected data are written into its own database within the IoT platform. **Data Integration:** The data integration component sends the data over TCP into a Message Queue. **IJS Side:**

	The Message Queue on the IJS (Institute Jožef Stefan) side receives the data.

3. TECHNICAL SPECIFICATIONS DEFINITION.

3.1. DANISH PILOT

3.1.1. Observable Features and Sampling Frequency

Table 11: Danish Pilot Observable Features

Observable Feature	Sampling Frequency	Observation Level	Historic Data Availability	Time Span of Historic Data	Data Source
Room temp	*Minimum Hourly*	Room	No	-	IoT GSM
Heat, energy	*Minimum Hourly*	Building and room	No	-	Iot and utility
Heat, flow	*Minimum Hourly*	Building	No	-	Utility
Heat, Forward temp	*Minimum Hourly*	Building	No	-	Utility
Heat, Return Temp	*Minimum Hourly*	Building	No	-	Utility

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Room CO2	*Minimum Hourly*	Room	No	-	Iot GSM
Room RH%	*Minimum Hourly*	Room	No	-	Iot GSM
Electricity, consumption	*Minimum Hourly*	Building	No	-	Utility
Solar, production	*Minimum Hourly*	Building	No	-	Utility
Electricity, Storage	*Minimum Hourly*	Building	No	-	Iot GSM
Outdoor temp	*Minimum Hourly*	Building	Yes	5 years	Danish Metrological Institute
Building data	*Static*	Building	No	-	Drawings and Danish Building Register (BBR)

3.1.2. Communication Protocol, Authorization and Security Mechanisms

The Center Denmark Data Platform can ingest data from different sources in a variety of ways, spanning from batch ingestion through sFTP, via push or pull from APIs to streaming using MQTT.

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Though flexibility is important, the first focus is data safety and security, as we store several types of sensitive data. This is achieved by only receiving data through secure encrypted communications. At rest the data is also encrypted, while also being placed in the platform, only accessible through an API, that supplies an extra layer of safety.

Access to data is handled through the Center Denmark Data Portal.

When a user logs in the first time, a user is automatically created. It is then possible to view and download the public data sets available.

When a data user has had their identity confirmed, access to closed data sets can be granted.

The portal is operated from the Principle of Least Privilege (PoLP), meaning that generally a user will only have access to the data they need.

Depending on the legal agreements of a project, sometimes it is decided, that all data for a project is available to all partners within the project. However, PoLP is the general rule, if nothing else is specified and covered legally.

3.1.3. Database Schemas and Data Models

At Center Denmark we work with several different data models. As the data to be ingested has yet to be specified through the use cases, the data model to be used, is also a work in progress.

CDK has a couple of existing data models that can be used as inspiration depending on which requirements the project will have. One data model is focused on smart buildings and based on SAREF and SAREF4ENER, which might be relevant: https://github.com/CenterDenmark/saref-cim-datamodel It is a theoretical data model that covers a lot of different unit types and data types, and as such is too complex to give a visual overview of in a report.

A more simplistic data model that we use, is the “Generic data model for district heating”. This data model is described in more detail in the Figure 9. In short it is focused on district heating data, but is being expanded to include other types of energy as well.

When the requirements for the data needed in SEEDS become clearer, it will be possible to define and describe a specific data model much more clearly.

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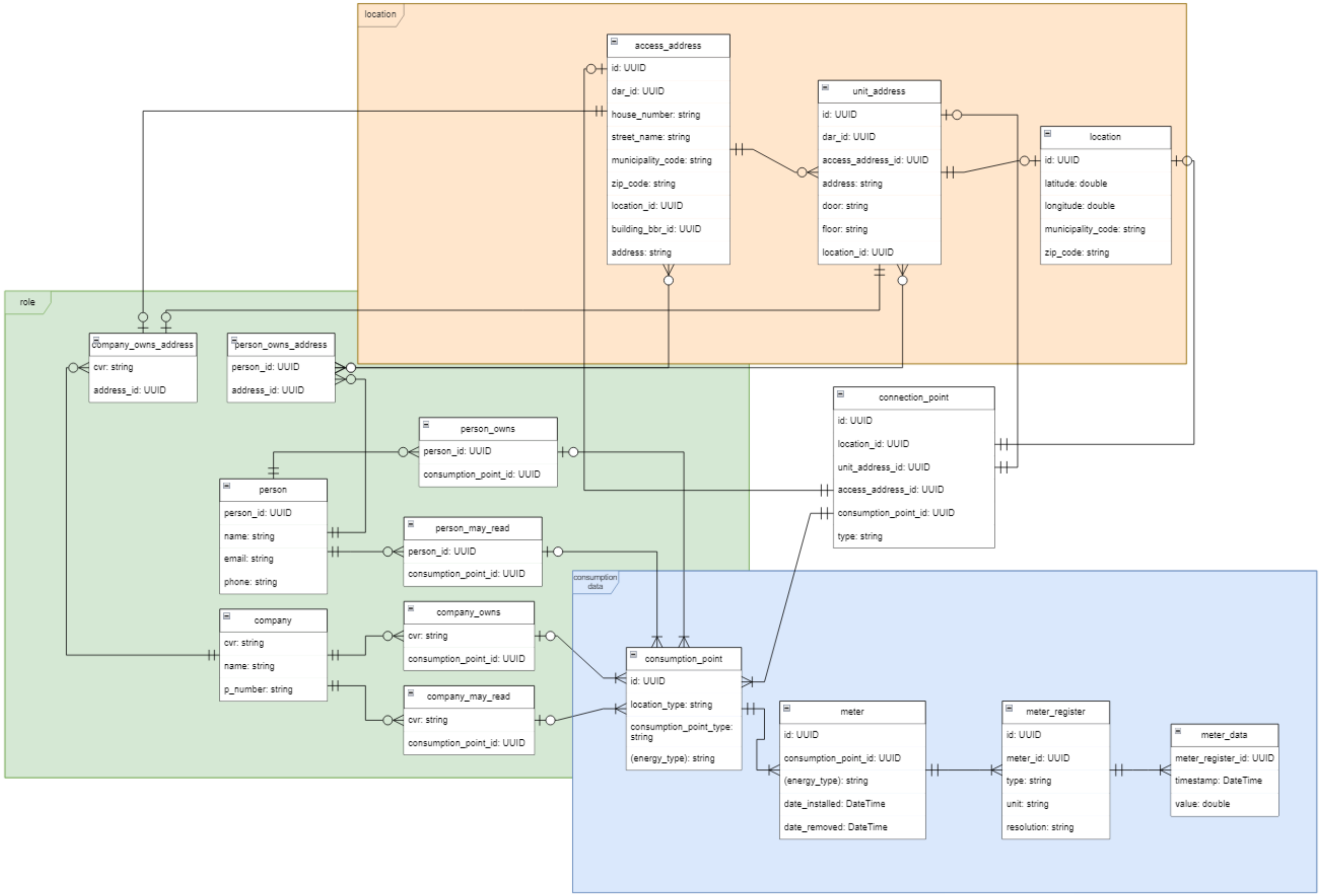

Figure 9: Generic data model for district heating diagram

3.1.4. Hosting Requirements

The Center Denmark Data Platform and Portal are fully scalable and based on clusterings of several servers for each component, which, beside scalability, also ensure high availability.

This means that it will be possible to scale the entire system for either more storage or more traffic by adding servers. Further, our servers are located in data centers where they can be upgraded, usually within a few days.

3.2. BELGIAN PILOT

3.2.1. Observable Features and Sampling Frequency

Below is an overview of the observable features of the De Schipjes pilot, which consists of 12 individual houses and a central heating system. The abbreviation 'COV' indicates that 'Change of value' sampling is used, which is a feature of BACnet, one of the used communication protocols. COV means that the sensor reports when its value change by more than a preconfigured threshold. This means that the sampling frequency is variable.
Note that not all sensors below are logged.

Table 12: Belgian Pilot Observable Features

Observable Feature	Sampling Frequency	Observation Level	Historic Data Availability	Time Span of Historic Data	Data Source
Zone temperature	*COV*	1 sensor per house	No	-	BMS
Distribution system temperature	COV	Multiple per house	No	-	BMS
Production system temperature	COV	Multiple	No	-	BMS
Weather forecasts	30 minutes	Temperature, humidity, solar, wind	No	-	Weather forecast provider
Zone temperature sensors	20 minutes	1 per house	No	-	Lorawan sensors + gateway

Energy meters house	20 minutes / none	Per house: electricity, electricity heat pump, heat	No	-	Energy meters: thermal/electrical, BMS
Energy meters system	20 minutes	Solar collector, geothermal borefield, heat pump, district	No	-	BMS
Solar sensors	20 minutes	Solar irradiation on 3 orientations	No	-	Lorawan sensors + gateway

3.2.2. Communication Protocol, Authorization and Security Mechanisms

The existing building management system operates using multiple Priva controllers. They internally communicate between using an unknown protocol. The man controller however supports the BACnet communications protocol. Builtwins has installed one local computer on site that communicates with the Priva controllers over the local network using BACnet/IP. This interface is used to set control setpoints for individual components and to read measurements from the system various Priva (sub)controllers. Measurements are collected either through periodic polling (every 20 minutes) or using COV subscriptions.
The local computer periodically polls from a coordination server whether or not MPC should be active. This communication happens through an encrypted https connection and token authentication. The same communication interface is used to periodically push new measurements to a cloud database. Furthermore, https and token authentication is used periodically to request weather forecasts from a weather forecast provider.
A Lorawan gateway is installed on the same network, which sends its measurements to the same cloud computer using token authentication. Lorawan sensors send a measurement to the gateway every 20 minutes, which is subsequently forwarded to the cloud server.
The BMS is cloud-hosted by Priva, which can be accessed publicly using https and which uses two-factor password + e-mail authentication. The communications protocol between the Priva cloud and the Priva controllers is unknown.
Periodic security updates are performed on the local computer and on the cloud servers. All local Builtwins devices are installed behind a firewall/router that is managed by Mintus.

Figure 10: Belgian Pilot – Communication diagram

The figure above provides a schematic overview of this information.

3.2.3. Database Schemas and Data Models

Measurements are stored using a graphite database wherein each measurement timeseries is saved in a unique file.

3.2.4. Hosting Requirements

As explained above, one local computer is installed on-site, together with a Lorawan gateway. Furthermore, cloud server infrastructure is shared with other MPC projects of Builtwins.

3.3. HUNGARIAN PILOT

3.3.1. Observable Features and Sampling Frequency

Table 13: Hungarian Pilot Observable Features

Observable Feature	Sampling Frequency	Observation Level	Historic Data Availability	Time Span of Historic Data	Data Source

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Solar radiation	*15 min*	Roof	No	-	Weather station
Wind speed	*10 min*	Roof	No	-	Weather station
Ambient temperature	*COV**	Roof	No	-	Weather station
Panel temperature	*COV**	PV Inverter	No	-	PV Inverter
Site consumption power, energy	*15 min*	EGS Sensor	No	-	EGS Sensor
E-Car charging consumption, power, energy	*15 min*	Local energy meter	No	-	E-car Charger
PV generation, power, energy	*15 min*	PV Inverter	No	-	PV Inverter
Storage charging/discharging power, energy	*15 min*	Local storage controller	No	-	Storage controller
Storage SoC (%)	*COV**	Local storage controller	No	-	Storage controller
Heat pump consumption power, energy	*COV**	Local heat pump controller	No	-	Heat pump controller

***COV means:** that the sensor reports when its value change by more than a preconfigured threshold

3.3.2. Logical System Architecture and Description

A holistic framework of the all the assets and the communication diagram of the Hungarian pilot is presented in the diagram in Figure 18.

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Communication protocols:

PV system: Modbus TCP

Energy storage: Modbus TCP

Car chargers: Modbus TCP

Heat Pump: Modbus TCP

Reverse-feed protection: IEC61850 (Depends on DSO Contract)

EGS sensor – Sicam MGC controller: IEC60870-5-104.

Communication with DSO (IEC60870-5-104)

Main control is established with the on-premise software, running on the Sicam A8000 CP8050. The main controller is capable to regulate on-site power generation and loads with developed logics for photovoltaic system, energy storage system, heating system and electric car charger taking into consideration continuously the overall consumption of the building with the Sicam EGS sensor. This metering provides the base signal for the central control device on which the Sicam Microgrid Control software is running.

Because the current DSO (E.ON) regulatory, reverse feed protection and isolation protection has to be established at the point of common coupling (DSO infeed). This protection functions are running on the E.ON-approved ComAp Intellipro protection device which also needs current and voltage signals from the DSO infeed (Point of Common Coupling). The activation of the corresponding protection sends MODBUS TCP (using IB-Lite plug-in module) to the EGS sensor which converts this tripping signal to IEC61850 Goose message and stops the power generation of the inverters of photovoltaic and energy storage system.

The heating system provided by DAIKIN has a build-in controller which sends measured signals and receives operational points from the Sicam Microgrid Controller using the internal network topology via Modbus TCP protocol. For the galvanic insulation media converter is used which connects this heating subsystem to the Microgrid Controller with fiber-optic cable.

Similarly to the heating subsystem Siemens Versicharge AC electric car charger is also integrated into the Microgrid ecosystem. The Siemens Versicharge AC electric car charger sends measured data and signals and receives charging limitation signal from the Microgrid Controller using Modbus TCP protocol. The service backend for this subsystem is called VersiCloud, which enables the patch management and asset transparency.

A rooftop-mounted & facade mounted photovoltaic subsystem is generating energy through its string inverter, which is also continuously controlled by the Sicam Microgrid Control system.

The PV inverter is sending measured and status information and receives operational points from the microgrid converter using Modbus TCP protocol. For energy monitoring purposes weather sensors are also integrated into this system which are collecting basic information like solar radiation, panel temperature, ambient temperature and wind speed.

The energy storage system is capable to store the CO2 neutral PV energy into its batteries and lets shift this energy intra-day. This subsystem's charging and discharging is controlled by the Sicam Microgrid Control software.

As written above the Sicam Microgrid Control software is continuously regulating the on-site consumption, energy storage and energy generation assets. This parameterized and commissioned system does this continuous control autonomously. Additionally this system provides interface towards aggregator company (E.ON) and provides data using Modbus TCP to the aggregator system, in which the complete building as a controllable microgrid can be monitored and regulated via receiving setpoints from the cloud using Modbus gateway.

The complete system uses local time synchronisation and the operation can be followed using the local IPC in which the HMI interface and the local archiving is running.

For marketing purposes, a dashboard display will be placed to share the main data about the microgrid: CO2 saving, e-charging energy, stored energy, and heating energy in a form of different charts.

3.4. GREEK PILOT

3.4.1. Observable Features and Sampling Frequency

An overview list of all the observable features and their sampling frequency of the C1 building is provided below, which consists of the automation for 20 student dorm rooms.

Table 14: Greek Pilot Observable Features – C1 building

Observable Feature	Sampling Frequency	Observation Level	Historic Data Availability	Time Span of Historic Data	Data Source
Electric Energy Consumption	*15 minutes*	Room	No	-	IoT Energy Meters in each room

Domestic Hot Water Consumption	*15 minutes*	Room	No	-	IoT DHW sensors in each room
Temperature	*5 minutes*	Room	No	-	IoT temperature sensors in each room
Humidity	*15 minutes*	Room	No	-	IoT humidity sensors in each room
CO2	*15 minutes*	Room	No	-	IoT CO2 sensors in each room
Thermal Energy Consumption (FCUs)	*15 minutes*	Room	No	-	IoT Thermal Energy sensors in each room
Fan Coil Status	*5 minutes*	Room	No	-	IoT smart thermostats in each room (with Fan Coil control)
Domestic Hot Water (Basement)	*15 minutes*	Building	No	-	Central IoT DHW sensor in basement
Thermal Energy Consumption (Basement)	*15 minutes*	Building	No	-	Central IoT Thermal Energy sensor in basement
Triphase Electric Energy	*15 minutes*	Building	No	-	Central IoT Triphase Electric

Consumption					Energy meter at building-supply-point

For the PV system, several key operational components will be monitored upon installation of the system. The proposed solution involves the installation of bifacial PV panels on the nearby field area in order to generate electricity from both sides of the panel, increasing their energy production potential. These panels will be installed at a fixed angle and south orientation. A reflection tracking system will be integrated into the PV plant to maximize the photovoltaic energy production. Parameters, such as electrical energy production and consumption, losses at the components, as well as voltage and current measurements will be captured to monitor the performance of the system. The algorithms used in the reflection system could take into consideration various factors, such as: Position of the sun, weather conditions, power demand, seasonal variations and adjust the mirrors accordingly to ensure optimal energy production throughout the year.

In the multi-source heat pump system, all operational parameters of the unit, including energy consumption, pressure levels, and supply ammonia temperature readings, will be monitored and accessible. This data acquisition will allow for real-time oversight of the system's performance (COP), enabling efficient management and optimization of energy usage (modulation control), as well as proactive detection and resolution of potential issues, such as pressure imbalances or temperature anomalies.

In the electric vehicle (EV) chargers, key parameters such as power output, energy consumption, voltage and current levels during charging sessions will be monitored. Additionally, the system could be able to monitor different operational and status indicators such as charging duration, session history or charger status (idle/active etc.) as well as EV battery SoC.

3.4.2. Communication Protocol, Authorization and Security Mechanisms

In the context of the multi-room automation system, all sensors and actuators within each of the 20 rooms, including those measuring electric energy, domestic hot water (DHW), indoor temperature, humidity, CO_2, and thermal energy, communicate via the Modbus RTU protocol to a central Programmable Logic Controller (PLC). Similarly, the central meters and sensors located in the building's basement, which measure DHW, thermal energy, and three-phase electric energy, are also integrated into the same Modbus RTU network. The PLC acts as the central hub for collecting and processing this data, ensuring that all sensor inputs are efficiently managed. The PLC stores all collected sensor data into two (2) dedicated database servers to incorporate data Confidentiality, Availability and Integrity. The database servers are the central hubs through which are forwarded to partners using authenticated MQTT and/or HTTPS API.

Below is an overview diagram of the communication between the devices of the C1 building.

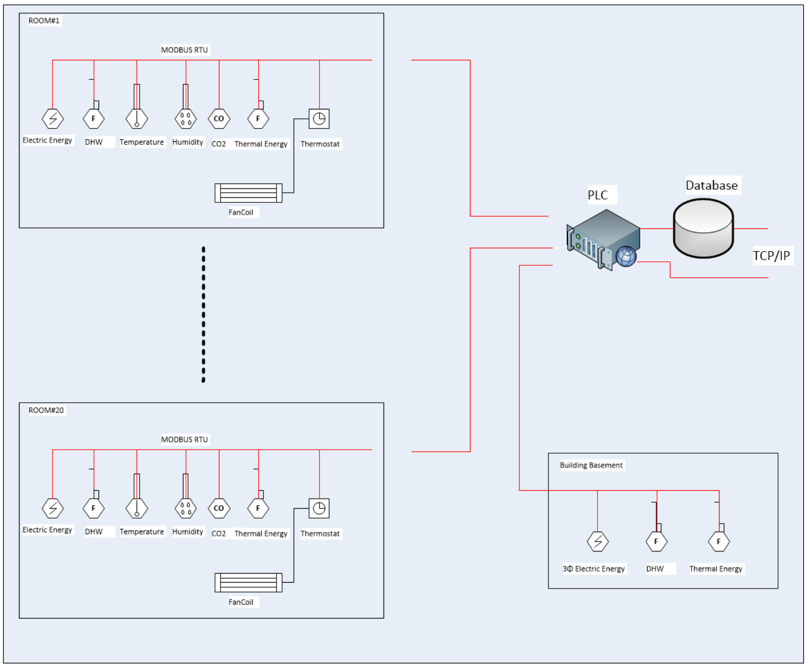

Figure 11: Greek Pilot Communication Diagram

For the PV system communication specifics between the IoT platform and the PV reflector servo mechanism have not yet been specified. Communication between the platform and the smart inverter system will be feasible by using a token-based REST API.

The multi-source heat pump will be directly connected with a ModBus controller that will allow for monitor and control of the heat pump remotely using the ModBus TCP protocol.

Communication between the platform and the EV chargers will be made according to the device protocol using TCP/IP.

3.4.3. Database Schemas and Data Models

The database uses a custom flexible scheme to store the amount of data produced by the sensors.

Additionally, in order to create a holistic framework to outline and monitor all the infrastructure of the Greek Pilot into the IoT platform, the building's internal rooms and sensors as well as the different energy systems (Multi-source heat pump, Bi-facial PV and EV chargers) have been divided and modelled into separate indicative data entities.

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Key Entities and Relationships:

1. **Building**
   - The central data entity of the data model is the Building entity. A building will contain multiple rooms. The building entity has an association with the PV System, Heat Pump and EV charger entities, representing the installation of these systems in the building.
2. **Room**
   - A building is further divided into multiple rooms (20 rooms and the basement room). Each room is belonging in a specific building. A room will have multiple Sensors installed, indicating the different devices or technologies monitoring various parameters in each room.
3. **PV System, Heat Pump, and EV charger:**
   - These three entities represent energy systems installed in the building. Each system will have multiple readings or sessions associated with it.
     I. **PV System Reading**: Each PV system can record multiple measurements, represented by the PV System Reading entity.
     II. **Heat Pump Reading**: Similarly, each heat pump records measurements, and these are tracked through the Heat Pump Reading entity
     III. **EV Charger Session**: Each EV charger records charging sessions through the EV Charger Session entity. The status of the EV charger (e.g. available, in-use) is tracked through the EV Charger Status entity.
4. **Sensor**
   - The Sensor entity represents the different types of sensors installed in the rooms for monitoring various parameters. Each sensor is associated with a Room and is classified by a Sensor Type, indicating what kind of measurement a sensor is taking (e.g. Temperature, humidity). Naturally, each sensor will have multiple readings over time, and these are captured and stored on a separate **Sensor Reading** entity.
5. **Sensor Type**
   - This entity classifies the different type of sensors that will be installed in the rooms. It defines the characteristics of the sensor, such as the unit of measurement and what the sensor will be monitoring.

An illustration of these entities and relationships, showing the data model of the IoT platform for the Greek Pilot, is presented below with an entity-relationship diagram (ERD).

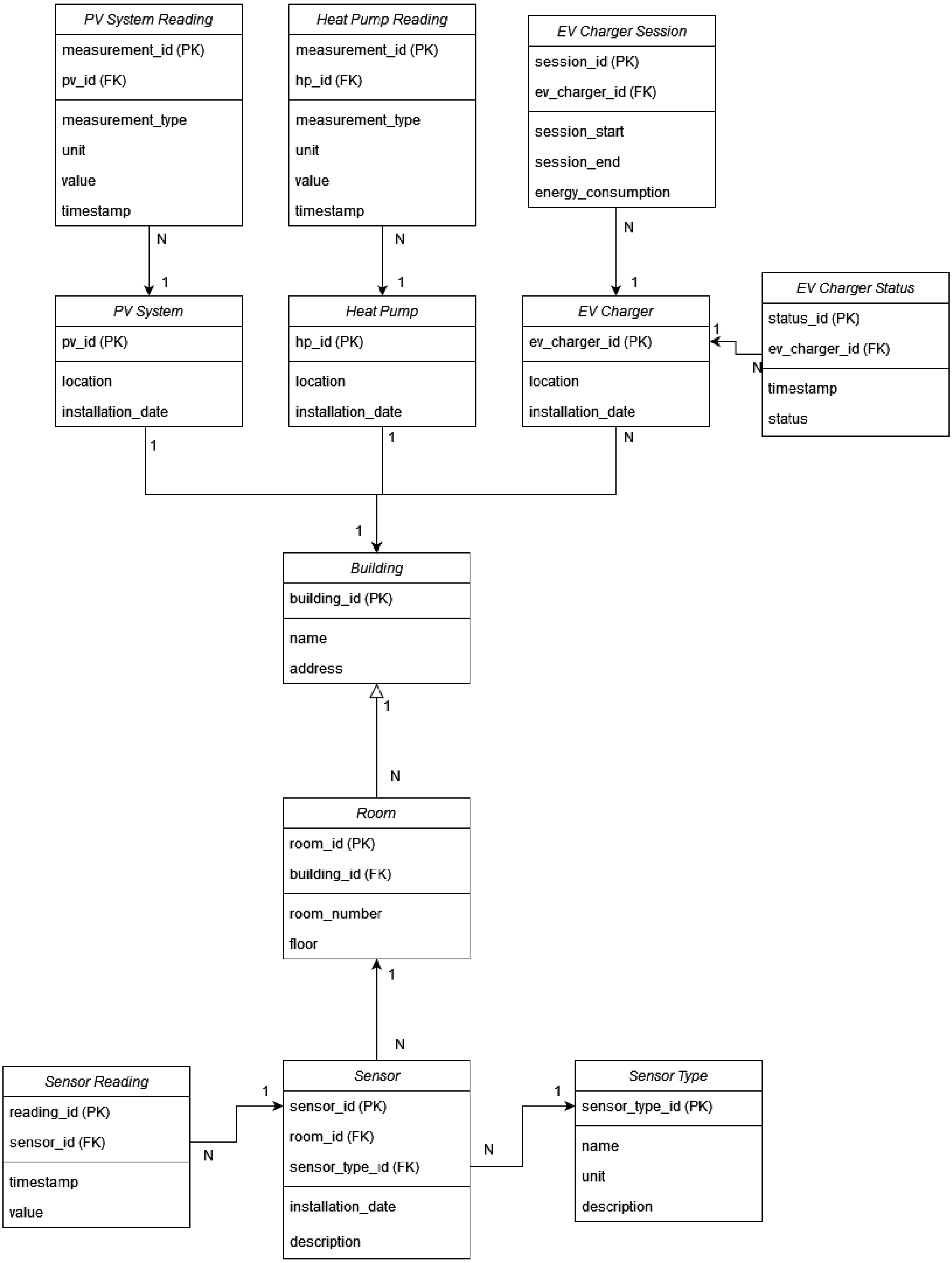

Figure 12: Greek Pilot ER diagram

3.4.4. Hosting Requirements

All the components of the IoT platform will be hosted on-premise.

3.5. SLOVENIAN PILOT

3.5.1. Observable Features and Sampling Frequency

All technological devices that will ensure flexibility at the facility are connected to the PETROL TP09 PLC via appropriate communication or signal protocols. The PLC will be integrated into the system as a master controller, which will take care of optimal control based on online measurements (e.g. temperature measurement...) and various input parameters (required references from other subsystems).

Measurements on PLC are in online mode, which means that the data is constantly available and the pooling time from PLC to SCADA system is practically every second. A visual display of the data is displayed on the SCADA screen and is refreshed every second.

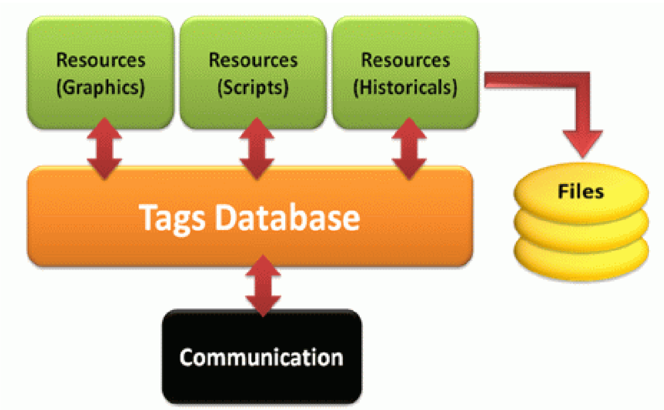

Figure 13: Slovenian Pilot – High level architecture of data acquisition

For the purpose of displaying historical data, the data is archived in the SQL Server database every 15 minutes.

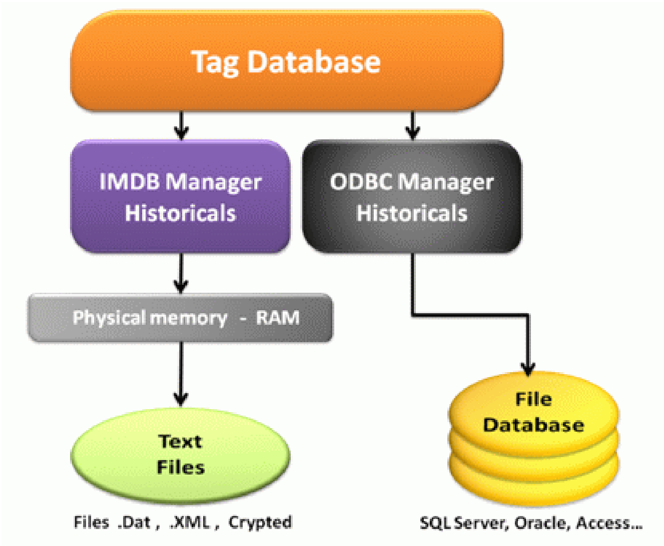

Figure 14: Slovenian Pilot – Historical data management architecture

The exact list of measurements will be determined in project design phase, but mostly they are the measurements as:

- Temperatures and pressure in the boiler system
- Operating statuses of circulation pumps, valves, heat pumps,...
- Room temperatures
- Measurements (energy, flow, power,..) from heat counters and water counters
- Measurements (energy, voltages, currents, power,..) from electrical counters
- ....

3.5.2. Communication Protocol, Authorization and Security Mechanisms

Basic automation is running on a programmable logic controller (PLC) Siemens Climatix POL648.80(PETROL TP09). This device fully meets our requirements in terms of communication, inputs, outputs (I/O) and the possibility of free programming. The automation itself which will be installed at the locations will enable proper connectivity to PETROL SCADA system a PETROL IoT and will also be able to operate completely autonomously separately from other system, if necessary. Depending on the input data that the automation will receive, it will control the system according to the specified parameters. Devices communicate with the SCADA system over MODBUS TCP/IP protocol.

The Petrol IOT platform uses standard security mechanisms. We connect to systems that have their own security mechanisms, the integration takes place via Kafka and its security mechanisms.

3.5.3. Database Schemas and Data Models

A data model containing all the agreed values will be prepared during the project.

3.5.4. Hosting Requirements

Petrol IoT platform runs on Azure Kubernetes Service (AKS).

4. TECHNICAL ARCHITECTURE DEFINITION

4.1. DANISH PILOT

Given the current state of development in the Danish pilot, there are still a lot of uncertainties. However, we will describe the system as we expect it to be once the building is completed and all automation systems and other components are implemented. This includes establishment of collection of 3rd party data to the Center Denmark platform.

4.1.1. Overview of Technical Architecture for Automation and IoT Ecosystem

As the diagram on the next page shows, there are different levels of depth to the system. Due to the nature of the system, being the intellectual property of the provider, the deeper in the system the value is, the less likely it is, that it will be available to us.

The system also handles a number of fire safety functions, such as automatic fire doors and smoke ventilation. This has been left out of this description, as it is connected directly to safety and the fire brigade, which means it is probably a closed and restricted system. Furthermore, it is probably not relevant to the needs of this project.

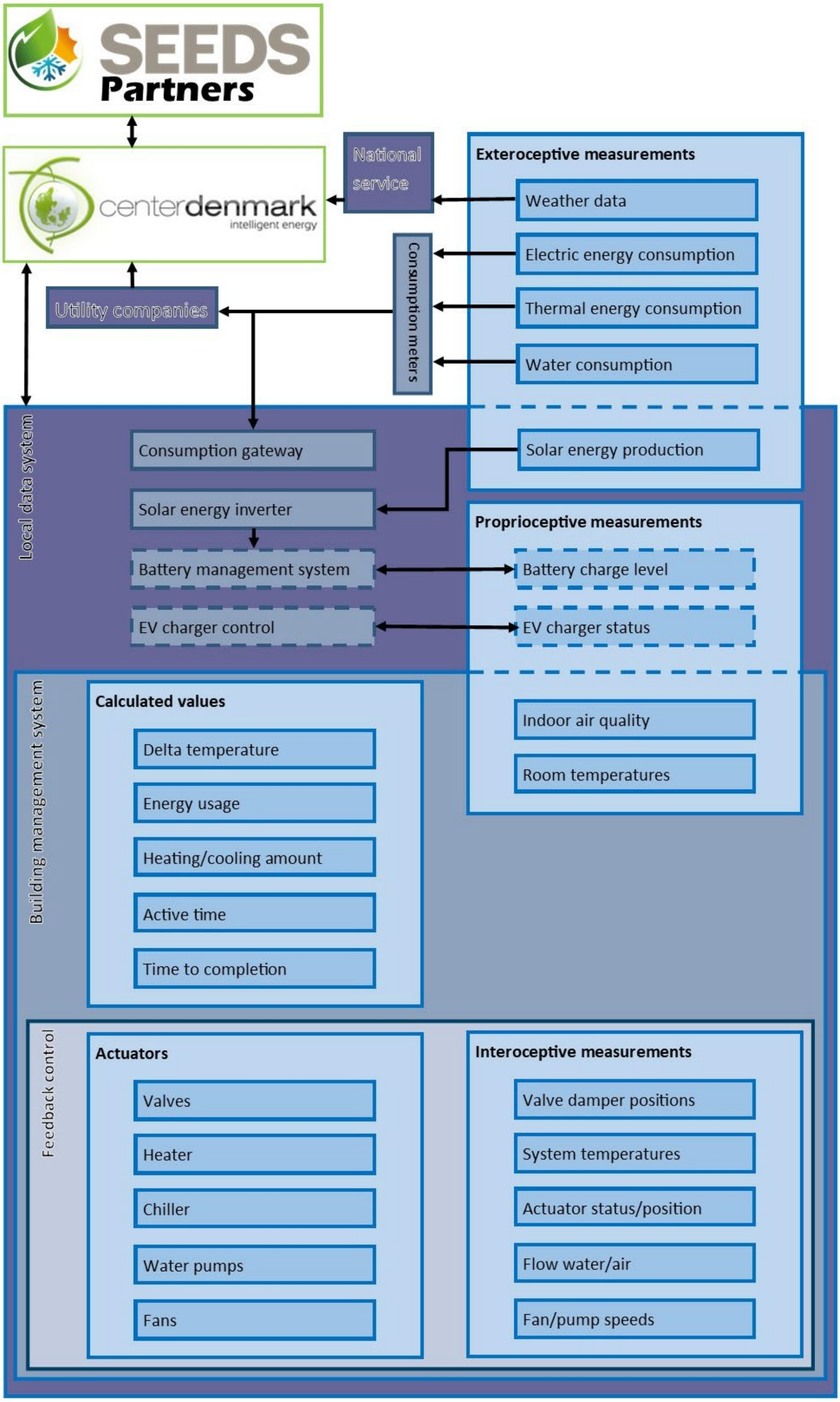

Figure 15: Danish Pilot – IoT architecture overview

4.1.2. Hardware Gateways and Sensing Devices

As all hardware for the automation of the building will be implemented by the BMS provider, it will be difficult to provide descriptions of it now, as there has yet to be made a final contract for this.

Center Denmark will work towards onboarding the data in a way, that enables us to provide it though our data portal, in close collaboration with the building owner and the automation supplier. As the diagram in 4.1.1 showed, there is a local data storage system, which collects data across the buildings in the Dandy Business Park. It is most likely that we will receive data through that system.

With our current understanding of the expected system, we expect to be able to supply the from the local system at a pretty high frequency, with a very limited delay. Probably in a frequency range of up to one measurement per minute, with a delay of minutes, perhaps down to less than a second, depending on the communication available. This will depend on the system that is implemented, as well as the requirements from the project partners, which will become more apparent, as the use cases are defined.

From the perspective of the project partners, all data will be made available in one place; the Center Denmark Data Portal.

Exteroceptive measurements

The weather data will be drawn directly from the Danish Meteorological Institute.

The water consumption, electricity consumption, electricity provided to the grid, and the data related to the district heating consumption will all be collected from the utility companies. This will be an early focus, as legal agreements for data, as well as the actual onboarding, can sometimes take a lot of time and effort. As there seems to be a local data collection of utility data as well, we will work towards receiving data from both sources. This is to ensure that we have data as early as possible, as well as the best data quality.

Solar energy production will be collected via the local data system.

Proprioceptive measurements

Both the room temperature and indoor air quality, we expect to have available for every individual room. Once again, the access to this data will be through the local data system, which collects data from the BMS system.

As there is currently less knowledge about the systems to be implemented concerning EV charging and Battery systems, we have chosen to insert these in dotted boxes. The building owners are prepared to implement these things, but will require input from SEEDS partners, to define requirements to selecting solutions.

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Interoceptive sensors

These are internal values, mainly used in feedback control loops. As such, we do not expect these values to be available, unless they are requested directly. Even then, it will depend on the system, if these values are exposed.

Calculated values

Some of these values may be available, but depending on the specific needs, defined in the future use cases, we will investigate what is available. As before, this very much depends on the capabilities of the system that will be implemented.

4.1.3. Control and Actuation Devices

The simplest actuation and control systems to describe are the EV charging and Battery Energy Storage system. However, these are also the components that we know least about. It is likely that the battery system will be built from used Tesla batteries and supplied by 4-leaf, but there are no agreements or negotiations on this part yet.

As for the actuators deeper in the system, they are usually not activated directly, but rather, a control loop will be provided a set point, which in turn sets the actuation of the component. As the order of the system has yet to be completed, it will not be possible to describe directly which components will be part of the system. However, a general description of the components of such system is given below.

Water carried heating system

The heating system is water carried and built around a district heating connection.

In most buildings there is a closed loop containing water, which is heated by the district heating water in a heat exchanger, which allows heat energy to travel from the primary side (district heating system) to the secondary side (local heating loop).

From here, the water is circulated past the radiators by a pump, to always have hot water available by the radiator, unless the circulation is seasonally closed. When a radiator valve is opened, hot water flows into it. The radiator loses heat energy to the surrounding air, and the cooled water runs out on the return side of the radiator. This water then returns to the primary heat exchanger, where it is heated and circulated again. It is currently uncertain whether the radiator valves will be controlled by the building automation, or they will be manual thermostats. It is also possible that they will be a hybrid.

The radiator valves as well as the circulation pump are actuators.

Ventilation system with cooling capabilities

The ventilation system provides fresh air to the offices and areas of the building. The air can be heated or chilled before being pushed through the system.

A modern ventilation system pulls air from outside the building, often through a filter, to avoid particulate matter from entering. Often the air is then moved through a heat exchanger, to absorb heat or cold from exhaust air, but that system can also be bypassed, if the ventilation is cooling the air, and the exhaust air is warmer than the outside air.

The air is then pushed through ducts throughout the building by one or more pumps, usually in several subsystems, e.g. one subsystem per floor of the building. For each room, there can be a local fan, but this is usually avoided, due to noise. Instead, the air is kept at an elevated pressure, and valves throughout the building open and close to let in the correct amount of air. If more valves let more air into the rooms, the pump will need to push more air into the system. Usually, the pressure is maintained by one or more flow transmitters, as well as pressure transmitters measuring throughout the system. A feedback loop then regulates the speed of the pump, to ensure the correct pressure.

When fresh air enters the room, the old air needs to be pulled out. This is done through a second system of ducts, much like the return side of the heating system. By maintaining a reduced pressure in the exhaust system, contamination to other rooms is avoided.

The ventilation system can be activated by two circumstances. Either by decreased air quality in the room, which requires increased circulation, or by elevated temperature, which requires cooling if the room is occupied.

The valves and pumps of the ventilation system are actuators.

4.1.4. Software Entities

There will be several entities in the software, but most of these will be in the deeper levels of the building management system and fall under the intellectual property of the providers.

It is common to build the system with every control loop as a unit, consisting of an actuator and the sensors that measure the response of the actuation. Entities higher in the software hierarchy can then send a command to this “Control Module”. Depending on the type of actuation, signals are returned, either when a given state is reached, or if a regulation is within a deadband. Further, alarms can send signals up the hierarchy, if something unexpected happens, which might either need to be handled by other control modules or perhaps, if it is a major fault, stop the system and send out an alert. The control module only knows its set point and when to send signals up the hierarchy.

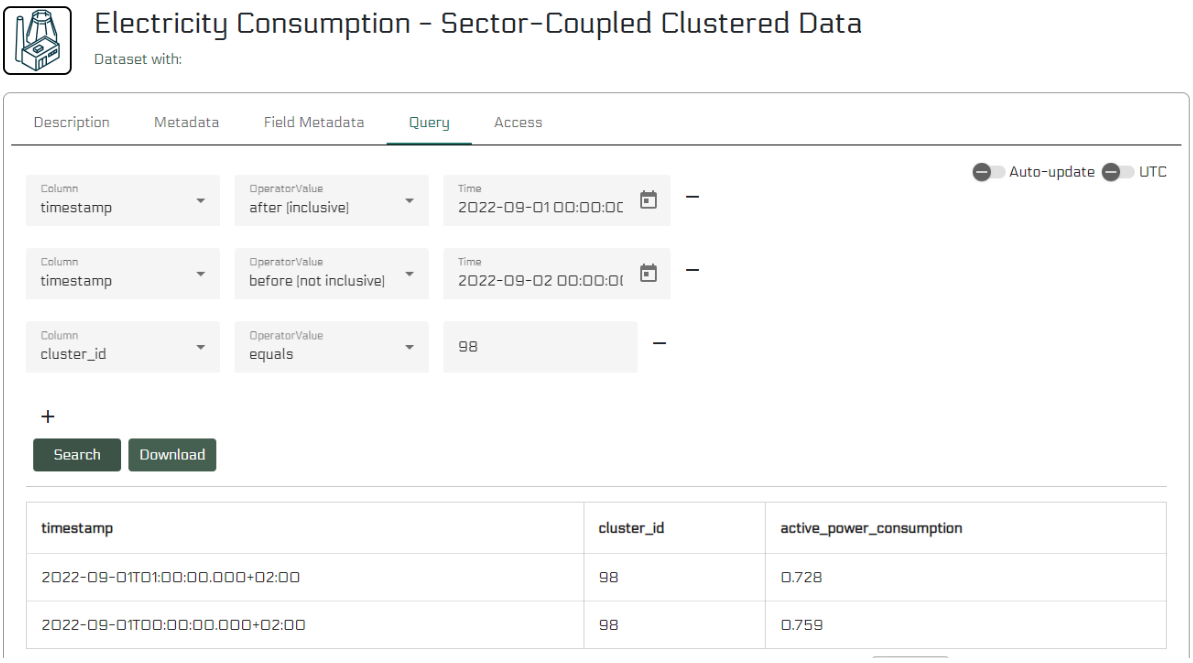
Above the control module is the “Equipment module”, which can have one or more control modules. The equipment module is usually related to a specific hardware component. Like the control module, the equipment module mainly knows the state that it is trying to reach and when to send signals up the hierarchy. Further, it knows which signals to send to its control modules to achieve the desired state.

Further up the hierarchy are several higher software entities, but referring to the figure in 4.1.1, I will now focus on the local data system. This system can obtain data from all subsystems within it, though, as mentioned earlier, some variables are not available. This is an effect of the system of Control- and equipment-modules. If these entities do not send the values up the hierarchy, they are not available higher in the system.

It is expected to have the values for the proprioceptive and exteroceptive measurements, and probably also the calculated values. If we need other deeper values, we will need to investigate the availability of these.

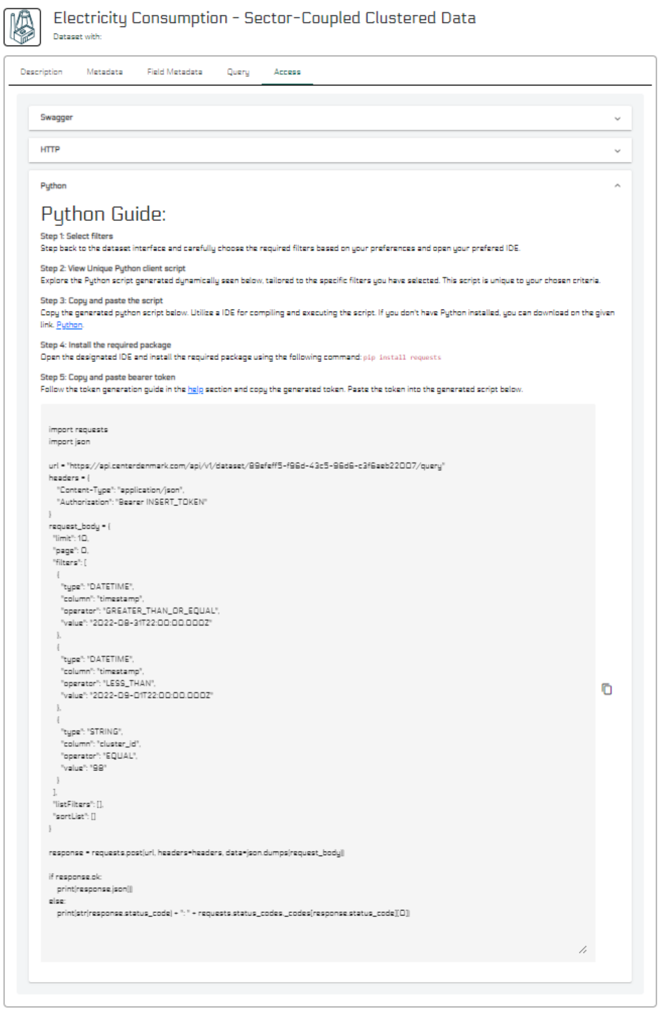
The Center Denmark Data Portal

From the perspective of project partners, all this data will be available in the same place; the Center Denmark Data Portal. Here it is possible to investigate the data available and “build” one or more data queries.



You can then choose to access the data in one of currently three ways; Swagger, HTTP or Python.

When a method is chosen, a guide shows you simple steps to accessing the data, as well as the specific code to acquire it, based on the query from before.



Before it is possible to do this, it is necessary to have a user on the portal. Then access to specific data can be granted. After that, a token can be created, which needs to be used with the custom code described above.

The Center Denmark Data Platform

Behind the data portal is an API to the Center Denmark Data Platform.

This platform is built on open-source components, combined with custom software, to ensure that data security and safety is upheld, as we often handle different types of sensitive data. Furthermore, high capacity, both for storage and traffic along with high availability, are focus points on our platform development.

Another focus is flexibility. This means that we can ingest data from a range of different sources, ranging from batches through sFTP servers, through push or pull from APIs, to streaming via MQTT.

Data sources

As shown in the figure in 4.1.1, there are several data sources that we need to ingest from.

As mentioned, we will have a starting focus on the utility companies, as there might be challenges in that area. It might also be possible to get access to the local data storage at Dandy Business Park, to be prepared to harvest data as soon as it starts flowing. Finally, the weather data from the Danish Meteorological Institute is publicly available online, so this should not represent a major challenge.

4.2. BELGIAN PILOT

4.2.1. Overview of Technical Architecture for Automation and IoT Ecosystem

The technical architecture consists of two main parts. The first part relates to everything that is installed on-site. The second part relates to everything that is installed in the cloud. Both parts are illustrated in the figure below.

Figure 16: Belgian Pilot - IoT architecture overview

The situation prior to the project is as follows: Each house contains a low-level controller that performs local loop control for the floor heating system, circulation pumps, booster heat pump control, etc. Furthermore, a thermostat in each house generates a heat demand signal that activates the circulation pump. Heating curves compute the demanded supply water temperature for each house, depending on the outdoor temperature. Each of these controllers is connected to the district-level controller, which aggregates the demand of each house into set points for the heat production devices. Priva controllers were used, which support BACnet/IP as a way of interacting with the system.

These existing controllers have been extended by a computer and sensor equipment from Builtwins. The local computer uses BACnet/IP to send alternate set points to the district-level and local controllers. Every 15 minutes new set points are sent. The existing control rules are thus bypassed. When MPC is disabled, these set points are removed such that the original control becomes active again. The MPC runs on the local computer and is thus robust against short interruptions of the internet connection.

Due to a difference between the temperature shown on the thermostat display in each building and the measured value in the BMS, an additional wireless temperature sensor was installed in each house. These sensors use LoraWan to broadcast their measurement, which is logged by a LoraWan gateway. The resulting measurements are forwarded to Builtwins' measurement database, which resides in the cloud.

The local computer furthermore connects to the cloud periodically to download weather forecasts and to check whether it should be writing to BACnet or not.

4.2.2. Hardware Gateways and Sensing Devices

As explained above, hardware controllers are provided by Priva. The local computer is an Intel NUC computer.

The existing building management system contains many sensors including temperature sensors, electrical energy sensors, heat energy sensors, flow switches, pressure sensors, etc. Furthermore, one Dragino LHT52 sensor was installed in each house. A Seeed SenseCAP M2 gateway is used to log the readings.

4.2.3. Control and Actuation Devices

The existing building management system has one valve per house to control the supply water temperature coming from the district heating system heat exchanger. A second valve opens or closes the flow of water to the floor heating system. Furthermore, a circulation pump is present in each house to circulate the heated water. Finally, another valve and circulation pump supply heat to the booster heat pump, which stores heat in a storage tank.

At the district level four pumps are used to circulate water between the district, heat pump, tanks and solar collector as illustrated on the figure below.

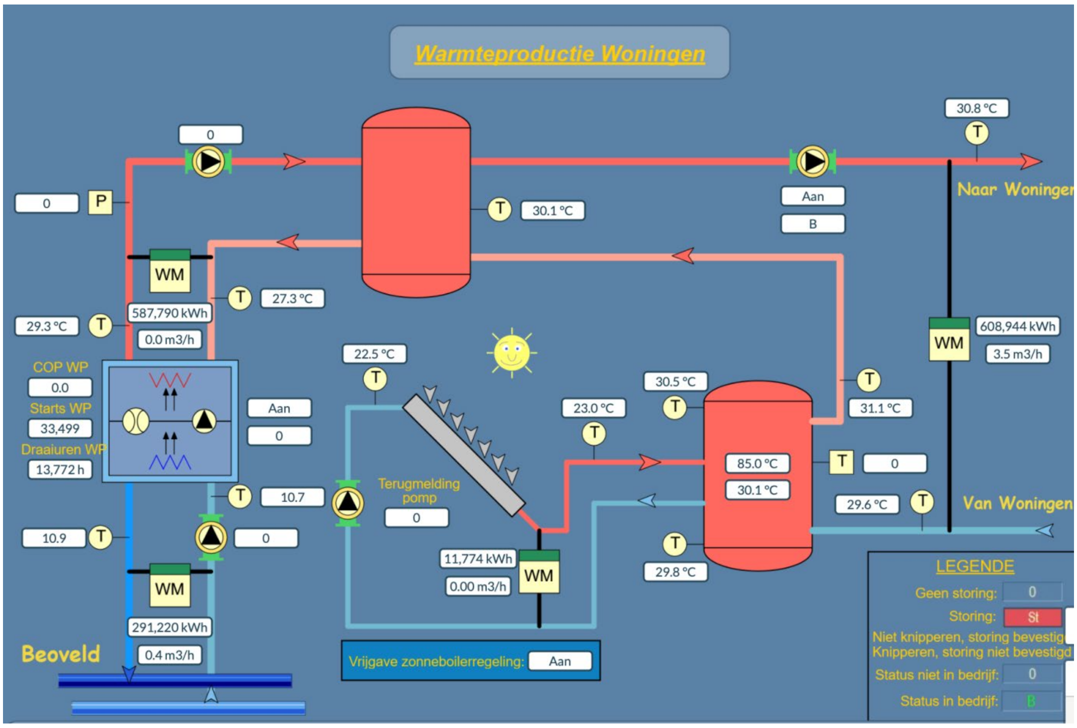


Figure 17: Belgian Pilot - Heating System Schematic

4.2.4. Software Entities

The existing BMS from Priva is accessible through a cloud interface. This existing BMS is used by Builtwins to monitor the system. Priva stores a limited period of data in the cloud.

For logging data over longer periods, Builtwins implemented its own logging methodology. This collects measurement data from each house through the district-level controller and sends it to the cloud using an encrypted https connection. The resulting data are stored in a graphite database. The database is coupled to a Grafana implementation that visualises the data. These data are stored for a period of 6 years upon which it is automatically overwritten by the newest data.

4.3. HUNGARIAN PILOT

4.3.1. Overview of Technical Architecture for Automation and IoT Ecosystem

The communication architecture of the designed system looks like the following:

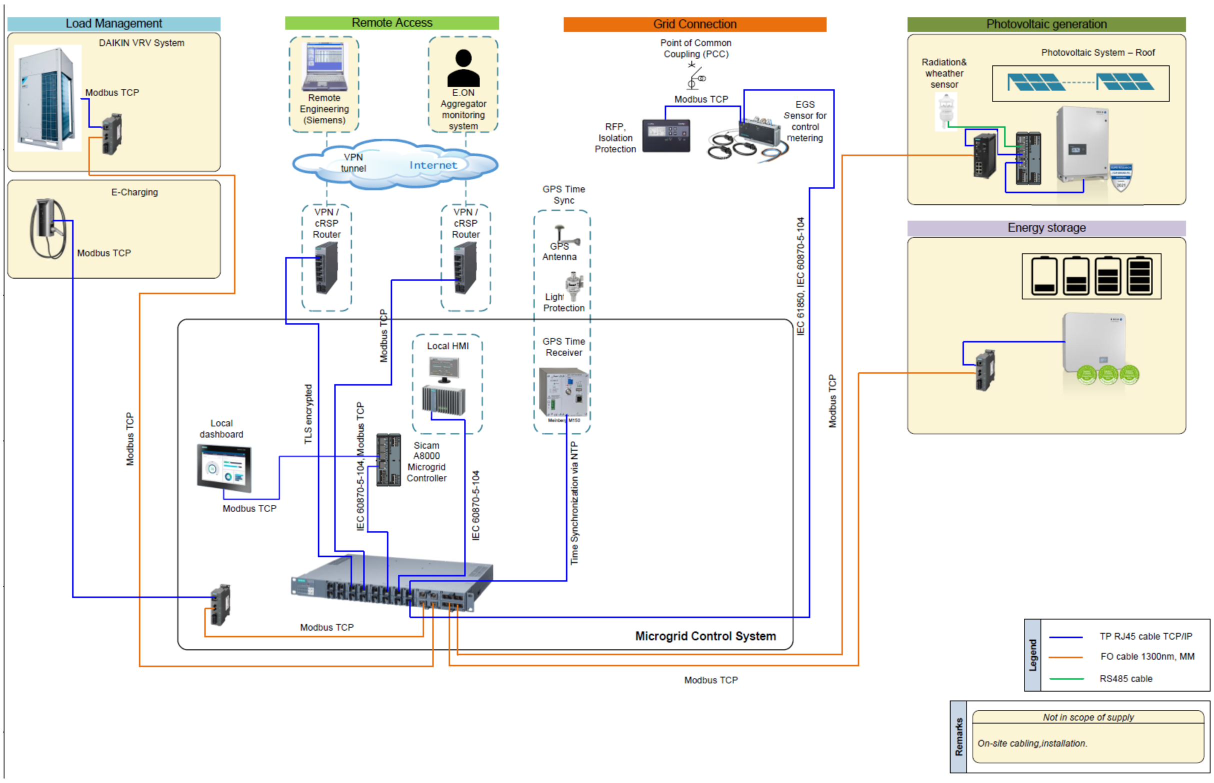


Figure 18: Hungarian Pilot - IoT architecture overview

4.3.2. Hardware Gateways and Sensing Devices

The gateways are used for protocol conversion, mainly Siemens Sicam portfolio is used for this purpose. For collecting the bottleneck consumption of the building, Siemens EGS sensor is used. Furthermore, general weather sensors are used for collecting environmental information. In the zone control individual controllers are used with built-in sensors for the VRV/VRF system.

4.3.3. Control and Actuation Devices

The controller is Siemens Sicam A8000 RTU device.

The actuation is done purely via communication between the PV-, Energy storage, heat pump- and ecar charging controllers and the main Sicam A8000 microgrid control device.

4.3.4. Software Entities

The pilot uses the build-in firmwares of the 3rd party and Siemens devices. The Microgrid Control Software is running as a logical function on the main controller Sicam A8000.

4.4. GREEK PILOT

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4.4.1. Overview of Technical Architecture for Automation and IoT Ecosystem

The IoT architecture as depicted in the figure 20 provides an integrated overview of energy management within the C1 building for the Greek Pilot. The system is centered around on a FIWARE-based IoT platform, which serves as a hub for data collection, visualization (T3.4.1), control and optimization tools (developed under other technical WPs). Sensory data and measurements from 20 different rooms and centrally measured data are incorporated within the IoT platform. Additionally, key energy assets of the pilot, such as the bi-facial photovoltaic (PV) panels, the multi-source heat pump (HP) system and the electric vehicles (EV) chargers, are also bi-directionally connected to the building's automation and control system. A historical data storage module ensures long-term data logging, feeding analytics for remote access and visualization by faculty managers and building operators.

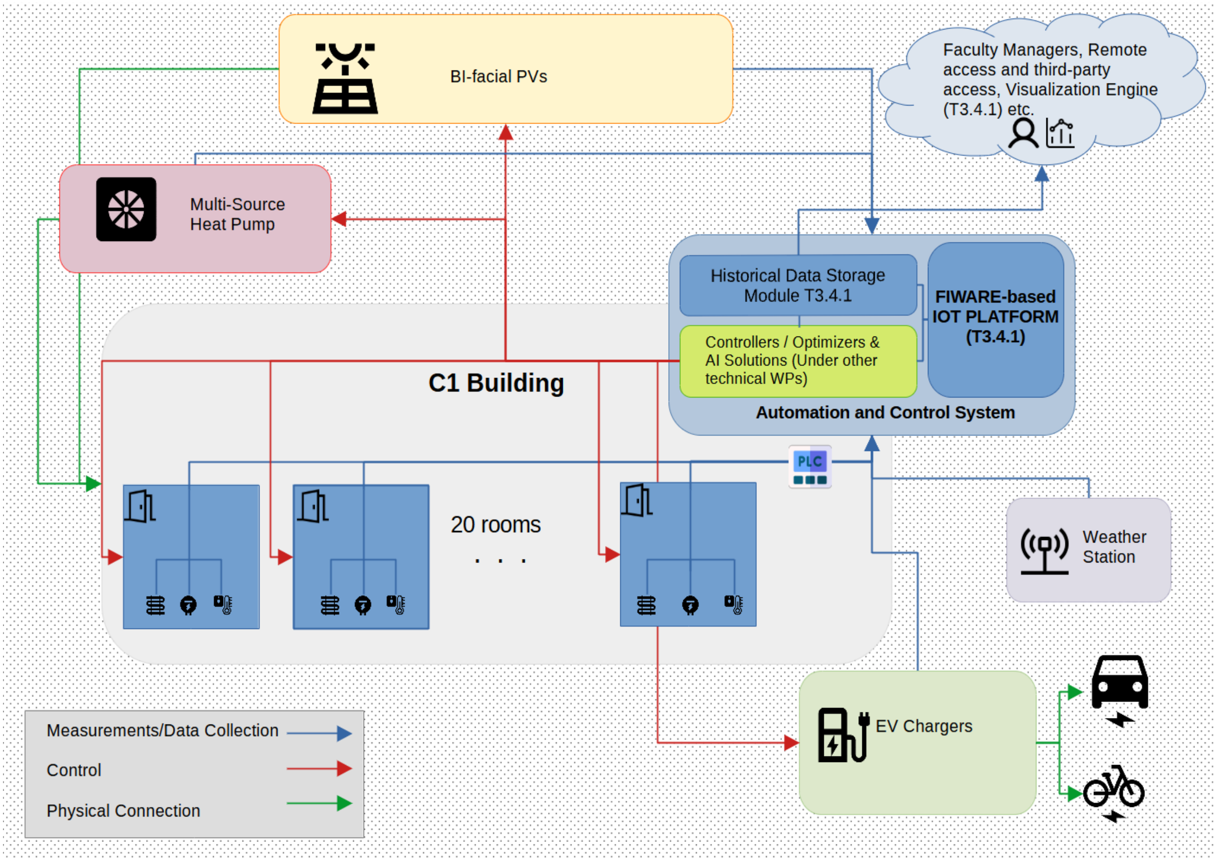

Figure 19: Greek Pilot IoT architecture overview

4.4.2. Hardware Gateways and Sensing Devices

The gateway of the IoT platform will be a dedicated server which will be mainly responsible for protocol conversion between the devices, external data sources and the platform's software components. A preliminary list of all sensing devices is described in section 2.4.2.

Monitoring of the multi-source heat pump system will be done by a Modbus MITSUBISHI FX5U-32MR/ES programmable controller that is going to be installed alongside the multi-source heat pump. Operational monitoring of the bi-facial PV system will be done using the remote capabilities of a smart inverter. The EV chargers will be monitored by using their specific remote access capabilities.

Table 15: Greek Pilot - Overview of IoT gateways

Gateway Type	Name	Protocols Supported	Indicative Monitored Features	Indicative Controlled Features
Room Automations Gateway	Room Automation Gateway	MQTT	Temperature, humidity, CO_2 levels, domestic hot water (DHW), energy consumption	Heating/cooling mode, setpoint adjustment
Renewable Energy Gateway	Bi-facial PV Gateway	HTTP/REST (Smart Inverter) *Not yet specified (Reflector system)*	Solar panel output, energy production, panel temperature, sun position, illuminance	Reflector's orientation control (two degrees of freedom; x-axis and z-axis)
Heat Pump Gateway	Multi-source Heat Pump Gateway	ModBus TCP	Heat pump energy usage, COP, source temperatures	Heat pump operational modes, energy source switching
EV Charging Gateway	EV Charger Gateway	*Not yet specified*	Charging status, energy usage, EV SoC	Start/stop charging, adjust power output, schedule charging

4.4.3. Control and Actuation Devices

The actuation of the devices throughout the Greek Pilot will be done exclusively by utilizing the MQTT protocol which will be responsible for bidirectional communication from/to the central PLC, and FIWARE-based IoT platform for the multi-source heat pump controller, the bi-facial PV reflector controller and the EV chargers. For the actuation inside the rooms, the central PLC

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will be connected with all smart thermostats of the fan-coils that are going to be installed inside in each of the 20 rooms.

For the actuation purposes of the multi-source heat pump system the same MITSUBISHI FX5U-32MR/ES controller will be used (see section 4.4.2). In the bi-facial PV system the way of actuation and control of the innovative PV's reflector system has not yet been specified.

4.4.4. Software Entities

As part of the FIWARE-based IoT platform architecture different software components are going to be used and/or developed. An open-initiatives first approach is followed throughout the architectural stack (see Figure 20). For this purpose, an open-community-based instance (e.g., ThingsBoard CE) is going to be installed and configured, as part of a gateway software that will forward all the devices and third-party measurements into NGSI-LD entities in an Orion-LD context broker via MQTT commonly used and aligned to FIWARE. Moreover, leveraging further the FIWARE open-initiative's developments, a QuantumLeap instance will be subscribed into the Orion broker that will enable historical data storage of the platform into a time-series database. Access to the context broker will be authorized by using a Keycloack instance. A visual analytics engine will be developed to deliver advanced dashboards and analytics with graph visualizations, leveraging the platform's historical data. Targeted at facility managers and building operators, the engine will enable users to monitor conditions, receive notifications, and configure custom settings for facility management.

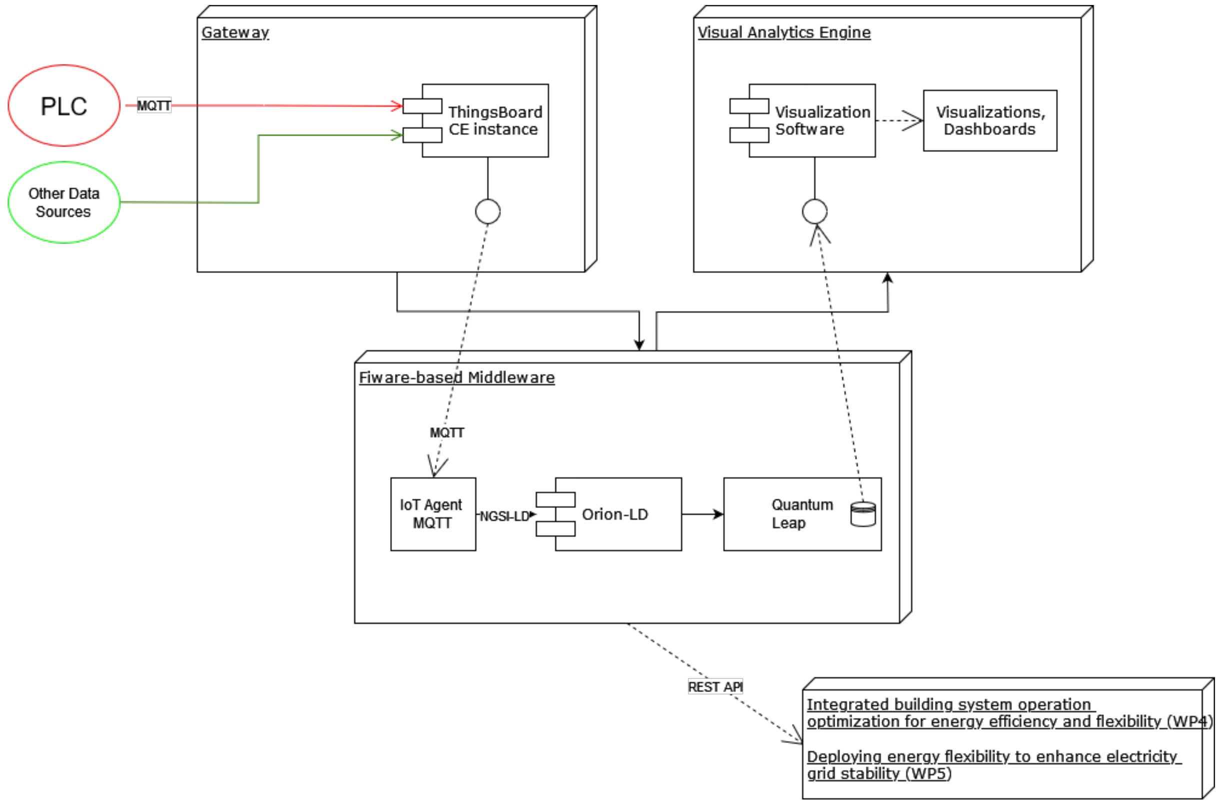

Figure 20: Greek Pilot - Software architecture overview

4.5. SLOVENIAN PILOT

4.5.1. Overview of Technical Architecture for Automation and IoT Ecosystem

PLC PETROL TP09 (Siemens Climatix POL648.80), with integrated TCP/IP interface for connection to the Central Control System (CCS) system, capture of I/O signals (4DI, 6DO, 11 universal), Modbus with RS485 communication and with additional modules: M-Bus interface (Siemens Climatix POL907) for reading calorimeters, water meters, additional expansion modules (Siemens Climatix POL965.00) for the needs of larger systems.

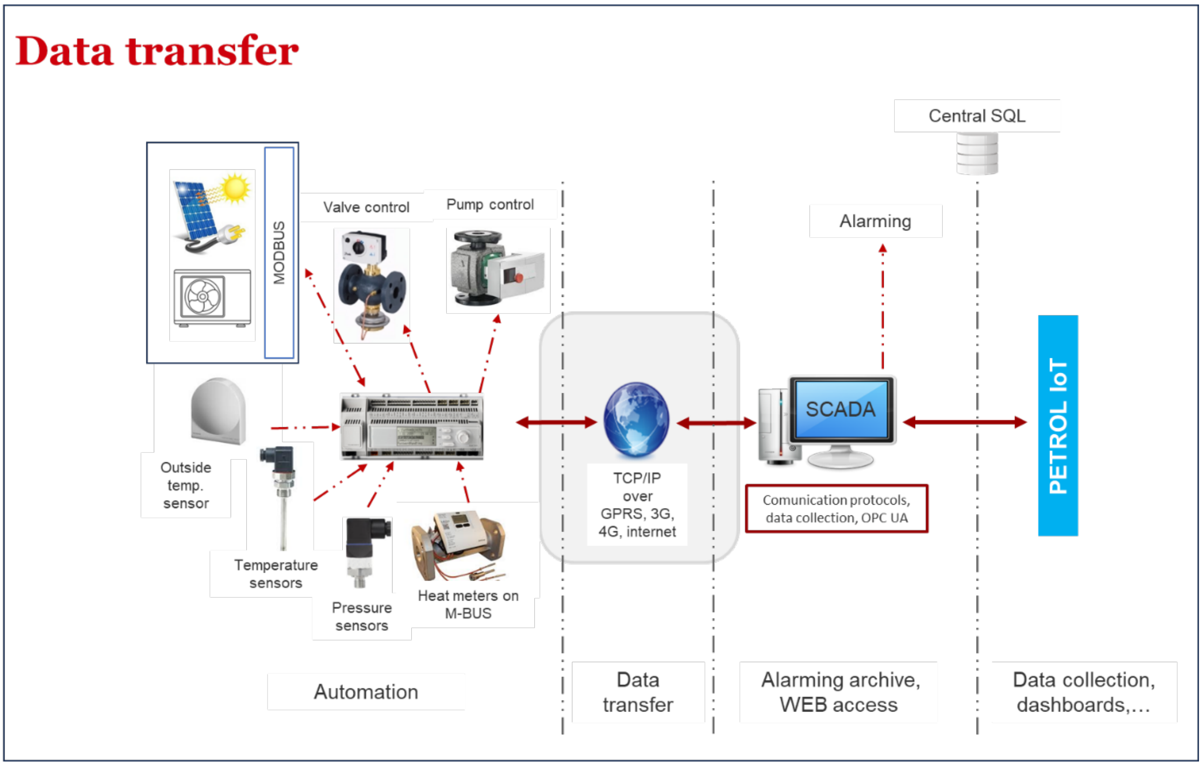

Figure 21: Slovenian Pilot – Facility automation architecture

The diagram on the Figure 22 illustrates the data flow in an IoT platform:

1. Data Collection:
   - The Data Collector collects data over the HTTPS protocol via a TCP/IP interface from a Central SQL database or OPC.
2. Database Storage:
   - The collected data are written into its own database within the IoT platform.
3. Data Integration:
   - The data integration component sends the data over TCP into a Message Queue.
4. IJS Side:
   - The Message Queue on the IJS (Institute Jožef Stefan) side receives the data.

This flow highlights the secure transmission of data from a central SQL database or OPC to a message queue through various components of an IoT platform, ensuring data collection, storage, and integration.

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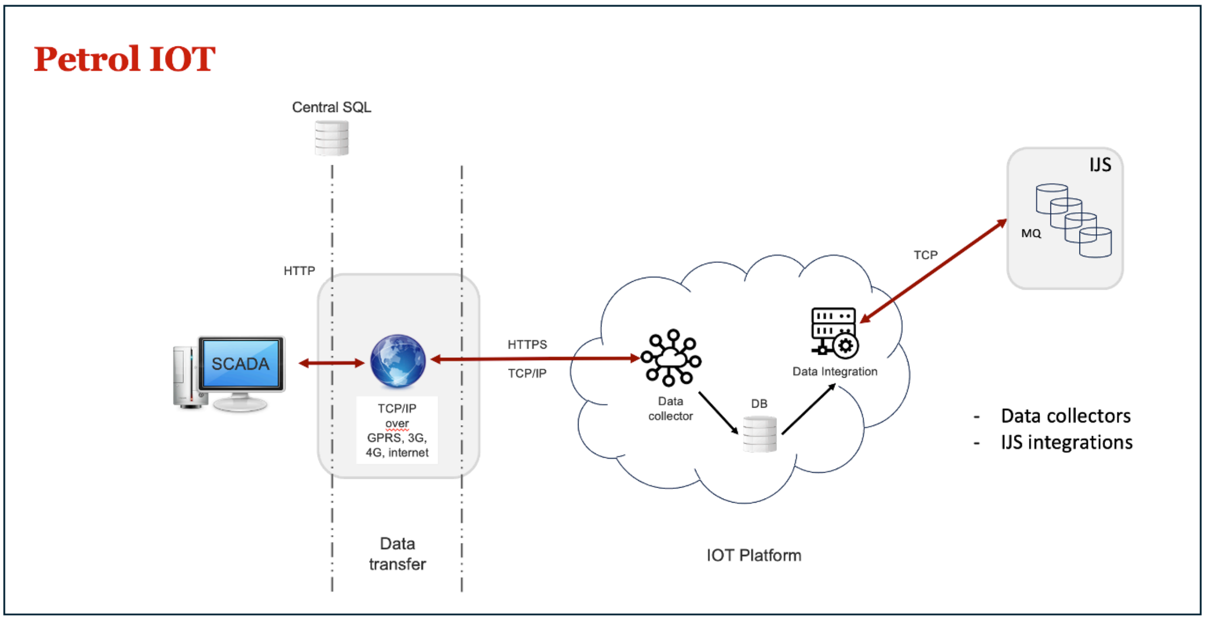

Figure 22: Slovenian Pilot: IoT architecture overview

4.5.2. Hardware Gateways and Sensing Devices

The sensors and other control equiment are connected to the PLC PETROL TP09 via the following I/Os:

I/O type	Signal type
Analog input (AI)	PT1000 ali NTC 10k
Analog input (AI)	4-20mA
Analog input (AI)	0-10V
Digital input (DI)	DI
Digital output (DO)	DO
Analog output (AO)	4-20mA
Analog output (AO)	0-10V
Mbus	Mbus
MODBUS RS485	MODBUS RTU

4.5.3. Control and Actuation Devices

The Slovenian Pilot focuses on provision of flexibility services through control of a set of actuation devices that can be included in a demand response scenario. These actuation devices include heat pumps, floor heaters, drainage heaters, HVAC systems, lighting, refrigerators and PV panels, though the exact set of devices will be somewhat different at each of the five pilot locations. All actuation devices will be connected to the PLC PETROL TP09 controller via interfaces that support MODBUS communication protocol. The need for additional interfacing equipment for existing actuation devices will be identified during the design phase at each pilot location.

4.5.4. Software Entities

Supervisory control and data collection is performed on the SCADA system. SCADA captures data form locations over MODBUS TCP/IP communication protocol. Main task of SCADA System is to capture and appropriately process data and archive it in a historical database. It also displays historical data tabularly or graphically. PETROL SCADA runs on the Movicon 11.6. platform (Progea/Emerson) which in addition to the basic SCADA system development functions also enables possibility of free programming.

Petrol has designed and developed an IoT platform that includes a Data Collector and Data Integration system. This comprehensive solution is tailored to gather, process, and integrate data from various sources, making it a proprietary product of Petrol.

5. CONCLUSIONS

In conclusion, Deliverable 3.1 – 'Automation and Monitoring Specifications" consolidates the outcomes from tasks 3.1 and 3.2, focusing on defining requirements, surveying the different pilot sites and providing the technical specifications and architecture needed for effective automation and monitoring across the multiple pilot sites.

By the collaborative effort between the pilot owners and the technology providers, each pilot site's current level of smartification and automation was assessed, gathering in-depth insights into each pilot baseline conditions. This approach allowed the identification of gaps in technology, the catalog of necessary devices and the definition of technical architecture for automation and monitoring. Each technical architecture was formulated to provide robust and scalable IoT ecosystems, designed to account for various site-specific factors.

Overall, Deliverable 3.1 provided a blueprint to address all the technical needs and requirements for the smartification of the pilots, thus marks a step forward in achieving the project's vision of integrated, scalable and replicable smart automation systems.

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