TwinERGY connectors to distributed smart grid assets and respective APIs

D8.1

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Deliverable

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TwinERGY connectors to distributed smart grid assets and respective APIs

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Statement of Originality

This deliverable contains original unpublished work except where clearly indicated otherwise. Acknowledgement of previously published material and of the work of others has been made through appropriate citation, quotation or both.

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Executive summary

This present document is D8.1 "TwinERGY integration with field devices and distributed smart grid assets (v1)" of the TwinERGY project, funded by the European Commission's Innovation and Networks Executive Agency (CINEA) under its Horizon 2020 Research and Innovation programme (H2020). The main objective of this deliverable is to register the stages of the smooth and seamless integration of the smart grid components in the TwinERGY solution. This is completely aligned with the purpose of Work Package 8 "TwinERGY system integration", based on the integration of all the components and the TwinERGY solution with the underlying components in the Smart Grid setup of the different TwinERGY pilot sites. This document intends to establish the methodology that is going to be approached to develop the necessary connectors that will ensure the connectivity, communication, and information exchange from the distributed assets, resources, and systems of presented at the TwinERGY project. It is worth remarking that this task is linked to the developments in other TwinERGY Work packages and Tasks from different phases (e.g., WP4: Methodological framework and Architecture Design from the *Design Thinking Phase* and WP7: Development of TwinERGY system modules and WP5: Data Collection and Communication Platform from the *Innovation Lab Phase* and WP9 Pilot from the *Scale Phase).*

As the pilot's installations activities remain ongoing, additional refinements, enhancements and testing activities are analysed and introduced as needed, the release of the second version of this deliverable (expected on M27) will cover the updates. Feedback that is continuously changing in other active technical Work Packages such as WP5 and the demonstration activities (WP9) will also contribute to the information update in the upcoming versions.

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1. Introduction

1.1. Scope of the document

This deliverable D8.1 "TwinERGY connectors to distributed smart grid assets and respective APIs" is one of the two designated deliverables associated to Task 8.1 "TwinERGY integration with field devices and distributed smart grid assets". This deliverable includes a description of the integration activities of the distributed smart grid assets that are present in the TwinERGY ecosystem. This deliverable would indicate the different integration activities that need to be undertaken to assure the connectivity, communication, and information exchange from the different distributed assets, resources, and systems that will enable the ingestion of data (both data in motion and batch data) to the TwinERGY Core Data Management Platform (CDMP) which is being developed in WP5 "Data Collection and Communication Platform", particularly at Task 5.3 "Core Data Ingestion, Curation and Management Services". To this end, this deliverable is:

- Compiling the information regarding different assets/elements which are part of the TwinERGY Pilot's ecosystem
- Presenting the methodology to be used in the integration of the different Smart Grid assets to guarantee the communication
- Offering insights regarding the architectural requirements that the TwinERGY system architecture requires. This is based on the development of the System Architecture, which is part of Task 4.4 "System Architecture".
- Documenting the integration activities and testing activities that each one of the pilots must perform in order to create the relevant connections

1.2. Structure of the deliverable

This deliverable is structured starting with an Executive Summary of the document. The introduction (Section 1. Introduction) gives readers the opportunity to understand the context of this deliverable within the Task and the Work Package. Section 2. Objectives is expected to identify the objectives of the deliverable regarding the project and the interconnection of this task with the rest of Work Packages (WP) and tasks involved. Section 3. TwinERGY Ecosystem at a glance, would present an overview of the TwinERGY ecosystem based on the Architectural design which is based on the Use Cases (UC) definitions and its developments. 4. Assets integration methodology provides the methodology that is going to be applied to perform the Assets integrations labour. 5. Assets integration and support activities will provide further information of the assets to

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be integrated, alongside the testing methodology to prove their correct integration. Finally, 6. Conclusions and Next Steps would summarise the key aspects regarding the work performed in this task.

1.3. Abbreviation list

Acronym	Full Name
1D	One dimension
CDMP	Core Data Management Platform
CIM	Common Information Model
HEMS	Home Energy Management System
HLUC	High Level Use Case
LEM	Local Energy Market
PUC	Primary Use Case
SGAM	Smart Grids Architecture Model
SUC	Secondary Use Case
UC	Use Case
WP	Work Package

Table 1: Abbreviation list

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2. Objectives

WP8 “TwinERGY system integration” is reflected on the Innovation Lab Phase within the TwinERGY project. In this phase, the underlying components in a Smart Grid setup would be integrated, so that accurate communication, connectivity, and information exchange are guaranteed among the different components in the TwinERGY project. This task would be largely based on the WP9 “Pilots” installation activities which provide the technical layout of TwinERGY ecosystem. Under this premise, this first deliverable associated with Task 8.1 “TwinERGY integration with field devices and distributed smart grid assets” is meant to give a broader idea of the TwinERGY ecosystem at a glance, based on the TwinERGY architecture, which is developed under the SGAM methodology [1] which is defined in Task 4.4 “System Architecture” [2].

The Smart Grid Setup differs widely across the different pilot sites in the TwinERGY project (Bristol, Steinheim, Benetutti and Athens). That is why, this task would take into consideration the definition of the High Level Use Cases (HLUC), Primary Use Cases (PUC), and Secondary Use Cases (SUC) already defined in Task 2.2 “Stakeholders Requirements” [3], which were elaborately detailed in Task 4.4 “System Architecture” [2]. Additionally, based on their installation plan defined in WP9 “Pilots”, the different pilot the demonstration leaders would be asked to list accordingly the different Smart Grid assets available to be installed at the respective pilot sites. This would set up a clear picture of which are the different integration steps that need to be performed during the task in order to achieve their integration within the TwinERGY Ecosystem.

This task decisively targets at allowing the Core Data Management Platform (CDMP) to retrieve adequate information, particularly real-time data, and batch data so that this data can be ingested and appropriately dealt by the CDMP so that it can retrieve information to the different Open APIs that would act as interconnectors of the different upstream analytic engines and end-user applications in TwinERGY. The CDMP is the Big Data Management Platform of the project, which allows communication across the TwinERGY project's energy value chain. This task would be directly correlated with the Data Collection Service, particularly with the Data Ingester functionality. The aim is that any asset involved in the TwinERGY ecosystem could flow information through stable and secure mechanisms (via direct batch data uploading or real-time data uploading through APIs). This task would be dealing with the connection of distributed data assets in the pilots with the CIM and the and the APIs residing in the CDMP that would fill the needed data for the project.

The integration envisioned for the Smart Grid setup would be done based on the Incremental approach integration. This method has been selected after the analysis of the advantages and disadvantages of different integration methods. The integrated assets would be listed based on the System Architecture and the project requirements. To uniform the different integration typologies of the different assets presented, an integration classification is presented. The different assets could be classified in one integration strategy according to the nature of the asset. Finally, an integration test schema will be introduced. This will help in the testing of the integration activities.

3. TwinERGY Ecosystem at a glance

TwinERGY ecosystem comprises different layers which assure the replicability and the scalability of the proposed solution in the context of Energy Communities:

- **Components and Communication Layer** consists of the different sources (smart appliances, storage systems, RES systems) as well the layer that collects the data generated by all the sources of the TwinERGY architecture.
- **Information Layer** where the content of the multiple data sources coming from the previous layer are brought together. This layer is built under accuracy and transparency principles, and the Core Data Management Platform (CDMP)
- **Function Layer** where the different modules and application consume the information provided by the CDMP
- **Business Layer** which will allow the creation of the decentralized energy market in a local level (LEM)

This architecture is presented in Figure 1. It has been further developed in WP4 "Methodological framework and Architecture Design", particularly in Deliverable 4.4 "System Architecture" [2] under the SGAM (Smart Grid Architecture Methodology) [1], serving as a model of the architecture of the Smart Grid system from the point of view of the relationships between the different actors, the interactions among the different systems, components and assets that cooperate towards offering functionalities defined in the project's requirements.

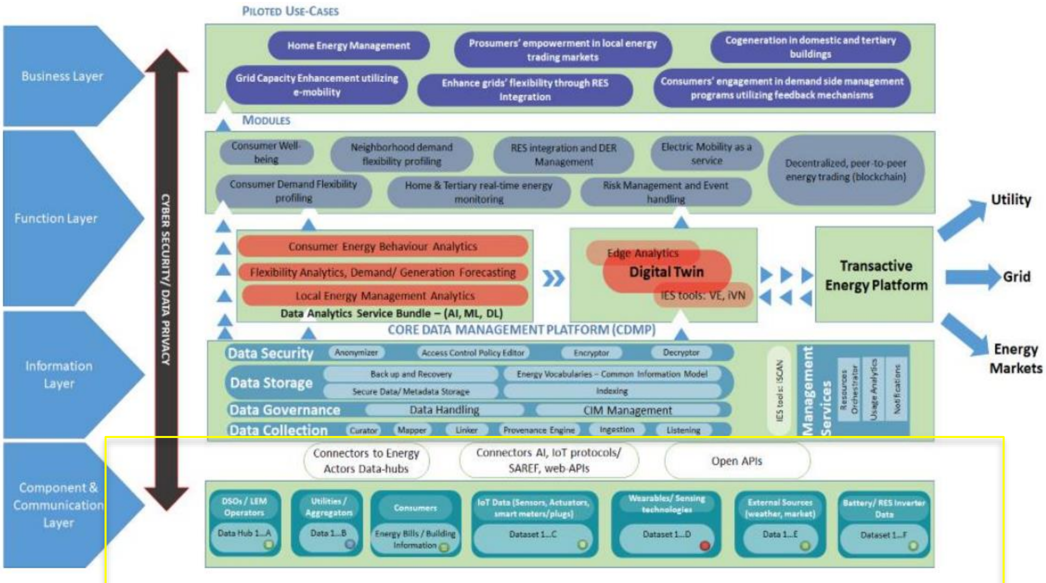

Figure 1: TwinERGY interoperable infrastructure

Attention must be paid to the selected rectangle in the figure which focuses on the layers that this task is dedicated to. As commented, the task is focusing on the integration of the underlying components in a Smart Grid setup, that would assure the connectivity, the communication and the information exchange to populate the TwinERGY Common Information Model (CIM).

The component layer, in which the different Smart Grid Assets are considered, needs to be connected to the information layer, which in the TwinERGY ecosystem is represented by the interoperable Big Data Management Platform (TwinERGY Core Data Management Platform). The diverse modules which compose the TwinERGY CDMP are represented in Figure 2.

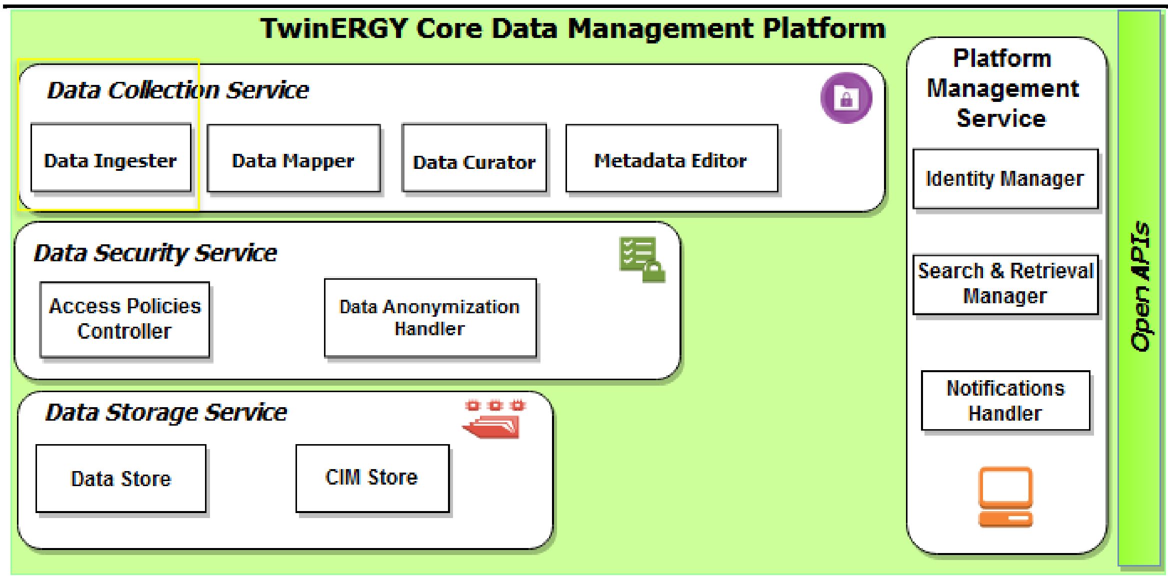

Figure 2: TwinERGY Core Data Management Platform Conceptual Architecture [4]

As it is specified in [4], there are several services in the Core Data Management Platform, which have several functionalities. Nevertheless, this deliverable would reference the only services that are directly involved with the aim of this task. The Data Collection service would be the responsible asset for the data ingestion in the platform. Any TwinERGY CDMP user can upload data to the TwinERGY Integrated Platform infrastructure via stable and secure mechanisms, such as direct batch data uploading or real-time data uploading through APIs (which would be the main purpose of this task). To carry out this goal, the **Data Ingester** functionality is going to be used. This functionality would allow the user to determine how the data will be ingested (directly via file uploading or data ingestion via API). The Data Ingester functionality allows the configuration of the uploaded data under an authentication schema, through the selection of an API URL, and the ingestion method to be used. This functionality, among the other functionalities of the TwinERGY Core Data Management Platform are described in [4], a document which would evolute into a final version in the upcoming months of the TwinERGY project.

It is crucial to identify the different assets that need to be integrated to provide information to the Data Ingester functionality. Firstly, it is important to place them accordingly to the project's requirements described in the Primary Use Cases (PUC) and Secondary Use Cases (SUC). They are described in [2]. Nevertheless, Table 2 will give a general overview of them:

Table 2: HLUC, PUC and SUC of TwinERGY

HLUC 1	Home Energy Management	**PUC 01.01**	Increase the building observability - Data gathering from the home monitoring system
		PUC 01.02	Data analysis. Behavioural rules analysis, minimization of the energy costs and increase the self-consumption from PV
		PUC 01.03	Optimal flexibility management system - Analysis of the optimal electrical appliances flexibility management
		PUC 01.04	Control of the smart devices
HLUC 2	RES generation in domestic and tertiary buildings	**PUC02.01**	Dispatch of existing RES in domestic and tertiary buildings to minimise cost/carbon emissions
		PUC02.02	Optimal future energy storage to maximise RES production
		PUC02.03	Maximum future RES capacity
		PUC02.04	Optimal CHP solution specific to the pilot site in terms of capital costs and network capacity
		PUC02.05	Optimal scenario of future energy storage and RES to minimise energy costs for the end user/carbon emissions
		PUC02.06	Optimal domestic and tertiary demand response, based on RES, to minimise cost/carbon emissions
HLUC 3	Grid capacity enhancement utilizing e-mobility	**PUC03.01**	Booking a charge session
		PUC03.02	Smart Charging to follow grid requests
		PUC03.03	Smart Charging to maximize RES integration
		PUC03.04	Smart Charging to minimize charge costs
		PUC03.05	Smart Charging to minimize time of charge
		PUC03.06	Grid Management
HLUC 4	Prosumer's empowerment in Local Energy Trading Markets	**PUC04.01**	Recording transactions of energy
		PUC04.02	Calculation and broadcasting of LEM pricing compared to DNO/DSO pricing
HLUC 5	Enhance grid flexibility through DER Management	**PUC05.01**	Prediction of energy consumption and RES production
		PUC05.02	Utilizing the Virtual-Power-Plant

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		PUC05.03	Grid status calculation and bottleneck detection
HLUC 6	Consumer's engagement in Demand Side Management Programs utilizing feedback mechanisms	**PUC06.01**	Increase residential demand flexibility
		PUC06.02	Decrease residential energy use
HLUC 7	Consumer's engagement in demand response programs utilizing a socio-economic context	**PUC07.01**	Social marketing to engage customers via competition.
		PUC07.02	End-users' engagement on utilization of shared DERs.
		PUC07.03	Enable co-creation for end consumers, prosumers, and public authorities.
HLUC 8	Consumer's engagement in demand response programs utilizing personalized comfort/health-oriented services	**PUC08.01**	Wellbeing best practice for indoor environment conditions
		PUC08.02	Physiological parameter and comfort feedback monitoring
		PUC08.03	Comfort relation within Demand Response optimal solution
HLUC 9	Consumer's Engagement in Demand Response Programs Utilizing Digital Twin Prediction Capabilities for Dynamic VPPs	**PUC09.01**	Explicit Demand Response Automation and display at a consumer and community level.
		PUC09.02	Implicit Demand Response Calculation and Communication to the end-user at both a community and consumer level.

The participation of each of the Pilot sites in the different High-Level Use Cases (HLUC) is presented at Table 3. The coloured cells in orange represent the active participation of each one of the Pilots in the defined HLUCs.:

Table 3: HLUC participation per pilot

HLUC	Bristol	Steinheim	Benetutti	Athens
HLUC.01				
HLUC.02				
HLUC.03				
HLUC.04				
HLUC.05				
HLUC.06				
HLUC.07				
HLUC.08				
HLUC.09				

Based on the definition of the different layers (following the SGAM methodology) in the different nine HLUC, a list of components transversally covering the four pilot sites have been created and it is presented in Table 4. This list has been extracted from [2].

Table 4: Physical Assets conforming to the TwinERGY Ecosystem based on the System Architecture

Components

Asset Controller/ Smart Meter	Inverter
Charging Point	LV Grid
Community battery Smart Meter	MV Grid
Community battery storage	MV-LV transformer
Community battery storage smart meter	Physiological sensor
Electric Vehicle	Physiological sensor controller
Energy asset/appliance	PV Panel
Environmental Sensor	PV Panel Smart meter
Home Battery Smart Meter	Raspberry Pi
Home Battery Storage	RTU
Home Battery Storage Smart meter	Sensor Smart Meter
Home storage smart meter	Wind Farm

To obtain further information regarding these components, the different pilot sites have been asked to identify the assets to be integrated. The following tables (
Table 6: Steinheim Pilot Site Assets to be installed ,
Table 6,
Table 7 and
Table 8) comprise information regarding the type of asset to be integrated, a description of the measurements to be gathered, the existence and the deployment status of these assets as well as the brand model information.

Table 5: Bristol Pilot Site Assets to be installed

Bristol								
Item	**Type**	**Equipment**	**Device**	**Measurements**	**Already existing (Y/N)**	**Deployed (Y/N)**	**Planned Deployment date**	**Asset Information (brand, model)**
1	Hardware	House Battery	AlphaESS Smile 5	PV output, grid supply, battery power flow, battery charge status.	Y	Y	-	SMILE5-BAT (Alpha-ESS) [5]
2	Hardware	House Battery	Tesla Powerwall	PV output, grid supply, battery power flow, battery charge status.	Y	Y	-	Powerwall (Tesla) [6]
3	Hardware	House Battery	Rayliegh	PV output, grid supply, battery power flow, battery charge status.	Y	Y	-	SMILE5-BAT (Alpha-ESS) [5]
4	Hardware	Current Clamp	Equiwatt Power Capsule	Grid Supply	Y	N	mar-22	Not Available Yet

5	Hardware	Smart Plug	Equiwatt Smart Plug	Appliance Consumption	Y	N	mar-22	Kasa Smart WiFi Plug Slim KP115 (TP-LINK) [7]
6	Hardware	Smart Meter	Various from different energy suppliers	Grid Supply	Y	Y	-	Not Available Yet
7	Hardware	Home Energy Monitoring System	Emonpi	Grid Supply	Y	N	mar-22	emonPi [8]

Table 6: Steinheim Pilot Site Assets to be installed

Steinheim								
Item	**Type**	**Equipment**	**Device**	**Measurements**	**Already existing (Y/N)**	**Deployed (Y/N)**	**Planned Deployment date**	**Asset Information (brand, model)**
1	Hardware	Energy Measuring	Smart Meter	Power Energy Voltage Current Frequency	Y	Y	February/March 2022	EM300 (TQ) [9]
2	Hardware	Energy Measuring	Smart Meter	Power Energy Voltage Current Frequency	Y	Y	February/March 2022	EM420 (TQ) [10]
3	Hardware	Energy Measuring	Smart Clamp/ Sensorbar	Current Power* Voltage* Energy* Frequency*	N	N	February/March 2022	EB203 (TQ) [11]
4	Hardware	Energy Measuring	Transformer Measuring Box	Power Energy Voltage Current Frequency	Y	Y	-	Grid operator hardware with configurable modbus interface
5	Hardware	Car Charging, Bidirectional charging	Bidirectional Charging Station	Power Energy	N	N	tbd	sospeso&charge (EVTEC) [12]
6	Hardware	Car-sharing, bidirectional charging	Car	StateOfCharge	N	N	June/July 2022	Honda-e [13]

7	Hardware	Community Battery	Battery	Power Energy Voltage Current StateOfCharge	N	N	June/July 2022	Scalebloc (INTILION) [14]
8	Hardware	Energy Measuring/ Device switching	Smart Plug	Energy consumption	partly	N		Shelly Plug S [15]

Table 7: Benetutti Pilot Site Assets to be installed

Benetutti								
Item	**Type**	**Equipment**	**Device**	**Measurements**	**Already existing (Y/N)**	**Deployed (Y/N)**	**Planned Deployment date**	**Asset Information (brand, model)**
1	Hardware	Energy Measuring	Smart Plug	Energy Consumption control (on/off) single electrical appliances	N	N	February/March 2022	Shelly Plug S [15]
2	Hardware	Energy Measuring	Smart meters	Energy consumption from electrical panel	N	N	February/March 2022	Shelly EM [16]
3	Hardware	Gateway	Raspberry Pi 0	gateway	N	N	February/March 2022	Raspberry Pi 0 [17]
4	Software	Gateway	Raspberry Pi 0	TLS comunication	N	N	February/March 2022	Raspberry Pi 0 [17]
5	Hardware	Indoor monitoring	AIRCARE	Fine Dust PM10 Fine Dust PM2.5 Electrosmog HF 10MHz-8GHz; Electrosmog LF 50Hz Noise pollution temperature; Humidity; Atmospheric pressure Ambient brightness	N	N	February/March 2022	AIRCARE PRO

6	Hardware	Indoor monitoring	Door/Windows Sensors	Open/close, local brightness, local temperature	N	N	February/March 2022	Shelly Door/Windows 2 [18]
7	Hardware	Users feedback	Wifi Button	Button for the communication with the users	N	N	February/March 2022	Shelly button WiFi [19]
8	Hardware	Energy storage	Pylontech battery - UP2500NB01V00101	Shared energy storage between 2 houses	N	N	February/March 2022	UP2500NB01V00101(Pylontech Victron energy) [20]
9	Hardware	Inverter	Inverter/Charger 1300W 24V 1600VA Victron Energy Multiplus Compact C24/1600/40	PV inverter to charge the storage system	N	N	February/March 2022	MultiPlus Compact (Victron energy) [21]
10	Hardware	Smart meters	Smart meter - emonPi Energy Monitor incl 2x CT clip and AC-AC sensor	Energy consumption and gateway	N	N	February/March 2022	Monitor incl 2x CT clip and AC-AC sensor (emonPi) [22]
11	Hardware	Energy generation from PV	Solar PV smart meter - emonPi Energy Monitor - Solar PV Bundle	Energy production meter and gateway	N	N	February/March 2022	Solar PV Bundle (emonPi) [23]
12	Hardware	Relay switch	Wifi or Ethernet Relay switch for AC loads	Control energy flow	N	N	February/March 2022	wiFI MQTT Relay [24]

Table 8: Athens Pilot Site Assets to be installed

Athens								
Item	**Type**	**Equipment**	**Device**	**Measurements**	**Already existing (Y/N)**	**Deployed (Y/N)**	**Planned Deployment date**	**Asset Information (brand, model)**

1	Hardware	Ambient Conditions Measuring	Smart Sensor	Humidity, Luminance, Air Quality, Noise Levels,Occupancy	Y	Y	December 2021	Multisensor 6 (Aeotec) [25]
2	Hardware	Ambient Conditions Measuring	Indoor Air Quality Sensor	Humidity, Luminance, Air Quality	Y	Y	December 2021	Homecoach (Netatmo) [26]
3	Hardware	Energy Measuring	Smart Plugs	Energy consumption	Y	Y	December 2021	Fibaro [27]
4	Hardware	Energy Measuring	3-Phase Smart Meter	Energy consumption	Y	Y	December 2021	Qubino [28]
5	Hardware	Energy Measuring	1-Phase Smart Meter	Energy consumption	Y	Y	December 2021	Qubino [28]
6	Hardware	Energy Efficiency	Lighting Equipment	-	Y	Y	December 2021	Philips Hue Gateway [29]
7	Hardware	Collective Measuring	Gateway	Collection of measurements	Y	Y	December 2021	Smartthings [30]
8	Hardware	e-Mobility Chargers (Public)	Alfen Twin4XL	Energy Consumption	Y	Y	September 2021	Twin4XL (Alfen) [31]
9	Hardware	e-Mobility Chargers (Domestic)	Wallbox Pulsar Plus	Energy Consumption	N	N	-	Pulsar Plus (Wallbox) [32]
10	Hardware	e-Mobility Chargers (Domestic)	Wallbox Copper SB	Energy Consumption	N	N	-	Copper Sb (Wallbox) [33]
11	Hardware	e-Mobility Chargers (Domestic)	Wallbox Commander 2	Energy Consumption	N	N	-	Commander 2 (Wallbox)

4. Assets integration methodology

Task 8.1 "TwinERGY system integration" intends to integrate the multiple components that conforms the underlying components in the TwinERGY Smart Grid setup. Different methods of integration are going to be evaluated in the following lines. Finally, a procedure composed of the different features of each of them is chosen. The defined procedure is composed of the following steps:

- Definition of all the interconnections between the different components. That is to say, the definition of how the component of communication is flowing. (As it is shown in Figure 3)
- Description of the information flow between the integrated components. This involves the definition of the data to be interchanged and the operations related to the sending and reception of data. This is further developed in Task 4.4 "System Integration" and Task 5.1 "Open Standards Review and Common Information Model Adaptation".
- Definition of the components' interfaces and communication protocols used.

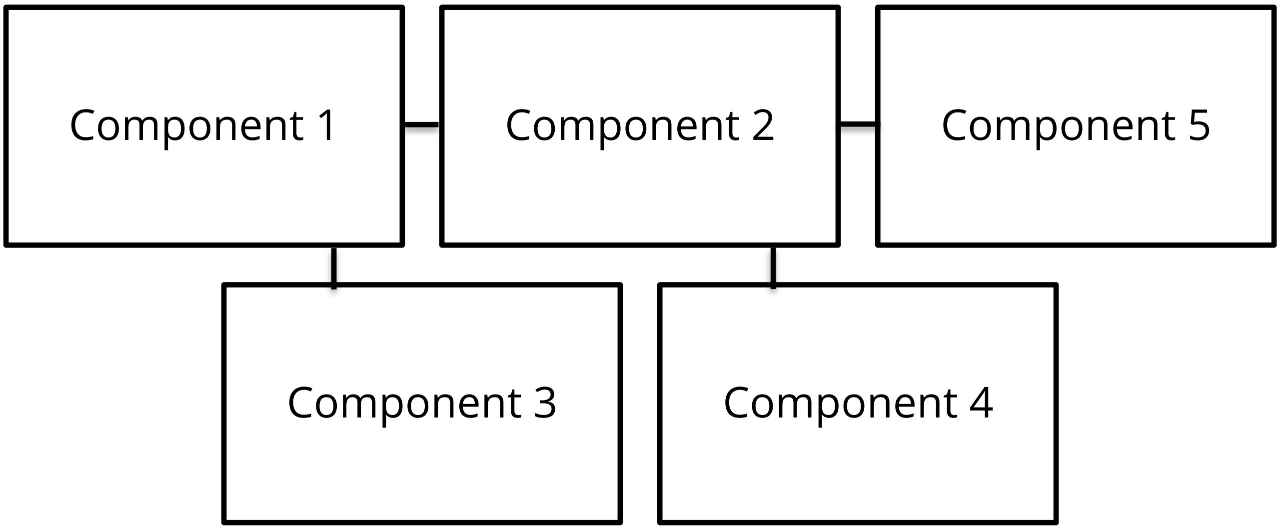

Figure 3: Example of definition of interconnection between different components

4.1. System integration testing protocols

This section deals with the testing protocols to be followed during the integration of the software and hardware in the TwinERGY ecosystem. Firstly, a justification of the selection of the most appropriate protocol is introduced. Later, the integration plan is introduced.

4.1.1. Testing procedure

During the development and deployment of a service, testing is an essential step so that the quality of the produced result is assured. Although testing is not the final step, after the integration procedures, it has to be introduced during the life of a project so as to assure the correct interconnection. The testing can be done within three different steps:

- Integration testing (verification of all components as a group)
- System testing (verification of matching with project requirements)
- User acceptance testing (verification if the system operates adequately in real-life conditions and how well it is received by the users).

Nevertheless, the integration testing can be done following one of the different approaches that are going to be explained afterwards:

4.1.1.1Top-down approach

This approach deals with the highest-level modules that have to be integrated and tested before low-level elements. This approach has consistent results, since the testing environment is close to reality. Nevertheless, it can be a hard-managing procedure, taking longer times to produce testing results.

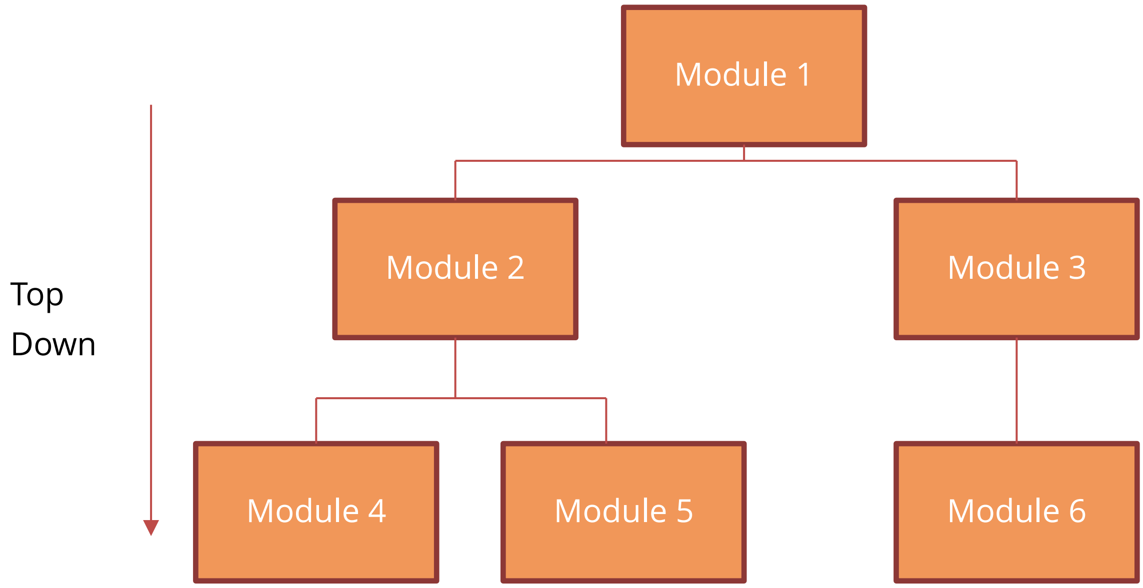

Figure 4: Integration Top-down approach

4.1.1.2 Bottom-up approach

This approach works the opposite way to the Top-down approach. The lowest modules are considered before the higher ones. This method has the advantage to have the lower-level units first integrated. This fact implies that the efficiency of the system is ensured. Nevertheless, the high-level logic and data flow are detected late in the development cycle.

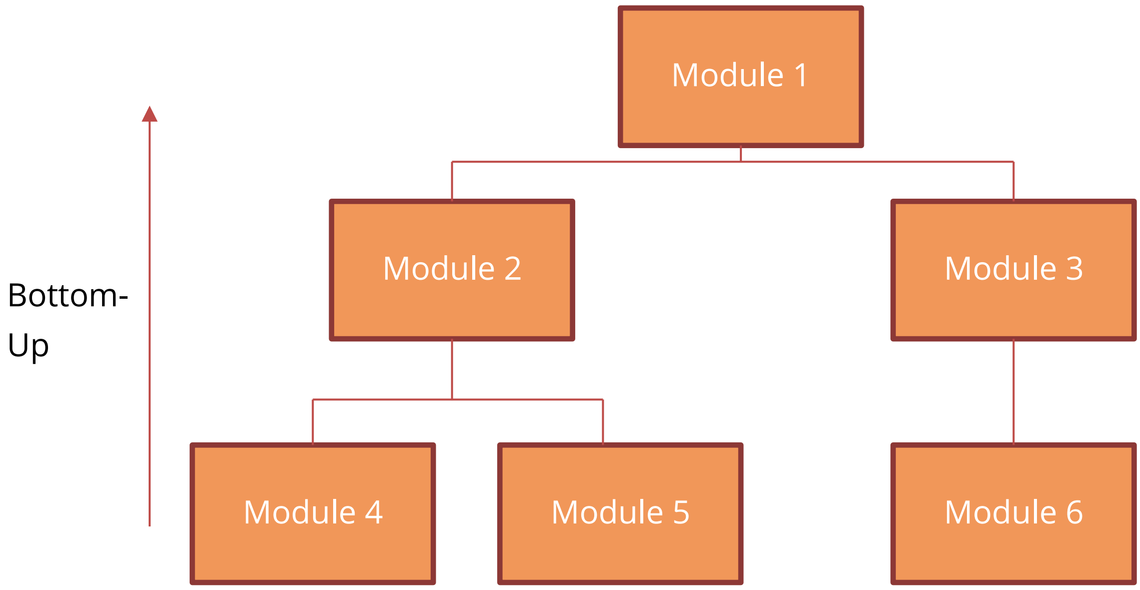

Figure 5: Integration Bottom-Up approach

4.1.1.3 Sandwich approach

This approach is a hybrid or mixed approach that combines the top-down and bottom-up approaches. The system is separated in three different layers: a middle layer (the testing is performed at this layer) and the layers below and above the target layer. This strategy is used in large-scale projects with a large number of individual modules. However, this method is not recommended for systems with strong interdependencies between their modules.

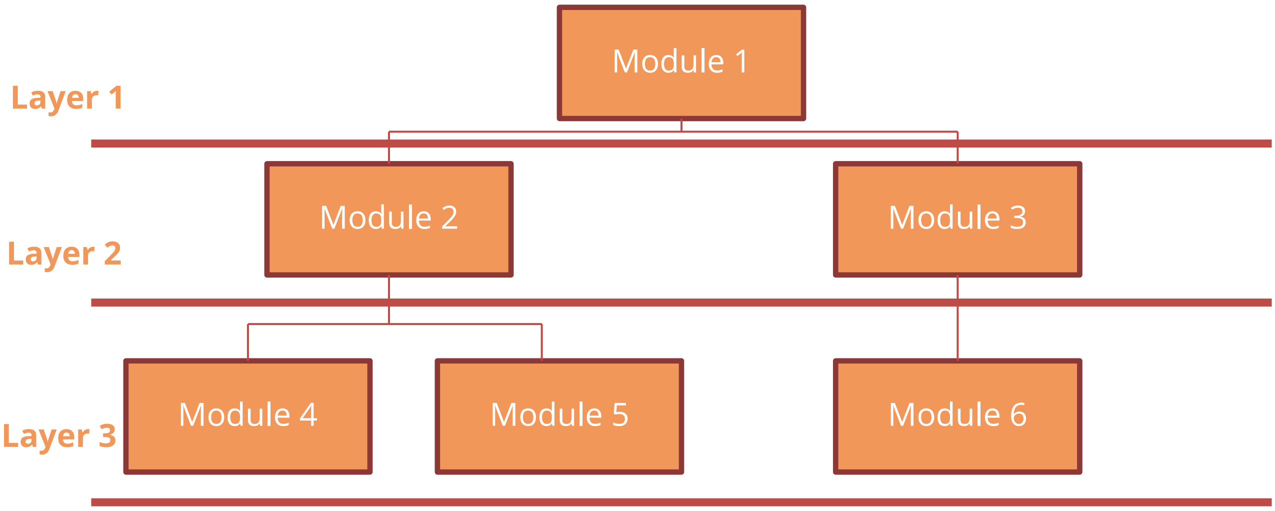

Figure 6: Integration Sandwich approach

4.1.1.4 The Big bang approach

This approach is the strategy where all components are integrated simultaneously, and the system is tested as a whole system. As an advantage, it can be said that this method is cost-effective, timesaving and it requires minimal planning. This approach requires that all the components have to be completed before the starting of the integration testing, since it is often difficult to trace the cause of error or failure, since the modules are integrated simultaneously, and the defects might prove rather complicated.

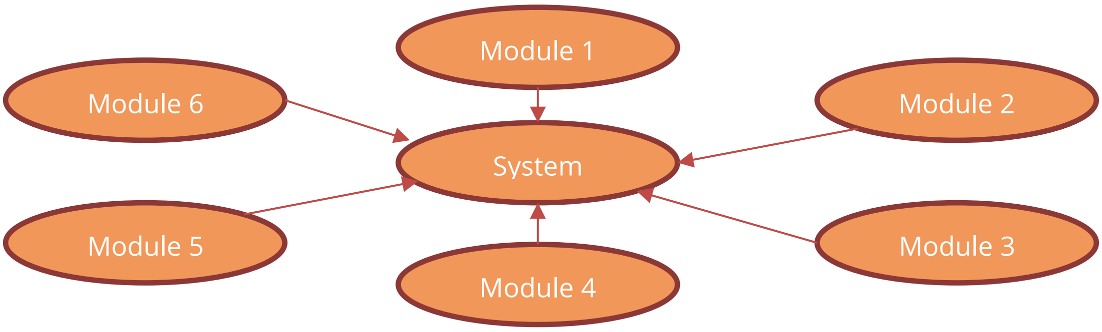

Figure 7: Integration Big Bang approach

4.1.1.5 Incremental approach

Within this approach, the components are integrated one by one, and the testing process is carried out after each step. As one of the main advantages of this method, the defects are found at an early stage and in smaller assemblies. This fact makes easier the identification of the root and the associated correction. Nevertheless, the incremental strategy is time-consuming, and it requires multiple checking steps to be developed in the testing processes.

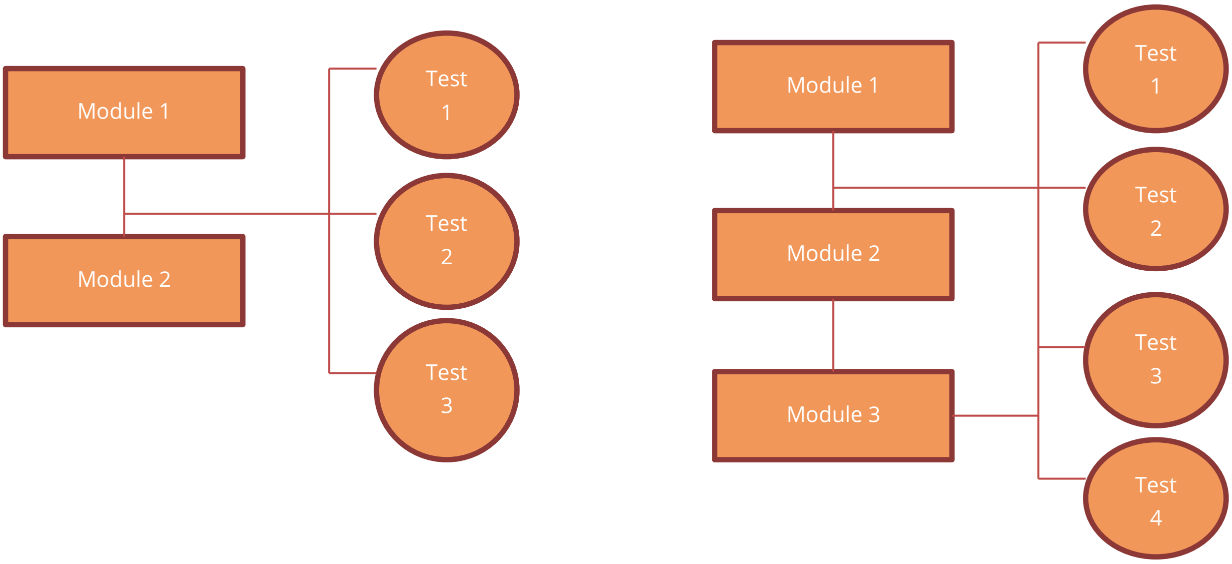

Figure 8: Integration Incremental Approach

5. Assets integration and support activities

This section is focused on a short definition of the integration strategies that need to be performed so that the hardware already mentioned in Section 4. Assets integration methodology is correctly integrated.

Taking into consideration of the already discussed integration strategies, the most accurate and appropriated method to be used in the TwinERGY project is the **incremental approach.** After the installation of each one of the assets, the testing, each component is integrated and tested in the whole system.

In order to ensure that all the components available in the TwinERGY ecosystem, an integration plan is going to be presented within this section. 5 different types of integrations are identified accordingly to the architecture defined and the Use Cases approach already pre-defined in other tasks in the project. Overall, the integration aims at:

- Definition of the integrated components to be tested and allocation of responsibility
- Overview of test activities, objectives, and techniques to be used
- Definition of test cases and test environment specifications

5.1 Integrated components to be tested

As a first step towards the integration, and its posterior testing, it is necessary to identify the different assets that are expected to be integrated. Within Section 3. TwinERGY Ecosystem at a glance, a general overview of the assets that the architecture requires to be installed, has been presented. Furthermore, Table 5, Table 6, Table 7 and Table 8 in Section 3. TwinERGY Ecosystem at a glance, give a more detailed vision of the project's assets to be deployed per each pilot. That would be of great help in determining the responsibilities in each of the asset's installation strategies since each of the pilots establishes different layouts in the pilot deployment assets as it will be specified in Table 9 in an upcoming section. Due to the diverse nature of them, and their system's requirement coming from the TwinERGY architecture, these assets would need different integration strategies. They will be explained in the following section.

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5.2 Integration strategies

Since the nature of the assets to be integrated is different, there is a need to create different integration strategies in order to cover the different cases identified in the HLUC definition and its representation in the SGAM methodology [2]. To carry out this work, a five-classification integration has been defined,as presented in Figure 9.

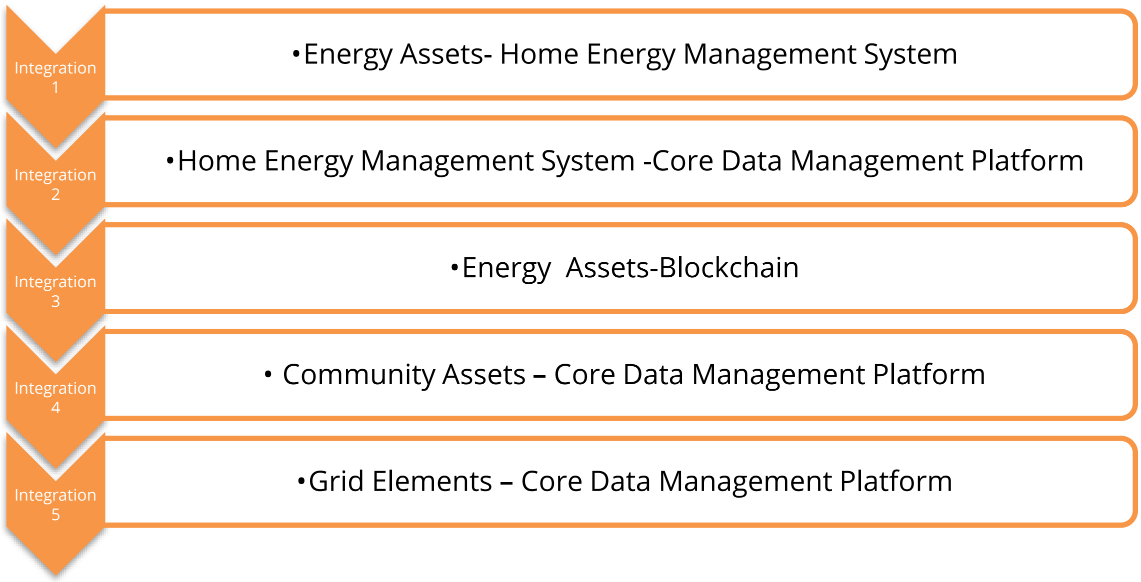

Figure 9: Integration types for the TwinERGY Ecosystem

The overall aim is to create the different pipelines and connectors that could assure the integration of these components to allow the connectivity, the communication, and the information exchange to enable the ingestion of real-time and batch data to the TwinERGY Core Data Management Platform in an interoperable manner. In order to facilitate the interconnection, all these assets should be accordingly installed based on WP9: Pilots progress requirements. Additionally, a workshop in which the CDMP platform, as defined in [4], is expected to be conducted in the upcoming months so as to clarify the process of integration to the platform developed by Suite5.

5.2.1 Integration 1- Energy Assets- Home Energy Management System

Energy assets presented in the different Pilot sites are the objective of this first integration step foreseen. The main source of data across the different pilot sites derives from the different energy and environmental assets that are planned to be installed. All these information flows will be collected by a centralized domestic system (Home Energy Management System- HEMS) which would provide communication between the different devices that may operate on a different communication technology. This system will provide a support communication between the different devices regardless their supporting communication protocol [34]. The already described system will provide the information to Core Data Management Platform (CDMP) which is being developed in WP5 "Data Collection and Communication Platform". HLUC 01 Home Energy Management perfectly represents this integration step. More details can be found in Deliverable 4.4 "System Architecture" [2]

5.2.2 Integration 2 - Home Energy Management System - Core Data Management Platform

This step is related to the integration of all these created gateways in which the information from the domestic pilot sites is collected through the HEMS to provide the information to the CDMP. This integration will be correctly performed based on the architecture defined by the Data Management Platform. The connecting details of this platform have been expressed in Deliverable 5.4 "TwinERGY Integrated Platform -Beta Release" [4]. The elaborated architecture in [2] has contemplated the interconnection between the two involved assets so that the information could properly flow

5.2.3 Integration 3- Energy Assets-Blockchain

This integration step is fully aligned with the HLUC04: Prosumers empowerment in local energy trading markets. This HLUC targets at receiving request from the energy transactions from TwinERGY devices (physical assets in the dwellings and Digital Twin Platform). In order to perform this functionality, the different assets (not only the domestic ones, but also community grid assets such as Community Batteries), are connected to the Transactive Energy Blockchain. As it has been presented in the system architecture in [2], the information would flow from the individual assets to this platform

5.2.4 Integration 4- Community Assets - Core Data Management Platform

Community energy assets presented in the different Pilot sites are the objective of this fourth integration step. This data would flow from the communal assets such as the community batteries that are planned to be installed. This information would flow from these communal asset's gateways to the Core Data Management Platform.

5.2.5 Integration 5 - Grid Elements - Core Data Management Platform

This fifth integration step is fully aligned with the HLUC05: Enhance grid flexibility through DER Management in which grid assets that take part into the TwinERGY ecosystem are represented. This HLUC targets predicting the energy consumption and RES production and consequently, takes into consideration different Grid assets which information needs to be compiled.

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5.3 Integration assets

Hereafter, in Table 9, the different physical assets identified in the system architecture are linked to each one of the pilot demonstrations sites that will include that specific asset. They will be defined and linked directly to each one of the described integration assets in the upcoming sections. The coloured cells in orange represent which physical assets would contain each pilot site.

Table 9: Integration assets listed

Integration asset	Bristol	Steinheim	Benetutti	Athens
Smart Meter				
Charging Point				
Community battery storage				
Electric Vehicle				
Energy asset/appliance				
Environmental Sensor				
Home Battery Storage				
Inverter				
MV-LV transformer				
Physiological sensor				
Physiological sensor controller				
Raspberry Pi/HEMS/ Gateway to collect measures				

5.4 Overview of testing activities

Testing components with *Hardware/Software interfaces* include activities whose main goal is to identify errors occurring from the API communication established for its integration. Other objectives include assessing the software's ability to detect hardware failures and its response in such cases, as well as assessing the hardware response time to received messages. It is therefore important to also test the validity and time lapse of the exchanged data in both directions.

For the definition of the appropriate test cases, the following steps have been followed:

- Review of use cases and project requirements as defined in Section 3. TwinERGY Ecosystem at a glance
- Definition of the features to be tested and categorisation in appropriate test groups
- Formulation of detailed test cases for the identified features. In order to define these tests that will prove the successful integration of the assets, a template is presented

in Table 10, is established in this section. This template is intended to register the type of assets that are going to be tested after integration, the responsible partners for integrating this measure (those pilot sites that would install the defined assets), the requirements for the testing procedure, the integration type (coming from the already defined integration types in Figure 9) and the pass criteria. Additionally, optional criteria are also introduced such as the possibility to indicate the no tested features, the dependencies, the results and the suspension criteria.

Table 10: Template Test cases for the asset's integration

Name	**The test case code and name (unique to the project)**
Asset under test	Asset Name
Responsible	Main partner responsible for the test
Requirements	The requirement, use case, or rule which is validated by the test case
Tested features	List of features to be tested
No tested features (optional)	List of features not to be tested
Integration Type	The integration type already identified in Figure 9 that adjust to the asset integration method
Integration Steps	This section indicates the integration steps to be followed
Dependencies (Optional)	List of test case codes which define test cases to be passed before this one
Results (Optional)	Short list of results
Pass criteria	Expected (measurable) results
Suspension criteria (Optional)	Conditions under which continuation of the test is considered pointless because testing results would be invalid

The different tests will be defined based on the assets in the list in Section 5.3 Integration assets.

5.5 Test Cases for the asset's integration

Table 11: Integration test definition for Smart Meters

Name	**ITC1.01 – Smart Meter Integration**
Asset under test	Smart Meter
Responsible	Bristol, Steinheim, Benetutti and Athens Pilot Sites
Requirements	
Tested features	Transmission of measures from Smart meters to the HEMS
No tested features (optional)	The accuracy of the measures is not evaluated here
Integration Type	Integration 1

Steps	The execution of this test must happen automatically upon the information publication in the HEMS
Dependencies (Optional)	
Results (Optional)	
Pass criteria	Data from the Smart Meter is correctly updated in the operational database.
Suspension criteria (Optional)	Any subsystem failure, any failure that is reported by one of the components along the communication chain, i.e. the messages do not reach their destination.

Table 12: Integration test definition for Smart Meters

Name	**ITC1.02 - Smart Meter Integration**
Asset under test	Smart Meter
Responsible	Bristol, Steinheim, Benetutti and Athens Pilot Sites
Requirements	
Tested features	Transmission of measures from Smart meters to the Transactive Energy Blockchain
No tested features (optional)	The accuracy of the measures is not evaluated here
Integration Type	Integration 3
Steps	The execution of this test must happen automatically upon the information publication in the Transactive Energy Blockchain.
Dependencies (Optional)	
Results (Optional)	
Pass criteria	Data from the Smart Meter is correctly updated in the operational database.
Suspension criteria (Optional)	Any subsystem failure, any failure that is reported by one of the components along the communication chain, i.e. the messages do not reach their destination.

Table 13: Integration test definition for Charging Points

Name	**ITC2.01 – Charging Point Integration**
Asset under test	Charging Point
Responsible	Steinheim, and Athens Pilot Sites
Requirements	
Tested features	Transmission of measures from the Charging Point to the CDMP
No tested features (optional)	The accuracy of the measures is not evaluated here
Integration Type	Integration 5
Steps	The execution of this test must happen automatically upon the information publication in the CDMP.
Dependencies (Optional)	
Results (Optional)	
Pass criteria	Data from the Charging Point is correctly updated in the operational database.

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Suspension criteria (Optional)	Any subsystem failure, any failure that is reported by one of the components along the communication chain, i.e. the messages do not reach their destination.

Table 14: Integration test definition for Community Battery Storage

Name	**ITC3.01 -Community Battery Storage Integration**
Asset under test	Community Battery Storage
Responsible	Steinheim, and Benetutti Pilot Sites
Requirements	
Tested features	Transmission of measures from the Community Battery Storage to the CDMP
No tested features (optional)	The accuracy of the measures is not evaluated here
Integration Type	Integration 4
Steps	The execution of this test must happen automatically upon the information publication in the CDMP.
Dependencies (Optional)	
Results (Optional)	The execution of this test must happen automatically upon the information publication in the CDMP.
Pass criteria	Data from the Community Battery Storage is correctly updated in the operational database.
Suspension criteria (Optional)	Any subsystem failure, any failure that is reported by one of the components along the communication chain, i.e. the messages do not reach their destination.

Table 15: Integration test definition for Energy Asset

Name	**ITC4.01 – Energy Asset Integration**
Asset under test	Energy Asset
Responsible	Bristol, Steinheim, Benetutti and Athens Pilot Sites
Requirements	
Tested features	Transmission of measures from Energy Assets to the HEMS
No tested features (optional)	The accuracy of the measures is not evaluated here
Integration Type	Integration 1
Steps	The execution of this test must happen automatically upon the information publication in the HEMS
Dependencies (Optional)	
Results (Optional)	
Pass criteria	Data from the Energy Asset is correctly updated in the operational database.
Suspension criteria (Optional)	Any subsystem failure, any failure that is reported by one of the components along the communication chain, i.e. the messages do not reach their destination.

Table 16: Integration test definition for Energy Asset

Name	ITC4.02 – Energy Asset Integration
Asset under test	Energy Asset
Responsible	Bristol, Steinheim, Benetutti and Athens Pilot Sites
Requirements	
Tested features	Transmission of measures from Smart meters to the Transactive Energy Blockchain
No tested features (optional)	The accuracy of the measures is not evaluated here
Integration Type	Integration 3
Steps	The execution of this test must happen automatically upon the information publication in the Transactive Energy Blockchain.
Dependencies (Optional)	
Results (Optional)	
Pass criteria	Data from the Energy Asset is correctly updated in the operational database.
Suspension criteria (Optional)	Any subsystem failure, any failure that is reported by one of the components along the communication chain, i.e. the messages do not reach their destination.

Table 17: Integration test definition for Environmenal Sensor

Name	ITC5.01 – Environmental Sensor Integration
Asset under test	Environmental Sensor
Responsible	Benetutti and Athens Pilot Sites
Requirements	
Tested features	Transmission of measures from Environmental Sensors to the HEMS
No tested features (optional)	The accuracy of the measures is not evaluated here
Integration Type	Integration 1
Steps	The execution of this test must happen automatically upon the information publication in the HEMS
Dependencies (Optional)	
Results (Optional)	
Pass criteria	Data from the Charging Point is correctly updated in the operational database.
Suspension criteria (Optional)	Any subsystem failure, any failure that is reported by one of the components along the communication chain, i.e. the messages do not reach their destination.

Table 18: Integration test definition for Environmental Sensor

Name	ITC5.02 – Environmental Sensor Integration
Asset under test	Environmental Sensor
Responsible	Benetutti and Athens Pilot Sites
Requirements	

Tested features	Transmission of measures from Smart meters to the Transactive Energy Blockchain
No tested features (optional)	The accuracy of the measures is not evaluated here
Integration Type	Integration 3
Steps	The execution of this test must happen automatically upon the information publication in the Transactive Energy Blockchain.
Dependencies (Optional)	
Results (Optional)	
Pass criteria	Data from the Charging Point is correctly updated in the operational database.
Suspension criteria (Optional)	Any subsystem failure, any failure that is reported by one of the components along the communication chain, i.e. the messages do not reach their destination.

Table 19: Integration test definition for Home Energy Storage

Name	**ITC6.01 – Home Battery Storage - HEMS Integration**
Asset under test	Home Battery Storage, HEMS
Responsible	Bristol Pilot Site
Requirements	The Home battery storage must be connected to the grid The Home battery storage must have a metering component able of sending measures The HEMS must be accessible
Tested features	Connection between the Home battery storage and the HEMS Transmission of measures
No tested features (optional)	
Integration Type	Integration 1
Steps	1. The Home battery storage accumulates energy 2. The meter associated to the battery registers the energy measures each X milliseconds 3. The meter sends the measures to the HEMS each X milliseconds 4. The HEMS receives the measures each X milliseconds
Dependencies (Optional)	
Results (Optional)	The HEMS has received a set of measures
Pass criteria	Per each cycle of measuring, the HEMS receives values that corresponds with the real register in the meter.
Suspension criteria (Optional)	Values received are incorrect or none value is received

Table 20: Integration test definition for Home Energy Storage

Name	**ITC6.02 – Home Battery Storage - Blockchain Integration**
Asset under test	Home Battery Storage, Blockchain
Responsible	Bristol Pilot Site

Requirements	The Home battery storage must be connected to the grid The Home battery storage must have a metering component able of sending measures The Blockchain must be accessible
Tested features	Connection between the Home battery storage and the Blockchain Transmission of measures
No tested features (optional)	
Integration Type	Integration 3
Integration Steps	1. The Home battery storage accumulates energy 2. The meter associated to the battery registers the energy measures each X milliseconds 3. The meter sends the measures to the blockchain each X milliseconds 4. The Blockchain receives the measures each X milliseconds
Dependencies (Optional)	
Results (Optional)	The Blockchain has received a set of measures
Pass criteria	Per each cycle of measuring, the Blockchain receives values that corresponds with the real register in the meter.
Suspension criteria (Optional)	Values received are incorrect or none value is received

Table 21: Integration test definition for Inverter

Name	**ITC7.01 –Inverter - Core Data Management Platform Integration**
Asset under test	Inverter, Core Data Management Platform
Responsible	Steinheim and Benetutti Pilot Sites
Requirements	The Inverter must be connected to the grid The Inverter must have a metering component able of sending measures The CDMP must be accessible
Tested features	Connection between the Inverter and the Blockchain Transmission of measures
No tested features (optional)	
Integration Type	Integration 4
Integration Steps	1. The Inverter's meter registers the energy measures each X milliseconds 2. The meter sends the measures to the CDMP each X milliseconds 3. The CDMP receives the measures each X milliseconds
Dependencies (Optional)	
Results (Optional)	The CDMP has received a set of measures
Pass criteria	Per each cycle of measuring, the CDMP receives values that corresponds with the real register in the meter.
Suspension criteria (Optional)	Values received are incorrect or none value is received

Table 22: Integration test definition for MV-LV Transformer

Name	ITC8.01 – MV-LV Transformer - Core Data Management Platform Integration
Asset under test	MV-LV Transformer, Core Data Management Platform
Responsible	Steinheim Pilot Sites
Requirements	The MV-LV transformer must be connected to the grid The MV-LV transformer must have a metering component able of sending measures The CDMP must be accessible
Tested features	Connection between the MV-LV Transformer and the CDMP Transmission of measures
No tested features (optional)	
Integration Type	Integration 4
Integration Steps	1. The MV-LV transformer's meter registers the energy measures each X milliseconds 2. The meter sends the measures to the CDMP each X milliseconds 3. The CDMP receives the measures each X milliseconds
Dependencies (Optional)	
Results (Optional)	The CDMP has received a set of measures
Pass criteria	Per each cycle of measuring, the CDMP receives values that corresponds with the real register in the meter.
Suspension criteria (Optional)	Values received are incorrect or none value is received

Table 23: Integration test definition for Physiological Sensor

Name	ITC9.01 – Physiological Sensor – HEMS Integration
Asset under test	Physiological Sensor, HEMS
Responsible	Steinheim, Benetutti and Athens Pilot Sites
Requirements	The Physiological Sensor must have a metering component able of sending measures The HEMS must be accessible
Tested features	Connection between the Physiological Sensor and the HEMS Transmission of measures
No tested features (optional)	
Integration Type	Integration 1
Integration Steps	1. Physiological Sensor registers the environment measures each X milliseconds 2. Physiological Sensor sends the measures to the HEMS each X milliseconds 3. The HEMS receives the measures each X milliseconds
Dependencies (Optional)	
Results (Optional)	The HEMS has received a set of environment measures
Pass criteria	Per each cycle of measuring, the HEMS receives values that corresponds with the real registered by the Physiological Sensor.

Suspension criteria (Optional)	Values received are incorrect or none value is received

Table 24: Integration test definition for HEMS Gateway

Name	**IT10.01 – HEMS Gateway – Core Data Management Platform Integration**
Asset under test	HEMS Gateway, Core Data Management Platform
Responsible	Bristol, Steinheim, Benetutti and Athens Pilot Sites
Requirements	The HEMS must be able to transmit information The CDMP must be accessible
Tested features	Connection between the HEMS gateway and the CDMP Transmission of measures
No tested features (optional)	
Integration Type	Integration 2
Integration Steps	Per each time that HEMS has new metering information: 1. HEMS have different measures received from assets 2. HEMS through HEMS gateway sends measures to CDMP 3. CDMP receives the information
Dependencies (Optional)	ITC6.01, ITC9.01
Results (Optional)	CDMP has received measures
Pass criteria	Per each cycle of measuring, CDMP receives values that corresponds with those in the HEMS
Suspension criteria (Optional)	Values received are incorrect or none value is received

6. Conclusions and Next Steps

In this deliverable, the procedure for the integration of the assets that would compose the Smart Grid setup of the different four pilots (Bristol, Steinheim, Benetutti and Athens) has been presented. The identification of these assets has been generated by the inputs collected by the System architecture based on the SGAM methodology, and the inputs coming from the installation plan in the Pilot sites. To unify these inputs into a single integration methodology, a series of integration steps has been presented. Additionally, this document includes the different test cases that would demonstrate the correct integration of the smart grid assets into the TwinERGY Smart Grid layout. The results of this integration activities will be presented at the second version of this deliverable D.8.4 "TwinERGY connectors to distributed smart grid assets and respective APIs Final Version" which is expected to be delivered at the ending of this task in Month 27.

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