Ref. Ares(2021)4152102 - 25/06/2021

Project Acronym:	FlexiGrid
Project Full Name:	Enabling flexibility for future distribution grid – FlexiGrid
Grant Agreement:	No 864048
Project Duration:	3,5 years (starting 1 November 2019)

Deliverable 8.1

Test cases and technical requirements definition, demonstration preparation

Work Package:	WP8
Task:	T8.1
Lead Beneficiary:	HES-SO
Due Date:	15/10/2020 (M12)
Submission Date:	14/10/2020
Deliverable Status:	Final
Deliverable Style:	Report
Dissemination Level:	Public
File Name:	FlexiGrid D8.1 Test cases and technical requirements definition, demonstration preparation

This project has received funding from the European Union's Horizon 2020 research and innovation program under grant agreement No 864048

Authors

Surname	First Name	Beneficiary	e-mail address
Page	Jessen	HES	jessen.page@hevs.ch
Rey	Tristan	HES	tristan.rey@hevs.ch
Wuilloud	Gaëtan	OIKEN	gaetan.wuilloud@oiken.ch
Büyük	Ali Fuat	OEDAS	ali.buyuk@oedas.com.tr
Gazioglu	İbrahim	OEDAS	Ibrahim.gazioglu@oedas.com.tr

Reviewers

Surname	First Name	Beneficiary	e-mail address
Baykal	Safak	T4E	safak.baykal@endoks.com
Oana	Carmen	SIMAVI	carmen.oana@siveco.ro
Vu Van	Thong	EMAX	thong.vuvan@emaxgroup.eu
Bobochikov	Teodor	EntraEnergy	teodor.bobochikov@entra.energy

Version History

Version	Date	Modifications made by
0.1	24/08/2020	Tristan Rey
0.2	30/08/2020	Ali Fuat Büyuk
0.3	06/10/2020	Ibrahim Gazioglu
0.4	09/10/2020	Tristan Rey

Figures

List of abbreviations

Abbreviation	Definition
API	Application Programming Interface
AMR	Automatic Meter Reading
CHP	Combined heat and power
DMS	Distribution management system
DSO	Distribution system operator
DR	Demand Response
EMS	Energy management system
ESS	Energy Storage Systems
EV	Electric vehicle
EVSE	Electric Vehicle Supply Equipment
FlexiGrid	Enabling flexibility for future distribution grids with high penetration of variable renewable penetration
HP	Heat pump
LV	Low Voltage
MV	Medium Voltage
PV	Photovoltaic panels
P2G	Power-to-gas
SoC	State of charge
SOEC	Solid Oxide Electrolyzer Cell
SOFC	Solid Oxide Fuel Cell
TBD	To be determined
TC	Test case
TSO	Transmission system operator
V2G	Vehicle-to-gas
WP	Work-package

Contents

Test cases and technical requirements definition, demonstration preparation

1. Introduction

WP8 aims to demonstrate flexibility measures and electricity grid services provided by local energy storages and EVs. The main objectives of this WP are to:

- Demonstrate the flexibility measures and electricity grid services provided by battery storage, electric vehicles, vehicle-to-grid (V2G) and power-to-gas solutions
- Perform real time control of integrated equipment to enhance renewable energy integration by coordinating energy uses and local renewable energy production while improving the grid resilience with suitable EV charging location and power-to-gas facilities.
- Demonstrate best price offering to EV users in order to enhance the resilience of the network and improve coordination between production (especially renewables) and consumption.
- Demonstrate the use of innovative battery technologies to minimize energy losses (AC/DC conversion) while charging EVs.

Towards the fulfillment of the objectives of WP8, Task 8.1 is responsible for defining the list of test cases which will be demonstrated in Task 8.3 at HES campus regarding the provision of flexibility. The main activities of Task 8.1 can be summarized as:

- Definition of test cases
- Definition of technical requirements
- Demonstration site equipment will be installed or checked
- Collectable data sets will be determined in order to be integrated with the IoT platform / HES own system.

In this report the outcome of the work in Task 8.1 is presented. The test cases that will be demonstrated within WP8 will be presented, along with the most significant technical requirements related to their implementation. The test cases are prioritized based on their significance and applicability, while the technical requirements include the resolution and the accuracy of the measurements. Furthermore, the devices that will be controlled in each test case have been identified.

The remaining of this report will be as follows. In Section 2, the demonstration sites are briefly described. In Section 3, the defined test cases along with their priority status are presented and explained, while in Section 4 the most significant technical requirements are illustrated along with the devices that will be controlled in each test case. Finally, in Section 5 conclusions are drawn.

2. Description of the demonstration sites

2.1 Description of HES Campus

The demonstration site of HES campus in Sion, Switzerland is shown in Figure 1.

Figure 1: HES campus map (red buildings, from left to right: number 19, 21 and 23).

The HES campus is currently under construction. It will host 3 buildings (buildings number 19, 21 and 23) which are mainly composed of offices, laboratories and classrooms. The campus is heated via the district heating network owned by OIKEN, the local energy utility and DSO. It will also have a CO_2-based thermal network allowing for both heating and cooling. Different heat pumps (HPs) for a total of 600kWth will be installed on the CO_2 network in order to test a large variety of technologies and to groom future engineers. Approximately 300kWp of solar PV will be installed on the roof and will be connected to the AC grid of the campus. This grid will be connected to the main distribution grid of OIKEN. Apart from that, HES campus will also host a ~20 kW power-to-gas (P2G) platform and electric batteries for a storage amount of ~300kWh.

2.2.1 Photovoltaic system

Approximately 300kWp of solar PV will be installed on the roofs of buildings 19 and 23 and allow self-consumption.

2.2.2 Energy storage systems

Two ESSs will be used. The first one is represented by the electric batteries which will allow to store the electricity produced by the solar PV. The second one will be constituted of the three gas storages of the power-to-gas platform: storage of O_2, H_2 and CO_2 (normally 8 m^3 each). Additionally, the methane will be directly injected into OIKEN's gas network. It is also to be pointed out that the thermal mass of the buildings will be used as a means to store energy and to offer flexibility.

2.2.3 Power-to-heat installation

The power-to-heat installation will be constituted of multiple heat pumps for a total of $600kW_{th}$ (approximately $100kW_{el}$). Coupled to this installation, the thermal mass of the building will serve as an energy storage and will allow to provide flexibility. The deployed building controllers will also allow the building operator to change the settings of variables such as temperature and air flow to control the heating, cooling, and ventilation system.

2.2.4 Power-to-gas platform

The power to gas platform will be constituted of a reversible solid oxide cell capable of working as a ~20kWel electrolyzer cell that, coupled to a methanization unit, converts water vapour and CO_2 into methane; the same cells works in reverse as a ~6kW solid oxide fuel cell (SOFC) converting methane back into CO_2. Three tanks of $8m^3$ each will enable the storage of oxygen, hydrogen and CO_2.

2.2 Description of OEDAS Pilot Site

The pilot area selected for the demonstration activities in OEDAS region is shown in Figure 2-3.

Figure 2: Overview of OEDAS pilot site

Figure 3: MV and LV network of the selected pilot area

The selected region for pilot activities is a village whose customers are residential loads only. Pilot site is located in city of Eskisehir. The area is powered by one 34.5kV/0.4kV MV/LV transformer which has an active power rating of 400kVA. Additional information about the technical specifications of the transformer is given in Table 1. Most of the houses have solar PV panels on their roofs; they are connected to the main distribution grid of OEDAS and produce electricity to allow self-consumption. These panels are connected through the 3rd party transformer and OEDAS is able to get active production and consumption values of the system via analyzers. But these PVs cannot be controlled by OEDAS because of property issues and will not be used in the proposed use cases. If necessary, permissions can be obtained from the owner of PVs, possibilities of using these PVs for different purposes in the project will be evaluated in further progress.

For the demonstration activities, one 50 kW DC fast electric vehicle charger will be installed on this pilot network. Additionally, 30 kWh battery storage systems will be installed and directly linked with this DC charger. Another DC charger (which will be compatible with V2G) will also be installed and provision of flexibility will be demonstrated with V2G compatible vehicles.

The main aim will be the discharge of this battery storage system during charging session of a vehicle and charging it from the grid when the grid status is clear. Charging/discharging processes of the battery storage system will be managed via the Battery Energy Management System (EYS in figure 4.)

Charging/discharging decisions will be managed by the EV Management Platform and the mobile application. Charging stations will be added to system in order to test the proposed flexibility activities of the project.

Figure 4: Low Voltage GIS overview of OEDAS pilot site

2.2.1 Transformer data

The transformer which is feeding a rehabilitation centre has a 400 kVA power rating. The loading rate of the transformer is low but it has daily peaks during the peak times of the day. Technical specifications of the transformer can be seen on Table 1. Consumption values of the transformer can be monitored with an automatic meter reading system in each 15 minutes.

Table 1: Technical specifications of Transformer

	P [kVA]	Vn1 [kV]	Vn2 [kV]	Uk [%]	Ur [%]*	Pfe [W]*
Söğütönü Toki TR 2	400	34,5	0,4	4,46	0,87	495

*according to EN 50588

2.2.2 Energy storage system

A 30kWh BESS li-ion-battery and a 45 kWh battery inverter are planned to be installed at the Sogütönü TR2 area. The energy storage system will be combined with a 50 kW DC charger for EVs and the main aim will be the charge of EVs both with the grid and this storage system during the charging session. Another battery storage system will also be installed in another project on the same pilot network.

2.2.3 Photovoltaic System

Solar panels are already available on the rooftops of the houses in selected pilot area. The total rated power of the panels is 150kW.

2.2.4 Electrical Vehicle DC Charging Systems

The 50 kW DC charger which is shown in Figure 5 is planned to be used during the demonstration. The DC charger will have connectors for both CHAdeMO and CCS and has a 22 kW Type-2 charging socket for AC charging as well. The charger will be integrated in the EV management platform via the OCPP 1.6J interface. Users can authenticate charging using an RFID card or a smartphone application and monitor charging status in real time.

Figure 5: Tritium Veefil RT50 electric vehicle charger

2.2.5 Vehicle to Grid (V2G) Bi-Directional Charger

A 10 kW DC V2G charger will be installed at the pilot site to demonstrate the use case about V2G. The charger will have a bi-directional option and it will be able to provide energy to the vehicle and supply energy to the grid, allowing to get benefits from different grid applications. Charging output of the charger will be 10 kW while discharging output can reach the level of 10 kVA. It will also have a OCPP 1.6J communication protocol and it will be integrated in the EV management platform and in the mobile application. As shown in Figure 6, a 41 kWh Nissan LEAF compatible with V2G option will be used for the demonstration of V2G use cases.

Figure 6: Nissan Leaf and V2G Charger

3. Proposed test cases

3.1 Test cases and controllable devices at HES campus

In Task 8.1 the following test cases have been defined to be demonstrated in WP8 at the HES campus for the advanced grid monitoring, control and flexibility intervention to be achieved. Table 2 includes the proposed test cases, their short description and their priority status. As the HES campus is under construction, their priority status is based on the estimated availability of the technologies (see Figure 4).

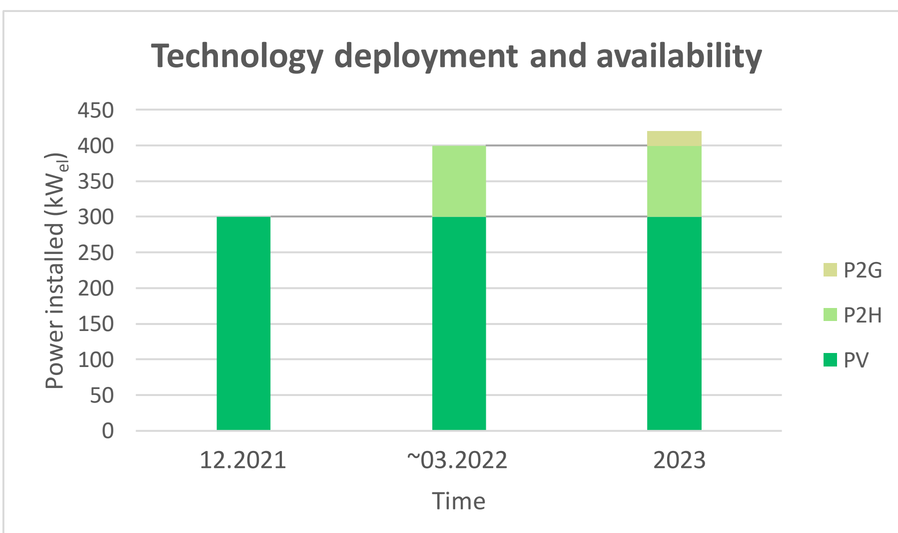

Figure 6: Technology deployment and availability on HES pilot site

Table 2: Test cases description and prioritisation for HES campus demonstrations.

Number	Name	Description	Priority status
8.1	Flexibility potential estimation	An estimation of the flexibility potential for the next x hours is performed.	High
8.2	Communication with OIKEN	Establishment and validation of a communication protocol between HES and OIKEN.	High
8.3	Reliable flexibility offer using batteries	Flexibility offer using batteries. HES proposes different load profiles and OIKEN chooses one of them. Evaluation of the ability to follow the load profiles.	Medium
8.4	Reliable flexibility offer using heat pumps	Flexibility offer using heat pumps. HES proposes different load profiles and OIKEN chooses one of them. Evaluation of the ability to follow the load profiles.	Medium
8.5	Reliable flexibility offer using the power-to-gas plateform	Flexibility offer using the power-to-gas platform. HES proposes different load profiles and OIKEN chooses one of them. Evaluation of the ability to follow the load profiles.	Low
8.6	Optimization of self-consumption	Optimization of the self-consumption of the electricity produced by the solar PVs.	Low
8.7	Reliable flexibility offer using the whole system	Flexibility offer using batteries, heat pumps and the power-to-gas platform. HES proposes different load profiles and OIKEN chooses one of them. Evaluation of the ability to follow the load profiles.	Low

In Table 3 are presented the expected controlled devices for each of the defined test cases along with their expected input and output.

Table 3: Expected controllable devices and input/output of the test cases that will be demonstrated at HES campus.

Number	Name	Controllable devices	Input/output
8.1	Flexibility potential estimation	None	**Input:** Weather forecasts, occupancy, internal gain predictions and current state **Output:** Estimation of the flexibility potential.
8.2	Communication with OIKEN	None	**Input:** None (No flex requests are sent by OIKEN, at least in a first step). **Output:** Confirmation of flex offer acceptance
8.3	Reliable flexibility offer using batteries	Battery storages converters	**Input:** Confirmation of flex offer acceptance **Output:** Flexibility offered to the DSO
8.4	Reliable flexibility offer using heat pumps	HPs	**Input:** Confirmation of flex offer acceptance **Output:** Flexibility offered to the DSO
8.5	Reliable flexibility offer using the power-to-gas plateform	SOFC, methanization unit, SOEC	**Input:** Confirmation of flex offer acceptance **Output:** Flexibility offered to the DSO
8.6	Optimization of self-consumption	Battery storages, converters, HPs, SOFC, methanization unit, SOEC	**Input:** None **Output:** Optimal management of the system for an optimization of self-consumption
8.7	Reliable flexibility offer using the whole system	Battery storage converters , HPs, SOFC, methanization unit, SOEC	**Input:** Confirmation of flex offer acceptance **Output:** Flexibility offered to the DSO

3.2 Test case description for HES campus demonstrations

In this subsection the above-mentioned test cases which will be demonstrated at the HES campus within WP8 are described in detail. The existing conditions prior to the test case's implementation as well as after the demonstration of the test case are illustrated. In addition, the main and alternative scenarios of each test case will be explained, and the main stakeholders involved in the test case are mentioned. Finally, the relation and interaction among the test cases are described, and the most important requirements for a successful implementation of the test cases are highlighted.

Table 4: Description of test case 8.1.

ID: TC.8.1	**Name: *Flexibility potential estimation***
Description: This test case aims to demonstrate that an accurate flexibility potential prediction can be performed. The prediction is compared with the flexibility that HES provided during other test cases of deliverable 8.1.	
Trigger: -	
Actors: HES	
Pre-Conditions: The required data are available: actual indoor temperature, occupancy and weather data; weather and occupancy forecasts.	
Post-Conditions: A prediction of the flexibility potential for the next x minutes/hours is made.	
Main Scenario: In the framework of flexibility provision to the local DSO, an estimation of the future flexibility potential is required. **Steps:** **1.** Data collection **2.** Elaboration of a prediction. **3.** Measurement of the predicted quantities. **4.** Comparison between the predictions and the measurements.	
Alternative Scenarios: -	
Special requirements: -	
Business rules and exceptions: -	
Related Test Cases: • All	
Related requirements: • Accurate building model, accurate model of the conversion/storage technologies	

Table 5: Description of test case 8.2.

ID: TC.8.2	Name: Communication with OIKEN
Description: This test case aims to test the communication between HES and OIKEN using the Eflex platform developed by Emax in WP7.	
Trigger: None	
Actors: HES, OIKEN	
Pre-Conditions: None	
Post-Conditions: A confirmation that the flex offer has been accepted by OIKEN is sent to HES.	
Main Scenario: HES posts some flexibility offers on Eflex. At some point, OIKEN needs flexibility and accepts a flexibility offer. A flexibility contract is set up and a confirmation is sent to HES. **Steps:** **1.** A flexibility potential prediction is made by HES. **2.** HES generates and posts flex offers on the Eflex platform. **3.** OIKEN accepts a flex offer generated by HES. **4.** Establishment of a flexibility contract. **5.** A confirmation is sent to HES.	
Alternative Scenarios: -	
Special requirements: -	
Business rules and exceptions: -	
Related Test Cases: • T.C. 8.1, 8.3, 8.4, 8.5, 8.6	
Related requirements: • Installation of communication hardware • Establishment of a communication protocol • Simulation of flexibility potential	

Table 6: Description of test case 8.3.

ID: TC.8.3	**Name: *Reliable flexibility offer using batteries***
Description: This test case aims to demonstrate the ability to offer flexibility using batteries. The main goal is, using the trace exchange presented in TC 8.2, to shift the power load using battery storage.	
Trigger: Confirmation of flex offer acceptance	
Actors: HES, OIKEN	
Pre-Conditions: Flex offers were posted by HES	
Post-Conditions: Flexibility was offered to OIKEN using battery storages.	
Main Scenario: Negative flexibility needs to be provided to OIKEN. Batteries are used to reduce HES' load on the grid. **Steps:** **1.** HES and OIKEN agree on a trace to follow (OIKEN accepts a flex offer). **2.** The trace is followed by using batteries only and flexibility was offered to OIKEN**.** **3.** Data analysis using indicators of performance allows to evaluate the deviation between the agreed trace and the actual performance of the system. The test is validated if specific criteria are respected. These criteria need to be established by HES and OIKEN.	
Alternative Scenarios: Similar scenario with a positive flexibility.	
Special requirements: -	
Business rules and exceptions: -	
Related Test Cases: • T.C. 8.2 • T.C. 5.12	
Related requirements: • Ability to control the battery storages (T.C. 5.12) • Ability to establish a trace to follow (T.C. 8.2)	

Table 7: Description of test case 8.4.

<table>
<tr><th>ID: TC.8.4</th><th>Name: Reliable flexibility offer using heat pumps</th></tr>
<tr><td colspan="2">Description: This test case aims to demonstrate the ability to offer flexibility using heat pumps. The main goal is, using the trace exchange presented in TC 8.2, to shift the power load using the heat pumps.</td></tr>
<tr><td colspan="2">Trigger: Confirmation of flex offer acceptance</td></tr>
<tr><td colspan="2">Actors: HES, OIKEN</td></tr>
<tr><td colspan="2">Pre-Conditions: Flex offers were posted by HES</td></tr>
<tr><td colspan="2">Post-Conditions: Flexibility was offered to OIKEN using heat pumps.</td></tr>
<tr><td colspan="2">Main Scenario: Negative flexibility needs to be provided to OIKEN. Heat pumps are used to reduce HES' load on the grid.
Steps:
1. HES and OIKEN agree on a trace to follow (OIKEN accepts a flex offer).
2. The trace is followed by using the heat pumps only and flexibility was offered to OIKEN.
3. Data analysis using indicators of performance allows to evaluate the deviation between the agreed trace and the actual performance of the system. The test is validated if some criteria are respected. These criteria need to be established by HES and OIKEN.</td></tr>
<tr><td colspan="2">Alternative Scenarios: Similar scenario with a positive flexibility.</td></tr>
<tr><td colspan="2">Special requirements: -</td></tr>
<tr><td colspan="2">Business rules and exceptions: -</td></tr>
<tr><td colspan="2">Related Test Cases:
• T.C. 8.2
• T.C. 5.13</td></tr>
<tr><td colspan="2">Related requirements:
• Ability to control the heat pumps (T.C. 5.13)
• Ability to establish a trace to follow (T.C. 8.2)</td></tr>
</table>

Table 8: Description of test case 8.5.

ID: TC.8.5	Name*: Reliable flexibility offer using the power-to-gas platform*
Description: This test case aims to demonstrate the ability to offer flexibility using the power to gas platform. The main goal is, using the trace exchange presented in TC 8.2, to shift the power load using the power-to-gas platform.	
Trigger: Confirmation of flex offer acceptance	
Actors: HES, OIKEN	
Pre-Conditions: Flex offers were posted by HES	
Post-Conditions: Flexibility was offered to OIKEN using the power-to-gas platform.	
Main Scenario: Negative flexibility needs to be provided to OIKEN. The power-to-gas platform is used to reduce HES' load on the grid. **Steps:** **1.** HES and OIKEN agree on a trace to follow (OIKEN accepts a flex offer). **2.** The trace is followed by using the power-to-gas platform only and flexibility was offered to OIKEN**.** **3.** Data analysis using indicators of performance allows to evaluate the deviation between the agreed trace and the actual performance of the system. The test is validated if some criteria are respected. These criteria need to be established by HES and OIKEN.	
Alternative Scenarios: Similar scenario with a positive flexibility.	
Special requirements: -	
Business rules and exceptions: -	
Related Test Cases: • T.C. 5.14 • T.C. 8.2	
Related requirements: • Ability to control the power-to-gas platform (T.C. 5.14) • Ability to establish a trace to follow (T.C. 8.2)	

Table 9: Description of test case 8.6.

ID: TC.8.6	Name: *Optimization of self-consumption*
Description: This test case aims to demonstrate the ability to use the whole system in order to optimize the self-consumption of local electricity (PV) production.	
Trigger: Triggered by HES	
Actors: HES	
Pre-Conditions: None	
Post-Conditions: Self-consumption was optimized, reducing the load on the grid	
Main Scenario: HES triggers the optimization of self-consumption. The installations are controlled optimally to maximize self-consumption while remaining in acceptable conditions inside the buildings. **Steps:** **1.** Triggering of the self-consumption mode. **2.** Load prediction is performed. **3.** Optimal control is established. **4.** Control of the whole system **5.** Steps 2-3 and 4 are repeated for each time step until the end of the self-consumption optimization **6.** Data and notably load reduction on the grid are analyzed to evaluate the quality of the results.	
Alternative Scenarios: -	
Special requirements: -	
Business rules and exceptions: -	
Related Test Cases: • T.C. 5.12, 5.13, 5.14 • T.C. 8.1, 8.2, 8.3, 8.4, 8.5, 8.7	
Related requirements: • Ability to control the whole system • Accurate building model • Ability to make internal/external load and consumption prediction • Efficient optimization algorithm	

Table 10: Description of test case 8.7.

ID: TC.8.7	**Name*: Reliable flexibility offer using the whole system***
Description: This test case aims to demonstrate the ability to provide large flexibility (positive or negative) using the whole system at the HES pilot site.	
Trigger: Confirmation of flex offer acceptance	
Actors: HES, OIKEN	
Pre-Conditions: Flex offers were posted by HES	
Post-Conditions: Flexibility was optimally provided to OIKEN.	
Main Scenario: Negative flexibility needs to be provided to OIKEN (request for an increased consumption). The whole system is controlled optimally to increase its consumption during a fixed amount of time. The additional amount of energy consumed is stored (e.g. batteries, thermal mass of the building, gas) **Steps:** **1.** HES and OIKEN agree on a trace to follow (OIKEN accepts a flex offer). **2.** The trace is followed by using whole system and flexibility was offered to OIKEN**.** **3.** Data analysis using indicators of performance allows to evaluate the deviation between the agreed trace and the actual performance of the system. The test is validated if some criteria are respected. These criteria need to be established by HES and OIKEN.	
Alternative Scenarios: Same but for positive flexibility. This comes down to a self-consumption optimization.	
Special requirements: -	
Business rules and exceptions: -	
Related Test Cases: • T.C. 5.12, 5.13, 5.14 • T.C. 8.1, 8.2, 8.3, 8.4, 8.5, 8.6	
Related requirements: • Ability to control the whole system • Accurate building model • Ability to make internal/external load and consumption prediction • Efficient control algorithm	

3.3 Test cases and controllable devices at OEDAS pilot site

In Task 8.1 the following test cases have been defined as possible to be demonstrated in WP8. Table 11 includes the proposed test cases (TCs), their short description and also their priority status.

The demonstration plan will be constructed according to that priority status.

Table 11: Test case description and prioritisation for OEDAS site

Number	Name	Description	Priority status
8.8	Definition of roles and validation of processes for flexibility trading with Eflex Platform	During this test case, main roles of possible asset owners will be defined and communication processes with the Eflex platform of WP-7 will be tested and validated.	**High**
8.9	Provision of flexibility by Battery Storage System	This test case will demonstrate flexibility measures and electricity grid services provided by battery storage.	**High**
8.10	Provision of flexibility by V2G platform	This test case will demonstrate flexibility measures and electricity grid services provided by electrical vehicle compatible with V2G. In this test case, V2G will be tested with various tariff schemes for provisioning the flexibility.	**High**
8.10b	Use of the V2G platform for load balancing	V2G technology will be used for load balancing. In this test case, smart charging algorithms will put in practice and in order to balance the load of transformer, charging/discharging activities of EV will be managed via the EV management platform.	**High**
8.10a	Use of the V2G platform for time shifting (arbitrage)	V2G technology will be used for time shifting (arbitrage). In this test case, a potential EV owner uses his/her EV to shift the time at which he/she consumes electricity. The user charges his/her EV at low prices and then discharges the EV to the grid during periods of high prices. The aim is to reduce the overall cost of energy.	**Medium**
8.11	Provision of flexibility by Demand Side Management	Demonstration of Demand Side Management/Demand response activities will be provided. EV drivers will be directed to the most suitable EVSE locations in order to make grid resilience within market mechanism.	**Low**
8.12	Provision of flexibility services with the whole system	This test case will demonstrate the flexibility measures and electricity grid services provided by the energy storage, the electrical vehicles and the V2G platform.	**Low**

Table 12 presents the expected controlled devices for each of the defined test cases along with their expected input and output.

Table 12: Expected controllable devices and input/output of the test cases.

Number	Name	Controllable devices	Input/output
8.8	Definition of roles and validation of processes for flexibility trading with Eflex Platform	-	**Input**: A flexibility offer is posted on the Eflex platform by a flexible asset owner **Output**: Acceptance of the offer by the DSO and validation of the communication and other processes.
8.9	Provision of flexibility by Battery Storage	Battery storage, inverter, DC charger	**Input:** Need for flexibility in the distribution network. **Output:** Flexibility offers using the battery storage system.
8.10	Provision of flexibility by V2G platform	EV, V2G charger, Vehicle to grid charging platform	**Input:** Need for flexibility in the distribution network. **Output:** Flexibility offers using the V2G platform.
8.10a	Use of the V2G platform for load balancing	EV, V2G charger, Vehicle to grid charging platform	**Input:** Need for flexibility in the distribution network. **Output:** Flexibility offers.
8.10b	Use of the V2G platform for time shifting (arbitrage)	EV, V2G charger, Vehicle to grid charging platform	**Input:** - **Output:** Charging of EVs when the electricity prices are low and discharging of EV batteries during peak times of day (when prices are high).
8.11	Provision of flexibility by Demand Side Management/Demand Response	EV,EV Chargers	**Input:** - **Output:** Implementation of demand side management with different price offers and tariff mechanisms for the EV user.
8.12	Provision of flexibility services with the whole system	Battery storages, EV, EV Chargers	**Input:** Need for flexibility in the distribution network. **Output:** Flexibility offers.

3.4 Test case description for OEDAS pilot site

Table 13: Description of test case 8.8

ID: TC.8.8	Name: Definition of roles and validation of processes for flexibility trading with Eflex Platform
Description: Based on the Eflex platform which is being developed in WP-7, possible flexible asset owners (flexibility service providers) will be able to post a flexibility offer for a time range and the DSO will be able to accept this offer considering its flexibility needs. Roles of both actors will be defined and with these roles, other test cases will be demonstrated. More importantly, communication and other related processes will be tested while posting/accepting possible offers.	
Trigger: -	
Actors: OEDAS, EMAX	
Pre-Conditions: According to the situation of flexible assets, flexibility offers are posted by asset owners (since the owner of flexible assets is OEDAS, in all test cases, the flexibility service provider will also be OEDAS or may be the retail company of OEDAS, it will be discussed).	
Post-Conditions: Flexibility offers are accepted by the DSO andan information is sent to the asset owner. Allrelated processes are checked and validated during this step.	
Main Scenario: The flexible asset owner posts flexibility offers and when the DSO needs flexibility, it accepts this offer. Related processes about communication and notification are checked and validated during tests. **Steps:** **1.** Flexible asset owners post flexibility offers on the Eflex platform. **2.** The DSO-OEDAS accepts a flexibility offer generated by flexibility asset owners. **3.** All related processes are considered and validated during these steps and necessary notifications are sent to each by both actors. **4.** The testing process is completed if the final configuration is satisfying the needs of the grid.	
Alternative Scenarios: -	
Special requirements: -	
Business rules and exceptions: -	
Related Test Cases: • T.C. 8.9, 8.10, 8.12	
Related requirements: • All requirements will be discussed with the WP-7 leader EMAX.	

Table 14: Description of test case 8.9

ID: TC.8.9	**Name*: Provision of Flexibility by Battery Storage***
Description: The main scope of this use case is to offer flexibility to the grid with the battery storage system when there is a need for flexibility. In this purpose, the battery energy storage system will be installed and it will be directly connected to a DC 50 kW charger. So, according to the electrical grid conditions, the battery storage system will charge itself from the grid and discharge energy through the DC charger. In this way, the battery storage system will be used as a flexibility asset. Also, the battery storage system will be used for time shifting purposes as well. According to the available tariff structure, arbitrage will also be demonstrated. All these scenarios will be managed via the Energy Management System of Battery Storage.	
Trigger: The emergence of flexibility needs in the grid.	
Actors: OEDAS	
Pre-Conditions: In normal condition, the DC charger gets energy from grid. According to the load profile and load characteristics of the existing customers which are fed by the MV/LV transformer, fast charging EVs connected to DC chargers can create daily peaks on transformer. In such a situation, if there is a need for flexibility, it is determined by the DSO considering the load profile of transformer and a flexibility request is sent by the grid operators.	
Post-Conditions: According to the state of charge of the battery storage system, flexibility is offered to electricity network for EV charging by using the battery energy storage system.	
Main Scenario: In case of any need for flexibility services, batteries will be used for the supply of load balancing/reduction on the network. **Steps:** **1.** The DSO monitors the hourly load consumption of the existing transformer via an automatic meter reading infrastructure. **2.** The DSO determines the time range of daily peaks according to the load profile of the transformer. **3.** Charging of battery storage system is performed during night time (when the electricity price is the cheapest and load rate is min.) **4.** When there is a need for a flexibility service during peak time, it is reported by the grid operator. **5.** The flexibility service is offered to the grid operator and provided by the discharge of the battery storage system only for EV DC charging. **6.** The testing process is completed if the new configuration is satisfying the needs of the grid.	
Alternative Scenarios: For alternative scenarios, charging of the battery storage system is performed during daytime and provision of flexibility by discharge can take place in peak times as well. Another option can be demonstration of time-shifting, independent from the grid conditions.	
Special requirements:	
Business rules and exceptions: -	
Related Test Cases: 8.8 Definition of roles and validation of processes for flexibility trading with Eflex Platform	
Related requirements:	

- Active/reactive power consumption measurements of the transformer
- SoC measurements of the battery storage system.
- Charging/Discharging measurements of the battery energy storage system.
- Evaluation of the data that were gathered from the energy storage management system.
- Ability to control the battery storages.
- Special requirements may be needed for the integration of IoT platform.

Table 15: Description of test case 8.10

<table>
<tr><th>ID: TC.8.10a-b</th><th>Name: Provision of Flexibility by V2G Platform</th></tr>
<tr><td colspan="2">Description: In this test case, the main goals are: 1) to demonstrate the use of the V2G technology coupled to the enhanced EV management platform and the mobile application, 2) to provide flexibility to the electricity distribution network using V2G compatible EVs. When there is a need for flexibility, the V2G option will act as a flexibility asset. In line with this, a 10 kW DC V2G charger will be installed on the pilot site. According to the load conditions of the network, vehicles will be charged by the grid or energy will be discharged from the vehicle to the grid. These processes will be managed by the EV management platform and with the mobile app. With the mobile app, potential users who leave the vehicle in the parking lot will provide their return dates and the level of battery charge will be required upon their return. With this information, smart charging algorithms will run in the background of the EV management platform to balance the daily load while the vehicle is plugged into the charger.</td></tr>
<tr><td colspan="2">Trigger: The relevant process is triggered by the DSO when the potential electric vehicle user agrees to participate in a DR event via the mobile app. With the information which is gathered from the charging preferences of the potential user, the vehicle’s battery can be used as a flexibility asset if flexibility is required by the DSO.</td></tr>
<tr><td colspan="2">Actors: OEDAS</td></tr>
<tr><td colspan="2">Pre-Conditions: In this scenario, the potential vehicle user who leaves his vehicle in the parking space agrees to participate in the DR event with his V2G compatible vehicle. This user books his session and sets his charging preferences (such as the desired battery level when he returns) via the mobile app. With this charging preference information collected from the EV management platform, the DSO will be able to use the vehicle’s battery for flexibility services.</td></tr>
<tr><td colspan="2">Post-Conditions: According to the information which is provided by the EV Management Platform, provision of flexibility is demonstrated for load balancing by using of the V2G platform.</td></tr>
<tr><td colspan="2">Main Scenario:

Scenario 1:
In this scenario, V2G will be used for load balancing when there is a need for flexibility services.
Steps:
1. The potential EV user leaves his/her vehicle in the parking lot and accepts to participate in the DR event.
2. The potential EV user sets his/her return date&time and the battery level required at his/her return.
3. If there is a need for flexibility, it is reported by the grid operator.
4. According to this information, the DSO uses the vehicle’s battery for load balancing, manages the charging/discharging activities of the vehicle’s battery via smart charging algorithms which run in the background of the EV management platform.
5. With this process, a flexibility service is provided by the V2G platform. Potential users may be incentivized (not in a real case) to participate in the DR event.
6. The testing process is completed if the new configuration is satisfying the needs of the grid.
Scenario 2:
In this scenario, V2G will be used for time shifting (arbitrage).
Steps:
1. The potential EV user charges his/her vehicle when the electricity price is low during night times or day times.</td></tr>
</table>

2. According to the load profile of the transformer, the DSO determines and reports if there is a need for flexibility during peak times. 3. The potential EV user discharges the vehicle to the grid during peak times (daily peaks). When the electricity prices are high, the user sells energy to the DSO. 4. This process is managed via the EV management platform. 5. The test process is completed if the new configuration is satisfying the needs of the grid.
Alternative Scenarios: Alternative scenarios may be considered in further progress.
Special requirements: A single-multi rate tariff structure of electricity market is required. (In the available three-rate tariff in Turkey, the period between 6 a.m. and 5 p.m. was regarded as daytime, between 5 p.m. and 10 p.m. as peak time and 10 p.m. and 6 a.m. as night time. So the electricity price is approximately equal to that in the one-rate tariff during the daytime, is the highest during the peak time, and is the cheapest during the night time)
Business rules and exceptions: -
Related Test Cases: 8.8 Definition of roles and validation of processes for flexibility trading with Eflex Platform
Related requirements: • Remote control of the V2G charger. • EV management platform and mobile application. • Monitoring of the SoC of vehicle. • Charging/Discharging measurements of the vehicle's battery. • Evaluation of the data that are gathered from the EV management platform/mobile app. • Special requirements may be needed for the integration of the IoT platform.

Table 16: Description of test case 8.11

ID: TC.8.11	**Name:** ***Provision of Flexibility by Demand Side Management/Demand Response***
Description: The main scope of this use case is to implement demand side management by promoting different incentive-based tariffs for EV users.	
Trigger: Emergence of flexibility or load balancing needs in the grid.	
Actors: OEDAS	
Pre-Conditions: -	
Post-Conditions: Possible users will be directed to different stations with a dynamic tariff structure according to the load status of the transformers which are feeding the EV charging stations.	
Main Scenario: **Steps:** **1.** Consumption values of possible transformers which are feeding the charging stations will be collected via the existing Automatic Meter Reading system with API service. **2.** Suitable charging stations from the grid perspective will be offered to the possible users. **3.** A flow chart of the dynamic price mechanism will be implemented to selected charging stations. **4.** Demand side management will be provided for load balancing using different incentive-based price offers and tariff mechanisms to the EV user by the EV charging management platform and the mobile application. **5.** The testing process is completed if the new configuration is satisfying the needs of the grid.	
Alternative Scenarios: -	
Special requirements: -	
Business rules and exceptions: -	
Related Test Cases: -	
Related requirements: • AMR values of the transformers of selected charging stations. • Flow chart for dynamic pricing. • Evaluating the data that were gathered from the electrical vehicle charging management platform.	

Table 17: Description of test case 8.12

ID: TC.8.12	**Name*: Provision of flexibility services with whole system***
Description: The main scope of this use case is to offer flexibility to the grid with all available flexibility assets.	
Trigger: The emergence of flexibility needs in the grid.	
Actors: OEDAS	
Pre-Conditions: A flexibility request is sent by the grid operators.	
Post-Conditions: Flexibility was offered to the grid operators using the whole system.	
Main Scenario: In case of any need for flexibility services, all platforms which are available to provide flexibility services will be used for the supply of load balancing/reduction on the network. **Steps:** **1.** When there is a need for a flexibility service, it is reported by the grid operator. **2.** The flexibility service is offered to the grid operator and provided by the whole system. **3.** The testing process is completed if the new configuration is satisfying the needs of the grid.	
Alternative Scenarios: -	
Special requirements: -	
Business rules and exceptions: -	
Related Test Cases: 8.8, 8.9, 8.10	
Related requirements: • Evaluation of the data that were gathered from the devices' management platforms. • Having the ability to control the battery storages. • Having the ability to control the V2G platform.	

4. Technical requirements and controllable devices

4.1 Technical requirements and controllable devices for HES campus

In this subsection, the most important technical requirements on the HES pilot site are presented. These requirements are categorized into three groups: hardware requirements (requirements for the different devices at HES campus), communication requirements (requirements for the communication between the devices and the central control unit) and software requirements (requirements on the monitoring/control software).

4.1.1 Hardware requirements for the HES campus

Hardware requirements presented in this section follow what was presented in D5.1. The controllable devices and their control parameters are listed in Table 18. Their required resolutions as well as a priority has been set for each controllable device. The priority is based on the time horizon of the installation of these devices.

Table 18: Specification of hardware requirements

Controllable device	Location	Control parameters	Resolution	Priority
Battery controllers	TBD	• Active power set points • State of charge	TBD	**High**
Heat Pump	Each building	• Active power set point	TBD	**High**
Building thermal inertia	Each building	• Heat supply • Indoor temperature • Outdoor temperature • Direct and diffuse radiation	TBD	**Medium**
SOFC/SOEC	TBD	• TBD	TBD	**Low**
Methanization unit	TBD	• TBD	TBD	**Low**

4.1.2 Measurements / Data sets

As HES pilot site is under construction, the metering infrastructure with the location of each measurement device cannot be clearly presented here. However, a first draft of the measurement that will be required is presented in Table 19. This list is non-exhaustive and is still subject to modification.

These measurements can be classified into 4 categories: temperature measurements, power measurements, state of charge measurements, mass flow measurements. These measurements will be communicated as data sets and will thus influence the communication requirements.

Table 19: Presentation of the required measurements

Measurement	Units	Associated device	Location	Resolution	Priority
Supply temperature	[K]	Heat pump	TBD	TBD	**High**
Return temperature	[K]	Heat pump	TBD	TBD	**High**
Electric power	[kW]	Heat pump	TBD	TBD	**High**
Indoor temperature	[K]	Building thermal inertia	TBD	TBD	**Medium**
Outdoor temperature	[K]	Building thermal inertia	TBD	TBD	**Medium**
Produced power	[kW]	Solar panel	TBD	TBD	**High**
Global tilted irradiance	[W/m2]	Solar panel	TBD	TBD	**Medium**
State of charge	[%]	Batteries	TBD	TBD	**High**
Input power	[kW]	Batteries	TBD	TBD	**High**
Output power	[kW]	Batteries	TBD	TBD	**High**

4.1.3 Communication requirements for HES campus

The communication requirements concern 2 different aspects:

- The transfer of data sets specified in sub-section 4.1.2. Concretely, the communication method, the size of the data sets and their shape still need to be determined. This will be done in a later stage of the project.

- The transmission of flex offers via the IoT platform and the Eflex platform developed in WP4 and WP7.

4.1.4 Software requirements for the HES campus

Table 20: Software that need to be developed during WP8 for HES campus

Software objective	Description	Type
Consumption prediction	• This software aims to predict the future consumption.	Prediction
Flexibility prediction	• This software aims to predict the potential flexibility that could be provided.	Prediction
Control algorithm	• This software allows to control the system optimally using the predictions which were elaborated.	Control
Flex offers communication	• An API needs to be developed to be able to share the flex offers generated by HES	Communication

4.2 Technical requirements and controllable devices for OEDAS pilot site

In this subsection, the most important technical requirements for the site of OEDAS are presented. The requirements are divided into hardware requirements and software requirements.

4.2.1 Hardware requirements for OEDAS pilot site

The controllable devices and their control parameters are listed in Table 21. Their required resolutions as well as a priority has been set for each controllable device. The priority is based on the time schedule of the installation of these devices.

Table 21: Description of hardware requirements for OEDAS pilot site

Controllable device	Location	Control parameters	Resolution	Priority
Battery storage and its inverter	Eskisehir/Yasam Koyu	• Charging/Discharging set points • State of charge • Other set parameters	TBD	**High**
DC Charging Station	Eskisehir/Yasam Koyu	• Remote On/Off Option	TBD	**High**
V2G Charger	Eskisehir/Yasam Koyu	• Remote On/Off Option • Charging/Discharging set points • Other set parameters	TBD	**High**
V2G compatible vehicle	Eskisehir/Yasam Koyu	• Remote charging • SoC	TBD	**High**

4.2.2 Measurements / Data Sets

As installations are still ongoing at OEDAS pilot site, the metering infrastructure with the location of each measurement device cannot be clearly presented here. However, a first draft of the measurement that will be required is presented in Table 22. This list is non-exhaustive and is still subject to modification.
Not all values are available in the pilot region for now. Basically, for the existing equipment such as transformers, the values can be read via appropriate services and API programs. The maximum time intervals need to be clarified and determined individually. Some integration will be necessary, and some API and APP development will be done in the scope of this project.

Table 22: Presentation of the required measurements

Measurement	Units	Associated device	Location	Resolution	Priority
State of charge	[%]	Battery Storage System	Eskisehir/ Yasam Koyu	TBD	High
Input power	[kW]	Battery Storage System	Eskisehir/ Yasam Koyu	TBD	High
Output power	[kW]	Battery Storage System	Eskisehir/ Yasam Koyu	TBD	High
Charging/Discharging Values	[kW]	Battery Storage System	Eskisehir/ Yasam Koyu	TBD	High
Temperature	[C^{0}]	Battery Storage System	Eskisehir/ Yasam Koyu	TBD	Medium
Active Power Consumption Value	[kW-kWh]	MV/LV Transformer	Eskisehir/ Yasam Koyu	15 min or 1 hour	High
Reactive Power Consumption Values	[kW-kWh]	MV/LV Transformer	Eskisehir/ Yasam Koyu	15 min or 1 hour	Medium
Voltage Profile per Phases	[V]	MV/LV Transformer	Eskisehir/ Yasam Koyu	15 min or 1 hour	Low
Current Profile per Phases	[A]	MV/LV Transformer	Eskisehir/ Yasam Koyu	15 min or 1 hour	Low
Active Power Consumption Value	[kW]	DC Charger	Eskisehir/ Yasam Koyu	TBD	High
Active Power Consumption Value	[kW]	V2G Charger	Eskisehir/ Yasam Koyu	TBD	High
Charging/Discharging Values	[kW]	V2G Charger	Eskisehir/ Yasam Koyu	TBD	High
State of Charge	[%]	V2G Vehicle	-	TBD	Medium

4.2.3 Communication requirements for HES campus

Communication protocols such as Modbus and OCPP1.6J will be used for the integration of several equipment in pilot site. Planned communication infrastructure is presented in Figure 7.

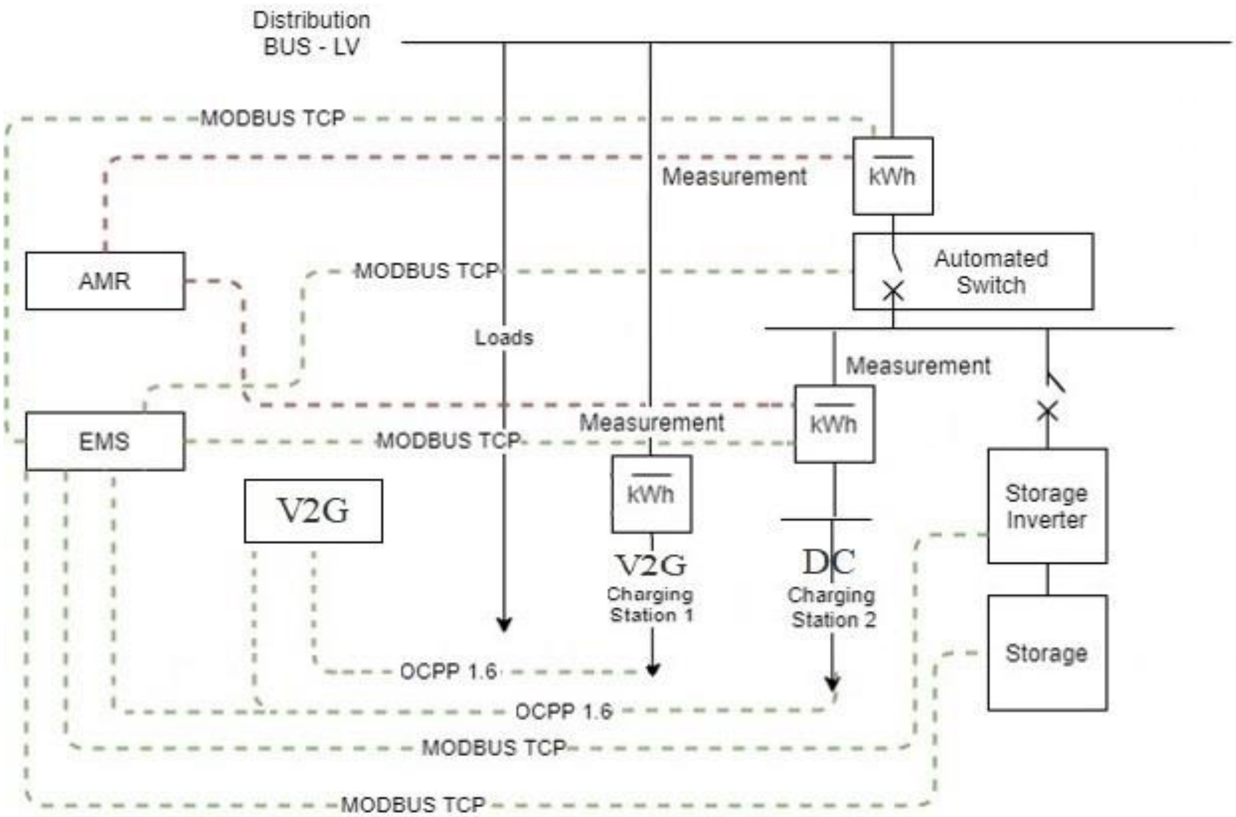

Figure 7: Planned infrastructure of OEDAS pilot site

4.2.4 Software requirements for OEDAS pilot site

Table 23: Software that need to be developed during WP8 for HES campus

Software objective	Description	Type
Battery Energy Management System	• This software aims to monitor, control and manage the charging/discharging events of battery storage system.	Monitoring, Control
EV Management Platform	• This software aims to monitor, control and manage the charging/discharging events of V2G chargers.	Monitoring, Control
Mobile app for possible EV users	• With this app, possible users will be able to set their charging sessions and preferences. And they will also be able to participate DR events through this app.	Mobile Application
Middleware development for API service	• REST API integrations of each equipment will be provided through this service gateway.	Communication

Structure of service gateway that is planned to developed by OEDAS is shown in Figure 8.

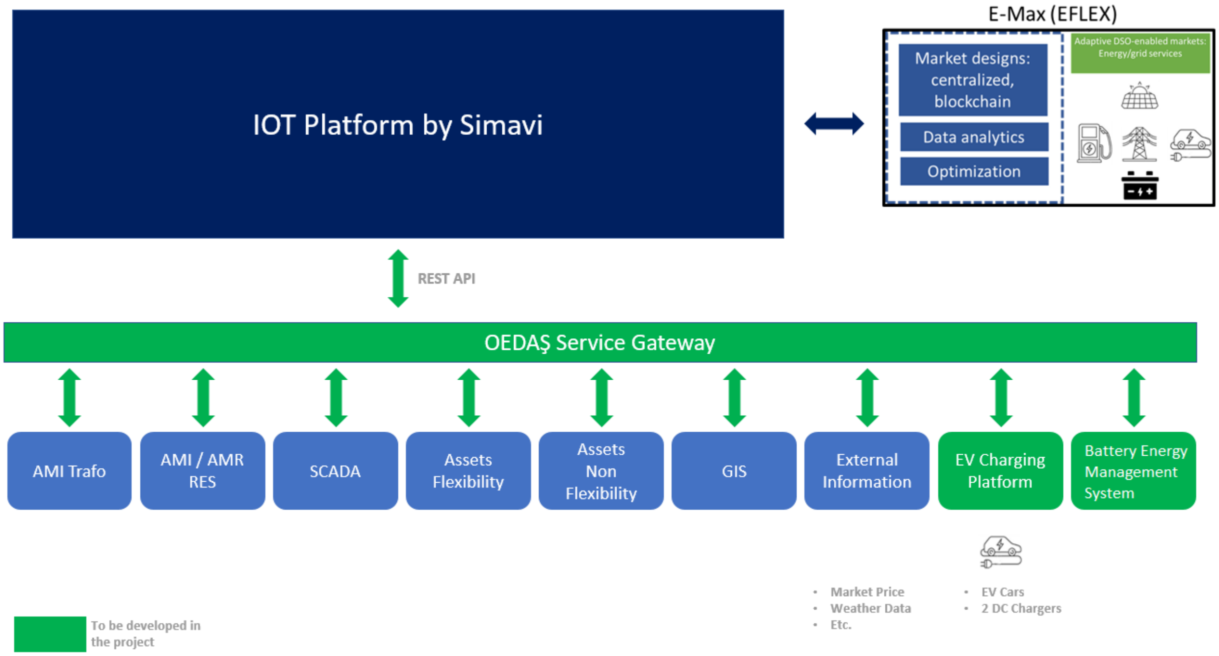

Figure 8: Planned service gateway for API integrations

5. Conclusions

In this report, the pilot areas in Switzerland and in Turkey were presented. Test cases that will be demonstrated on both sites were defined and prioritized. In addition, the most significant technical requirements (i.e. hardware, communication and software requirements) of each test case have been identified. The outcome of this deliverable is expected to facilitate the preparation of the test site for the demonstration activities, as well as their seamless and successful implementation.

On the Swiss pilot site, the main goal is to be able to control the different energy conversion units and storages and to be able to use them for the supply of flexibility to the local DSO. For the Turkish pilot site, the aim is to show that a coordinated real-time control of local devices improves the integration of renewable energies by coordinating energy consumption while at the same time improving grid stability with V2G technology. OEDAS will demonstrate several use cases with different flexible assets such as battery storage, EVs and V2G. Also OEDAS will try to implement dynamic pricing use case with basic demo.