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Statement of Originality

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Executive summary

This present document is D7.1 “Module’s Interoperability” 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 become the ground-floor base for the development of Work Package 7 – Development of TwinERGY system Modules. This document intends to design the initial specifications of the different modules to be developed as well as to assure the interoperability between them. Therefore, the deliverable focuses on the different functionalities that each participant in the project has overviewed for the modules developed in the context of the TwinERGY project. These nine modules will work complementary with the aim of increasing consumer empowerment as a major challenge in active energy markets as well as to reduce bill, tackling at the same time energy poverty. To address this challenges, TwinERGY project will develop a series of modules based on low-cost, well-being and security principles. These challenges will translate into different functionalities that the modules foresee to provide to the TwinERGY ecosystem. These different functionalities will be compiled in each module’s respective section.

In addition, this deliverable explains the relations that participants have foreseen as a mean to identify the interconnection among the 9 modules developed in the project as well as with the rest of the rest of the components of the TwinERGY solution. The modules will extract information from data collection services (raw data supported by the Core Data Management Platform (CDMP)), the Digital Twinning Platform (through the iSCAN Platform) but also from derivative data coming from other modules through the TwinERGY Interoperable Platform.

Furthermore, this deliverable reflects the configuration of the Interoperability platform from which the modules would be able to communicate data with each other once their development reaches an advanced status. This platform of communication will allow all the modules to receive and send messages about their calculations and their statuses under a real-time basis. For that purpose, a NATS system is implemented. This system will allow a scalable, secure, heterogeneous, concurrent, and flexible platform that will be reflected in a web application that will support the smooth communication of the modules in a user-friendly way.

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1. Introduction

1.1. Scope of the document

Within WP7 “Development of TwinERGY system modules”, the project expects to deliver nine different modules that aim at providing consumer with several services that are based on data analysis. Under the context of T7.1 “Modules’ specifications and system interoperability”, the different modules’ developers have been asked to design the specifications of their modules based on the different data they are able to extract from not only the energy infrastructure and the distributed resources in the network, but also from the rest of the modules available developed in TwinERGY.

All the developments from WP7 would enable consumers to have access to different services, from consumer comfort and well-being information to event risk management in which consumers would be helped to minimize the risk associated to the system following a consumer-oriented perspective. The list of services provided by each module is quite diverse, and the modules would support a wide range of functionalities based on a consumer perspective. Furthermore, some modules would perform the energy monitoring on a real-time basis, from which demand flexibility profiling schemas could also be shown to consumers, at a consumer and at a neighbourhood levels accordingly. The grid status, and the predictions associated to its management would also focus on one of the modules. A transactive energy platform is also going to be developed in the project, and this module would reflect DLT/blockchain technologies. An EV platform is also being considered, which will enable EV drivers to search for charging points, but also to optimize the charging process of their EV, with benefits not only to the driver, but also for the grid in terms of energy management. Lastly, a web-based platform in the form of a social network is expected to be delivered. This module will encourage social engagement among TwinERGY system Users and enhance this engagement by adopting and applying gamification capabilities.

This deliverable also has a goal set, which is to reinforce the communication among the different modules. This fact is going to be performed through the elaboration of an intercommunication platform among them. To that purpose, the “TwinERGY Interoperable Platform” is introduced in order to help in the definition of the interconnection between the different modules as it will be reflected in the different chapters on this document. The platform would be used for WP7 modules as a mean of communication where all the modules can receive and send messages about their calculations, status and real-time environment, considering the differences in the

language used. In order to achieve this goal, this deliverable will give hints of the technology to be used in the platform, as well as the explanation of the protocol to be followed in the future implementation, and its future validation once the modules are fully developed.

1.2. Structure of the deliverable

This deliverable is structured starting from a defined executive summary of the document. The introduction (Chapter 1) would give the opportunity to the reader to understand the context of the document in this task. The following chapter (Chapter 2) is expected to identify the objectives of the deliverable regarding the project and the interconnection with other Work Packages (WP) and their associated tasks. A brief introduction to the different modules is done (Chapter 3) where they are contextualized under the scope of TwinERGY objectives. Thereafter, the methodology followed to gather the different functionalities and interconnections between modules is explained in the following section (Chapter 4). Based on the methodology, the different partners will provide a detailed explanation of the modules' functionalities and their interaction (Chapter 5). The last chapter before the conclusions (Chapter 6) lays the foundations regarding the interoperability of the different modules by the introduction of an intercommunication platform. This section will describe the rationale behind the definition of this platform as well as the implementation and the different phases that will be set in order to launch this platform.

1.3. Abbreviation List

Table 1. Abbreviation list

Acronym	Full Name
BTM	Behind the Meter
CDT	Consumer Digital Twin
CDMP	Core Data Management Platform
CEP	Clean Energy Paclage
DER	Distributed Energy Resources
DLT	Distributed Ledger Technologies

DNO	Distributor Network Operator
DR	Demand Response
DR	Demand Response
DSO	Distributed System Operator
DSO	Distributed System Operator
DT	Digital Twin
EPES	Electrical Power and Energy System
ESCO	Energy Services Companies
EU	European Union
EV	Electrical Vehicles
GHG	Greenhouse Gas
GUI	Graphical User Interface
H2020	Horizon 2020
HEMS	Home Energy Management System
HVAC	Heating Ventilation Air Conditioning
ICE	Internal Combustion Engine
IoT	Internet of Things
LEC	Local Energy Communities
OSI	Open Systems Interconnection
P2P	Peer-to-Peer
RES	Renewable Energy Sources
RES	Renewable Energy Source
SAREF	Smart Applications REFerence ontology
SAREF4BLDG	SAREF for Buildings
SAREF4ENER	SAREF for Energy

TEM	Transactive Energy Module
TES	Transactive Energy System
TLS	Transport Layer Security
TRL	Technology Readiness Level
TSL	Transport Layer Security
TSO	Transmission System Operator
UC	Use Case
VPP	Virtual Power Plants
WP	Work Package
TMV	Thermal Mean Vote

2. Objectives

WP7 “Development of TwinERGY system Modules” is reflected on the Innovation Lab Phase within the TwinERGY project. Within this phase, partners are expected to deliver their prototypes so that they can be tested and scaled. For this purpose, as a first step, a prototype phase is proposed. The sets of data and technologies tools proposed in a previous phase (Design Thinking Phase from WP4: Methodological Framework and Architecture Design and WP6: Development of Digital Twin Platform & System Dynamics) will allow for the exploration of the ideas that would be used to validate, in a cost-effective manner these objectives. For this purpose, in WP7, partners will deploy the solution in 8 different tasks [1]:

- T7.2: Consumer Comfort/Well-being Module
- T7.3: Consumer and Neighbourhood demand flexibility profiling Module
- T7.4 Home & tertiary real-time Energy Monitoring Module
- T7.5 DER Management Module
- T7.6 TwinEV Module
- T7.7 Transactive Energy Module
- T7.8 Social Network Module
- T7.9 Risk Management and event handling Module

As a continuation, a deploying phase is being proposed. Through this step, TwinERGY will prove the effectiveness of the technical and non-technical solutions from where the new created solutions can be deployed. WP8: TwinERGY system integration will make feasible this target. Finally, the Innovation Lab phase concludes with the validation, in which the residents test the final solution. It is worth mentioning that the Innovation Lab phase (WP7 & WP8) is going to receive inputs from the Ecosystem Analysis Phase, from which the foundations of the TwinERGY project will be settled down.

On a last step, users would test the developed prototype solution to validate it on the Scale Phase (WP9: Pilots). Throughout this phase, the different pilots based on different countries will allow the study of a solution replicability though the different activities performed in the pilots thanks to the Design and Innovation Lab phases. In Figure 1 it can be seen the interconnection between the different WPs and the different phases within the TwinERGY project that would affect WP7 activities.

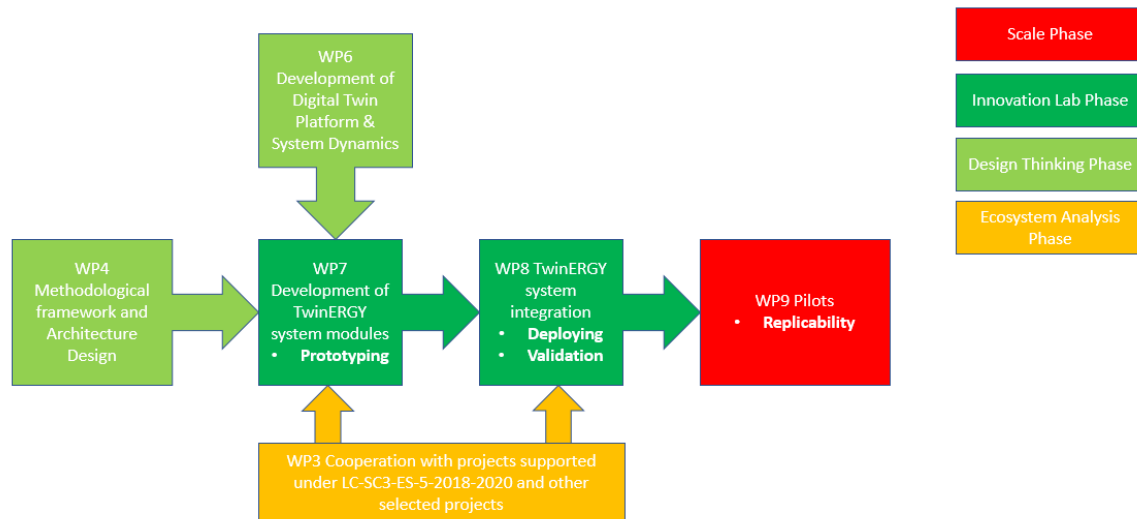


Figure 1: Interconnection between different WP in TwinERGY

Interoperability is defined as the ability for computer software to communicate with other for an effective exchange of information [2]. It is important to remark the importance of this aspect, since there is no single software used in the context of the project. Due to the high interdependency of TwinERGY modules, there is a need to allow the cooperation between them in terms of sharing relevant calculated information. Nevertheless, it must be taken into account that each one of the modules developed has its own characteristics, its own language and its development has been done under different premises. This sets a scenario in which the platform, in order to cover the interoperability of modules, must comply with a series of specifications such as: Operation under real time premises, scalability of the platform, heterogeneity, concurrency, flexibility, and work under secure premises to ensure data integrity. Under these different premises, this deliverable is providing some of the hints and the methodology that it will be applied to develop the modules of the TwinERGY interoperability platform. For that purpose, the consortium agreed to use NATS technology, a publishing and listening message service that allows the exchange of messages among listeners and senders regardless the structure of the message. This section is further explained in Chapter 6. TwinERGY module's interoperable platform.

The differences between the Interoperability Platform developed within this WP and the Data Collection and Communication Platform developed in WP5, should also be highlighted. Throughout different tasks, WP5 will allow the design of a common information model that would be reflected at the Core Data Management Platform (CDMP). The most remarkable aspect of this platform is the delivery of data-at-rest and data-in-motion ingestion from the different Pilot's distributed system. This platform will work under security, encryption, and privacy assurance services according to the

requirements elicited for the energy domain. In addition, CDMP will feed both the different TwinERGY modules (WP7: Development of TwinERGY system modules) and TwinERGY Digital Twins (WP6: Development of Digital Twin Platform & System Dynamics) with raw data from the field and processes. Nevertheless, both WPs have successfully addressed the crossover with WP5, setting different platforms, in order to not interfere with its purposes. WP7 is going to develop the interoperability platform to cover the message exchanging of derivative data between modules. In this way, a platform to exchange derivative data can be applied to the modules, differentiating it from CDMP that will be exclusively used to exchange raw data. Accordingly, WP6 would also implement its own message platform exchange in the Digital Twins. For that purpose, iSCAN platform [3] as the backend of the Digital Twins as the data exchange platform from the derivative data resulting from the analytics between the Digital Twins and the rest of applications.

3. TwinERGY Modules

TwinERGY is developing nine different modules that work complementary with the aim of increasing consumer empowerment as a major challenge in active energy markets, as well as to reduce energy bills and tackle energy poverty, maintaining low-cost, well-being and security both in terms of privacy and personal habits. The solution will be based on a set of technological solutions that would rely on interoperable specifications. These modules are being developed in the different tasks associated to WP7: “Development of TwinERGY system modules”. These modules are listed on Table 2 and are expected to provide consumers with different services which will be based on the data analysis from their close environment. This section is intended to provide a general overview of the different modules based on the needs they are addressing to the actual energy schema and the needs they cover on the different consumers.

Table 2: Modules' list

Module Identifier	Module	Responsible partner
M1	Consumer Comfort/Well-being	UoP
M2	Consumer Demand Flexibility Profiling	IES
M3	Neighbourhood Demand Flexibility Profiling	IES
M4	Home & Tertiary real-time Energy Monitoring	STAM
M5	DER management	TH OWL
M6	Risk Management & event handling	STAM
M7	TwinEV	ETRA
M8	Social Network	ED
M9	Transactive Energy	WEC

These different modules are expected to enable an energy ecosystem to deliver real added value services to the consumers and retailers and Local Energy Communities (LEC). According to the proposal, there are a set of actions that are expected to be seen

not only in the modules, but in the context of the TwinERGY solution focused on the consumer:

- Increase of awareness and knowledge about consumption partners, energy behaviours, generation and demand forecasts, and demand/storage flexibility capacity.
- Increase of local intelligence based on Digital-Twin consumer-centric Energy Management and Control Decision Support mechanisms to optimize demand response.
- Promote self-consumption and RES integration by leveraging local storage capacity.
- Achieve the best energy deal for consumers through a series of open infrastructures for publishing flexibility sources establishing contracts for flexibility utilization and market participation.

On the other hand, a set of actions is also being presented for retailers and Local Energy Communities:

- Forecast Demand Response potential and demand flexibility of prosumers in short and very short term.
- Segment, classify, cluster and aggregate demand and storage [4] assets for the formulation of VPPs.
- Monitor the evolution of Demand Response events and signals to revise pre-defined strategies.
- Gain access to a variety of DER assets and a Transactive Energy Marketplace
- Negotiate with DER in terms of frequency, duration, and capacity.
- To ensure DR settlement and prosumer remuneration by Distributed Ledger Technologies (DLT).

The different modules are going to be integrated with the rest of the components in the TwinERGY solution. As previously explained, the different 9 modules deployed, will extract information not only from data collection devices (raw data), but they will also collect data from the Digital Twinning Platform (through the iSCAN Platform), but also some derivative data from other modules through the TwinERGY Interoperable Platform (Based on NATS 2.0 Technology) that is going to be explained and developed through this document, specifically in *Chapter 6. TwinERGY module's interoperable platform*. Figure 2 which is shown down below, gives an overview of how the different tools are being interconnected.

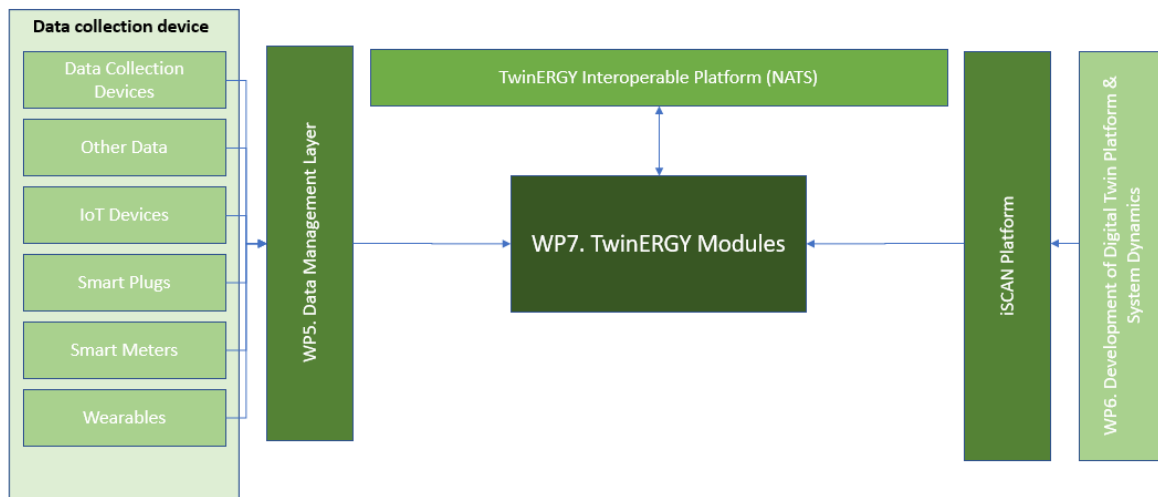


Figure 2: TwinERGY Interoperable Architecture

Although it will be further studied when all the modules are at a further developing phase, it is intended that with a specific common user profile, to access to the different modules of the TwinERGY solution. The aim is to avoid having several register procedures for each module for those users that would be using several of the developed modules.

3.1 Consumer Comfort / Well-being Module

Improved accommodation satisfaction, productivity and well-being can be achieved by securing a thermally comfortable indoor environment. According to various studies, 38% of building occupants are satisfied with the thermal environment. Moreover, perceived well-being as well as productivity are reduced when thermal conditions deviate from the desired ones [4], [5]. Continuous predictions of occupants' thermal comfort level along with indoor environment conditions and their real time feedback on thermal preference in order to assess their thermal tolerance is imperative, since major savings in terms of heating, ventilation, and air conditioning (HVAC) operation optimization could yield [6], [7].

The most popular models to estimate occupants' thermal comfort level is the thermal mean vote (TMV) and the adaptive model [8], [9] which, does not consider occupants' physiological factors. Therefore, a personalized approach that infers (or predicts, as it is encountered in relevant literature) individuals' thermal comfort level, instead of the average response of a large population shall be followed. Personal comfort models have a much higher inference (predicting) power since personal factors are considered. These models encounter environmental parameters (air temperature, air humidity), occupant's physiological parameters (skin temperature, heart rate), as well as activity

and feedback behavior [10]. Occupants' physiological parameters such as skin temperature, heart rate, and motion shall be measured by using wrist wearable sensors that are capable of aggregating vital signals without relying on stationary infrastructure. Moreover, indoor environmental parameters such as air temperature and humidity along with clothing insulation parameters will be considered as well. Therefore, the personal comfort level shall be inferred using all the above aggregated physiological, environmental and activity data which eventually will be incorporated into the consumer digital twin thus, creating a human-in-the-loop system. In addition to the above, real time feedback regarding thermal preference, via stationary infrastructure, shall be available too, leading to assessing occupant's thermal tolerance limits on the scale provided by ASHRAE 55 standard [11]. Capturing by an autonomous single point wrist wearable multisensory device in real time the transitions of skin temperature, heart rate and activities behaviour, such as resting, walking, cooking is a challenge since, the accuracies of wearable sensors might cause uncertainties to thermal comfort inference.

In a nutshell, the objective of this module is to infer as unobtrusively possible the occupants' personal thermal comfort level on the scale provided by ASHRAE 55 standard utilizing physiological and activity data collected by wearable sensors and indoor environmental data. Compared to other technologies, such non-intrusive approaches do not disturb occupants and enjoy high acceptance rate by them. Eventually, the thermal comfort level shall be used for advertisement by the consumer Digital Twin towards optimizing the use of domestic conditioning systems, but it can also be applied to general mechanical systems in buildings. The envisaged methodology framework to be followed adheres to a model specifically developed for occupants accounting the great variation in personal factors.

Consumer Comfort/Well-being is a module that it is going to be developed by UOP. It is intended to achieve a Technology Readiness Level (TRL) of 7 at the end of the project, in which the tool would be expected to have a person-centric use as well as cooperative approach within the context of the TwinERGY project.

3.2 Consumer demand flexibility profiling Module

In an attempt to reduce greenhouse gas (GHG) emissions in the built environment, the EU has mandated the uptake of renewable energy systems (RES) within the bloc, mandating member states to a RES utilization target of 30% by 2030 [12]. This transition from traditional electricity generation systems, namely high emitting power plants, to the deployment of both large scale and decentralized/distributed wind and solar generation facilities is driving unprecedented change in power grid infrastructure and

systems [13]. This move to utilize a greater proportion of RES generation, while being a positive step in terms of GHG reduction, is challenging the status quo with respect to how Transmission System Operators (TSOs) and Distribution System Operators (DSOs) can balance electricity demand and supply, which currently utilizes supply side management techniques, such as imports, peaks and flexible generators and pumped hydro storage, to name a few.

In addition to the move from a “business as usual” distribution model, the increased use of RES electricity, particularly that provided through solar PV, creates some technical issues in the distribution of electricity on the grid. The level of solar PV generation achieved throughout the day is dependent on the weather conditions and the availability of sunlight to create electricity. As such, the amount of electricity generated is dependent on the weather conditions, which are generally quite variable. Furthermore, the generation curve associated with solar PV is unlikely to correspond to the electricity demand within a building or community. From a residential building perspective, this generally arises since the period of generation corresponds to the time when the house is unoccupied, while the maximum demand corresponds to lowest generation. In the event that there is no form of energy storage, which is a typical scenario for many buildings within the EU, it is likely that the PV system is not being utilized to its full potential, resulting in the exportation or loss of a large proportion of generated solar energy while maintaining a reliance on the grid supply. Figure 3 illustrates an example of this for a residential building in the United States where there is poor balancing of the supply and demand, resulting in the sub-optimal utilization of the solar PV generation, which is indicated by the yellow line on the chart.

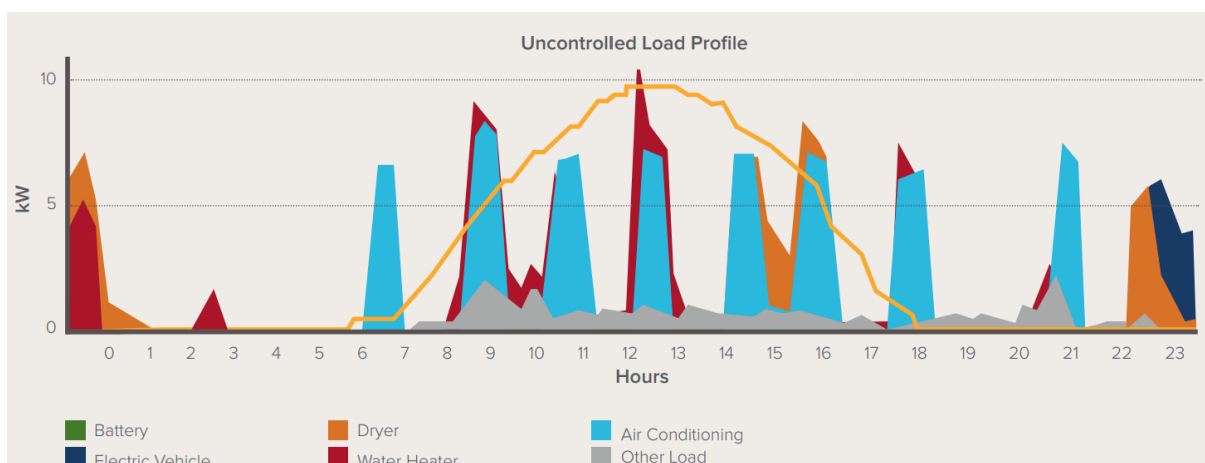


Figure 3: Typical residential demand profile compared to solar PV generation [14].

In order to address these challenges, the concept of demand response (DR) and flexibility has begun to gain traction as a viable alternative for balancing the supply and

demand of electricity. DR can be described as the adjustment of power consumption of an electric utility customer to better match the demand for power with the available supply and is being seen as a primary enabling concept for the practical uptake of RES, particularly solar PV in non-commercial and non-industrial buildings. Since DR can facilitate the integration of renewable energy sources, marked by intermittency, it is widely believed the DR will reduce the carbon-intensity and cost of power systems, however, DR is yet to realize its full potential owing primarily to market and regulatory barriers, as well as a lack of roll out of some technological solutions, such as battery storage, at sufficient scale. Currently, demand response is being used almost exclusively in energy intensive industries, such as metal, paper and cement production where load shifting is a feasible strategy for energy management. Although multiple trials have demonstrated that DR flexibility works, and technology rollouts progress at a reasonable pace with the Smart Home market in the EU, the gap with the respective US market size volumes persists and the residential DR market has been slow to gain traction [1]. Nevertheless, the ongoing transition from the traditional, centralized energy delivery mechanism employed throughout the EU to one comprising decentralized community micro-grids that are supported by the utilities is accelerating the adoption of community micro-grids, virtual power plants and DR flexibility as an alternative distribution model within the EU.

Implementing DR actions is dependent on the identification and leveraging of flexibility within the system. Flexibility refers to those loads within buildings or community grids that can be shifted or implemented at alternative times where it might be more beneficial for balancing the supply and demand. An example of this would be the use of an EV charging station at a time corresponding to maximum PV generation. By identifying flexibility and implementing demand response actions, coupled with the installation of energy storage technologies, electricity demand of a building can be balanced against the generation profile of solar PV electricity, leading to the optimal usage of PV electricity on a daily basis. An example of such a strategy implemented in a residential building is presented in Figure 4.

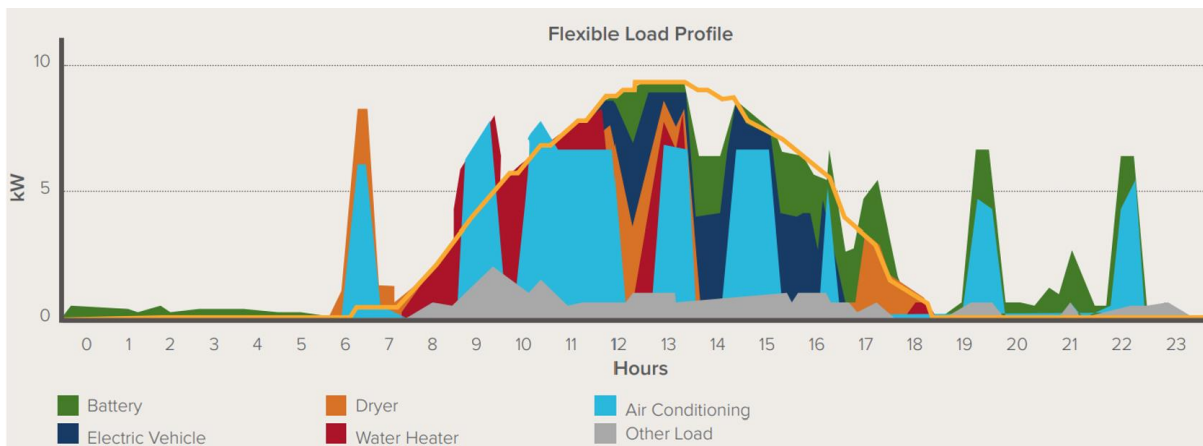


Figure 4: Residential demand profile compared to solar PV generation following the implementation of battery storage and demand response actions [14].

Flexibility in the TwinERGY platform is going to be addressed through the Digital Twins that are developed within WP6 but also through Consumer and Neighbourhood demand flexibility profiling modules, which will operate at two scales, namely the consumer (building) level and the community level. At the building level, the Consumer Demand Flexibility module will be developed to enable the calculation of flexibility for individual buildings/consumers. The flexibility will be calculated both for implicit and explicit demand response. Beyond the estimated amount of flexibility itself, the controllability and predictability features of it, based on the available loads, will also be estimated to allow better informed decisions to be taken from the aggregators/prosumers. An interim step in the calculation and profiling of flexibility would be the disaggregation of the electrical load in the individual dwellings. That will ensure a more accurate and complete characterization of the available flexibility. It will be based on physics-based dynamic building simulation models that will be developed for the buildings on available static data (e.g. energy performance certificates, info provided by the occupants) and calibrated with dynamic data harvested by the on-site sensing and monitoring equipment (at least one smart meter and one thermostat per building). Big data output from the simulations will subsequently be used to train ML techniques that can both estimate flexibility metrics (virtual sensors) and optimize the dispatch of that flexibility.

At the neighbourhood scale, the module will profile flexibility for whole neighbourhoods. As such, this module will consider all the buildings and technical building systems along with power and heat networks, mobility networks, infrastructure and other assets. The module will allow an integrated estimation of flexibility that leads to the understanding of all the impacts the dispatching of available flexibility can have through a multi-vectorial approach. The module will utilize a combination of physics-based and data-based modelling tools in calculating the flexibility in district-level.

Consumer & Neighbourhood demand flexibility profiling are modules that are going to be developed by IES. It is intended to achieve a Technology Readiness Level (TRL) of 8 at the end of the project, in which the tools would be expected to profile flexibility for the whole neighbourhood and the consumer side within the context of the TwinERGY project.

3.3 Neighbourhood demand flexibility profiling Module

The general aspects described in the previous section (3.2 Consumer demand flexibility profiling Module) also hold for this module at a Neighbourhood scale.

3.4 Home & Tertiary real-time Energy Monitoring Module

The Home & Tertiary real-time Energy Monitoring module is placed in the buildings' energy efficiency category of services provided in by the Energy Communities. It can be provided thanks to the aid of capillary monitoring, communication, coordinated control, distributed storage, and Active Demand management. The traditionally monodirectional system would see the network change to bidirectional, thus making the consumer an active part of the process and above all it would contribute to greater control of voltage and frequency at a distribution level.

The change to a distributed generation model consisting of small self-production plants, with the abandonment of traditional power plants, will bring not only an improvement in terms of environmental impact but also an advantage for individual consumers and businesses, which would become an active part of the process. Until now, energy efficiency and Demand Response measures have been treated as separate elements from a technological, regulatory and market point of view. This module aims, to consider them two sides of the same coin through concept, methodological and technological innovations including: the removal of entry barriers, or the possibility of obtaining an improvement in terms of energy efficiency and consequently economic for the end user, without the need to install sensors, home automation or control systems; attention to billing will deviate from the classic static models based on the average cost of energy, but will take into account the real rates applied to have a correct estimate of the expenditure by the end customer; take into account the demand and production forecasts during a certain period; a multi-objective optimization with dynamic constraints that through the output of the developed models, through the construction of multi-objective algorithms, will take care of the implementation of optimized consumption policies in the buildings. As related to the UC01, the first step is to obtain

a greater facilities' observability; the amount of monitored data, both static and dynamic, are going to be gathered and then processed and analysed.

Data gathering is crucial for the energy efficiency and energy management processes; depending on the data available, different actions are able to be taken, and eventually, the monitoring system is going to be improved. Depending on the availability, the static parameters will regard many aspects of the facility such as:

- Typology (apartment/household/public building)
- Footprint area
- Number of floors
- Numbers of occupants
- Nominal Power supply
- Photovoltaic plant peak power
- Energy Tariffs timing and costs

The dynamic parameters refer to:

- Energy consumption
- Photovoltaic production
- Electrical Storages
- Indoor parameters (temperature and humidity)
- Weather conditions

The data will be achieved and made available through an online graphical interface to improve the users' awareness about their energy profile. Starting from the main electrical appliances inventory and their behavioural rules, this module is going to deliver the optimal load distribution during the week.

Through the Graphical User Interface (GUI), the users can fulfil the typical usage habit of their main electrical appliances during the week. The usage routines could be updated and overwritten by the user every time is needed. In relation to the energy monitoring and costs information, this data can be used to find and shape the optimal load profile, reducing costs in the energy bill and maximizing self-consumption.

Home & Tertiary real-time Energy Monitoring is a module that it is going to be developed by STAM. It is intended to achieve a Technology Readiness Level (TRL) of 8 at the end of the project, in which the tool would be expected to generate a building Energy

Management system that aids users to manage self-consumption and maximization of self-sustainability.

3.5 DER management module

Towards reducing the overall CO₂ emissions of a country, it is important to avoid using energy that has been produced by fossil-based power plants, that run on coal or natural gas, for example. To achieve this goal, the use of wind turbines or photovoltaics provides a possible solution with a high potential. However, the classic energy grid is designed around large-scale producers like aforementioned fossil-based or nuclear power plants. In contrast to these facilities, the classic renewable energy production relies on smaller production units like wind parks or single roofs. This fact bears a new challenge, because if a major part of energy production should come from RES, many additional smaller sites will be necessary. This means that a huge number of producers must be coordinated to ensure a stable energy grid. Renewable Energy Sources (RES) are highly dependent on weather, which means the weather forecast and its correct interpretation is crucial for reliable energy production predictions, which in turn are required for ensuring grid stability. Also, it is important to utilize various ways to store the excess energy in times of very high-RES energy production and low consumption levels.

The DER management module shall solve these problems. By identifying power supply bottlenecks in real-time, the power grid can be stabilized, and the share of renewable energies can be maximized. Since weather conditions are volatile, there is no way to easily maintain a stable energy production. To counter this, it is necessary to take the upcoming weather changes into account. Typically, weather forecasts are readily available for most location, thus it should be possible to utilize this information to make a reasonable assumption about the amount of energy that is produced in the next hours or even throughout the whole day. These forecasts can help establish a baseline of data rules, which would allow algorithmic approaches to more accurately decide on actions that are most sensible for a given situation.

One practical option is the use of battery storage to compensate peaks and dips in the energy production. When there is a high level of RES production, as is the case for PV systems during the day, the excess energy can be stored and used at night or when there is little sunlight. Another feasible approach is the concept of demand response. Here, a Home Energy Management System (HEMS) schedules the use of appliances such as a heat pump or a washing machine to times, where it is convenient in terms of RES production levels. Combining both options bears high potentials for improving the energy usage in common households. Sophisticated systems combined with efficient

renewable energy production and storage possibilities, can play a big role in maximizing the use of eco-friendly energy and minimize necessary shutdowns of wind turbines or PV-systems to accommodate for a stable power grid.

The DER-module is developed by TH-OWL in support with STAM and IES. It is intended to achieve a Technology Readiness Level (TRL) of 8 at the end of the project, in which the tool would be expected to calculate the grid status and calculate its display in a real-time basis.

3.6 Risk Management and event handling Module

The Electrical Power and Energy System (EPES) is evolving rapidly, increasing its efficiency and business continuity through, among other evolutions, the growing capability of combining distributed energy resources (DERs). Digital services are a key enabler of this capability, building on an increased level of collaboration between all stakeholders connected to the power supply chain that relies on near real-time availability and exchange of data and knowledge. Dedicated hardware solutions have changed to software and hardware solutions that makes protecting the systems more and more sophisticated. This has induced a full redesign of the roles and responsibilities; regulated stakeholders in charge of the transportation and distribution of electricity (power network operators, such as TSOs (Transmission System Operators) and DSOs (Distribution System Operators) are expected to interact and cooperate with commercial stakeholders, like ESCOs (Energy Service Companies), aggregators, new market operators, to ensure a cost-effective competitive functioning of the electricity grids.

DR strategies include increasing building energy efficiency, limiting demand when pre-set limits may be exceeded, and shifting demand from peak to off-peak times (e.g., using energy storage). Controls to limit demand involve a sequence of automated or manually performed changes to the building HVAC (e.g., relaxing temperature and system set points) and lighting systems (e.g., dimming and bi-level switching).

Depending on their position in the power grid and their contribution in the grid stability, single building and distributed energy plants are going to become critical infrastructures for the EPES. Both physical and cyber event/issues are becoming as crucial parameters into the related cost-benefits analysis.

The Risk Management and event handling Module is going to be developed by integrating two models, Rampart (STAM – IT) and STPA44 (UoP), which both exploit the

potential of energy demand flexibility (as a parameter of the network) to address local and global grid situations.

The Risk Management and Event handling Module is developed by STAM. It is intended to achieve a Technology Readiness Level (TRL) of 7 at the end of the project, in which the tool would be expected to identify security gaps, planning and management of preventive actions and countermeasures.

3.7 TwinEV Module

Nowadays, the European Union (EU) is combating climate change through interventions in the transportation sector. Over the last 25 years, European rules have promoted the reduction of pollutants emissions through the carefully guidance of vehicles' manufacturers. Nevertheless, today's huge effort is required in the reduction of CO₂ emissions through the electrification of transportation. The main regulatory framework related to e-mobility is aforementioned as follows:

- Directive on Alternative Fuels Infrastructure (2014/94/EU)
- CO₂ Emissions for Cars and Vans Performance Standards (EU 2019/631)
- Trans-European Network for Transport (TEN-T) Regulation review
- Clean Vehicles Directive (2019/1161 EU)
- Sustainable and Smart Mobility Strategy

Performing a comparison between an Electric Vehicle (EV) and an Internal Combustion Engine (ICE) vehicle, it can be stated that EV perform at a higher efficiency with less mechanical reliability and have no direct associated CO₂ emission. Furthermore, EV store energy through electrochemical batteries (less energy density than liquid fuels). However, EV batteries could be charged at least 5 times slower than liquid fuel refuelling [15].

E-mobility is a key element in the future energy system. This practice generates effects both as an additional load and as a flexibility resource for market actors and system operators. The capabilities of EVs are many and varied since they can provide valuable system flexibility services and the management of congestion in transmission grids. For this purpose, the development of a suitable charging infrastructure is required to address different stakeholders' needs in the electro-mobility value chain. According to the literature [15], leaving the charging process uncontrolled could hinder some of present challenges in the power system, such as peak power demand at certain times. The benefits of managing the charging process regarding the power profile will open

new opportunities to the system. So as to mention that a smart EV charging approach can support the integration of RES resulting in a reshape of the power demand curve (reducing the system costs and CO₂ associated emissions).

Some other underlying aspects associated to the correct spread of smart charging are the standardization, as well as the dynamic pricing definition, market rules. These facts require the cooperation among many different actors from diverse sectors such as: vehicle, battery, electronic industries, ICT, mobility service providers, transport authorities, electricity market aggregator, consumers, and power grid operators. To avoid some of the opportunities beforementioned, ENTSO-E [15] suggest some topics which could facilitate the implementation of smart-charging solutions.

- Coordinate charging infrastructure and electric grid scenario.
- Manage the charging process (considering V2G charging approach if possible) to smooth peaks in the load curve.
- Deploy electromobility enablers in public and private charging infrastructure, with metering and communication capabilities.
- Enable a new ecosystem centred around the consumer needs, by enhancing defined roles, responsibilities to exploit the potential of EV charging as a flexible resource.
- Update market rules and regulatory framework.

Within the context of the TwinERGY project, the TwinEV module hopes to adjust its goal of consumer engagement in Demand Response and local optimization in the field of the EV and its dual role as a demand and storage asset. The objective is to analyse the impact that the charging scenarios could imply on the community in terms of grid congestion and the welfare of individual members. To achieve this goal, the TwinEV module will compile EV user's preferences and requirements to adjust the services and features to be provided.

The objective of TwinEV is to provide the required and optimized State of Charge of the users' EV at proper times, considering minimum charging prices and the delivery of maximum green electricity supply to EV, based on local energy demand rationalisation. In this sense, Electrical vehicles offer a huge flexibility potential. EV has the potential of shifting the demand, and it can be even improved if V2G functionalities are applied, since they can give back energy to the distribution grid when necessary. It is worthwhile to remark that this last functionality could have a positive impact into the grid. In case of congestion, DSO would be able to send signal to EV to limit their congestion constraints

on the grid. Furthermore, additional ancillary services can be provided by electric vehicle's battery in terms of voltage control, peak shaving, and energy buffering for RES intermittency.

For TwinEV module to perform the optimized State of Charge and to be centralized at the consumer engagement, there are several constraints and parameter that must be considered. Physical limits such as battery capacity, current State of Charge (SoC), maximal and minimal power generation, localization of Charging Points, their respective power on charge process play an important role in the determination of a proper charging profile. These inputs would be compiled through the preferences of each EV users, the technical requirements of the grid and the different assets, as well as the calculation of the Demand Response campaigns resulting in flexibility assessment. [16]

User's will count with a user-friendly interface in which EV users would be able to address issues of payment, security, quality, and configuration of their EV charging profile. Regarding public infrastructure, the most suitable charging point would be indicated to EV user, based on some principles such as prices, route cost to station, the energy stock and the waiting-charging times. The platform will be also able to process booking and parking processes for these regarded public EV chargers. Furthermore, this would be combined to produce the calculation of the optimal State of Charge (SoC) for the user, in terms of minimization of the costs and maximization of the green electricity. This last part is required to be replicated at the private (domestic) EV chargers as well.

TwinEV is a module that it is going to be developed by ETRA. It is intended to achieve a Technology Readiness Level (TRL) of 8 at the end of the project, in which the tool would be intended to have a user-centric and cooperative approach within the context of the TwinERGY project.

3.8 Social Network Module

According to the European's Commission Package entitled 'Clean Energy for All Europeans', [17] there is a particular concern to pose citizens as the central players into the energy markets future, as part of the decarbonization effort and targets of 2050. Towards these efforts, the Local Energy Communities (LEC) can drive and empower the end-users to consume energy following a more responsible manner, contributing to energy savings and steering the grid to become more flexible. The participation of citizens and communities as partners in energy projects are transforming the energy system. Community energy initiatives are offering new opportunities for citizens to get actively involved in energy matters. Community energy refers to the collective energy

actions that foster citizens' participation across the energy system. It has received increased attention in recent years, developing a wide range of practices to manage community energy projects.

The active participation of residential customers in demand response schemes as well as their participation in energy communities possibly with shared assets (e.g., battery storage system, rooftop production, charging point infrastructures) play an increasingly societal role that implies the concept of fostering citizens' positive contribution in energy matters and raising acceptance of green technologies. It is therefore, essential to promote residential customers' awareness via monitoring functionalities of their consumption/production. Such functionality may sensitize residential customer about his/her consumption profile, with visualized dashboards providing breakdown analysis on the share of use the different household devices towards comprehending not only the energy footprint but also the composition of their profiling. Customers access to data on energy profiles and bills, increases potentially the visibility and awareness of energy consumption.

The technological advancements even behind-the-meter premises lately are foreseen to take place with multiple sensory devices beyond smart-meter with multiple IoT based devices. Concurrently, the expected increase load growth due to the *electrification-of-everything* (e.g. Electric-heat-water pumps, electric vehicles etc.) along with the liberalization of electricity markets (i.e., electricity companies will have to improve their operation due to competition) will, eventually, render their involvement (via Demand Response schemes) into electricity value chain, affecting electricity companies, in return to reduction to their bills. The incorporation of residential consumers may be enhanced via the competition amongst them.

The social network module within the scope of TwinERGY project aims at providing a social network platform, which will employ a social competition strategy, designed to encourage demand response engagement and reduction in energy usage. In other words, it will enhance the engagement of residential households via a streamlined competition among neighbouring households. The social network module will provide a web-based application which will provide a full set of comprehensive dashboards for the monitoring of consumption/production profiles aggregated at device level along with information and statuses of any shared assets with the aid of TwinERGY Digital Twin Platform. There will be specific graphs to present the energy saving of end-users. The main objective of the module will be to act as a social comparison tool by comparing the energy use between several neighbouring end-users focusing particularly on the

individuals own behaviour which to some extent has implication on the consumption regular profile. The social comparison will also lead social competition among within the community or the neighbourhood providing rewards (i.e., TwinERGY points) to the participating households. The competition will be performed based on gamification functionalities which in turn will be relying on specific KPIs such as energy efficiency, participation on the local community, utilization of shared assets etc., as a matter of providing the corresponding rewards. The Social Network Module will also work as a generic networking platform which will enable users to interact through specific basic social tools (e.g. post/comment tool etc).

Social network is a module that it is going to be developed by ED. It is intended to achieve a Technology Readiness Level (TRL) of 8 at the end of the project, in which the tool maybe provide a user-centric and cooperative approach within the context of the TwinERGY project. The social network module will rely its design and implementation on well-established application developed in the frame of ChargED project [18] that was further updated in the frame of BENEFFICE project [19] to also incorporate advanced features (i.e. the CO2 virtual coin as a reward) and will now be introduced to the TwinERGY users further enhanced by the intelligence and the accuracy/ reliability of forecasts and results that the Digital Twin module brings.

The Social Network Module is developed by ED. It is intended to achieve a Technology Readiness Level (TRL) of 8 at the end of the project, in which the tool would be expected to enhance the engagement of residential households through comprehensive dashboards to present households' consumer profiles to act as a comparison tool by comparing the energy use between different end-users.

3.9 Transactive Energy Module

The energy industry is undergoing a major transformation due to a number of factors including environmental regulations, new technologies, and active prosumer participation in decentralized generation, storage, and smart load management at the grid edge and Behind the Meter (BTM). The proliferation of Distributed Energy Resources (DERs) has caused operational issues for grid operators due to their variability, and unpredictability of the impact of DERs on the grid. Properly designed incentive-compatible local energy markets (LEMs) can help align prosumer incentives with grid operator objectives. The existing centralized markets cannot handle large volumes of small quantity transactions involved for such a realization. A Transactive Energy System (TES) platform providing for both peer-to-peer and peer-to-market transactions provides a natural solution turning the DERs around from being a

problem into a solution for grid management based on market mechanisms. Another issue with the current energy markets is the relatively high transaction costs for market participation, delivery verification, and settlements. Blockchain technologies can provide solutions in that respect. A Blockchain-enabled Transactive Energy system can support incentive-compatible LEMs for the mutual benefit of the prosumers, the grid operators, and the passive consumers, and to pave the way for consistent and efficient regulatory reform options where needed.

Specifically, Transactive Energy (TE) is a system which consists of coordinated participants that use automation tools to communicate and exchange energy based on value and certain grid reliability constraints. It basically uses market-based economic transactions and control functionality for energy trading and sharing among prosumers within an electric power system. With a transactive energy system (TES), energy is becoming a commodity for customers. Energy can be traded among them either on a real time basis or on a predefined schedule, in case also storage is present.

The main concept lies on the determination of two different energy prices; price of the external grid and internal LEM price. LEM firstly settles internally before coordinating with the external grid. To be more specific, LEM internally resolves production and consumption at a lower price (compared to the external grid) to incentivize the consumers. Two main categories can be distinguished:

- **Internal LEM price < Levelized feed out price of the external grid:** In that case, since the selling price of the grid is higher compared to the internal price of the market, a consumer is incentivized to buy his energy at a lower price from another LEM participant instead of purchasing from the grid.
- **Internal LEM price > Levelized price of the external grid:** A participant that produces energy within the LEM will be better rewarded if he sells his energy within the market rather than directly to the grid.

This is achieved mainly due to the fact that there are no transfer losses in energy produced and exchanged between the participants of a Local energy Market on contrary to the energy exchanges in a large-scale grid with many different voltage levels.

The European Clean Energy Package (CEP), explicitly defines for a first time, the engagement of consumers and energy communities to the energy sector. The role of energy communities is defined in the following laws of CEP:

- Renewable Energy directive EU 2018/2001 clearly defines renewable energy communities.

- Internal Electricity Market directive EU 2019/944 defines the roles and responsibilities of participants in an energy community.

Energy communities are considered a new entity in the market structure, defining exact characteristics like size, ownership structure and purpose. To be more specific, in terms of governance the participation, they should be open to everyone but voluntarily and the customers should be allowed to leave the community anytime they want, without losing their access rights to network. The owner of the community can be any citizen, local authority etc. if it does not have direct relation to the energy sector. Finally, the purpose of the community is primarily to create social rather than financial benefits.

The following Figure 5 provides the layered architecture of the proposed TES platform. The 7-layer architecture is based on the Open Systems Interconnection (OSI) reference model. Each layer of the OSI Model handles a specific job and communicates with the layers above and below itself.

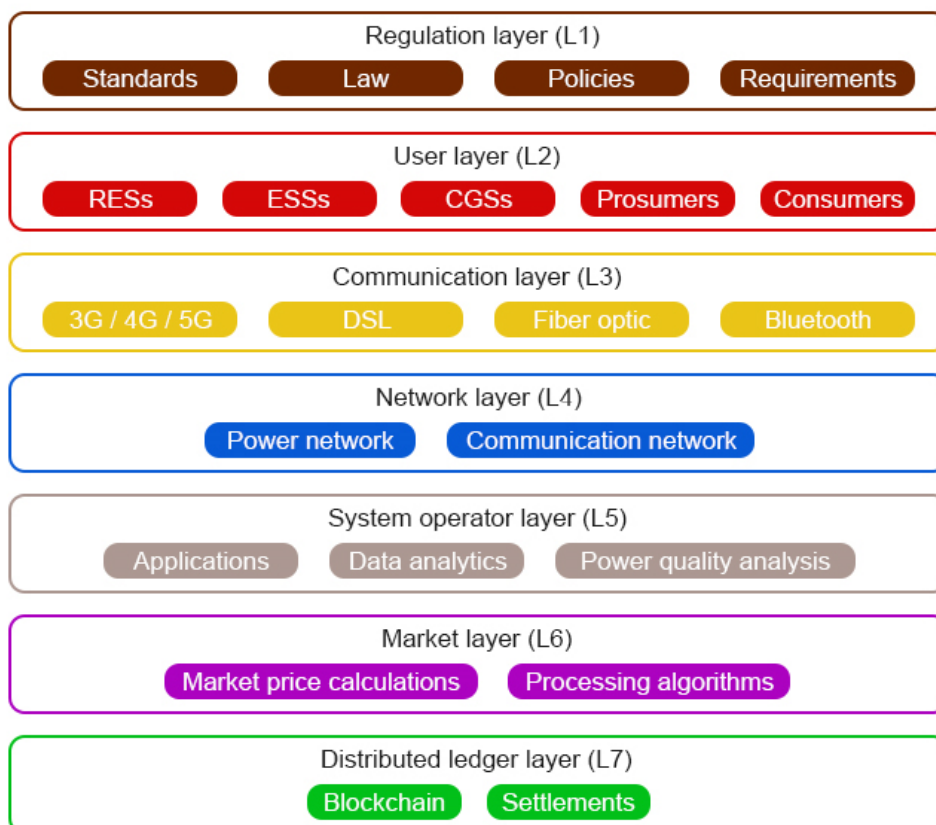


Figure 5: 7-layer architecture

Regulation layer 1

Includes laws, regulation, standards, and policies relevant to the energy markets. As well as data protection and information security. The rules are necessary for providing the framework and the guidelines for LEM design. These comprise the legal frameworks and guidelines surrounding the TEM.

User layer 2

Includes Prosumers, energy sources and IOT devices. Refers to the participants of the microgrid and their hardware platforms for exchanging information. These are the actors that interact with the TEM.

Communication layer 3

Includes 4G/5G, Fibre optic & Bluetooth and are used by layer 2 to communicate with the subsequent layers. Communication systems in TEM should meet specific requirements on bandwidth. Reliability, coverage cost, security, and latency.

Network Layer 4

Includes the power and communication networks that facilitate the routing of information between the layers. Refers to the microgrid setup and specifically whether it uses traditional network or its own infrastructure (standalone network or grid connected).

System operator layer 5

Includes applications, databases, data analytics and power quality analysis which interact with layer 2, 6. And is usually handled by an independent system operator.

Market layer 6

Includes the DNO/DSO and LEM pricing as well as the settlement for energy transactions. It determines the MCP for interactions among the participants of the market. This layer interacts with layer 5 and 7.

Distributed ledger layer 7

Includes private permissioned blockchain that records the energy transactions and LEM pricing. A digital platform is provided to each participant for ensuring energy and economic validation.

The Transactive Energy Module is developed by WEC. It is intended to achieve a Technology Readiness Level (TRL) of 8 at the end of the project. The tool is expected to

be used as a transactional platform that offers its participants to sell their flexible energy loads and excess capacity to an open market to the micro-grid operators or other levels.

4. Inputs

This section aims to describe the process that has been followed to gather the different specifications of the 9 different modules developed within the TwinERGY Project. In this chapter, the methodology used to gather the functionalities of the modules that participate in TwinERGY will be explained. The aim is to have a preliminary list of the module's functionalities that would be based on the project's requirements. Furthermore, these specifications will be correctly aligned with the project Use Cases (UC). Once there is a correct visibility of these functionalities, relevant partners will identify their possible iteration with other developed modules, as a mean to define the Interoperability platform that is going to be explained within the following chapters.

4.1 Functionalities

Each of the partners within Task 7.1 is responsible for one or more of the modules presented for the TwinERGY project as it has been presented in Table 2. In order to have a clearer understanding of each of the modules' functionalities, partners were asked to identify the goals of their modules in a structured template. This template is organized in three parts: Functionalities, Input and Output data, and classes of Information. From the functionalities sheet (Figure 6), the following inputs were expected:

- **Functionality Identifier:** Through a name-based identifier associated with a key number, functionalities from the different modules are registered.
- **Name:** By means of a short name, the functionality is identified.
- **Description:** This part provides to the functionality a brief description of the targets to be achieved.
- **UC Identifier:** The Use Case associated to each of the functionality.
- **Input Data Identifier:** The functionality may have associated some input data which could be essential to the operation of the module. In this part, the identifier associated to this data input will be referenced. Just as a note, this identifier is fully developed in "the Input data" sheet on the template.
- **Output Data Identifier:** As the abovementioned identifier, this one is associated to the output data generated from each of the modules. These data sets are fully developed in "Output data" sheet on the template.
- **Interoperability:** This column is set to identify if the module is interconnected to any other module by means of exchanging information. This item will allow to determine whether the module will exchange data or not.

- **ID of WP7 module if known:** This column identifies the module from which the functionality is planned to exchange information.

Func. ID	Name	Description	U.C.	Input Data Id.	Output Data Id.	Interoperability	
<small>Functionality identifier: Key of module #</small>	<small>Functionality short name</small>	<small>Complete functionality description</small>	<small>Use case identifier (if known)</small>	<small>From the sheet "Input data", keys of the inputs related to this functionality</small>	<small>From the sheet "Output data", keys of the inputs related to this functionality</small>	<small>Interconnection with another WP7 module? (YES/NO)</small>	<small>ID. of WP7 module if known</small>

Figure 6: Functionalities sheet at the template

Regarding the "Input data" sheet from the template, partners were asked to fulfil it based on the functionalities' requirements from data ingestion from the modules (Figure 7). This part of the sheet is structured as it is explained as follows:

- **Data Id:** This identifier will give name to the input datasets that each module is intended to be using as an input.
- **Name:** This column will give name to the data sets in a short manner.
- **Description:** In this column, the complete description of the data will be explained in the context of the input data
- **Func. ID:** In this column, the association of each functionality to the input data will be done.
- **Data class (SAREF/new):** In this part, it will be indicated the classification of data in terms of its class. More information will be given at 6.3 Examined standards.
- **Comments:** If further information was available from the input data, partners were asked to fulfil this column

Data Id.	Name	Description	Func. ID	Data class (SAREF/new)	Comments
<small>Data identifier (used in the list of Functionalities)</small>	<small>Data name</small>	<small>Complete description of the data</small>	<small>Functionality identifier (declared in Functionalities)</small>	<small>Indicate here the SAREF/SAREF4BLDG/SAREFAENER class. If the type cannot be identified with a known class, indicate "new". In this latest case, include in a new sheet the properties it has.</small>	<small>Any comment needed for the complete understanding of the data</small>

Figure 7: Input data sheet from template

In terms of "Output data" sheet from the template, partners were required to identify the output data sets that are the result of their modules. To this purpose, the template (Figure 8) was structured based on the following topics:

- **Func. ID:** In this column, the association of each functionality to the input data will be done.
- **Data class (SAREF/new):** In this part, it will be indicated the classification of data in terms of its class. More information will be given at 6.3 Examined standards.
- **Comments:** If further information was available from the input data, partners were asked to fulfil this column

Data Id.	Name	Description	Func. ID	Data class (SAREF/new)	Comments
<small>Data identifier (used in the list of Functionalities)</small>	<small>Data name</small>	<small>Complete description of the data</small>	<small>Functionality identifier (declared in sheet Functionalities)</small>	<small>Indicate here the SAREF/SAREF4BLDG/SAREF4ENER class. If the type cannot be identified with a known class, indicate "new". In this latest case, include in a new sheet the properties it has.</small>	<small>Any comment needed for the complete understanding of the data</small>

Figure 8: Output data sheet from template

Although in 6.3 Examined standards is further explained the data classes that are considered in each of the modules, modules' developers were asked to identify the data classes that could be appearing in their modules. To achieve this aim, in Figure 9 the template for this categorization is reflected:

- **Data class:** this section will identify the group of data that it is going to be regarded.
- **Attributes:** In this column, partners will be asked to identify the characteristics or properties of an entity
- **Attribute type:** In this part, the attribute type is being identified in terms of its nature. If it is a string, a true/false argument...
- **Attribute meaning:** In this column, each attribute is going to be explained in terms of the context within the data class.

Data class	Attributes	Attribute type	Attribute meaning

Figure 9: Data classes sheet from template

Despite the amount of information requested from partners, this deliverable it is going to be showing the most relevant information compiled as it can be found in Annex 1. Functionalities description.

4.2 Iteration with other modules

The interoperability platform will be based on the message interchange between the different modules. This information will be the result of the iteration between the different modules in the context of TwinERGY. For that purpose, partners have been asked to complete fulfil a section in the demanded template which the name "Module's interoperability". The aim of this sheet in the template is to further develop the iteration among the modules. The sheet has been divided into different sections (Figure 10):

- **Demanding module:** The modules' identifier that is demanding data from the other module. The list of module's identifiers has been defined at Table 2.
- **Demanded module:** The modules' identifier that is being demanded data from the "demanding module". The modules' number has been defined at Table 2.

- **Functionality associated:** Functionality identifier associated to the data exchange between modules. The method to compile the functionalities has been explained at 4.1 Functionalities.
- **Data identifier:** The associated data identifier from the input and output data that it is going to be exchanged.
- **U.C:** The Use Case identifier in which this information will be exchanged.
- **Description:** Brief information associated to the data transaction between the modules involved.

Demanding module	Demanded module	Functionality associated	Identifier data	U.C.	Description
<i>As a demanding module partner, please introduce the module identifier</i>	<i>As a demanded module partner, please introduce the demanded module identifier</i>	<i>Identifier of the functionality associated to the data interchanged between modules</i>	<i>Data identifier</i>	<i>Use case identifier (if known)</i>	<i>Description of the data interchanged between the modules</i>

Figure 10: Modules' interoperability sheet from the template

The following Table 3, intends to reflect the identified interconnection between the modules, based on what has been collected from the template:

Table 3: Interconnection between the modules

Modules	M1	M2	M3	M4	M5	M6	M7	M8	M9
M1									
M2	X		X	X					X
M3		X		X			X		X
M4	X	X	X						X
M5		X	X	X			X		X
M6					X				
M7		X	X		X				X
M8			X	X					
M9				X	X		X		

This table collects the relationship that each demanding module (column) expects from the demanded module (row).

Annex 2. Modules' interoperability will provide the most important information that has been compiled from the partners regarding the modules' interoperability. Nevertheless, it should be noted that both functionalities and the interconnection between the modules can be affected by possible changes across the definition of these modules,

since each of the modules is going to be developed in different tasks where they would target more defined functionalities.

5. Specifications and functionalities

Throughout this chapter, each one of the nine modules is going to be analysed in terms of the objectives to be achieved. Furthermore, the different actions that are taking place during the modules' running process are also being described within this section. Based on the different partners inputs following the methodology explained in Chapter 4, each partner will have the opportunity to detail the different functionalities that they have foreseen for their respective modules. Finally, each module would briefly describe the iterations with other TwinERGY modules in terms of data exchange so that it can be set up the basis for the Interoperability platform among the modules that is being developed at the following chapter.

5.1 Consumer Comfort / Well-being Module

5.1.1 Overview

As explained in Chapter 3, the Consumer Comfort / Wellbeing module is going to be designed to infer as unobtrusively as possible the occupants' personal thermal comfort level on the scale provided by ASHRAE 55 standard utilizing physiological and activity data collected by wearable sensors as well as indoor environmental data. Compared to other technologies, such non-intrusive approaches do not disturb occupants and enjoy high acceptance rate by them. Eventually, the personal thermal comfort level as well as the corresponding thermal tolerance will be incorporated into the consumer Digital Twin thus, creating a human-in-the-loop system capable to optimizing the use of domestic conditioning systems, but it can also be applied to building management systems. In the context of the project, Consumer Comfort / Well-being covers a range of features such as:

- Personal thermal comfort level
- Personal thermal tolerance / preferences
- Demand flexibility campaigns
- Consumer Digital Twin
- Reduction of CO₂ emissions
- Monitoring of physiological parameters which contain useful medical information.

The actors that could contribute to the smooth operation of the module are listed as follows:

- End consumers / prosumers
- Home environment / energy monitoring module

5.1.2 Detailed functionalities

The main purpose of this section is to define the Consumer Comfort / Well-being module functionalities within the TwinERGY solution. Consumer's Comfort / Well-being Module is responsible for the delivery of the occupant's comfort sensation level comprising a wearable unit for the data acquisition and a backed unit for the data analysis. The wearable unit is low cost, long autonomy wireless device which unobtrusively acquires physiological signals, efficiently estimates the desired parameters (such as heart rate, skin temperature, body acceleration) and transmits them to the backend unit, via low consumption communications protocols (Lora wan) [20]. The backend unit is responsible for storing, sorting, analysing the received data and associating them with demographic data, indoor and outdoor environmental information as well as thermostat setting indications accrued from home IoT devices towards assessing the occupant's comfort sensation level and thermal tolerance.

The main functionality of the module is the inference of an index value, placed on a 7-point thermal scale depicting the occupant's comfort level within a specific indoor thermal environment (house, office, etc). A value between -3 and +3 is produced, which actually assesses the deviation from the neutral thermal sensation [21]. The factors that affect the occupant's comfort level are: i) the indoor environmental factors and ii) the individual factors. Specifically, the indoor environmental factors comprise temperature and relative humidity while the individual factors comprise weight, height, activity status, clothing insulation and metabolic rate. Additionally, the module can assess individuals' thermal tolerance by taking into account their thermal behaviour feedback. Moreover, the module feeds the entailed information to several entities such as the Consumer Digital Twin and the Building Digital Twin. Below the required by the module input data are depicted:

Table 4: Input data required by Consumer Comfort/Well-being Module

Input	Description	Origin
Weight	Occupant's Demographic data	CDMP
Height	Occupant's Demographic data	CDMP
To, Ho	Outdoor Temperature, Humidity	CDMP
Ti, Hi	Indoor Temperature, Humidity	CDMP
Clo	Occupant's Clothing Insulation	CDMP

Tth	Thermostat Temperature Setting	CDT
HR	Occupant's Heart Rate	CMDP
Tsk	Occupant's Skin Temperature	CMDP
Xi,Yi,Zi	Occupant's Body Acceleration	CDT

The envisaged initialization process regarding the comfort/wellbeing module is:

- A wearable unit shall be provided to the end – user / occupant.
- The end – user / occupant will complete and submit a registration form.
- The end – user / occupant will confirm the email address with an auth key link.
- The end – user / occupant will complete and submit a demographics data form.
- The end – user / occupant will complete and submit a preferences form.

By completing all the steps above, the end – user occupant is going to have access to the comfort / well-being module. Then, the wearable unit is properly setup to transmit data that integrate the ID of the unit, which matches the stored data will the User ID. These specific features are going to be further explained as follows within a brief description. Nevertheless, this module is going to be further developed at Task 7.2 “Consumer Comfort / Wellbeing Module”.

Login for end-users

End users (occupants) will be able to login into the platform to access the functionalities that the module can provide. The access to the module is done by a username and an assigned password. This first screen is linked to the next functionality, which is the creation of an account. Furthermore, it will allow the reset of the password if the user can no longer remember it. The login part is intended to check the username and the encrypted password and return a session token if the call has been successful. On the other hand, resetting the password generates a new one that is sent by an email. Below, related mock-ups are provided (Figure 11).

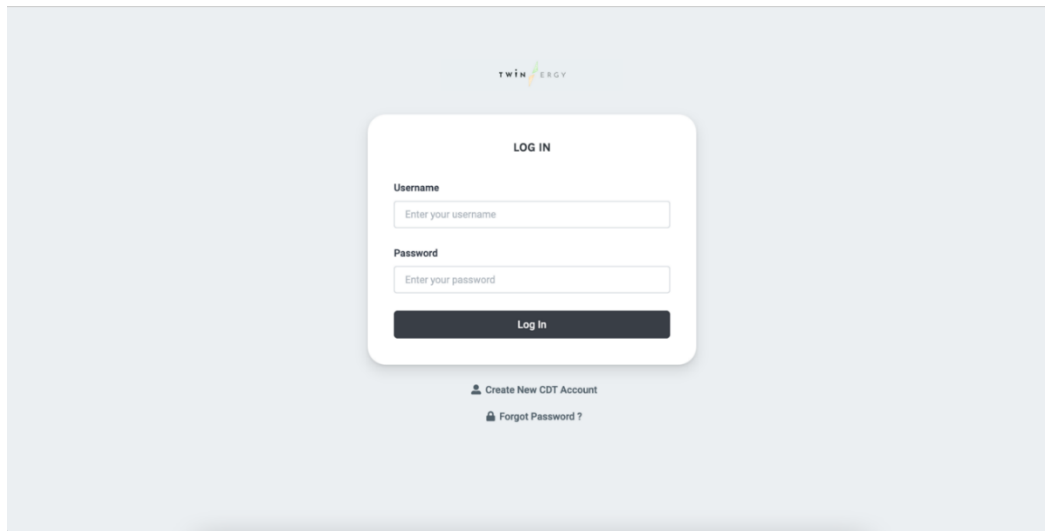


Figure 11: Login and access screenshot for the Consumer/Well-being module

Creation and configuration of the account

The creation of the account is going to be a prerequisite to access the functionalities of the module. This functionality is able to check the data in the creation form and returns a true value when the account has been created and validated. On the other side, the configuration of this account is performed in a separated section of the module through which the user can feed in the module the requested info as well as define and configure the interfaces). Figure 12 and Figure 13 show how this functionality is viewed on the application.

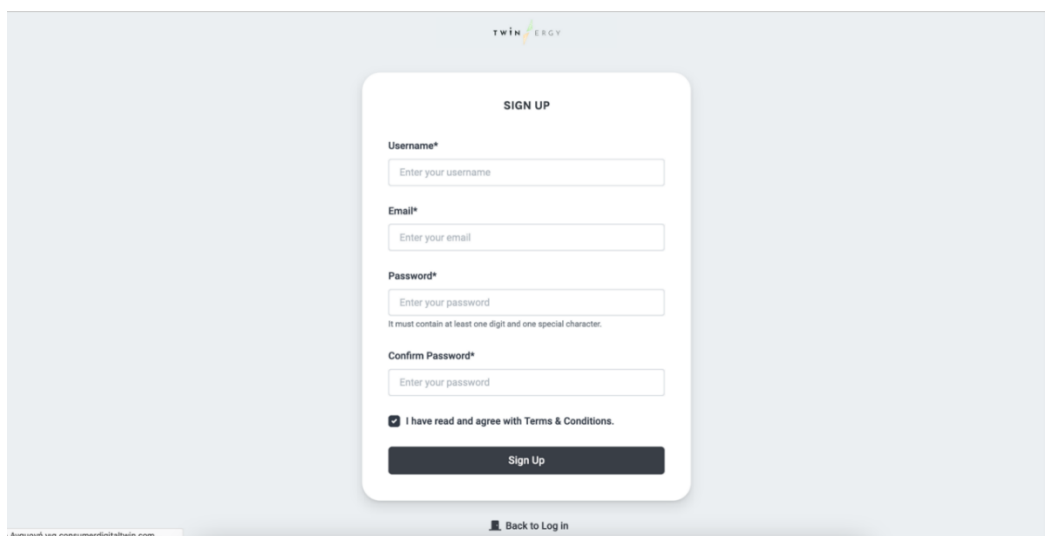
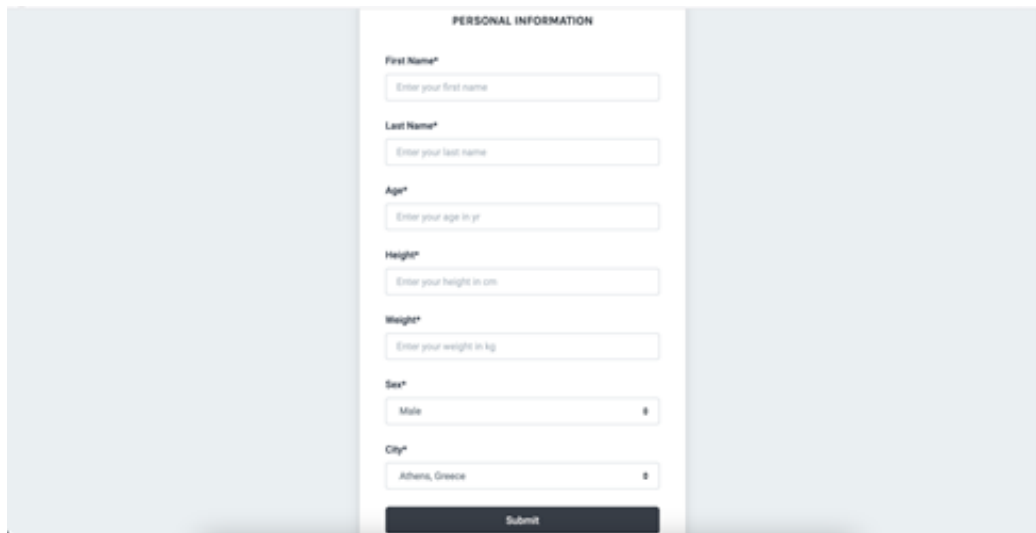


Figure 12: Screenshot for the configuration and creation of an account



The screenshot shows a web form titled "PERSONAL INFORMATION". It contains the following fields:

- First Name***: Text input field with placeholder "Enter your first name".
- Last Name***: Text input field with placeholder "Enter your last name".
- Age***: Text input field with placeholder "Enter your age in yr".
- Height***: Text input field with placeholder "Enter your height in cm".
- Weight***: Text input field with placeholder "Enter your weight in kg".
- Sex***: Dropdown menu with "Male" selected.
- City***: Dropdown menu with "Athens, Greece" selected.
- Submit**: A dark button at the bottom of the form.

Figure 13: Screenshot for the configuration of an account for the Consumer/wellbeing module

Handling of operation and connectivity issues

Following the configuration of the wearable unit and the establishment of a secure connection to the backend unit, data start flowing amongst them. Aggregated data comprise heart rate, activity status, skin temperature, metabolic equivalent, clothing insulation factor, indoor / outdoor conditions, and operational parameters, such as battery alert etc. The process of inferring comfort level and thermal tolerance occurs in the backend Consumer Digital Twin.

Comfort Level and Physiological Data Monitoring

The occupants shall have the opportunity to monitor their comfort level along with the physiological data shaping that value. More explicitly, visualized data in the form of charts (e.g. line charts, bar charts, etc.) and cards will be available from the Comfort / Well-being Module for them to observe. Figure 14, Figure 15 and Figure 16 show screenshots regarding the occupants comfort level and physiological data monitoring.

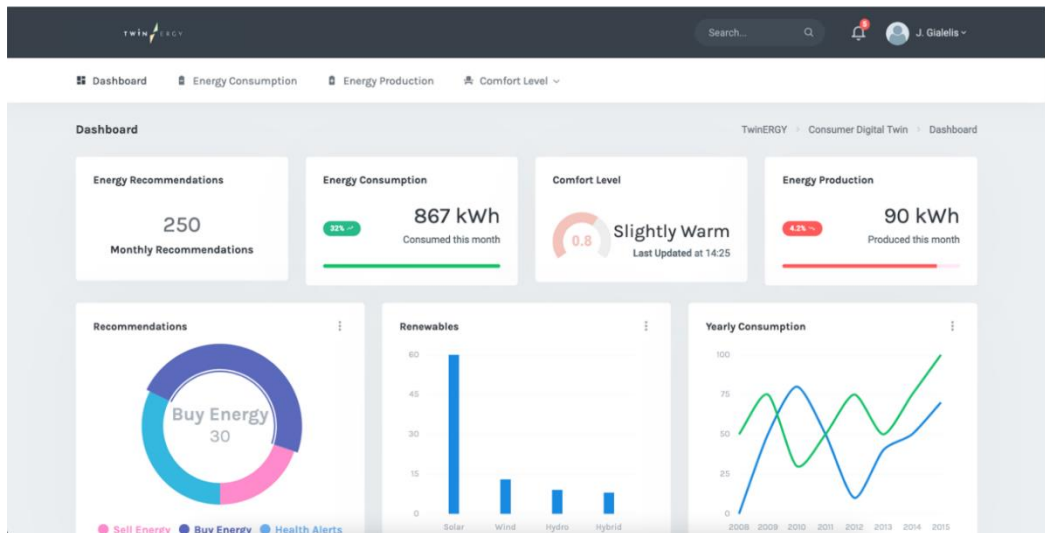


Figure 14: Screenshot for the occupant's last comfort level value

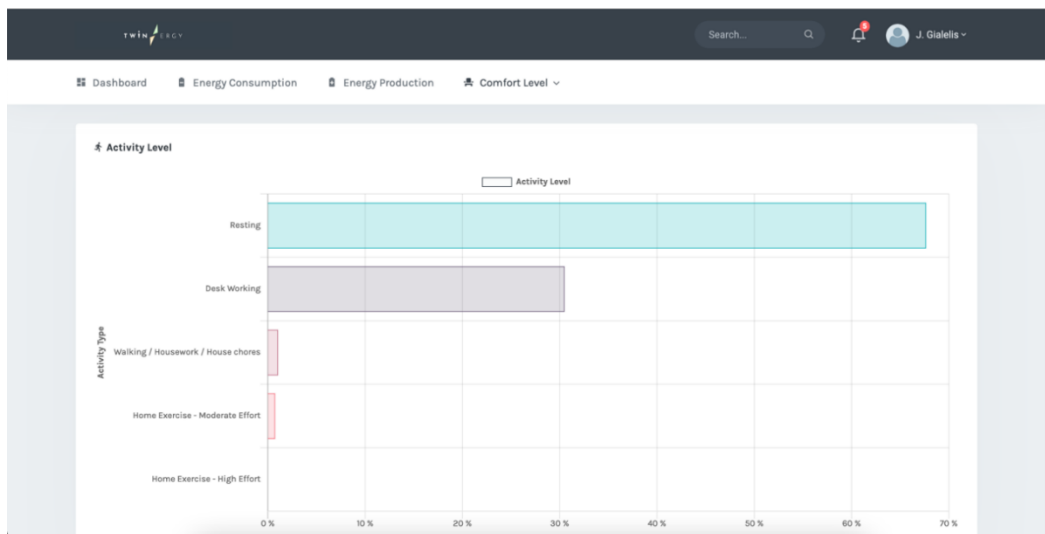


Figure 15: Screenshot for the occupant's activity level

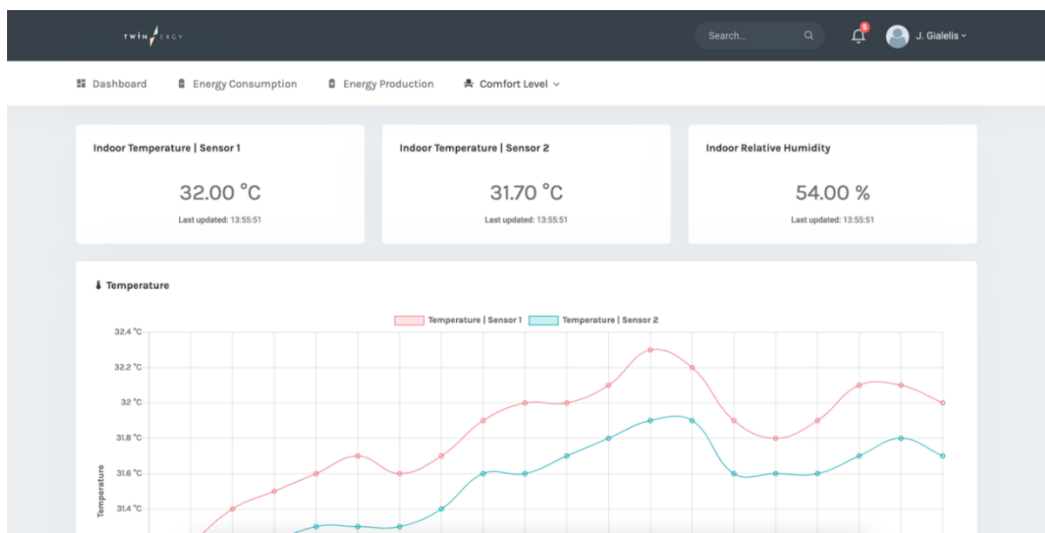


Figure 16: Screenshot for the occupant's indoor environmental factors

5.1.3 Interaction with other modules

Consumer Comfort / Wellbeing requires data accrued from the Home & Tertiary real-time Energy Monitoring Module, as following:

Table 5: Data accrued from other modules at Comfort/Well-being module

Input	Description
To, Ho	Outdoor Temperature, Humidity
Ti, Hi	Indoor Temperature, Humidity

5.2 Consumer demand flexibility profiling Module

5.2.1 Overview

As described in Chapter 3, the Consumer Demand Flexibility Profiling Module is intended to facilitate the calculation of flexibility for individual buildings or consumers, both in terms of implicit flexibility (i.e. the actions taken by a consumer in response to dynamic conditions, such as price signals, for example) and explicit flexibility, which refers to automated actions that are managed and dispatched by an aggregator.

At their core, identifying and leveraging flexibility are optimization problems, which are defined by their inputs, constraints, and objective functions. In the context of the TwinERGY project, flexibility actions and the associated objective function optimizations will be completed at the Digital Twin level. A hybrid approach will be taken to identify the relevant inputs for each building, with real-time data from the demonstration buildings, supplementing the physics-based model components of the DT platform as well as inputs from other modules such as the Transactive Energy Module, where dynamic pricing may impact on the optimization solution, and external factors such as the local weather conditions. The constraints will include the physical capabilities of the equipment, the comfort metrics & associated user preferences and will leverage static information with respect to component and system performance metrics, as well as dynamic metrics such as battery charge/discharge level for example. In addition to these factors, the preferences of the consumer, as well as their willingness to participate in flexibility actions will provide a key constraint to the implementation of flexibility of the tool. This User Feedback will be gathered through an interaction with Consumer Comfort/Well-Being and will ensure that any flexibility actions represent the preferences of the user with respect to their comfort, their priorities in terms of operating their residence and their willingness to participate in flexibility within their building. Finally,

the objective function is the solution for which the system is being optimized for. The TwinERGY project has many objective functions that may be used by the flexibility algorithm. These include but are not limited to:

- Minimise total energy consumption.
- Minimise total CO2 emission.
- Minimise total energy costs.
- Maximise share of renewable energy / self-consumption.
- Maximise/minimise machine utilisation.
- Maximise share of heat recovery.
- Maximise efficiency factor of the different energy types.

It is anticipated that, for the purpose of the TwinERGY project, the flexibility algorithms will be integrated entirely within the DT engine, allowing for the platform to seamlessly leverage the power of the DT platform. As a result, flexibility calculations will be undertaken concurrently with the prediction functionality of the DT to ensure that the forecasted energy consumption that will be used within other TwinERGY Modules, is as accurate and representative of the actual conditions in the pilot sites as possible. As a result, Consumer Demand flexibility profiling is intended to perform as a read-only, cloud-based dashboard in which the user can obtain information regarding how flexibility actions are being implemented in their buildings. Although the design of this dashboard is ongoing and remains in flux, it is anticipated that the following building level information will be displayed.

- Summary of Energy Consumption over a Specified Period, including proportion provided by Renewables.
- Forecasted Energy Consumption for the Following Day.
- Forecasted Renewable Energy Generation for the Following Day.
- Identification of Flexible Loads for the Following Day.
 - Proposed HVAC System Settings for Optimized Flexibility Conditions.
 - Identification of Battery Charging/Discharging Potential.
 - Identification of Optimum Usage Time for Using Flexible Appliances.
- Outline of Consumer Flexibility Preferences.

5.2.2 Detailed functionalities

It is anticipated that this module will contain limited functionality, operating primarily as a read-only cloud-based dashboard platform that provides the user with information regarding their current and forecasted energy consumption & generation, preferences

for implementing flexibility and proposed flexible actions. The primary computational actions will be implemented within the DT as a core functionality of the energy forecasting process for the TwinERGY platform. To this end, the process flow for computing the consumer flexibility will be described loosely in the following sections, while also describing the core requirements of the Module itself. Consumer Demand flexibility profiling module will provide the following functionalities to the user:

- Login page for end-users where they can log in to view the flexibility within their building.
- Creation of a user specific account that represents their building.
- A number of informational dashboards that provide the user with an outline on various energy and flexibility related data for their building.

Log-In Page

The first step in gaining access to the module's Interface is completed through logging into the platform portal. It is intended that this module will be a web-based platform that is accessed through a web browser, such as Google Chrome, Mozilla Firefox or MS Edge. The login page will be accessed either through a central TwinERGY platform webpage or directly via its own URL. On this page the user will be asked to provide their unique username and password in order to access their specific building dashboard within the module. A mock-up of a potential log-in portal for this module is presented in Figure 17.

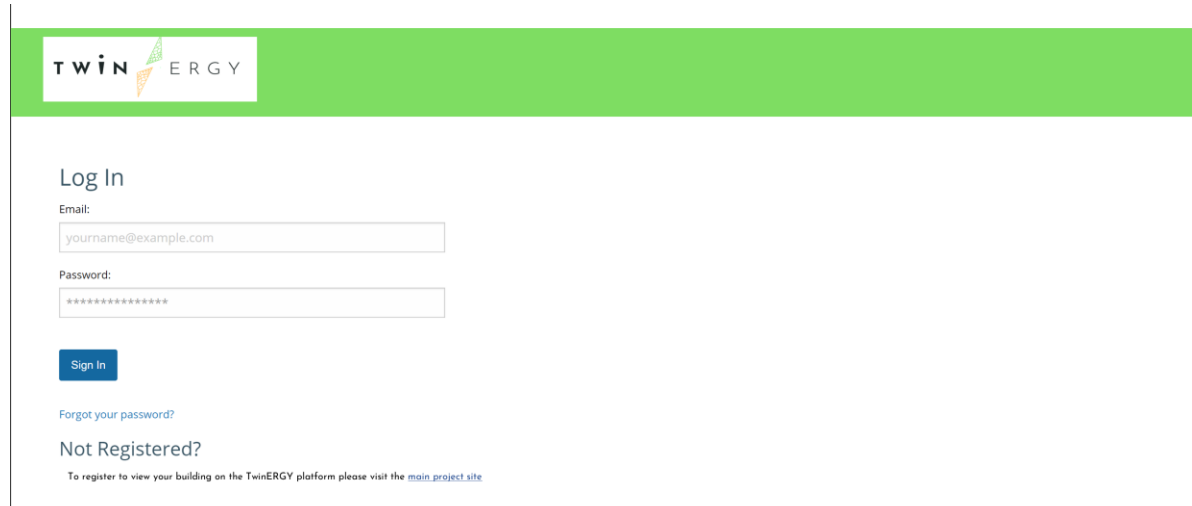


Figure 17: Mock-Up of a potential log-in page for consumer demand flexibility profiling module.

Once the user successfully enters their credentials, they will be redirected to the home page of the module. Should the user forget their password or have other difficulties logging into the page, a "Forgot Password?" link will be provided. This link will forward the user to a password recovery page where they will be able to complete a password

recovery process and reset their password in order to access their account. This process will be completed in accordance with current GDPR and data protection best practices. In the event that the user is logging on for the first time, they will be asked to follow a link created their TwinERGY account.

Account Creation

In the event that the user doesn't have an account with the TwinERGY platform or has not visited the platform interface previously, they will be invited to click a link to "Create an Account". Once this link is clicked, the user will be forwarded to a unique landing page in which they will be able to insert their relevant information to create an account. The user will be able to input their address in order to identify their building and, following verification of their identity and address will be enrolled in the TwinERGY platform. At this point, the user will also be able to define an account recovery mechanism in the event that they are locked out of their account. This process, as well as the storage of all personal information and data will be implemented in accordance with best practice GDPR and data protection guidelines.

Landing Page and Informational Dashboards

Once the user has correctly logged into the TwinERGY Consumer demand flexibility profiling webpage, they will be automatically redirected to the landing page, on which a virtual representation of their building will be displayed to the user. The user will then be able to scroll down the page to review a number of pre-set, building specific dashboards that present them with information related to the performance of their building, as has been highlighted in the previous section of this report. The information displayed through these dashboards will be accessed by the Module through an API that is linked back to the DT platform through the iSCAN system, which is being used within TwinERGY to support the DT through the storage of data. As a result of this, real-time, up-to-date data will be presented to the user to inform them of their current building consumption, RES generation, forecast energy consumption and available flexibility. Although the design of this dashboard and the module itself has yet to commence, it is anticipated that a range of data visualization techniques will be reviewed and researched to ensure that the information is displayed in an appropriate and user-friendly manner to maximize the use of the module within the overarching TwinERGY platform. A potential sample dashboard design is presented in Figure 18 below.



Figure 18: Potential dashboard interface design strategy for Consumer demand flexibility profiling.

Leveraging the DT to Calculate Consumer Flexibility

The TwinERGY platform is based on the use of DT to forecast energy consumption at the building and neighbourhood level. The DT comprises physics-based energy models of each of the pilot sites, which are developed using the systems and loads within the building. Once the initial building model is complete, it is then calibrated using actual occupancy use patterns and settings, real weather conditions and metered data to act as a virtual representation of the building itself, the Digital Twin. This DT can then be used to undertake tasks such as forecasting and predictive analysis, “what-if” analysis, load optimization and flexibility calculation.

Once the DT has been created, through the use of site-specific information as provided by the pilot sites, as well as using actual weather conditions and energy consumption data, it will be used to compute the forecasted energy consumption for the building. This process will be completed using forecasted weather conditions, as well as the user preferences with respect to internal comfort conditions that have been defined through Consumer Comfort/Well-Being module. It is anticipated that the output from this module will be used as one of the optimization constraints within the building, enabling for the optimization of the building’s energy consumption with respect to their desired comfort. In addition to these preferences, the user will also be asked for their willingness to participate in flexibility actions, which will also be communicated back through the user preferences. The users will also be polled on which objective function they would like to optimize their building performance for, ensuring that the inputs to the flexibility optimization algorithms are fully defined with respect to the users’ goals and preferences.

Once the preferences have been defined, the DT will access the dynamic energy pricing that has been calculated by the Transactive Energy Market. This information will be used as an additional objective function to ensure that the flexibility actions proposed by the DT can present the best value for money to the user. Finally, the DT will access the forecasted weather conditions for the following day. Once this information has been gathered, the DT will run its simulations for the day ahead, forecasting both the energy consumption of the building but also the potential generation of any RES that is installed on the home. This step will occur iteratively as the flexibility algorithms run through multiple simulations to identify the most optimal solution for leveraging flexibility in a manner that is most consistent with the users' defined preferences.

Having identified the most appropriate flexibility dispatch for the following day, the DT will record the final strategy and output it to iSCAN as a time-series data stream where it is accessible to any other module. It is anticipated that this information will be automatically pushed, through the use of APIs to both Neighbourhood demand flexibility profiling and Home & Tertiary real-time Energy monitoring for use by those respective modules. The Consumer Demand Flexibility Module will also access this information and display it to the user through its dashboard.

Regarding the inputs that this module is going to have, it is just worth mentioning that this module will act as a read cloud-based dashboard into the Digital Twin (DT). According to the Figure 2, this module is going to have access from the DT via the iSCAN database. So, the inputs for the flexibility calculation will further be analysed in WP6: Development of Digital Twin Platform & System Dynamics.

5.2.3 Iteration with other modules

As stated previously, Consumer demand flexibility profiling module itself will not be used to complete calculations and determine the flexibility of the buildings. Instead, this process will be completed using the DT and its physics engine. Based on this distinction, it is anticipated that the flexibility algorithms, when integrated into the DT engine, a number of the modules will be required to interact with these DT based algorithms, both in terms of receiving information as inputs to the flexibility calculation to providing inputs to other modules. The flexibility algorithms will receive input, constraint and objective function parameters and limits from a range of sources, including through the output of other modules. Furthermore, the forecasting and identification of flexibility in the building level loads will provide the inputs to other modules within the TwinERGY platform. Consumer demand flexibility profiling module itself will then act as a read-only cloud-based dashboard that indirectly interacts with other modules through its

presentation of the flexibility data associated with the relevant pilot building. These interactions are as follows:

Consumer Comfort / Well-Being Module

This module will be responsible for identifying and defining the comfort criteria and user preferences that will be used to optimize the flexibility within the building. User requirements with respect to comfort and IAQ conditions, as well as their willingness to participate in flexibility actions will provide the constraints required to identify the optimized flexibility strategy for the building, while also ensuring that the flexibility actions provided to the user are fit for purpose and consistent with their stated requirements.

Transactive Energy Market

Where a given user indicates a desire to use “Minimize Energy Cost” as an objective function in dispatching flexible actions, the DT will require energy cost inputs. In TwinERGY, the platform is exploring the potential for dynamic energy pricing as a means for creating a Local Energy Market. This dynamic pricing structure, which depends on factors such as building energy forecasting and renewable energy generation, for example, which will be computed by Transactive Energy Module. The output of this module will then be used as an input to the flexibility algorithm to optimize the function with respect to minimizing energy cost.

Neighbourhood Demand Flexibility Profiling

In order to identify flexibility at the neighbourhood scale, will provide its building level flexibility and energy consumption forecasting for a day ahead to Neighbourhood Demand Flexibility Profiling Module, which will use it as a means to defining the available dispatchable flexibility for the neighbourhood. It is anticipated that each individual building will be represented on the Neighbourhood Demand Flexibility Profiling Module.

Home & Tertiary Real Time Energy Monitoring

The Consumer Flexibility Profiling Module will provide Home & Tertiary Real Time Energy Monitoring with the forecasted Energy Consumption for the building, as calculated by the DT. This forecasted data will be calculated based on the optimal use of the flexibility, based on user preferences and system limitations and the manner in which flexibility was leveraged will be provided to the Home & Tertiary Real Time Energy Monitoring module. This module can then implement the proposed flexibility strategy either through implicit or explicit dispatch strategies within the Module.

5.3 Neighbourhood demand flexibility profiling Module

5.3.1 Overview

The Neighbourhood Demand Flexibility Profiling Module will operate in a similar manner to Consumer Demand Flexibility Profiling Module, however it will use the Community Digital Twin to present a single pane of glass dashboard for the entire neighbourhood. This module will again be used as a read-only, cloud-based dashboard to allow the user to view the flexibility profile within their neighbourhood and will include:

- Flexibility Profile for each Building in the Neighbourhood (see Section 5.2).
- Overview of RES Generation across the Neighbourhood.
- Overview of Energy Storage Capacity across the Neighbourhood.
- Overview of PV Charging Stations and their Capacity/Availability.
- Dynamic Pricing Structures being Implemented in the Neighbourhood at a given time.

As with the previous module, it is proposed that the Community DT will complete the computational processes that are required to identify and profile flexibility within the neighbourhood, while the module itself will provide the user with a dashboard view of the outputs from the flexibility algorithms.

5.3.2 Detailed functionalities

The module will provide the same functionality as that described for the previous module, however, the calculation and profiling of flexibility within the DT will be completed with less input from the user. Furthermore, once the user reaches the landing page, following successful login to the platform, they will not view their building, but instead will see either a nodal diagram of their neighbourhood (Figure 19) or a high level block diagram of the buildings within their community (Figure 20). The manner in which the user manipulated these landing pages is currently being discussed, and further information will be provided in due course.

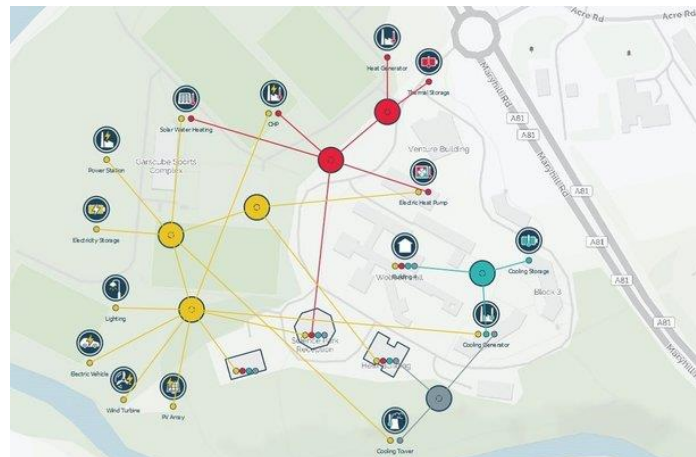


Figure 19: Nodal diagram of the neighbourhood.



Figure 20: Block Diagram of Neighbourhood

The calculation and profiling of flexibility at the neighbourhood level will be completed using similar algorithms as those used in the previous explained module, although the inputs and constraints are likely to change. It is anticipated that there will be less consideration of user preferences at the neighbourhood level as this will have been considered and implemented within the building level flexibility. As a result, flexibility at the neighbourhood will focus on explicit measures, optimizing the use of RES and minimization of GHG emissions at the neighbourhood level, while ensuring that each of the forecasted energy demands from the buildings are satisfied within the neighbourhood, while also addressing the objective functions defined in 5.2.1 but at the neighbourhood scale. Dynamic energy pricing will also act as a key constraint within this DT as peer-to-peer trading, as well as the use of community battery storage facilities will be considered within the optimization calculations with the aim of minimizing the energy cost to the community.

Once the optimal flexibility profile has been identified for the community, it will be returned as time series data to iSCAN where it will be available to all modules,

particularly Module 7.5 DER Management, where the flexibility strategy will be implemented within the neighbourhood.

Regarding the inputs that this module is going to have, it is just worth mentioning that this module will act as a read cloud-based dashboard into the Digital Twin (DT). According to the Figure 2, this module is going to have access from the DT via the iSCAN database. So, the inputs for the flexibility calculation will further be analysed in WP6: Development of Digital Twin Platform & System Dynamics.

5.3.3 Iteration with other modules

It is anticipated that the Neighbourhood Flexibility Profile will have interactions with a number of other modules, both through the receipt of input required to identify and profile flexibility but also to provide input to other modules as follows:

Consumer Flexibility Demand Profiling

The building level flexibility profiling, energy consumption forecasting & building level RES generation will represent a core input to the Neighbourhood Flexibility Demand Profiling Module. This module will provide the building level loads and RES generation that will act as constraints in the calculation of flexibility within the neighbourhood, as well as impacting the dispatch of community level RES and battery storage assets within the module.

TwinEV

The TwinEV module will also provide an important input to Neighbourhood Demand Flexibility Profiling, through the representation of EV charging stations within the neighbourhood. As the user will be able to reserve a charging spot within the community, it is important that this input is provided for the optimization of flexibility within the neighbourhood.

Transactive Energy Market

As with Consumer Demand Flexibility Profiling, the Transactive Energy Market's dynamic pricing structure is an important input into the flexibility profiling at the neighbourhood level. The utilization of community owner RES production, battery storage and EV charging stations will dictate the tariffs and will be an essential input to the flexibility profiling algorithms that are leveraged by the DT.

Home & Tertiary Real Time Energy Monitoring

Since Home & Tertiary real-time Energy Monitoring will provide real-time energy monitoring as well as providing the user with implicit guidance on how best to operate

the building, it is possible that the flexibility profile identified by Consumer Demand Flexibility Profiling will not be fully realized in practice. Home & Tertiary real-time Energy Monitoring will provide input with regards to the adjusted forecasted energy consumption, that is any variations from the output of Consumer Demand Flexibility Profiling that are inconsistent with the actions implemented by the user. This will be used by Neighbourhood Demand Flexibility Profiling in the event that there is a large discrepancy between the forecasted and actual energy consumption at the building level doesn't have a major impact at the neighbourhood level.

DER Management

The Neighbourhood Flexibility profile will be provided to DER management module, who will then analyse and implement the proposed measures at the community level. They will provide grid dispatch and control strategies to ensure that the neighbourhood flexibility objective functions are satisfied.

5.4 Home & Tertiary real-time Energy monitoring

5.4.1 Overview

The goal of the *Home & Tertiary real-time Energy Monitoring Module* is the development of a user-friendly building Energy Management system aiming to support users managing self-consumption and maximize self-sustainability. Additionally, it increases residential awareness and engagement to demand side management programs. Furthermore, it reduces reluctance and fear of participation in DR programs.

The Home/Tertiary EMS is going to leverage data about energy demand, renewable production and storage system at building level. Based on the energy monitored and forecasted patterns the module will find the optimal flexibility solution to improve self-consumption. Whenever is feasible, the main and smarter electrical appliances are going to be remotely controlled (eventually through smart plugs), in order to optimize the energy patterns taking into account renewable production forecast and applying dynamic pricing policies. Moreover, the user's special needs and preferences, will enter the optimization loop, preserving comfortable and healthy indoor conditions.

The outputs offered through a user-friendly GUI of a web and mobile application will drive the users into a positive state of mind regardless the participation in demand response programs. With the true horizon to trigger a social pressure loop and a word of mouth about the benefits of these energy efficiency processes.

In the context of the project, EMS covers a range of features such as:

- Behavioural DR and Energy Consumption Reduction
- Self-consumption increasing
- Economic savings
- Reduction of CO₂ emissions
- Bills Optimization
- Focusing on savings, comfort and peak shaving.

The actors that could contribute to the smooth operation of the module are listed as follows:

- Energy final users
- VPP operator
- Retailer
- DSO operator

5.4.2 Detailed functionalities

The main purpose of this section is to define the EMS module functionalities within the TwinERGY solution. These functionalities, as commented before, are based on the different objectives in Section 3; the system produces a set of outputs that are then made available to the user through a mobile and web application. The scenario depicted by the application is:

- End-users' account Login/Configuration
- Configuration of the building
- Main features and electrical appliances inventory
- Energy monitoring graphs
 - Historical
 - Forecast
- Energy billing optimization
- Optimal flexibility solutions

These specific functionalities are going to be further explained as follows within a brief description. Nevertheless, this module is going to be further developed at Task 7.4 "Home & Tertiary real-time Energy Monitoring Module".

End-users' account Login/Configuration

The first step, essential for any web application, is identifying the user (Figure 21), which must be preceded by registration. During the registration phase, the only confidential information required is Name, Surname, and email address (Figure 22).

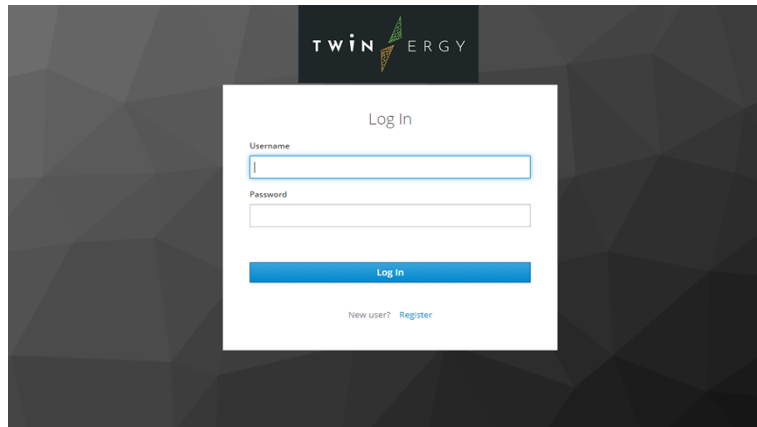


Figure 21: Log in the Home/Tertiary EMS module

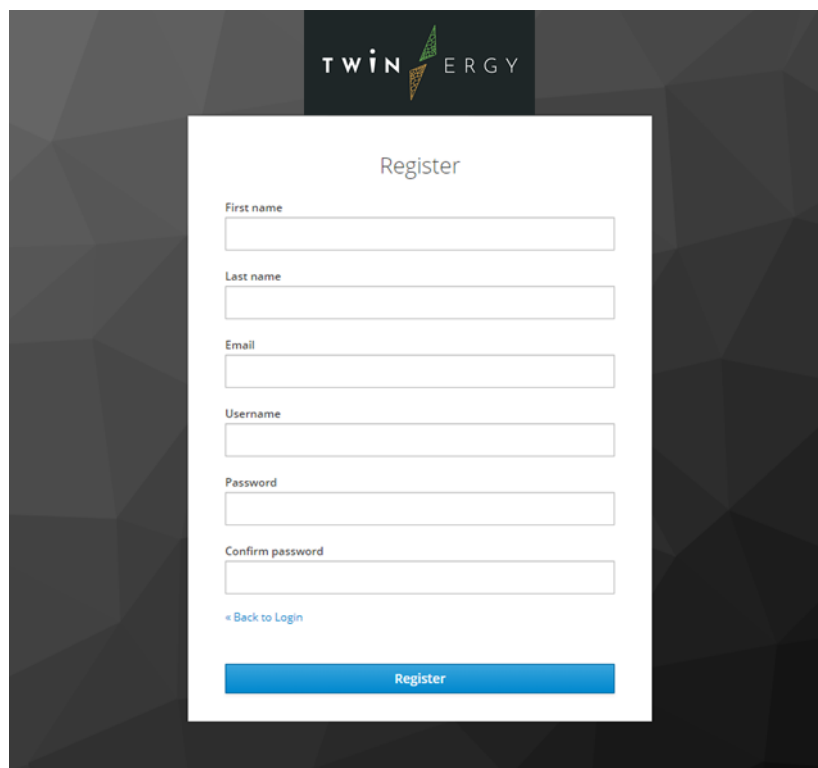


Figure 22: Registration in the Home/Tertiary EMS module

Configuration of the building

During the asset configuration, it will be possible to enter a series of information, some of which are mandatory and others are optional. In all graphical interfaces, the data to be entered will be indicated by an asterisk. Among them are recalled:

- Name of the asset
- Typology
- City
- POSTAL CODE
- Heating area [m²]
- Average number of occupants

Optional information, albeit important, not essential elements for operation.

Main features and electrical appliances inventory

For individual electrical loads, the user will have the ability to enter the details of the typical time of use during the days of the week and if their flexible use is permitted, with indications organized by hourly intervals and divided for each day of the week. If the load is associated with a monitoring device, the cycle of use will be defined by overwriting the information previously provided by the user. Power lines and loads are organized in a hierarchical manner, and therefore they provide information on the individual electrical loads associated with a power line and therefore on the details on consumption. The general specs required are:

- Name of the load (unique)
- Type of load
- Reference asset
- Year of installation
- Typical use cycles of the appliance during the week

The EMS Module allows to enter an hourly usage detail, for each day within the week. Furthermore, by checking the availability of the appliance for use with flexible hours, an additional configuration bar will appear, to specify the times during which the user is willing to change his own appliance use routines. Depending on the type of load, additional information will be entered. To create a more user-friendly application, the insertion of the rated power of the devices will be supported by drop-down programs, for the most common loads. Below is the list. However, the possibility of a personalized entry by the user will be guaranteed.

Energy monitoring graphs

In the dashboard, the consumption data for the entire asset is going to be provided, with a chromatic scale that allows the distinction of the individual energy meters installed.

The data in the GUI will be provided with different aggregation level and paired with trends and analytics.



Figure 23: Energy monitoring graphs

Also an indication of the energy consumption of the entire asset can be provided, related to its heated surface. A speedometer display is available for the representation.



Figure 24: Speedometer display for heated surfaces

Forecasting

Through the dashboard, the possibility to show the forecasts of the energy consumption and/or productions with different aggregation details, will be offered. In the next figure (Figure 25) a graph of the asset consumption data with an hourly aggregation for an entire week, is depicted. The cyclicity of the consumption patterns during the weekdays and the identification of the base load during the night and on weekends, is presented below.

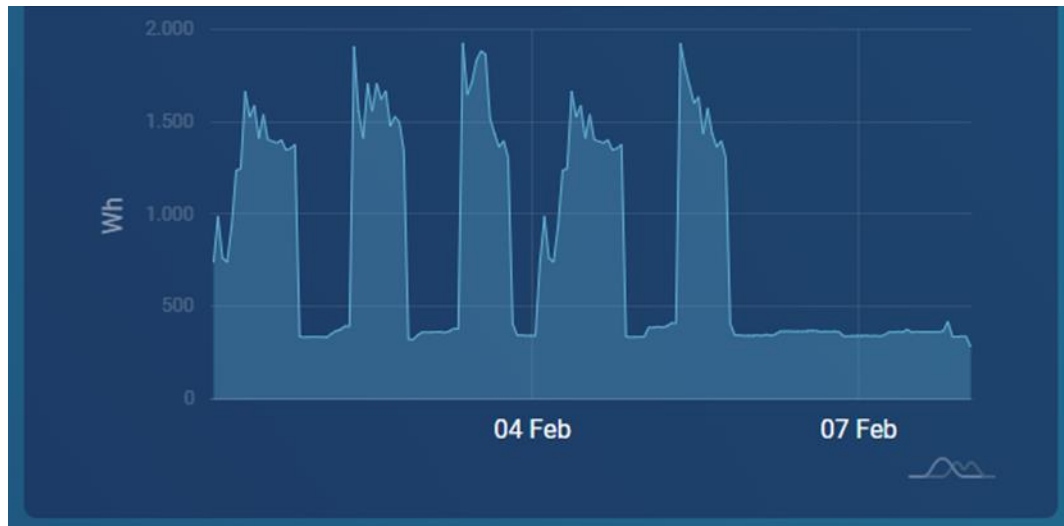


Figure 25: Energy forecasting

Energy Bill Optimization

As long as the prices components in the energy bills and the cost formula rules are available, the module is able to verify the correct checking of the bill, comparing it with the data provide from the energy monitoring system. In the Italian Pilot, also the Optimal billing electrical energy contracts will be provided to the end-user in relation with its energy patterns monitored.

Optimal flexibility solutions

Finally, the Optimal flexibility feature. It will be based on the IES module flexibility optimal solutions and using them for handing over a time series data or instruction list to present to the user and/or automatically implement the actions. It focuses on optimization in the temporal distribution of loads during the day, accordingly to the user comfort and taking into account:

- Reduction of energy consumption
- Money savings
- Smoothing of power peaks
- Minimization of user discomfort

The main output data in the dashboard are presented as follows:

- **Total initial expenditure in the canonical appliances use:** It comprises a fixed component (which depends on the optimal solution available) and the real component (which depends on the real Users behaviour)
- **Optimized spending:** Also divided between real and optimal component, it provides savings as a percentage.
- **Optimized hourly distribution of individual appliances during the day of the week:** A heat map shows in bright red the periods where the smoothed power peaks are recorded thanks to the redistribution of the loads.
- **Optimized distribution of each load during the week:** For each electric loads, the pre- and post-optimization cost and the savings are going to be achievable by the user. In this way, the user is left with the evaluations in terms of costs VS benefits, connected to the variation or their own use routines for all certain appliances.

The module requires a set of inputs to calculate the optimal flexibility solution for a specific building. These inputs are listed in the following table (Table 6):

Table 6: Requirements H&T EMS

Input	Description	Origin
Energy Demand	Active energy demand monitored for different aggregation level (Entire facility/power lines/single appliance)	CDMP
Demand forecast	Forecast of demand over the next 24 hours and 1 week	M2 - IES
Production forecast	Forecast of production over the next 24 hours and 1 week	M5 - THOWL
Building supply max. power	Maximum power to be delivered simultaneously, considering, demand and production.	CDMP
Building supply min. power	Minimum power to be received simultaneously (Base load)	CDMP
Energy price	Curve of energy price	Pilots and M9-WEC

5.4.3 Iteration with other modules

H&T EMS module is expected to interact with other modules and its calculations to obtain valuable data sets for its own interest.

Consumer and Neighbourhood demand flexibility profiling

These two modules are being developed by IES. The EMS module requires the Forecast Energy consumption only at domestic level. These predictions would allow to determine the expected demand profile within a period. This is a valuable input that would contribute to the calculation of the flexibility algorithm. In addition to this, based on the aggregated demand monitored data, it is possible to estimate the disaggregated (single appliances) profiles and the consequent forecasts. Furthermore, the optimization algorithm requires as an input the production forecast within the following 24 hours and for the next week. The difference between optimal and real energy user patterns in output, it is going provide as input for the M3 Neighbourhood demand flexibility profiling (IES).

Transactive Energy

This module is being developed by WEC. This module is a trading decentralised platform that will provide novel block-chain enabled services to the transactive energy market. Whenever is possible, the EMS module would perform an optimization based on the curve of the dynamic energy price. This module is expected to provide these prices to EMS module in order to help the flexibility algorithm into taking into account the different cost tariff, the energy production from renewable and the impact on the power grid.

Consumer Comfort / Well-being Module

This module is being developed by UoP. This module, using wearable wireless devices, responsible to monitor and acquire physiological signals and extract the various vital signs after suitable processing (such as heart rate, breathing rate, body temperature, sweating index, etc). Based on these physiological data and some indoor parameters such as temperature and humidity, this module is going to provide a comfort parameter inside a scale of values. The curve of comfort is going to be used as input in the EMS module towards finding the optimal flexibility solution. The main comfort type, related to the energy efficiency is considered the thermal comfort, but also other types such as the acoustic one are going to be calculated.

5.5 DER management Module

5.5.1 Overview

Renewable Energy Sources (RES) can, in most cases, do not generate power at will and it is therefore important to invest into technologies that allow to fully harvest these energy reserves whenever they are made available. Thus, it is necessary to utilize methods that can make such energy sources accessible for longer periods of time and maximize their consumption. This requires accurate forecasts about current and estimated energy consumption, as well as measures and strategies for an adaptive and efficient energy distribution.

There is a major imbalance between the production and the consumption of RES. Especially in regions where a large number of RES systems are deployed, there may be periods where wind turbines or PV-systems generate more energy than is needed or can be consumed at the time. This can lead to instabilities within the power grid and often requires a temporary shutdown of the RES systems. Unfortunately, this approach results in a massively wasted RES-potentials of up to several TWh per year (e.g. 6.5 TWh in 2019 in Germany [22]). It is therefore crucial to search for and find smart approaches to making the power demand more flexible and more responsive.

For that, a DER management module will be developed that can transfer measured and estimated energy levels, consumption forecasts and other relevant grid information into a network model which projects the current grid status to calculate and display its status in real time. This way, grid bottlenecks will be reliably detected, reported and acted upon. Supplementary estimations of the expected loads across the grid and the expected generation of RES are integrated, so that critical network conditions can be predicted and mitigated by targeted switching or similar countermeasures. During regular operation, dynamic signals are calculated for all network participants and distributed across the network to influence the power flow, such that its proportion of RES is maximized. Feedback loops caused by unexpected behaviour change among consumers must be measured, detected and their impact on the network mitigated. The field of action for the DER management module is therefore on the same level as the microgrid controllers of the DSO's and requires a close cooperation to execute the corresponding circuit changes within the power grid.

5.5.2 Detailed functionalities

The following presentation of the DER-Module functionalities is based on an example day of the small village Hagedorn in Steinheim (Westphalia) in Germany. The village has 38 houses with 103 inhabitants. There are more than 10 PV-Systems in a range of 8-

38kW peak. Two independent transformer stations and low voltage grids supply them with electric energy. Due to the state of development, the description of inputs and outputs can differ from the final form of the DER module. The functionalities and objectives will remain. The inputs that the DER module requires to perform its functionalities are listed as follows (Table 7):

Table 7: Requirement DER module

Input	Description	Origin
Smart Meter Data	Smart meter data with Power, Voltage and Current values and grid position	CDMP
Grid information	Grid information, such as node data, limits, etc.	CDMP
RES Asset Data	RES Asset data with type, nominal power and relevant information for production prediction (for example the orientation of a PV-System)	CDMP
DER Asset Data	Data about the DER-Assets controllable by the grid operator for bottleneck countermeasures and overall optimisation of the use of local renewable energy	CDMP
Weather data	Weather data for	CDMP
Consumer demand flexibility information	Consumer demand flexibility at a specific part of the grid	Consumer flexibility module
Neighbourhood flexibility information	Neighbourhood flexibility information for demand response signal calculation	Neighbourhood flexibility module

Grid Status Calculation

The grid status calculation is the core element in the DER module. Every other functionality depends on this function or uses it to deliver its functions. The grid status calculation will support different depths of calculation due to different data assets in the pilot sites. Its target is to determine the state of the grid. On the lowest level, the grid status is calculated on the measured smart meter data and scaled to the number of

households in the area. On the highest level, it uses the information of the smart meters in the grid and maps it onto a network model of the underlying grid. Its objective is to determine the state of each node in the grid, measured or calculated. This calculation needs to be executed in real-time for all services within the DER module.

Grid bottleneck detection

Build upon the grid status calculation, the bottleneck detection uses technical information of the grid (maximum loads at specific points, voltage limits) to detect bottlenecks such as deviating voltages or overpower situations. Figure 26 shows the voltage at Node 1 (a transformer station) of each phase (L1, L2, L3) and the corresponding limits (V_Min, V_Max). On this example day, the voltage was near the default voltage at 230V. Figure 27 shows the voltage at Node 2, a household next to that transformer station on the same day. It shows a lower voltage on L1 in the night and around 14:00. This could indicate a high energy consumer. Secondly, during the day all three phases have higher voltage levels than the transformer station, which indicates additional energy generation such as a photovoltaic system. In this example, the energy limits are not exceeded and therefore no bottleneck is detected. However, such monitoring technology allows to identify similar situations where set limits are potentially breached.

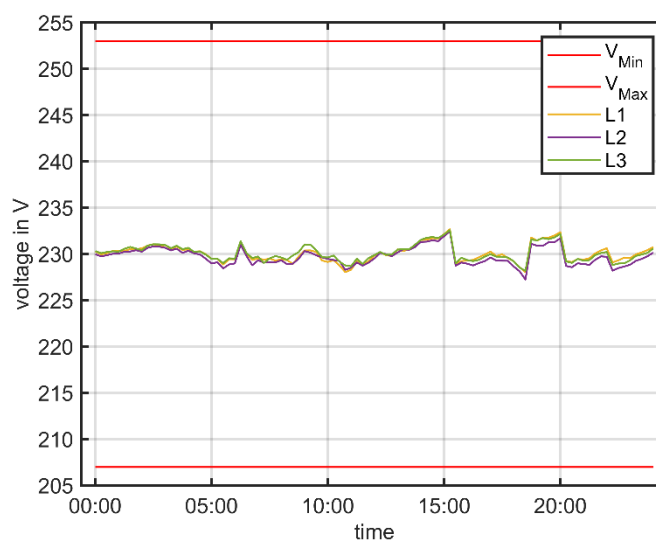


Figure 26: Voltage deviation detection at Node 1.

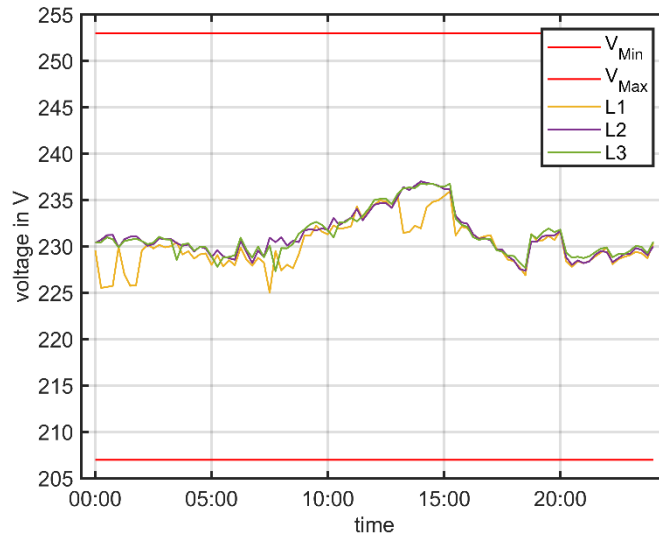


Figure 27: Voltage deviation detection at Node 2.

Load prediction

The load prediction uses historical load data, weather forecast data and information about end-user behaviour to predict future load levels across all relevant grid nodes. The load prediction is combined with the DER energy generation prediction to determine the future grid status and to optimise the RES usage in the local grid. Figure 28 shows the prediction of an example day in a small village with vaguely 50 habitants. The lowest energy consumption is during the night, while the peak load is at midday. The consumption in the evening has a local peak at 20.00. This and similar information can be utilized to accurately predict the grids load levels at different sites throughout a day.

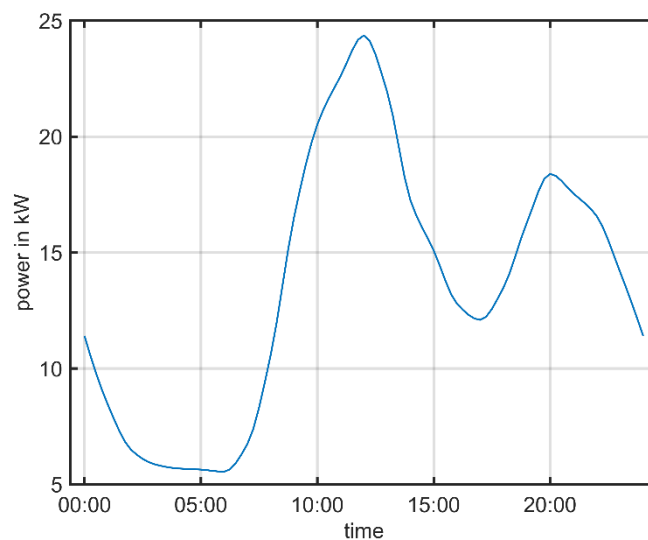


Figure 28: Load prediction

DER production prediction

Based on the local RES resources and the local weather forecast, the estimated RES utilization and subsequent energy generation is calculated. Dependent on the technology (photovoltaics, wind power units, biomass, combined heat and power units, waterpower units), the DER production prediction uses different calculations. Figure 29 shows the DER production prediction on a sunny day in a small village. The generated energy by the wind power unit is very low due to low wind speeds that are predicted by the local weather forecast. The generated power of the photovoltaic systems on the other hand reaches up to 125kW at 12:00 due to predicted sunshine at midday.

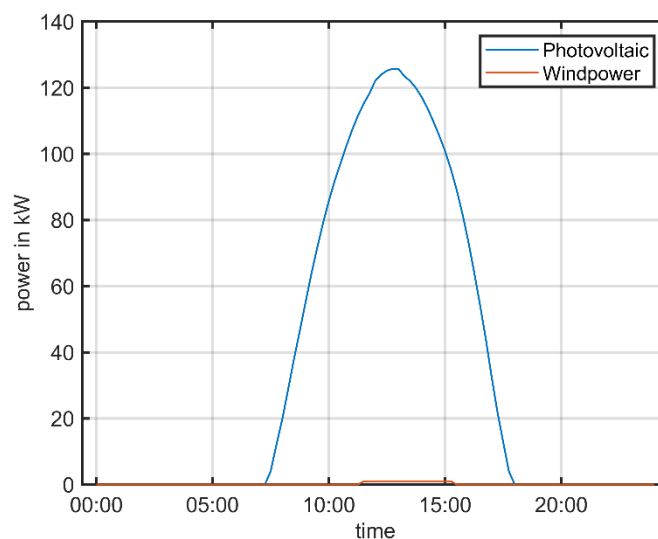


Figure 29: RES production prediction

Grid optimisation through public infrastructures

The demand prediction and the DER production prediction allow to predict the state of the entire grid. This data can be used to calculate the demand from the medium voltage grid and the share of self-consumption. With this information, public infrastructures, such as charging stations and battery storages, can be optimised. The example village is assumed to have a normal energy consumption at night and an energy surplus during the day due to many deployed photovoltaic systems. Figure 30 shows a possible battery power plan. It discharges during the night up to 5:00 and recharges during the surplus time at midday. The charging process helps in decreasing the power surplus at the transformer station and fills up the battery storage to have power buffers available for local demand response. The discharging process similarly helps to stabilize the transformer station performance by increasing the RES share of the whole village and cover energy demands that could not have been shifted to more suitable times through end-user behaviour. If the battery storage is empty, the energy will be provided by the medium voltage grid.

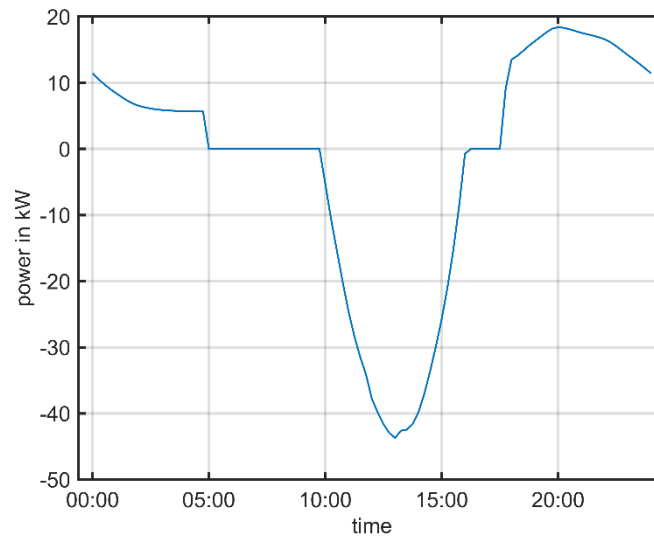


Figure 30: Battery storage predictive control power curve.

Calculation of a dynamic signal for demand response

Another grid optimisation approach is enabling flexibility of the consumers within the power grid. Utilizing the demand and RES generation forecasts, a dynamic signal is generated to indicate to consumers at what time of day their personal energy demand would result in the best possible RES share and grid optimisation. It uses information gathered from profiling the flexibility by the neighbourhood demand flexibility module. This is done by analysing the estimated power of the community after successful optimisation and selecting the best time slots with a corresponding signal. Figure 31 shows the respective power curve at the transformer station for an optimized battery storage. Between 8:00 and 17:00 an energy surplus is predicted and is therefore considered to be the best time for an end-user to engage consumption. As an example, a dynamic signal with 3 levels is shown. Level 1 indicates energy demand from the medium voltage grid, which shall be minimized if possible. Level 2 indicates all times where energy is drawn from the battery storage, or a small energy surplus is present. Level 3 indicates the times where a big energy surplus is forecasted. Overall, the consumers shall be incentivized to shift their loads from the lower to the higher level.

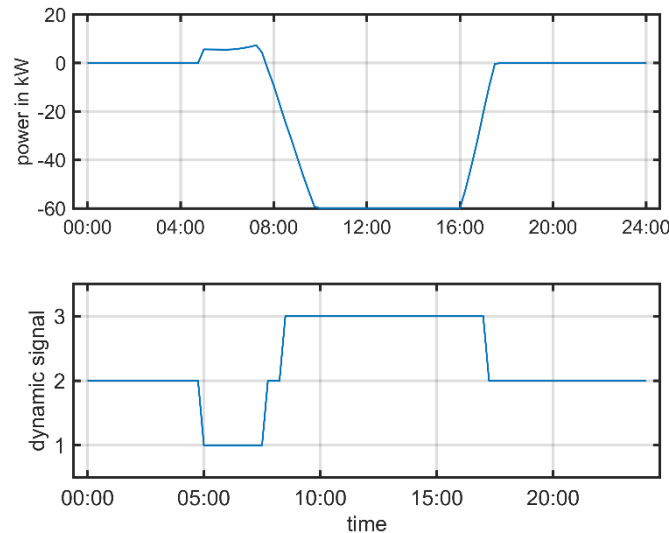


Figure 31: Dynamic signal for demand response

Feedback detection of demand response

The feedback detection uses the current grid information to measure the feedback of the demand response by the consumers. If the feedback becomes too strong, the public controllable devices shall react and adapt their consumption accordingly.

5.5.3 Iteration with other modules

Consumer demand flexibility profiling

The DER-Management module requires flexibility information for countermeasures on local grid bottlenecks and local optimisation.

Neighbourhood demand flexibility profiling

The DER-Management module requires flexibility information of the neighbourhood to calculate the dynamic signal. The flexibility information could be used for bottleneck countermeasures if other grid countermeasures are not available.

Home and Tertiary real-time energy monitoring

The DER-Management module can provide local services (RES forecasting of a specific building) and forecasts of the village for the H&T-Module.

TwinEV

The TwinEV-Module requires the maximum and minimum power, which the grid could supply. This will be calculated within the grid status and bottleneck detection functionalities. Secondly, for RES optimised charging the Module needs to know the forecasted RES energy surplus which will be provided.

Transactive Energy Module

The Transactive Energy Module requires RES forecast/the dynamic Signal for consumer to calculate the value of the consumer demand response.

5.6 Risk Management and event handling Module

5.6.1 Overview

The Risk Management and event handling Module developed inside TwinERGY aims to identify the security gaps, supports the security operation planning and management and helps draw up the adequate preventive actions and countermeasures. The module is based on new analysis techniques that can better consider threats that are based not on individual component failures but on systems theory. In cooperation with UoP, STAM will develop a Risk Management and event handling tool with the aim to minimize the overall risk on the TwinERGY system in a cost-benefit perspective.

The module will be composed by two main sub-modules. The first one will allow performing of a secure operation planning and management, evaluating the possible threats and the corresponding impacts associated to a series of unplanned events on the low level of the grid. According to the outcomes of this first analysis, the second sub-module will allow to evaluate a series of preventive actions and countermeasures to mitigate the expected impacts and minimize the overall risk on the system in a cost-benefit and a consumer-oriented perspective. The module will be designed to cover risk down to asset and customer levels. In the context of the project, the Risk Module covers a range of features such as:

- Anomaly patterns Detection
- Fault Anomaly Detection
- Communication and cyber events detection

The actors that could contribute to the smooth operation of the module are listed as follows:

- Energy final users
- VPP operator
- Retailer
- DSO operator

5.6.2 Detailed functionalities

Risk Management - Scenario Evaluation

Based on the event historical records provided by the pilots or the record collected during the TwinERGY project, a statistical analysis will be carried out. The probability of different scenario will be targeted, and the risk evaluated. Also, existing countermeasures and possible new countermeasures related to the DR will be include in the analysis.

Anomaly patterns Detection

The anomaly detection functionality helps building managers to identify tenant consumption patterns. Anomaly detection benefits tenants by helping them understand how their home actively consume energy. They can then modify their anomalous activities, analyse energy consumption costs and benefits, and eventually reduce their wasteful activities.

Fault Anomaly Detection

Comparing a set of typical power consumption patterns with real the monitored consumption curves, anomalies and faults of the main single appliances (such as the heat pump) will be detected. Also, parameters related to the power supply such as, range of voltage and frequency, are going to be taken into account as Power Quality matters.

Communication and cyber events detection

This functionality indagate the consistency in the communication flows between sensors, appliances, gateway, and the user by the remote interface. The presence of cyber-threats and security lacks will be underlying. The preventive measures, the consequences and the possible countermeasures will be analysed and selected inside a cost-benefits framework. The inputs that the Risk Management module requires to perform its functionalities are listed as follows (Table 8):

Table 8: Input requirement for the Risk Management Module

Input	Description	Origin
Energy Demand	Active energy demand monitored for different aggregation level (Entire	CDMP and M4

	facility/power lines/single appliance)	
Demand forecast	Forecast of demand over the next 24 hours or more	M2
Building supply max. power	Maximum power to be delivered simultaneously, considering, demand and production.	CDMP
Building supply min. power	Minimum power to be received simultaneously (Base load)	CDMP and M4
Peak_Demand_Power_line	Peak demand of power lines monitored in the electrical panel	CDMP and M4
Reactive_energy_loads	Reactive energy of single appliances monitored	CDMP and M4
Reactive_energy_lines	Reactive energy of power lines in the electrical panel	CDMP and M4
Power_factor	Power factor of the power lines in the electrical panel	CDMP and M4
Sub_net_state	Information regarding the relevant risk indicators of each element of the sub-grid	M5
Countermeasures	Set of controls to be applied on a specific sub-grid in a certain timespan as possible countermeasures	M6 and M5

5.6.3 Iteration with other modules

H&T Energy monitoring system

This module is being developed by STAM. This module will gather the energy data provided by the pilots. The energy patterns will be analysed in order to find anomalies also in relation with the DR action and possible DR countermeasures.

DER management

This module is being developed by TH-OWL. This module requires the maximum and minimum power to be supplied considering, non-controllable demand, production, and EVSE-related demand. DER management module is set to provide grid status functionalities such as the expected load and generation in the grid, as well as the grid

status calculation in real time. This valuable information from the grid status is being used in the Risk module as well.

5.7 TwinEV Module

5.7.1 Overview

As explained in Chapter 3, TwinEV module is going to be designed to calculate the optimal State of Charge on EV in terms of minimization of costs and maximization of green electricity to supply. This optimization would be considering the huge potential in terms of flexibility that EV can provide to report benefits to the grid management, in terms of grid congestion management, ancillary services, peak shaving and energy buffering to gather the RES intermittency. In addition to this, EV would be considered to act as a battery (V2G capacities). All these functionalities would be addressed to the EV user through the distribution of a user-friendly interface which it is going to be fully depicted at T7.6 "TwinEV module". Through it, the EV user can perform an optimized charging process for its EV, based on the principles of security and quality of energy performance.

The module will allow the EV driver the selection of a suitable public charging station in which they can proceed with the charging process. The selection of the charging point can be specified based on factors such as dynamic pricing, route cost to the station, arrival times and amount of battery. In addition to this, the module would let EV users to handle the booking of the charging point as well as proceed with the payment of the charging process. The result of this charging process could have a direct impact on the grid management (Voltage and Congestion control), as well as the implementation of RES into the grid. Furthermore, V2G capabilities would affect the development of grid processes [15].

On the other hand, EV in the private field could be used as a distributed storage asset that with the integration to Local flexibility Markets and Demand Response Campaigns within the context of TwinERGY project. TwinEV would help in this case in the assessment of a Smart Charging profile for EV, taking into account Demand Response campaigns from the domestic field. In the context of the project, TwinEV covers a range of features such as:

- Smart Charging of EV
- Vehicle-to-grid
- Demand Response Campaigns
- Participation in Energy Markets

- Participation in Local Flexibility markets
- Voltage Control and Grid Congestions through DSO
- Integration of RES and surpluses
- Reduction of CO₂ emissions

The actors that could contribute to the smooth operation of the module are listed as follows:

- EV user
- End consumers (MV/LV) / Prosumers
 - In the case of private charging case, the EV user and End user will be the same figure.
- Charging Point Operator (Aggregator, Customers, Business...)
- VPP operator
- Retailer
- DSO operator

5.7.2 Detailed functionalities

The main purpose of this section is to define the TwinEV module functionalities within the TwinERGY solution. These functionalities, as commented before, are based on the different objectives in TwinERGY Modules. The scenario depicted by the TwinEV is:

- Login for end-users in which EV users would be able to log into the module to access the application.
- Creation and configuration of an account in which EV users are able to define their device to use data for booking, charging sessions and payment.
- Find the most suitable charging point getting a ranking for the most suitable station.
- Booking a charging station for a future charging session.
- Handling of the charging session process
- Smart charging

These specific functionalities are going to be further explained as follows within a brief description. Nevertheless, this module is going to be further developed at Task 7.6 "TwinEV Module".

Login and end-users

Regardless of whether the EV users are going to use a public charging point or a private charging point, EV users will be able to login into the TwinEV platform to access the rest of the functionalities that the module can provide. The access to the module is done by a username and an assigned password. This first screen is linked to the next functionality, which is the creation of an account. Furthermore, it will allow the reset of the password if the user can no longer remember it. Down below, (Figure 32) presents the screen to the first approach to the mock-ups of the TwinEV module regarding this functionality. On one hand, the login part is intended to check the username and the encrypted password and return a session token if the call has been successful. On the other hand, resetting the password generates a new one that is sent by an email.

Creation and configuration of the account

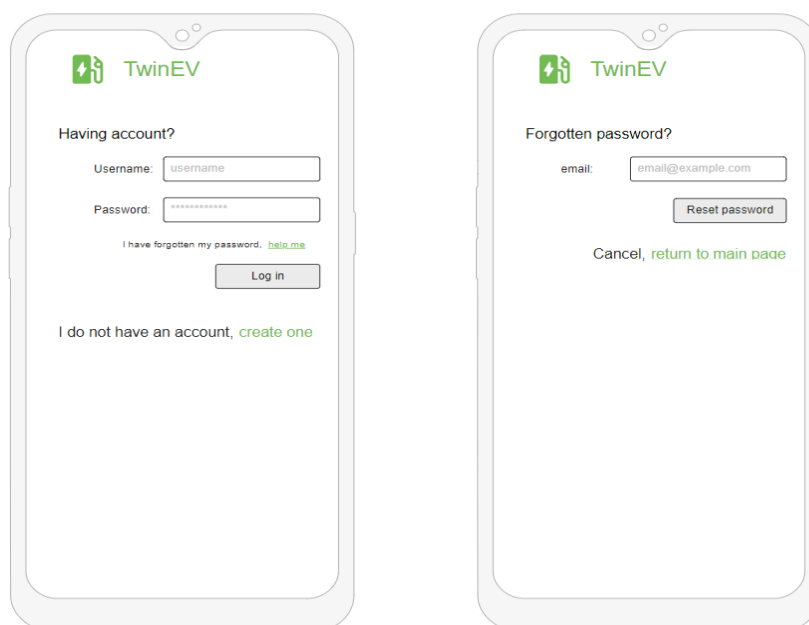


Figure 32: Mock-up for the TwinEV login

The creation of the account is going to be a prerequisite to use the services and functionalities presented at TwinEV module. This functionality is able to check the data in the creation form and returns a true value when the account has been created and validated. On the other side, the configuration of this account is performed in a separated section of the module. The user is required to provide a configuration for its account. Each EV user must define information for its vehicle's data such as battery information, type of vehicle, and V2G features. Furthermore, the user is asked to provide the selection of the payment mode.

Find the most suitable charging point

Based on the current position from the EV, users can search charging stations near their current position. The available charging stations are ranked based on a parameter set such as the movement expenses to reach the charging point, the energy price, the queue time to charge, the expected State of Charge, the availability of the charging point. Down below (Figure 33), it is presented the Mock-up for this TwinEV functionality.

The user is required to identify the desired charging time that he/she has available for the charging process. In addition to this, both the current and desired battery level are inputs for the part of this part of the module.

Booking a charging station

This part of the module will allow EV users to book a charging point for a charging session. The available stations to charge will be presented to the user. Based on some of the dynamic inputs that the user could provide, such as the moment of charge, the desired and current battery level, the EV user is able to book a charging slot within the

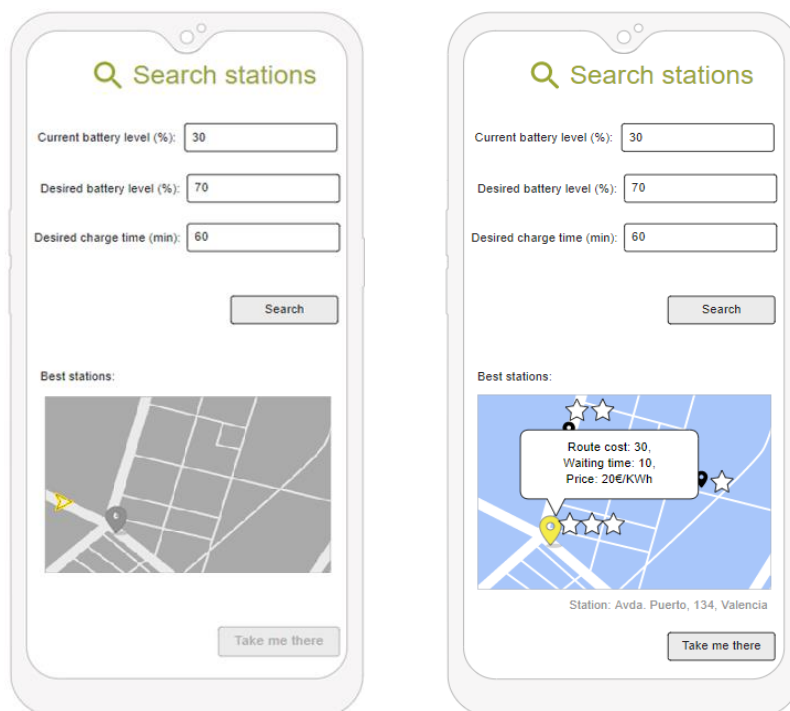


Figure 33: Mock-up for the search of stations



Figure 34: Mock-ups for the booking section

selected charging station. In Figure 34, it is presented the different mock-ups for this part of the module.

Handling of the charging session process

Once the charging session has been booked, the EV user can start its charging process. This part of the module indicates the part the status of the charging session, providing useful information to the EV user regarding the process of charging.

Down below (Figure 35) it is shown the proposed firsts Mock-ups for this part of the TwinEV module:

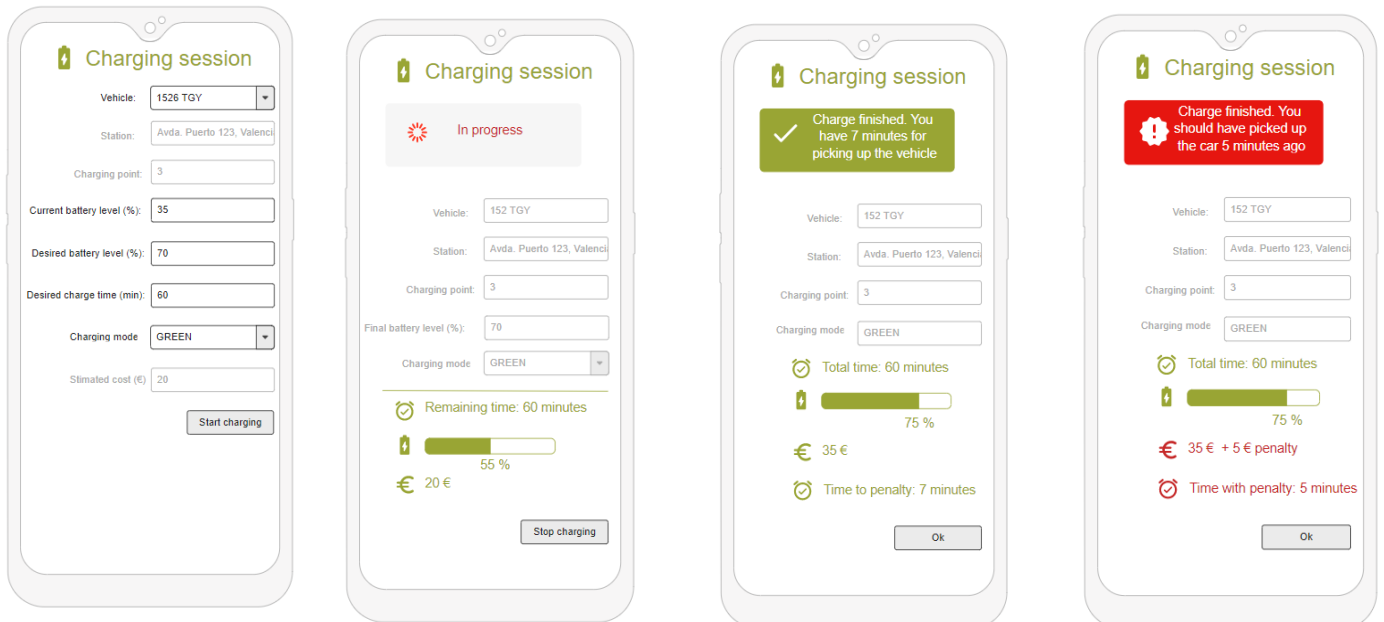


Figure 35: Mock-ups for the Charging Session information

The management of the payment process it is an interesting aspect that should be implied within the charging session module. It is important to stablish the relevant channels to perform the process of payment of the public charging session.

Smart charging

The purpose of this functionality is to introduce the concept of intelligent charging and how the TwinEV project is going to cope with it. TwinEV module is going to receive important data from both other modules and the system deployed within pilots to optimize the energy consumption in the charging operation. The amount of energy will vary on aspects and restrictions that the Charging Points will directly encounter. TwinEV is able to calculate the optimum charging profile for a recharge. This represents the amount of power that should be delivered to a concrete charging session at a concrete moment. This calculation will be based on TwinEV algorithms that would adjust both the inputs from the system and the user preferences which have been compiled in the previous explained functionalities.

As referenced before, the SMAC requires a set of inputs to calculate the optimal charging profiles for a specific charging session. These inputs listed in the following table (Table 9)

Table 9: Requirements TwinEV

Input	Description	Origin
Demand forecast	Forecast of demand over the next 24 hours	Module
Production forecast	Forecast of production over the next 24 hours	Module
Supply point max. power	Maximum power to be delivered simultaneously, considering, non-controllable demand, production and EVSE-related demand	Module
Supply point min. power	Minimum power to be received simultaneously, for V2G operations	Module
Energy price	Curve of energy price for cost optimization	Module
EV battery capacity	Capacity of the EV that is charging	Module
EV SoC	Battery SoC of the EV that is charging	Module
Nominal power of connectors	Max. power the connector is able to deliver	CDMP
Nominal discharge power of connectors	Max. power the connector is able to receive, for V2G operations	CDMP
Target slots	Time when EV is required to be charged	Module
Target SoCs	Minimum SoC required by the EV at the target slot	Module
Flex. Order	Support operations to the grid consisting of modifications on the supply point power flow limit (either upper, allowing greater	Module

	demand, or lower, imposing demand limitations).	
Opportunity cost	Additional cost considered to disincentive long-lasting charging sessions	Module

Based on these inputs, the algorithm will be able to optimize the charging profile, in terms of minimization costs and RES integration. The origin of this inputs can be either from other screenshots in the TwinEV module, information from the pilot's asset or derive from other modules. The last one is going to be explained in the forthcoming section.

5.7.3 Iteration with other modules

TwinEV module is expected to interact with other modules and its calculations to obtain valuable data sets for its own interest. Based on Table 9, TwinEV is going to be describing the main iterations with some of the modules that have been of interest to the functionalities of TwinEV.

Consumer and Neighbourhood demand flexibility profiling

These two modules are being developed by IES. Based on the TwinEV functionalities beforementioned, the module requires a set of information that would be valuable for the development of the module. TwinEV requires the Forecast Energy consumption at both a domestic and a Neighbourhood level. These predictions would allow to determine the expected demand profile within a period. This is a valuable input that would contribute to the calculation of the algorithm. Furthermore, the optimization algorithm is required to have as an input the production forecast within the following 24 hours. Consumer and Neighbourhood demand flexibility profiling have identified some functionalities that can be run with the aid of calibrated models in the scope of the domestic field that can provide the predictability of the forecasting of energy at a given time. In addition to this, the Neighbourhood demand flexibility profiling can predict the renewable generation for a given period based on the capacity available and the weather forecast.

DER management

This module is being developed by TH-OWL. Based on TwinEV requirements, this module requires the maximum and minimum power to be supplied considering, non-controllable demand, production, and EVSE-related demand. DER management module is set to provide grid status functionalities such as the expected load and generation in

the grid, as well as the grid status calculation in real time. This valuable information from the grid status is being used in TwinEV module so as to provide the optimal charging profile to EV users.

Transactive Energy

This module is being developed by WEC. This module is a trading decentralised platform what would serve novel block-chain enabled transactive market. Since the TwinEV is going to allow the charging of EV in public infrastructures, TwinEV is going to make use of the TE module since a financial transaction may be required. In addition to this, TwinEV module would perform an optimization for the charging curve in which the price of energy is required. TE module is expected to provide these prices to TwinEV module. Furthermore, VE consume energy from the grid. This energy consumption could greatly benefit from the Transactive Energy module. V2G functionalities are expected to be proven within the context of the project. For that purpose, it is expected also an energy transfer from the EV to the grid. This module is aimed to be helping through this process.

5.8 Social Network Module

5.8.1 Overview

As explained in Chapter 3, social network module is going to be designed to enhance the engagement of residential households by providing comprehensive dashboards to present households' consumer profiles, by providing breakdown analysis per device - when applicable. The social network module will provide a web-based interface which will provide a comprehensive dashboard for the monitoring of consumption/production profiles aggregated at device level along with information/status regarding potential shared assets with the aid of Digital Twin Platform. There will be specific graphs to present the energy saving of end-users. The main objective of the module will be to act as a social comparison tool by comparing the energy use between several neighboring end-users focusing particularly on the individuals own behavior which to some extent has implication on the consumption regular profile. The social comparison will also lead social competition among within the community or the neighborhood providing rewards (i.e., TwinERGY points) to the participating households. The competition will be performed based on gamification functionalities which in turn will be relying on specific KPIs such as energy efficiency, participation on the local community, utilization of shared assets etc., as a matter of providing the corresponding rewards.

The social network module will rely its design and implementation on well-established application developed in the frame of ChargED [18] project that was further updated in

the frame of BENEFFICE [19] project to also incorporate advanced features (i.e. the CO2 virtual coin as a reward) and will now be introduced to the TwinERGY users further enhanced by the intelligence and the accuracy/ reliability of forecasts and results that the Digital Twin module brings.

5.8.2 Detailed functionalities

In Table 10, are described the required inputs identified -so far- as preconditions for the operation of social network module along with their origin (data-provider). These inputs essentially refer to consumption profiles both aggregated for each end-users and any profile assigned per monitored device. Other inputs, refer to generation profiles for any micro or mini generation installed at a consumer or building level. Important information that needs to be considered in the social network is the status of any shared DER, which might affect the consumption behaviour of an end-user. Subsequently, forecasts on consumption and generation profiles are also substantial for the operation of the social network module in order to perform social competition among neighboring end-users. The inputs that the Social Network module requires to perform its functionalities are listed as follows (Table 10):

Table 10: Input requirement for Social Network Module

Input	Description	Origin
Consumer consumption	Consumption data of a consumer	CDMP
Device Consumption	Consumption data of household device	CDMP
Generation profile	Information analytics from Digital Twin Platform related to the local energy community (e.g. citizen engagement, consumer behavior)	DT
Generation profile	Generation data profiles from installed micro/mini generation	CDMP
Neighboring consumers	Group of neighboring consumers at the proximity of a community (list of users/communities)	CDMP
	Consumption patterns (e.g. installed capacity, specific consumption patterns)	DT
DER Status	Status of DERs (e.g. BESS SoC)	CDMP

Generation Forecast	Generation forecast in regard to a specific micro/mini generation	DT
Demand Forecast	Demand forecast of a specific end-user	DT

The main purpose of this section is to define the social network module functionalities within the TwinERGY solution. These functionalities, as commented before, are based on the different objectives in Section 3. The scenario depicted by the social network model is:

1. User Profiling

- Creation of households' accounts and login in the application module in order to have access to the set of functionalities.
- Creation and configuration of an account in which a user can add details about household devices, productions units and energy habits.

2. Main Functionality

- Comprehensive dashboards for monitoring consumption and savings.
- Recommendations for end-user.
- Challenges and Rewards display.

3. Social Networking

- Each user of the application to post and vote for issues in the portal
- Display Status updates on registered issues.
- Display Community info screens.
- Enable co-creation for end consumers, service providers and public authorities.

These specific functionalities are going to be further explained as follows within a brief description. Nevertheless, this module is going to be further developed at Task 7.8 "Social network Module".

User registration & log-in

Each demo user that will download the application will be able to create an account inside the app using:

- a username: the email provided to the installer during the configuration of the hardware kits.
- a password: the users selected one of their preference according to the rules.

The log-in and the registration screens are shown in the table below.

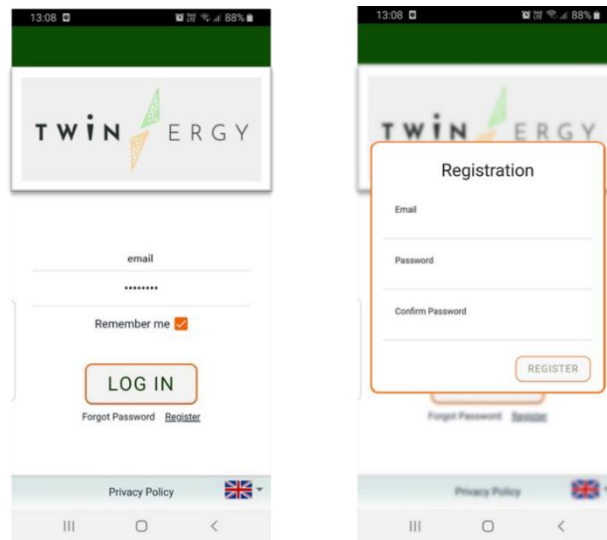


Figure 36: Log-in and Registration screens

Creation and configuration of a profile

After the registration, the user will have to complete the profile information by providing inputs in regard to:

- a) My account: details such as name full name, email etc.
- b) My community/neighbor Group.
- c) My Household: details about the dwelling/building/apartment.
- d) My Devices: list all consumption loads based on certain categories (i.e. based on temporal characteristics).
- e) Sun and Wind: any production units present are added here along with shared DERs.
- f) Energy habits: the end user states some typical consumption habits by providing answers to a predetermined set of questions (e.g., kitchen-oven usage, washing machine usage).

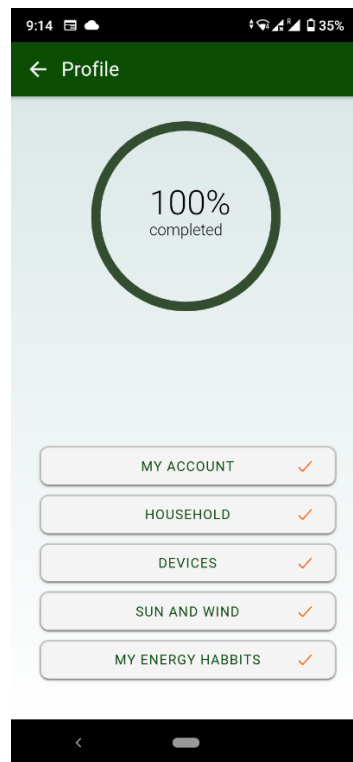


Figure 37: Profile's tabs

Comprehensive dashboards for monitoring consumption and savings


Screenshots of the Energy Dashboard screen are shown in the Figure 38 below:



Figure 38: Energy Dashboard Screens (Consumption, Savings)

In the Energy Dashboard screen the user can view the total daily, weekly or monthly cumulative consumption per pre-defined time frames within the day, week or month

("Consumption" tab). The orange dotted line above each graph is the indication of the daily, weekly and monthly baseline respectively. The user should keep the consumption below the dotted line in each case in order to achieve savings. The user has also to option to view the daily, weekly or monthly savings simply by pressing the "Savings" tab.

In addition, the user by clicking to the "info"  icon, will be presented with a description of what it is shown in each diagram. In the Energy Dashboard the user will have the option to click on the "More" button at the upper right side of each graph in order to see more detailed information regarding his/her consumption in the "Energy Details" screen. In the Energy Details screen – Overview tab, the user can select to view daily, weekly or monthly consumption. There will be also some comparisons available with the daily, weekly or monthly average consumption or the consumption from the last day, week or month. The green arrows show reduction in the consumption while the red arrows show increase in the consumption.

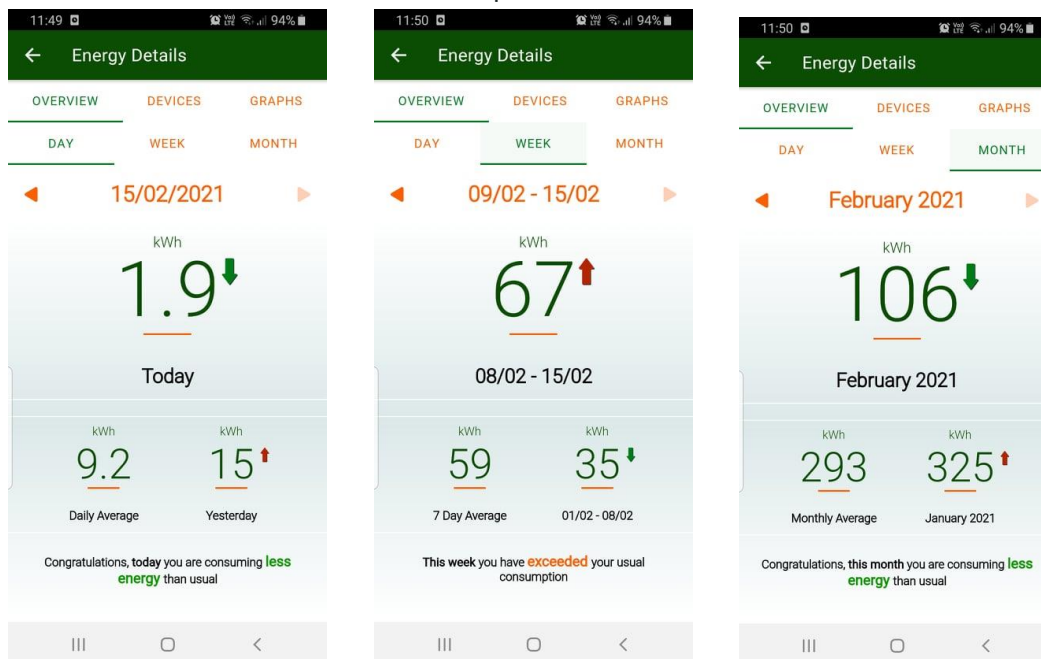


Figure 39: Energy Details screen (Overview tab: daily, weekly, monthly)

In the Energy Details screen– Device's tab (Figure 40), the user will view the results of a disaggregation algorithm and how the total consumption is distributed (in %100 percentages) in multiple different categories of devices such as:

- HVAC systems (e.g. air-condition, electric heater, electric radiator, etc.)
- Freezers and refrigerators
- Water Heaters and Boilers
- Finite state machines (e.g. fan, humidifier, iron, coffee maker, hairdryer, vacuum cleaner etc.)
- Washing machines (e.g. for clothes, for dishes, dryers, combo washer dryers etc.)

- f) On/Off devices (e.g. waffle maker, saver, trimmer, TV, toaster etc.)
- g) Kitchen related appliances (e.g. oven, stove, microwave)
- h) Continuously varying devices (e.g. laptop, desktop PC, PS4, Xbox etc.)
- i) Electric vehicles

The user by pressing in each one of the categories can see more information on each category (what kind of devices this category includes and the total consumption in kWh) for the respective day, week or month of his preference.

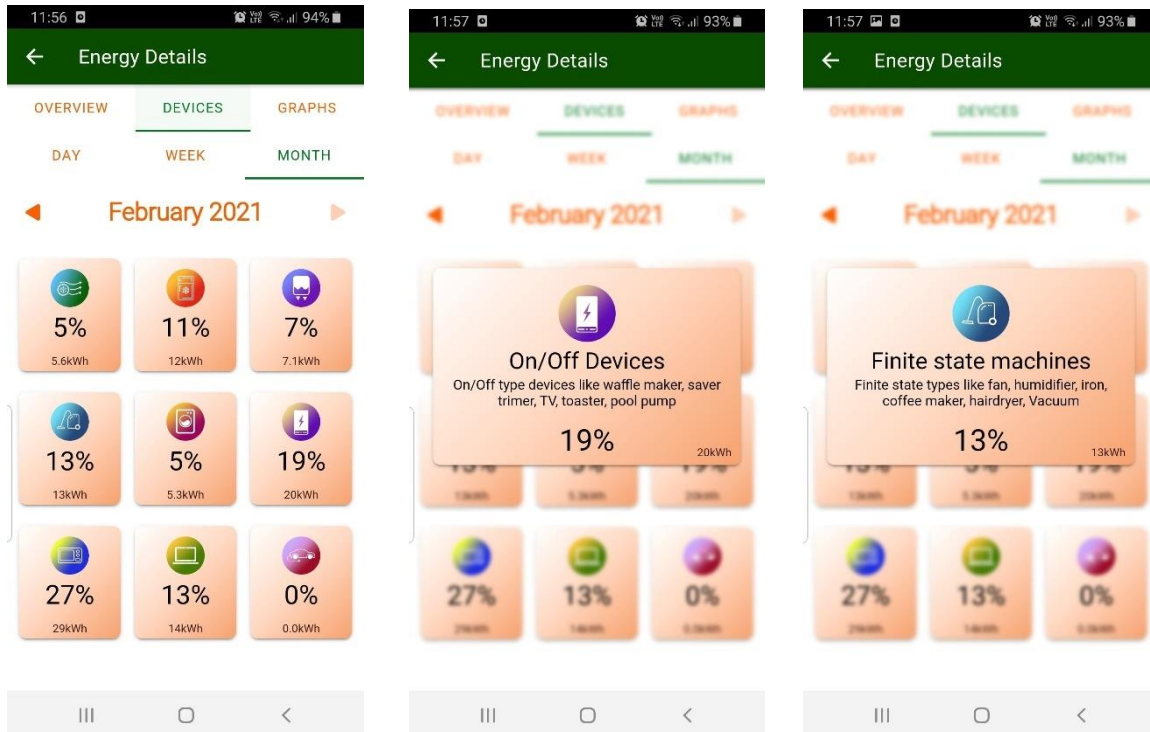


Figure 40: Energy Details screen (Devices tab)

In the Energy Details screen – Graphs tab, the user can see useful graphs related to a) his/her daily, weekly, monthly consumption, b) the consumption per device category (daily, weekly, monthly) and c) a pie chart with the percentage consumption per device category (daily, weekly, monthly).

Challenges and rewards display

The user will be able to see a ranking based on certain KPIs (e.g., energy-efficiency, DERs utilization, off-peak consumption) considering neighbouring end-users' behaviour. The user will be able to view in the "Badges" tab the list of available badges and their status (which are already won and which not). The user by pressing the "More" button can view more information regarding the badges, how he/she can win each badge from each category and the amount of TwinERGY Points to be won with each badge.

Display Community info screens

The social network module will also provide the capability to the end-user to have an overview of the status and the patterns (i.e. forecasts and historical data) of the shared assets and DERs of a community. This particular functionality will be steered by the Digital Twin Platform which will provide all the necessary data to be previewed in these dashboards.

Enable co-creation for end consumers, service providers and public authorities

The social network platform will also provide an interface to enable the co-creation among several different neighbouring end-users and flexibility actors. This particular functionality will provide the capability to coordinate requests of the community and resolve them in an efficient manner via upvoting/downvoting. Each might be able to take the chance to support a request by earning multiple TwinERGY points.

Generic Functionalities

The social network platform will also provide generic functionalities such as:

- Notification alerts related to user/group activities.
- Main dashboard (central navigation point).
- Social Tools (follow user/post comment/like comment/connect).
- Public User Profile.
- Main directory.
- Public access content functionality (share content with non-registered users)
- Search functionality.

5.8.3 Iteration with other modules

The social network module needs to get continuous consumption data from:

- 1) household devices
- 2) smart metered data
- 3) generation data profiles from installed DERs.

Such data may be requested by the Digital Twin Platform along with the modules:

- Neighbourhood demand flexibility profiling and
- Home & Tertiary real-time Energy Monitoring.

The social network module will obtain information regarding group of neighbouring consumers at the proximity of a community (list of users/communities) information which possibly may be provided by Home & Tertiary real-time Energy Monitoring module.

The social network module in order to support the consumers to achieve co-creation activities need to have information regarding shared DERs in community such as Current or forecasted status of community Battery, PVs; this type of information may be request by the Digital Twin Platform along with the DER management module. The outputs of the social network module such as recommendations for consumption, challenges amongst end-users and user rewards aim to have a direct impact on the end-users' behaviour either as an individual process or through the integration with another module It is not clear though which of the modules might take advantage of such outputs. So far, within the activities of T7.1 there were no requests identified from other modules to consider the social-network module's outputs.

5.9 Transactive Energy Module

5.9.1 Overview

Transactive Energy Module enables grid decentralization and democratization by connecting the micro-grid operators to the DER managers and their customers. It aims for an integrated energy business model through energy service expansion, customer engagement and financial inclusion. It allows them to balance the grid and provide solutions to a several grid problems, such as grid power quality and reliability. The core of this use case is a transactional platform that offers its participants to sell their flexible energy loads and excess capacity on an open market to the (micro) grid operators or to each other. Microgrid operators provide balancing and grid services at a local and micro-grid level. A micro-grid could be a collection of a) IoT devices, b) buildings, c) neighbourhoods/substations, and d) regions that operate at a regional level to balance multiple neighbourhoods, districts and/or substations. It could potentially include the high voltage grid. Each component of the system (e.g., device, building, neighbourhood, distribution grid and transmission grid) is a self-contained ecosystem, replicated and nested within the next layer of the system, like in a fractal configuration. All components operate with identical information and control models and each have operational decision-making capabilities. This platform offers a path to grid decentralization, energy democratization, and a way to effectively leverage and monetize the emerging DER infrastructure.

The Transactive Energy Module (TEM), based on Hybrid Blockchain technologies will be developed to solve current intractable optimization problems and create a premiere Transactive Energy (TE) protocol layer settlement process, marketplace, and governance framework to allow energy-related Apps to be written and interoperate with each other.

Through the application and study of this Use Case in two of the TwinERGY project pilot sites (Bristol in the United Kingdom and Benetutti in Italy), grid infrastructures would be analysed to implement state-of-the-art equipment that can monitor and track energy consumption and distribution. Pilot sites, consisting of apartment buildings and individual houses will be equipped with smart meters, EV charging points, local and public storage facilities and IOT devices such as smart plugs. These are integrated with the Transactive Energy Module giving prosumers a powerful insight of their power consumption and redistribution to the local energy market (LEM).

The TEM will allow for prosumers to buy and sell energy from the LEM. It will also allow TE participants to transact in a P2P configuration outside an organized LEM/DSO or an ISO/TSO market. These transactions are stored as an immutable record on the blockchain specifying the actors participating in the transaction and the origin of the energy. To further support the LEM, the TEM will process and broadcast price forecasting of the DNO and LEM. Other TwinERGY modules will be able to listen to the broadcast and make energy consumption or discharge decisions on behalf of the prosumer.

For non-ISO/TSO and non LEM/DSO organized energy market transactions one pricing option could be to use a double-sided market in which TE participants pay a unique price based on their preferences and local supply and demand conditions (analogous to the stock market). Another option could be to use a proxy market price using a reference market price of the LEM organized market or the ISO/TSO market, (e.g., the 5-minute real-time auction price).

5.9.2 Detailed functionalities

Within the context of TwinERGY, the main objective of the TEM is to record and validate the various transactions using DLT technologies. Various transactions, as already described in the previous section, will be completed between the participants. Due to the limitations of the physical infrastructure of the pilot sites in which the TEM is being deployed, some of the functionalities under study cannot be tested. The TEM will focus on creating functional prosumer accounts, creating relations with IOT devices and record energy transactions within the confines of what is possible with the available equipment and infrastructure. This will include transactions from PV systems and batteries to the main grid. Where possible, transactions as a result of flexibility responses will also be recorded to reflect a cost saving. In addition, the TEM will use an algorithm to calculate the pricing of the LEM. The price will be based on external DSO pricing, battery SOC and load forecasts. In Table 11 the different inputs for the Transactive Energy module are being defined:

Table 11: Input requirement for Transactive Energy Module

Input	Description	Origin
DSO pricing	TEM receives day ahead pricing from DSO's and processes this data in the TEM algorithm to calculate LEM pricing	External sources
Prosumer account	TEM receives a signal that a new prosumer has joined the ecosystem and creates a dedicated prosumer account in the TEM	CDMP
Device ID	TEM receives a signal that a new device has joined the ecosystem and rather this device has a relation to one or more prosumers	CDMP
Consortium ID	TEM receives a signal that a new consortium is formed. For example, where a new public battery is installed	CDMP

A number of algorithms have already been proposed regarding the financial settlement, social incentives and the rules of the economic transactions. Using the TEM, small scale DER owners actively participate in the wholesale energy market, which was practically prohibitive before in many EU countries. The granularity of the proposed market largely depends on how often the system is updated and new data generated. The required data for the implementation are described in detail below:

- Market data: Retail prices of the grid (feed in/ feed out). For every time interval the internal TEM price should be compared to the retail price of the grid.
- Generation data: Forecasted and real data measurements of assets which produce energy in a LEM (e.g rooftop PV panels)
- Consumption data: Forecasted and real data measurements of the aggregated load inside a building. Information of flexible loads (e.g HVAC, electric water heater) is also required for providing demand response services.

Eventually the TwinERGY ecosystem will interconnect LEMs allowing them to exchange and transact Energy between and among each other. This approach makes the TwinERGY ecosystem highly scalable.



Figure 41: Inter-connected Local Energy Markets

The wider concept of Transactive Energy is for prosumers to be able to trade their energy in a peer-to-peer auction. In addition, the energy sold is to be distributed and tracked between prosumers. A prosumer would have the ability to sell and distribute its energy equally or unequally to other prosumers or public storage facilities. Specific grid infrastructure and equipment are required to allow for the concept to be utilised.

The grid infrastructure determines function capability for the implementation of Transactive Energy. There are two infrastructures considered for the implementation in the TwinERGY project. The first is the most encompassing and called “Peer 2 Peer infrastructure”. Here each house, apartment, public building, storage facility or RES will have a direct connection between each other. Each individual line is provisioned with a smart meter. This allows for accurate auctioning and tracing each transaction of energy.



Figure 42: Peer 2 Peer infrastructure

The second model is called “Pooled infrastructure” where Prosumers and RES distribute energy in a pool which is then equally shared with all participants. The limitation of this approach is that it is only possible to measure and trace energy distributed to the pool or from the pool. When energy is consumed from the pool it is not possible to trace the origin which in turn eliminates the possibility for the implementation of auctioning and dynamic pricing between prosumers.



Figure 43: Pooled infra structure

VPP Creation and Market Participation

As DERs proliferate and opportunities for active or flexible demand grow, “Aggregators” of these resources (or DER Aggregators or DERA) for the creating of the VPPs have the potential to help unlock the value of distributed resources and bring them into energy markets at scale. Aggregation is defined here as the act of grouping distinct agents in a power system (i.e., consumers, producers, prosumers, or any mix thereof) to act as a single entity when engaging in power system markets (whether wholesale or retail) or Transactive Energy trading.

Today’s VPPs offer an ideal optimization platform for providing the supply and demand flexibility needed to accommodate the fast-ramping needs of renewables, to balance wind and solar intermittency and to address corresponding supply forecast errors. For example, if one wind power source generates more energy than predicted and another generates less, a VPP will balance the two, resulting in a more accurate forecast. In addition, the wind power becomes a more reliable source of capacity in the market. Often, in energy markets, market participants fire up large and less efficient power plants to grapple with small gaps in demand. They may deploy a 600-MW gas plant when only 5 MW is needed. With a VPP, when the DSO/TSO asks for 5 MW, the VPP will do two things. It will look for places to reduce load, so the system may not need all of the 5 MW. It will also look for places where it can self-generate electricity by discharging batteries, or dispatching wind or solar facilities.

VPPs incorporate short-term load, distributed generation forecasting and aggregation capabilities. They perform near real-time shifting of commercial and residential net loads to provide the services needed by the grid. Under the control of a VPP, demand on the system can be optimized and tweaked automatically, making day-ahead call-outs a thing of the past. VPPs have the ability to go beyond simple load curtailment and to leverage continuous communications and bi-directional control to deliver dispatchable grid support. As a result, aggregated DERs can be orchestrated by VPPs with second to minute response speeds. By design, VPPs can coordinate and control more efficient and clean sources of distributed energy so there is no need to overbuild or deploy fossil-fuel plants to balance electric demand and supply. The objective is to feed an automatic generation control signal to VPP that indicates the DSO/TSO’s needs a certain amount of capacity at a certain point in time. The system can then go get that capacity within the bounds of what is currently available, at a specified confidence range, such as 2 MW with 95% confidence or 3 MW at 70% confidence. [23]

The objective of the VPP design we propose is to develop a demand side reserve resource consisting of an aggregated large number of devices that can curtail entirely or partially segments of subscribed loads for limited duration of time. We focus on small loads at the scale of individual appliances, household or buildings which would otherwise not be deployable as demand side resources by the system operator due to their large number and informational requirement or not meet availability criteria for participating demand response (PDR) due to uncertainty of the active energy used at any particular point in time. We characterize controllable demand in terms of capacity increments and account for the uncertainty of harvested energy resulting from curtailment of such capacity segments.

A key aspect of controllable load segments is the uncertainty of energy yield resulting from curtailment. The design we propose is based on aggregation large number of such devices into a portfolio controlled by a proprietary dispatch algorithm in the cloud to produce a virtual power plant (VPP) that can emulate a dispatchable conventional generator. The aggregation of many small controllable load segments along with the dispatch algorithm governing their controllers, mitigates the uncertainty in energy yield resulting in a VPP with supply reliability within conventional statistical norms. This approach is analogous to creating financial managed portfolios underlying high quality bonds by aggregating large numbers of "Junk Bonds" with high probability of default. Demand side resources consisting of load segment within household and buildings are controlled by smart devices and dispatched through the WEC cloud algorithms. The dispatch frequency of each device is based on subscription contracts with the customer in accordance with the customer's selection from a menu of contracts specifying probability of curtailment or priority of curtailment vs. compensation. The customer selections are aggregated into a portfolio comprising the VPP elements.

Based on the composition of the contract portfolio and the yield statistics of the curtailable load segments, the DER Aggregator can construct a supply function, maximizing expected return, that emulates a conventional generator supply function. The VPP supply function which is bid into the Day-Ahead wholesale energy market or reserve market specifies committed energy as function of wholesale price. The awarded quantity is realized through deployment of load control by the WEC cloud algorithm. Like with conventional generators, VPP deviations within acceptable bounds are settled in the real time market.

Figure 44 illustrates the creation of the VPPs and their participation in the market.

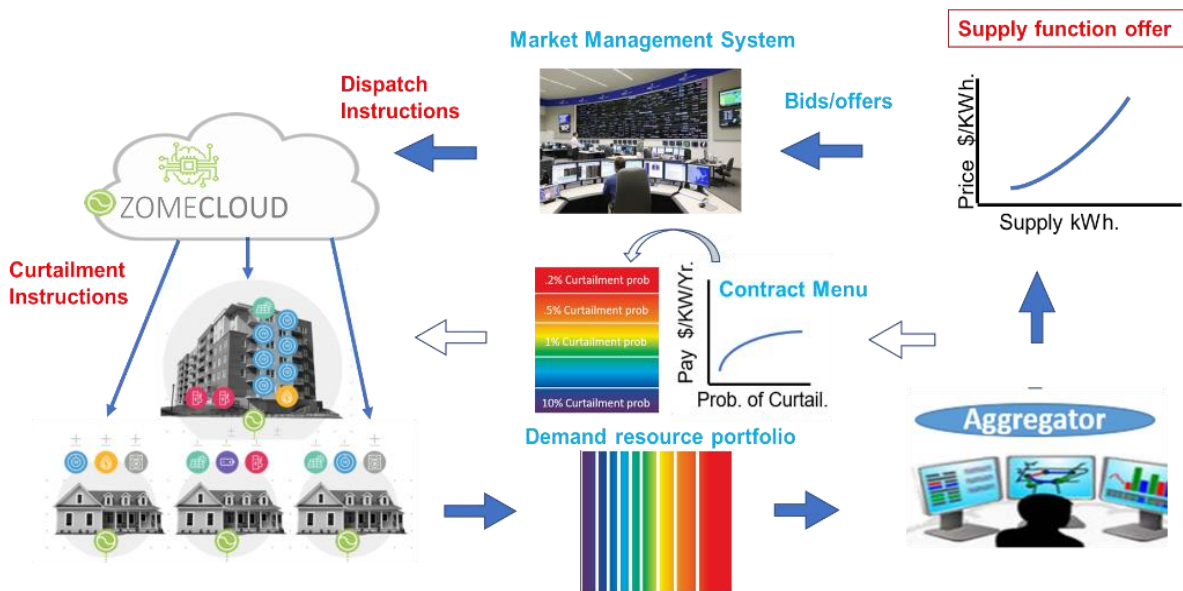


Figure 44: Building VPP Demand Resource Portfolio Creation for Market Participation

For yield characterisation we characterise controllable demand. The energy yield and probability of available distribution will initially be assumed and eventually calibrated to measurements and device data. The yield distribution will guide the deployment of controllable demand capacity to deliver a specified amount of energy with a given probability.

Overview of specific functionalities

“Create account”.

- Prosumer joins TwinERGY project.
- Receive signal from other TwinERGY module to create prosumer account.
- TEM confirms account created.

“Register Device”.

- New device joins TwinERGY ecosystem
- Receive Signal from other TwinERGY module to register a device (PV, HVAC etc.)
- Signal includes owner and TEM creates relation between prosumer and device.
- TEM confirms device is registered and relation created.
- (2) Function to remove devices

“Register Consortium”.

- New prosumer consortium is formed.
- Receive Signal from other TwinERGY module to register a consortium.
- Signal includes participants and devices creates consortium relations.

- (2) Function to add and remove prosumers and devices

“Calculate and broadcast LEM and DSO/DNO Pricing”.

- TEM receives input data from other TwinERGY modules.
- TEM receives input data from DSO/DNO.
- TEM calculates LEM pricing.
- TEM broadcasts LEM/DSO/DNO pricing on set interval
- TEM records pricing on the blockchain

“Process energy transaction”.

- TEM receives request from other TwinERGY module or device to process a transaction.
- Data input includes prosumer, device, units and destination.
- TEM processes and settles the transaction.
- TEM records transaction on the blockchain with reference to price hash

“Communicate an account balance”.

- TEM receives request from another TwinERGY module to communicate the balance an account.
- Data input includes the ID of a Prosumer, Prosumer Consortium or Device.
- TEM communicates balance.

“Communicate transaction history”.

- TEM receives request from another TwinERGY module to communicate the transaction history of an account.
- Data input includes the ID and date range of a Prosumer, Prosumer Consortium or Device.
- TEM communicates an array of transaction.

“Load and generation forecast”.

- TEM receives input data from DSO/DNO.
- TEM receives input data from TwinERGY digital twin.
- TEM calculates day ahead load and generation forecast.
- TEM broadcasts load and generation forecast.

5.9.3 Iteration with other modules

The TEM will have interoperability with several other modules in the TwinERGY ecosystem. Important inputs from other modules will be fed into TEM for the different

list of outputs that are to be provided. While architecture and function design is still under development the TEM has identified data input/output requirements with the following modules:

- Home and tertiary real time energy monitoring module.
- DER management module.
- TwinEV module.
- Consumer and neighbourhood flexibility module

While the TwinERGY project evolves, interoperability with other modules is expected also.

Home and tertiary real time energy monitoring module

This module is developed by STAM. Basic information like amount of energy used, storage capacity and load patterns will be calculated within this module, always taking into account certain needs and comfort levels of the prosumers. The above will be used as a solid basis for dynamic price calculation that transactive energy module is responsible for.

DER management module

This module is being developed by TH-OWL. The DER management module is set to provide grid status functionalities such as the expected load and generation in the grid, as well as the grid status calculation in real time. Grid bottlenecks and constraints are also to be provided here and respective countermeasures are taken to mitigate the risks. This grid information is being used in Transactive Energy module for the calculation of DSO and LEM pricing.

TwinEV module

This module is being developed by ETRA. Since the TwinEV is going to allow the charging of EV in public infrastructures, TwinEV is going to make use of the TE module since a financial transaction may be required. In addition to this, TwinEV module would perform an optimization for the charging curve in which the price of energy is required. TE module is expected to provide these prices to TwinEV module. Furthermore, EV consume energy from the grid. This energy consumption could greatly benefit from the Transactive Energy module. V2G functionalities are expected to be proven within the context of the project. For that purpose, it is expected also an energy transfer from the EV to the grid. The TE module is aimed to be helping through this process.

Consumer and neighbourhood flexibility module

The Consumer Demand Flexibility Profiling Module is intended to facilitate the calculation of flexibility for individual buildings or consumers, both in terms of implicit flexibility (i.e. the actions taken by a consumer in response to dynamic conditions, such as price signals, for example) and explicit flexibility, which refers to automated actions that are managed and dispatched by an aggregator.

The Neighbourhood Demand Flexibility Profiling Module will operate in a similar manner to Consumer Demand Flexibility Profiling Module, however it will use the Community Digital Twin to present a single pane of glass dashboard for the entire neighbourhood. This module will again be used as a read-only, cloud-based dashboard to allow the user to view the flexibility profile within their neighbourhood.

6. TwinERGY module's interoperable platform

In this section we describe the process that we have followed in Task 7.1, with the aim of achieving a stable implementation of an intercommunication platform among all the modules. Our intention here is to begin to explain the rationale behind this platform, followed by the description of requirements and needs, and a description of the alternative standards that we have considered. Finally, we give a detailed description of the implementation.

6.1 Introduction

The modules developed during WP7 conform a distributed ecosystem where all they are communicating with each other. As can be deduced by reading previous sections in this deliverable, these modules are highly interdependent. That means that each of them needs information generated by one or several modules as well as they generate information that can be needed by the rest of the modules. For instance, TwinEV module generates a charging curve for an eVehicle charging session, and this information is used by other modules, such as DER management module.

Moreover, the status of a module can affect the rest. For instance, if a module fails during its execution, the modules that are waiting for its inputs may hang. So, those waiting modules need to know this situation in order to follow a plan B: using previous data received from the module, making an estimation of what data would be received, or any other action. This point is important, so to ensure that the information is interchanged among them, since it is related to the tolerance to failures of the complete ecosystem. Besides, the modules need to receive the information immediately. It makes no sense to receive information with a great delay or corresponding to a previous time period. Therefore, all modules need to work with the latest data, corresponding to a real time schema.

Such a situation implies that the WP7 needs a common platform of communication, where all modules can receive and send messages about their calculations and their statuses in a real time environment. Traditional solutions like checking the common database for new/modified information and reading the new/modified data can lead to a potential bottleneck and so have to be avoided, and those solutions do not solve the problem of knowing the status of the rest of the modules. However, not only these

exposed points have to be taken into account. Each module has its own characteristics, it is implemented in a different language, and it is deployed in different premises. This implies that the communication channel has to be independent of the modules. All these topics or issues have led us to look for an independent and unified framework that also guarantees security. The requirements and needs are exposed in the next subsection.

6.2 Requirements and needs

Considering that the platform must be decentralized, it has to solve typical problems in this kind of architectures. On the other hand, we have to deal the problems exposed in the introduction, such as synchronization among modules or bottlenecks. So, after an analysis, we consider that our platform presents these main needs and requirements:

- **Real time:** Data has to be sent and received immediately.
- **Scalability:** The communications have to work independently of the size or the amount of information sent/received.
- **Security:** Data have to be confidential and accessible, and the system has to ensure data integrity.
- **Heterogeneity:** Communicating modules have to be able of communicating without a previous knowledge of the architecture of the rest of modules.
- **Concurrency:** All information sent have to be accessible by interested modules simultaneously.
- **Flexibility:** The platform must be open to changes and updates.

6.3 Examined standards

Considering requirements, we divided the revision of standards in two parts. On one hand, standards (ontologies) for data modelling. On the other hand, standards for communication.

Data modelling

Regarding to this point, we have considered that TwinERGY project is related to energy systems, so the information interchanged is related to the knowledge domain of energy. Therefore, we need to model interchanged data by following an ontology. In this area we have selected some extensions of Smart Applications REFerence ontology [24] which is intended to enable interoperability between solutions from different providers and among various activity sectors on the Internet of Things (IoT). It facilitates the matching of existing assets in the smart applications domain. SAREF models the knowledge with these main classes, among others:

- **Device:** tangible object designed to accomplish a particular task. Examples of devices are: a light switch, a temperature sensor, an energy meter or a washing machine.
- **Function:** the functionality necessary to accomplish the task for which a device is designed. For instance: Sensing, metering, event, actuation
- **Command:** Orders associated to functions: Start, stop, etc.
- **State:** Represents real states of a device: On, off, etc.
- **Service:** recovery of a function, making it visible
- **Profile:** Specification of a device to collect information about a device's property or commodity
- **Measurement:** Measurement of a physical quantity
- **Property:** Property where the measurement is referring to
- **Unit of measure**

In next Figure 45 we show the relationship among classes in SAREF ontology.

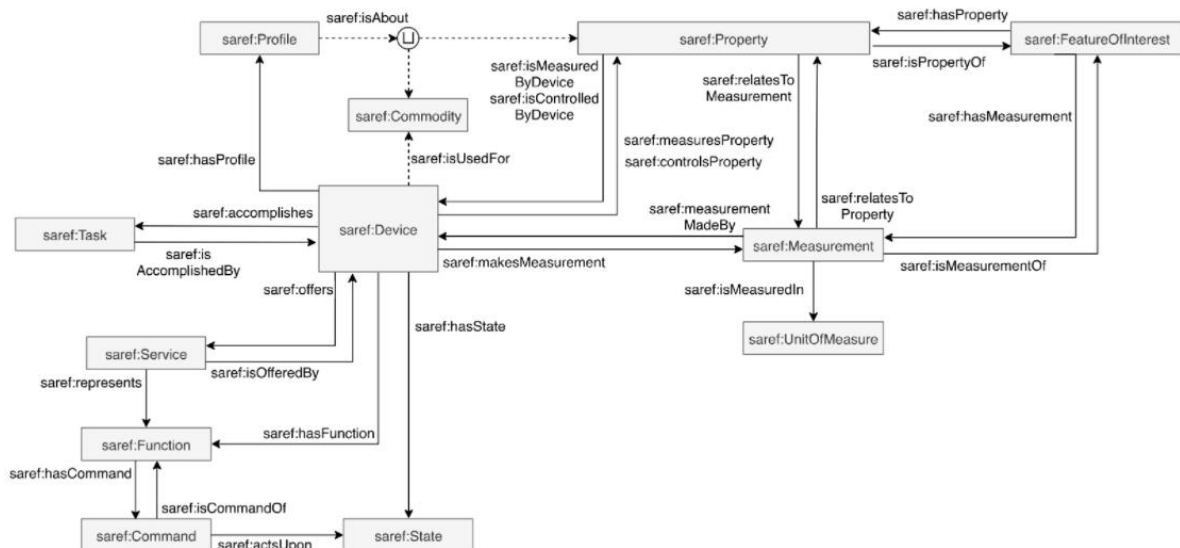


Figure 45: Relationship among SAREF classes

However, for data modelling in TwinERGY, the use of the basic SAREF is insufficient. Then, we have considered to include two extensions of this ontology, which cover all aspect. They are SAREF4ENER [25] (SAREF for energy) and SAREF4BLDG [26] (SAREF for buildings).

SAREF4ENER [25] is focused on modelling of energy systems. As main characteristic, it extends basic SAREF classes by including more properties. For instance, while class *Device* in SAREF only includes properties “has manufacturer” and “has model”, class *Device* in SAREF4ENER adds more properties like “power source”, “vendor code”, etc. Besides, SAREF4ENER has new classes not considered in SAREF, such as: *Power profile*,

Resume cost estimated, etc... On the other hand, SAREF4BLDG [26] is focused on buildings' life cycle. It includes new classes like *Building* or *Physical Object*. However, we have been careful with the selected classes in the modelling, in order to avoid overlaps.

Communication standards

Regarding to this point, we have been checking different approaches of communication. From the moment that we consider the TwinERGY ecosystem as a distributed system with real time approach, the communication must follow a schema of message exchange protocol.

The first option that we have considered is OpenADR 2.0 [27] standard, which facilitates common information exchange between electricity service providers, aggregators, and end users. OpenADR 2.0 [27] is a two-way signalling system composed by servers and clients:

- Servers (Virtual Top Nodes or VTNs), which publish information about grid conditions. They manage resources, create and transmit events and request reports.
- Clients (Virtual End Nodes, or VENs). Communicates with a VTN receiving and transmitting Smart Grid messages that relay grid situations, conditions, or events. They receive events and respond to them, generate reports and control demand side resources.

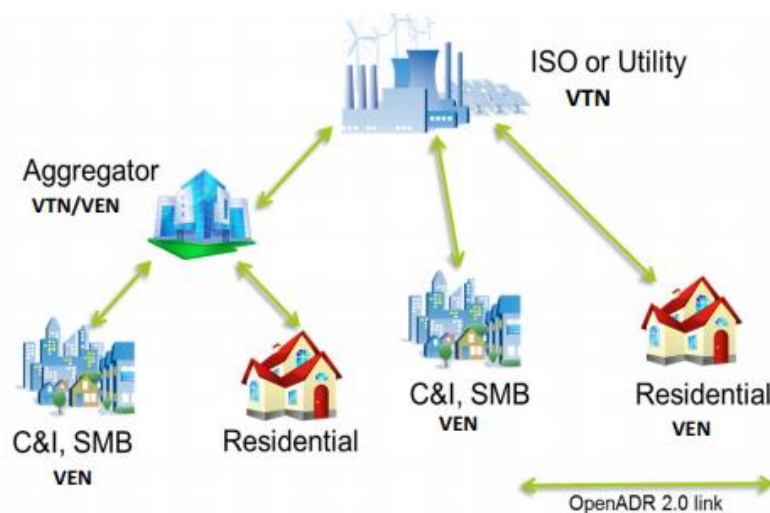


Figure 46: OpenADR 2.0 schema

This approach in a first step is good for our needs. However, messages have a complex format in XML, so they include a lot of parameters that must be analysed by the receivers and therefore, they have to be codified by the senders. For instance, this would be a message related to inform about a new vendor:

```

<oadr:oadrPayload xmlns:oadr="http://openadr.org/oadr-2.0b/2012/07"
xmlns:ei="http://docs.oasis-open.org/ns/energyinterop/201110"
xmlns:ns3="urn:ietf:params:xml:ns:icalendar-2.0"
xmlns:ns4="http://docs.oasis-open.org/ns/energyinterop/201110/payloads"
xmlns:ns5="http://www.opengis.net/gml/3.2" xmlns:ns6="http://docs.oasis-
open.org/ns/emix/2011/06" xmlns:ns7="urn:ietf:params:xml:ns:icalendar-
2.0:stream" xmlns:ns8="http://www.w3.org/2005/Atom"
xmlns:ns9="http://docs.oasis-open.org/ns/emix/2011/06/power"
xmlns:ns10="http://docs.oasis-open.org/ns/emix/2011/06/siscale"
xmlns:ns11="http://www.w3.org/2000/09/xmldsig#"
xmlns:ns12="http://naesb.org/espi"
xmlns:ns13="http://www.w3.org/2009/xmldsig11#"
xmlns:ns14="urn:un:unece:uncefact:codelist:standard:5:ISO42173A:2010-04-
07">
  <oadr:oadrSignedObject>
    <oadr:oadrPoll ei:schemaVersion="2.0b">
      <ei:venID>ven-tno-01</ei:venID>
    </oadr:oadrPoll>
  </oadr:oadrSignedObject>
</oadr:oadrPayload>

```

Figure 47: Example of a message related to inform a new vendor

After a discussion among technical partners, it was agreed that this disadvantage was a big problem in a system where there can be big number of messages per second. So finally, this protocol was abandoned.

The second approach has been a single message exchanger where format of messages is not so restrictive. There are some standards that we have checked, such as AMQP or NATS. In both cases, they are messaging protocols that enables conforming client applications to communicate with conforming messaging middleware brokers. In order to not extend this deliverable, we summarize that NATS includes more features and advantages that AMQP so finally we have chosen NATS [28].

NATS [28] is based on publishing and listening messages, that is to say, there are publishers (senders) and listeners (receivers), which are connected remotely to a server, similar to a mailbox. Publishers sent messages to the server and the server distributes messages among listeners according to the subject of the message, in a sense similar to the address in a mail. The server never stores messages, only distributes them.

The subject is similar to a mailbox address but in fact, is not one. That is to say, listeners connected to the server indicates what subjects are interested on, so the server know which to send that message. In Figure 48 we depict an example where a module is sending information about weather in different cities and there are different modules that want to receive only weather messages related to a city. The sender includes the

name of the city in the subject and each receiver subscribes to messages whose subject is related to a city:

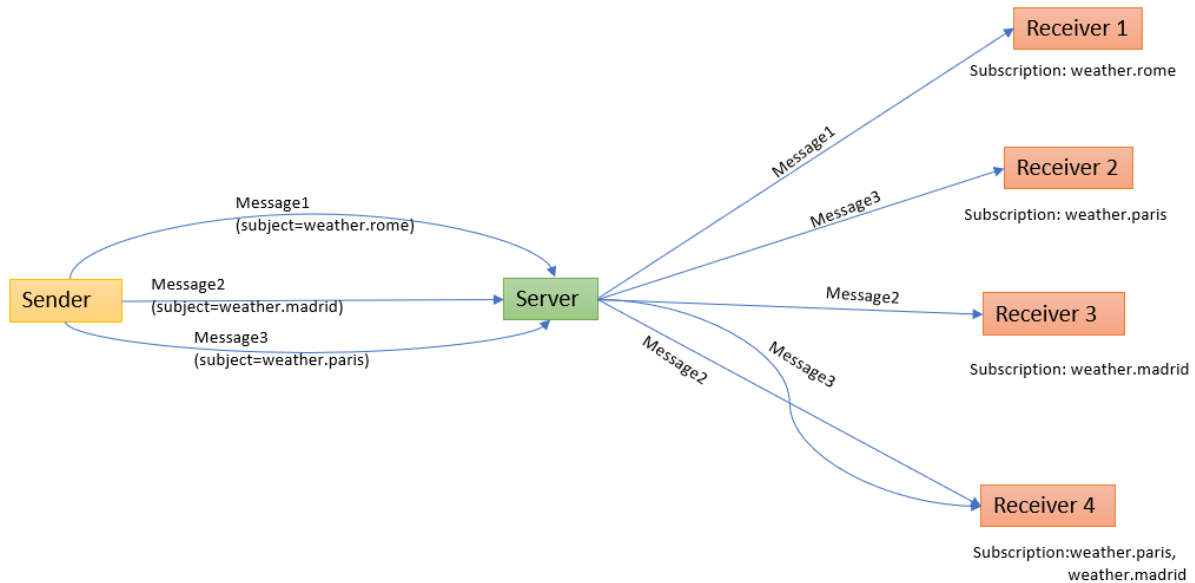


Figure 48: Example of messages sending in NATS

As it can be seen in Figure 48, a module can be subscribed to more than one subject. Since a module can need messages related to a several types of subjects, NATS [28] allow to use shortcuts in order to make easier this definition. Continuing with the example of sending weather in cities around the world, if a module wants to receive weather information from all capitals in Europe, the sender can send messages with subjects like “weather.europe.city_name”, “weather.asia.city_name”, etc. and the receiver can subscribe to “weather.europe.*”. Of course, modules that only want information about a city in Europe still can subscribe to “weather.europe.city_name”.

In addition to this schema of subscriptions, NATS [28] allows to send a request and waits for a response. This is very helpful in case that a module wants to request information directly to another one. In this case, the communication can be synchronous (sender locked until receiving the response or timeout) or asynchronous (sender continues working while waiting for the response).

As we commented in OpenADR [27], the messages are very complex. In NATS [28] this is not a problem at all, because programmers can model the data as they want, so information is easily readable. NATS [28] allows to send messages in plain text or structured in JavaScript Object Notation (JSON format), which is incorporated in the most of modern languages. JSON is an open standard file format and data interchange format that uses human-readable text to store and transmit data objects consisting of attribute–value pairs.

Regarding security, NATS uses modern Transport Layer Security (TLS) semantics to encrypt clients, route, and monitoring connections. Besides, NATS can be configured to force client authentication in different ways:

- Connection by user/password.
- Connection by token.
- Connection by NKEY: Server has a list of known public keys and clients have to respond to the challenge by signing it with its private key.
- Connection by credentials file.

Some other helpful features exist in NATS, but we do not expose them here in order to not extend this section. In any case, NATS covers all needs in the communication:

- Request information to a module.
- Send notifications of statuses.
- Publish data that is distributed among interested modules.
- Secure communications.

6.4 Final implementation

In summary, the defined interoperability platform is composed by a NATS system, where WP7 modules connect to the server and send/receive messages to/from the NATS server. Containing information about modules' status, their calculations or measures registered, these messages are composed following the SAREF ontology and its extensions. With this aim, modules will contain clients to the NATS server, in charge of subscribing to desired messages (depending on the subject) and/or publishing messages.

But once the platform is defined, it is needed to define data to be sent as well as message format. Despite SAREF is used for modelling the data, it is important to be sure that subscribers are able to identify the type of data received. With this intention, we have firstly identified the inputs and outputs data for each module and its correspondence with SAREF ontology. For this point, technical partners have identified the data defined in the excel file of functionalities and modelled them as classes of SAREF, SAREF4ENER and SAREF4BLDG ontologies. In case of data that cannot have some correspondence with these classes, partners have identified also and modelled in a similar way. For instance, the "flexibility grid neighbourhood delivered" can be modelled as class "Power max" in SAREF4ENER, whilst "user survey responses" corresponds with a new class.

The second step has consisted of the definition of messages to be interchanged. For this task, on one side we have defined the data structure in messages and on the other side, the subject to identify the message type and the sender. Taking advantage of rules for composing subjects, we structure the subjects in this way:

`{MOD}.{TYPE}.{SUBTYPE}`

Where:

- {MOD} is the module identifier,
- {TYPE} is the message type, and
- {SUBTYPE} is the message subtype.

For example, subject "M3.notify.error" indicates that Module 3 is notifying an error, and "M4.synchronization" indicates that Module 4 needs to synchronize with another module.

Depending on the message type (indicated in the subject), the message itself has a different format. As we commented before, NATS allows to send plain text or text structured in JSON format. In our case, we choose JSON format, with the aim of allowing send complex data.

Finally, and after defining subjects and message structure, we have defined the set of messages to be sent and received among modules. For this task, technical partners have translated their input/output data from modules functionalities to messages. For this definition we have used a table template like this:

Table 12. Definition of messages for interoperability platform

Message	Subject	Payload
Message name and description	Message subject	Message itself
Descriptive name of the message Short description of the message	Being {MOD} the sender identifier (module in WP7), the subject has to have this format: <i>{MOD}.{type}.{subtype}</i>	Description of the JSON containing the data to be sent.

We have to distinguish between messages in common to all the modules, and specific messages sent by single module. In the first case, common messages correspond with notifications of a situation has happened. As an example, a notification of error is a message that can be sent by any of the WP7 modules. In the second case, specific messages are related to particular situations for a module. For instance, a message containing the predicted flexibility in the grid for the next step of time is a particular message sent by the Neighbourhood Demand Flexibility Profiling Module.

Please, consider that the duration of modules' development (tasks T7.2 to T7.9) are longer than the duration in T7.1, so the definition of the set of messages is going to be opened while those tasks are in progress as a living document. This is natural in the sense of changes in developments may occur, due unexpected restrictions or functionalities extensions. In the moment of delivering this document, the set of common messages is:

- Notification of an error during a calculation or operation. It includes a code of error and a human-readable text about the problem.
- Notification of the status of a module. It includes a code of status and a human-readable text about the status.
- Database changed: Notification that a module has updated data in the common storage system/database. It includes data such as the element that has been affected, the action itself and the moment of the operation.
- Synchronization: Messages to synchronize operation between modules. That is, a module needs that one or several modules start to make something at the same time. It includes the moment where the synchronization must be done and the modules affected.
- Data requests: A module needs data from another one in this moment. This message contains the operation identifier and the parameters to execute the request.
- Data response: This is the opposite operation to the previous one. The module that has received the request, send a response. In this case, the message contains the response.

The complete definition of these common messages is in *Annex 3. Definition of common messages interchanged*. The definition of the messages related to each module is in *Annex 4. Definition of messages related to modules*.

Last but not least, the NATS [28] server has been deployed in ETRA premises. One open discussion among partners is how many servers are needed for project requirements: a single server for all pilot sites or one server per pilot, due the huge number of messages that we anticipate that are going to be exchanged. So, in the moment of delivering this document, only one for development proposes is online (<nats://natsTwinERGY.etra-id.com>). This has allowed us to check the different ways of connection in NATS, being the connection by token the chosen one, as it is the easiest one for client modules.

Complementary to the NATS server itself, a web application has been developed by ETRA, NATS console, being accessible in this URL <https://twinegy-console.etra-id.com>. It consists of a tool related to monitor the server and publish/subscribe messages. Since the access is authenticated, only partners can work with it. The application has been created with the aim of supporting the development of modules in WP7 in different ways: a developer can send easily messages to be read by his/her module, check if a message has been sent from his/her modules, or test response time from his/her modules. The application is composed by these screens:

- **Dashboard:** The main page, where statistics are shown (connections, subscriptions, memory used, etc...)

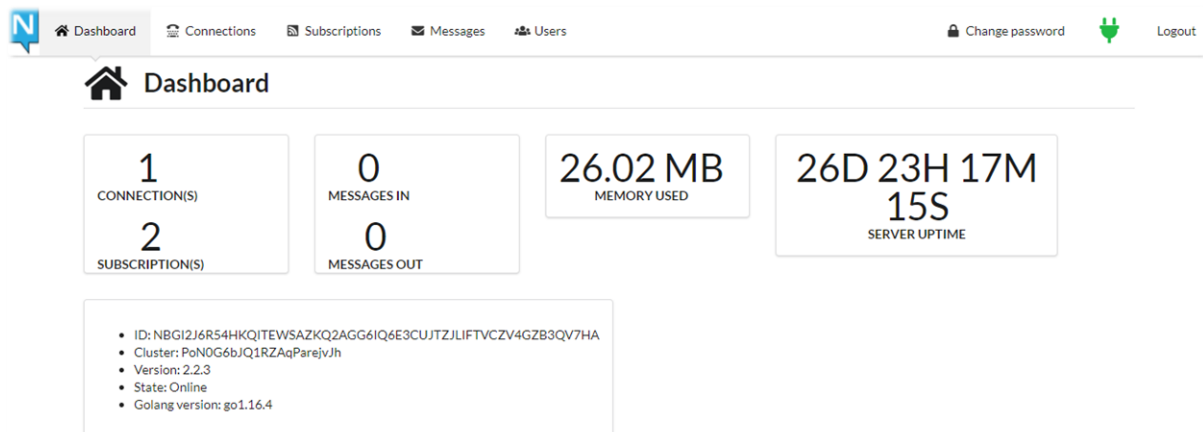


Figure 49. Dashboard view

- **Connections:** List of applications connected to NATS server. For each client connected, it shows its address, its activity and other information. Besides, if user clicks over the number of subscriptions of a client, the application goes to the view Subscriptions with the filter client set to the client.

Client id.	Address	From	Last activity	Idle	Messages in	Messages out	Pending bytes	Subscriptions	Language
23649	192.168.32.1:44188	2021-06-22 14:12:54	2021-06-22 14:13:12	2m 12s	0	0	0	2	typescript v1.2.15

Figure 50. Connections view

- **Subscriptions:** List of active subscriptions, allowing filter by a client and/or a subject. Per each subject, it informs about the client identifier, and the number of messages received with that subject. Besides, when the user clicks on one subject in the table, the application goes to Messages and start to listen that subject.

Client id.	Subject	# Messages
23652	example.subject1	0
23652	example.subject2	2
23652	example.*	2

Figure 51. Subscriptions view

- **Messages:** This screen allows to send messages with a subject, as well as listen to messages related to a subject.

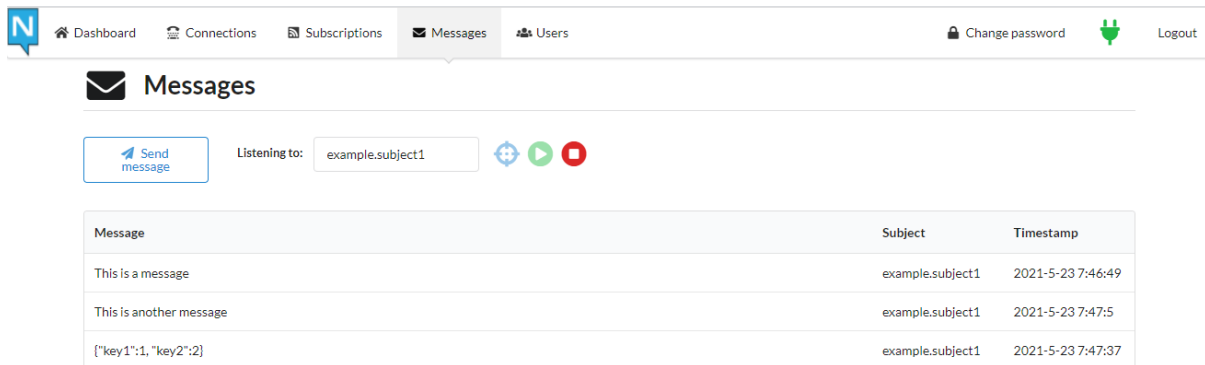


Figure 52. Message's view

The application starts to listen when the user inserts the subject in the field "Subject to listen" and click on green icon "play". On the other side, the subscription ends when the user clicks on red icon "stop". Alternatively, the application allows to subscribe to one existing subject, instead of filling that field:

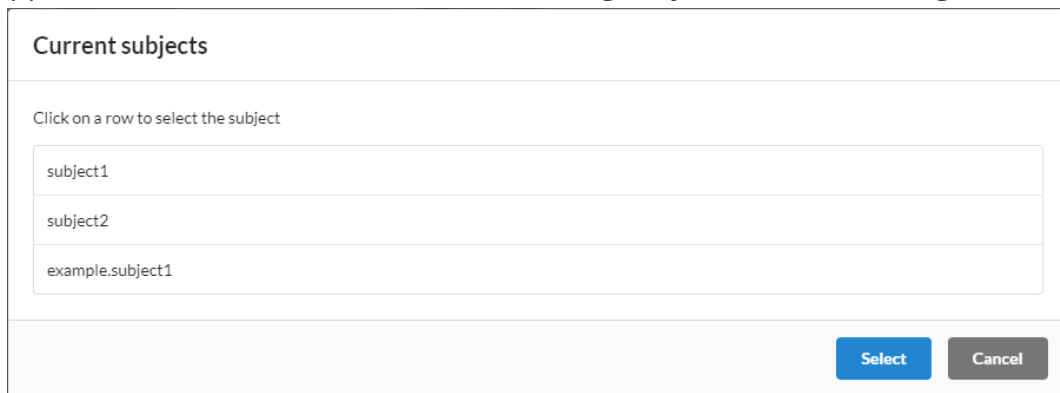


Figure 53. Window to select one existing subject

Finally, the user can send messages with a subject, with the button "Send message". One window to complete the information will appear.

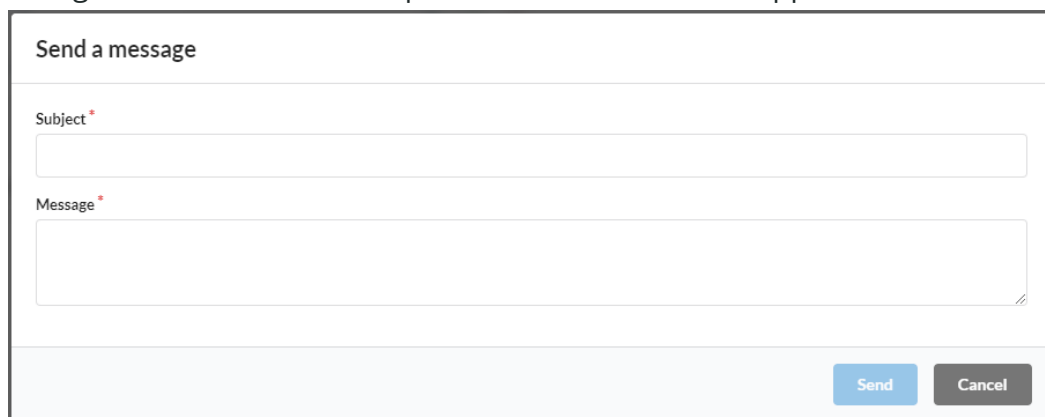


Figure 54. Window to send messages

6.5 Testing the platform

With the aim of checking that the platform is working, all technical partners have to ensure that their modules are able to connect to the platform and also to send/receive all different messages.

Since the delivering date of this document is previous to have a first version of modules in WP7, the real tests have not been started. So, for this needed task, we have defined a set of test cases to be implemented in test applications sending and receiving dummy data. These test applications have to reproduce the environment that the final real application will have, so the test cases not only ensure that each module will be able to connect, but it will be able to operate with the platform in the same way as in the real environment. These test cases are defined to be coded in the programming language that each partner has intention of using in their modules.

The test cases have been executed during the final part of the Task T7.1 by all the partners, getting successful results for all. Before exposing the list of test cases implemented, here we describe the structure of them. They are defined in tables like the following Table 13:

Table 13: Definition of test cases

Test case	Identifier. Name
Summary of test	A description of the test (scope, features to be tested, etc.)
Pre-conditions	List of conditions to be met before starting the test
Dependencies	List of previous test cases that have to be executed and passed before starting this test
Steps	List of steps that conforms the test case
Post-Condition	The final status after the execution of the test.
Acceptance criteria	What conditions have to be met in order to consider the test case as passed

Due this is a first step of testing of the platform, we have defined only three test cases:

1. Test of connection (Table 14).
2. Send/receive messages (Table 15).
3. Request/reply data (
4. Table 16).

Regarding to the real testing of the platform, it will be done as partners involved in WP7 start to develop the real modules, as well as they include the interchange of messages in their codes.

Table 14: Test 1 of connection to NATS

Test case	TC01. Test of connection
Summary of test	A module checks if it can reach the NATS server and connect to it.
Pre-conditions	<ul style="list-style-type: none"> • The NATS server is online and running
Dependencies	None
Steps	<p>1. Execute the instructions for connection to NATS. For example, in Javascript:</p> <pre>const nc = NATS.connect({url: "urlNATSserver", token: "keyToken", json:true}); nc.on('connect', (c) => { console.log(`Connected to server`); nc.close(); console.log(`Connected to server`); }); nc.on('error', (err) => { console.log(`error in connection:`); console.log(err); });</pre>
Post-Condition	The connection is done or an exception is generated
Acceptance criteria	The connection is done and no exceptions are generated

Table 15: Test 2 of connection to NATS

Test case	TC02. Send/receive messages
Summary of test	When a message related to notifications of error is generated, it is received by listeners subscribed to that type of messages
Pre-conditions	<ul style="list-style-type: none"> • The NATS server is online and running • There is one client application, called PUB, connected to the NATS server, actuating as publisher. • There is another client application, called LIST, connected to the NATS server, actuating as listener
Dependencies	TC01
Steps	<ol style="list-style-type: none"> 1. LIST subscribes to subject "test.messages". For instance, in Javascript: <pre>nc.subscribe("test.messages", (msg) => { console.log(msg.code); console.log(msg.message); });</pre> 2. PUB sends a message with subject "test.messages" and content {"code": 200, "message": "OK"}. For instance, in Javascript: <pre>nc.publish("test.messages", {"code":200, "message": "OK"});</pre>
Post-Condition	The application LIST receives the message with subject "test.messages" and content {"code": 200, "message": "OK"}.
Acceptance criteria	<ul style="list-style-type: none"> • The application PUB has not problems when sending the message. • The application LIST has to receive a message with subject "test.notification.error" and content { "code": 500, "message": "Test" }

Table 16: Test 3 of connection to NATS

Test case	TC03. Request/Reply data
Summary of test	A module request to another one for data and the second one responds.
Pre-conditions	<ul style="list-style-type: none"> • The NATS server is online and running • There is one client application, called REQ, connected to the NATS server, actuating as requester. • There is another client application, called RESP, connected to the NATS server, actuating as responder.
Dependencies	TC01, TC02
Steps	<ol style="list-style-type: none"> 1. RESP subscribes to messages of subject "getTime" and type "reply", and for those messages calculates the local date time and returns it . For instance, in Javascript: <pre>nc.subscribe("getTime", (msg, reply) => { if(reply) { const date = new Date().toLocaleString(); nc.publish(reply, {"time": date}); } });</pre> 2. REQ receives the response. For instance, in Javascript: <pre>nc.requestOne("getTime", (msg) => { console.log("the time is" + msg.time); });</pre>
Post-Condition	REQ receives a response with the local date time
Acceptance criteria	REQ receives the response and none exception is produced

7. Conclusions

The document presents the nine different modules that are in charge of providing customers with several services. These are quite varied and are addressed in several ways to different energy related aspects such as consumer empowerment, energy markets (under the perspective of local intelligence), promotion not only self-consumption and RES integration, but also addressing consumers to achieve the best energy deal. These different modules are being developed in posterior phases of the project under different tasks related to *WP7: Development of TwinERGY system Modules*. Nevertheless, this document is intended to reflect a brief overview related to the context in which the modules are being developed and the functionalities they foresee to provide. For that purpose, partners have prepared not only a detailed description of the functionalities, but also, they have identified the potential actors to be participating in the modules running process.

It should be highlighted that the different modules conform a distributed ecosystem from which modules are highly interdependent. As it has been shown in Chapter 5 and 6, these modules require a structure that allow the exchange of information. Related to the exchange of information among the different modules, this deliverable has targeted the creation of an Interoperability Platform for the modules, to allow them to exchange data. In order to achieve this goal, TwinERGY consortium agreed to use a single message exchanger based on NATS technology. This technology will allow an effective messaging method that distributes message among modules regardless its data language, since NATS allows JSON files in plain or structure way. NATS covers all the needs in the communication process among the modules, allowing them to request information to each other, send notifications and publish data in a secure way. Although this platform is defined in this deliverable, it must be taken into account that its implementation it is not completed during the duration of this task since module's development will be taking place in the rest of WP7 tasks (T7.2 – T7.9).

Consequently, changes may occur during this development phase, having a direct effect on the message schema (which has been defined in Chapter 6 and specified in *Annex 3. Definition of common messages interchanged.* and *Annex 4. Definition of messages related to modules*). Therefore, this deliverable will be used as a reference to conduct the communication of modules, once they will have reached a more advanced phase of development covering the challenges of interoperability among the modules. To aid in the smooth communication among the modules, this deliverable has introduced the web application for this NATS console that will act as the Interoperable platform for the

messages interchanged between modules in TwinERGY. This application has been created to support in a user-friendly manner to check the interchanged messages among the modules.

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Annex 1. Functionalities description

In this table it is presented the different functionalities presented by the modules up to the date of this deliverable.

Table 17: Functionalities list from modules

Func. ID Functionality Identifier: Key of Module	Name Functionality short name	Description Complete functionality description
M1.01	Personal data	Provide values calculated for each consumer/occupant
M1.02	Comfort level	Assesment of Comfort Level
Consumer.Flex.01	Forecasted energy consumption	Simulations can be run using the calibrated models of each building in each pilot site to generated forecasted time series demand
Consumer.Flex.02	Load disaggregation	Based on the calibrated model and historical demand data for a building, the load data can be disaggregated into individual channels
Consumer.Flex.03	Flexibility identification	Similar to the iVN, the forecasted RES production and demand data can be used to identify flexibility opportunities in the future
Consumer.Flex.04	Consumption optimisation	Through the user-specific dashboard, and based on specific building information, implicit demand response actions can be identified through optimisation and suggested to the user.
Neighbourhood.FI ex.01	RES production forecasting	The iVN can predict the renewable generation for a given period based on the capacity available and the weather forecast for the site in question
Neighbourhood.FI ex.02	Flexibility identification	Based on the forecasted RES production and expected demand profile, the iVN can provide information to the aggregator potential constraints or opportunities in terms of demand flexibility within the time period

Neighbourhood.FI ex.03	Demand response optimisation	Through the user-specific dashboard, and based on specific pilot site information, implicit demand response actions can be advised, and explicit actions can be identified for the operator using the optimisation algorithm
Neighbourhood.FI ex.04	Power system analysis	The iVN will evaluate all potential demand response actions and ensure network stability throughout, alerting the operator if any violations of equipment operating limits occur.
H&T-EMS.01	Energy Monitoring	Energy monitoring system
H&T-EMS.02	Optimal Energy Billing	Check the correct electrical energy billing+optimal billing (if available)
H&T-EMS.03	Electrical Flexibility Management	Based on the output of the "Consumer demand flexibility profiling Module" this functionality will translate flexibility actions into users' actions that will be communicated either through a GUI or actuated directly as loads control (e.g. smart plugs). Also the comfort and wellbeing module output are going to be taken into account.
H&T-EMS.04	Anomaly Detection	Checking of requested power versus nominal power of buildings' key loads.
H&T-EMS.05	Optimal RES Selector	Based on the weather forecast and on the PV weather forecast from the M5 module, the service will provide the best PV module tipology and their number
DERMgmt.01	grid status calculation	Provides grid status calculation in realtime for control purposes.
DERMgmt.02	grid bottleneck detection	Uses grid status results and compares with grid hardware information to detect bottlenecks.
DERMgmt.03	expected load	Load prediction functionality for predictive control of the grid

DERMgmt.04	expected generation	DER generation prediction based on weather data, resources etc.
DERMgmt.05	countermeasure calculation	Uses flexibility information provided by different technologies, such as batteries, ev-charging-stations, etc. to calculate countermeasures against current and predicted grid bottlenecks
DERMgmt.06	dynamic signal calculation	calculates a dynamic signal for demand response by the community
DERMgmt.07	feedback detection & countermeasure	detects feedback of the demand response of the habitants, if the feedback is to strong for the grid, countermeasures in direct operation with the DSO will be calculated and rolled out
Risk.01	Event Management-Situation Awareness	Anomaly in energy the behaviour of specific loads or structures
Risk.02	Risk Management-Scenarios evaluation	Quantitative Scenario Risk evaluation for different event and assets
TwinEV.01	logIn	It allows the user to log in the TwinEV module application
TwinEV.02	resetPassword	It allows the user to resset the password for his/her user in the TwinEV module application
TwinEV.03	createAccount	This function allows the creation of an user to be used in the TwinEV module platform
TwinEV.04	updateAccount	Update of an existing user account in the TwinEV module platform
TwinEV.05	deleteAccount	Deletion of an existing user account in the TwinEV module platform

TwinEV.06	configureEVehicle	Configuration of one or more vehicles associated to a charging profile
TwinEV.07	getFreeStations	Searching of available stations
TwinEV.08	bookingStation	This function is used by the eVehicle owners to book a Charging Point from a station from the available list.
TwinEV.09	routeCalculation	This function is used for the calculation of the cost of the route to the Charging Point
TwinEV.10	mostSuitableStations	This function will generate a list of the available charging points ranked under certain circumstances
TwinEV.11	minPrices	This function will create an optimal charging curve for eVehicles in terms of minimization of the pricing charge
TwinEV.12	maxGreenElectricity	This function will create an optimal charging curve for eVehicles in terms of maximization of the green energy providing from the grid
TwinEV.13	chargingSession	This function will create a charging session for the eV users
TwinEV.14	V2GMode	This function will analyse through the smart charging process the possible energy that can flow between the grid and the car in both ways in order to contribute as an asset in the DSO management
TwinEV.15	chargingPoints	This functionality will allow to manage the configuration of the charging points. This is to be used by either private users who own a charging point or CPO (Charging Point Operators)
SocialNetwork.01	Display consumption/generation information	Display information related to households consumption in a comprehensive manner
SocialNetwork.02	Display potential candidate users	Display potential candidate users from the neighborhood and allow the end-user to select whom to challenge

	for social comparison	
SocialNetwork.03	Social Competition challenges	Encourage demand response engagement and reduction in energy usage through social competition challenges
SocialNetwork.04	Offer rewards	Reward users with 'TwinERGY Points' or badges that can be redeemed in exchange for "eco positive" goods and services
SocialNetwork.05	Display information from DTP	Display community analytics screens with the aid of Digital Twin Platform
SocialNetwork.06	Co-creation of services	Enable co-creation for end consumers, service providers and public authorities (e.g. search services, group chat, stack overflow, group users based on location)
SocialNetwork.07	Customization of notifications regarding community	User to be able to parametrize the notification for co-creation (e.g. community batter SoC, production)
TwinTEP.00	Authenticate_module	Allows a TwinERGY module to authenticate against the TEP, establish connection and start communication.
TwinTEP.01	Account_creation	Allows a prosumer to have access to a transactive account that can be managed by TwinERGY modules via API.
TwinTEP.02	Account_inactivation	
TwinTEP.03	TwinERGY_IOT_creation	Allows a TwinERGY module to create a device in the TEP and link the device to one or more prosumers
TwinTEP.04	TwinERGY_IOT_relation	creates a new relation between a prosumer and an existing TwinERGY device
TwinTEP.05	Reward_prosumer	Rewards the prosumer with Twinergy tokens for the sale of Kwh

TwinTEP.06	Reverse_transaction	Burns tokens of a prosumer that were originally received via a reward
TwinTEP.07	Request_balance	Allows TwinERGY modules to retrieve the balance of a prosumer
TwinTEP.08	Pay_out_prosumer	Burns prosumer TwinERGY tokens and transfers the Ethereum equivalent to a prosumer ERC20 wallet on the Ethereum Mainnet.
TwinTEP.09	Prosumer_TX_history_twinergy	Allows TwinERGY modules to retrieve the transaction history of a prosumer on the TwinERGY blockchain
TwinTEP.10	Prosumer_TX_history_Ethereum	Allows TwinERGY modules to retrieve the transaction history of a prosumer on the Ethereum Mainnet blockchain
TwinTEP.11	Twinergy_IOT_device_history	Allows Twinergy modules to retrieve a transaction history of a TwinERGY IOT device
TwinTEP.12	Grid_operator_TX_history	Allows Twinergy modules to retrieve a transaction history of a grid operator
TwinTEP.13	Invoice_grid_operator	Sends a payment request to the grid operator to settle and back the TwinERGY tokens supplied with Ether.
TwinTEP.14	P2P_Transact	Exchanges KWH for Currency between prosumers

Annex 2. Modules' interoperability

In this table, it is presented the different interconnections between modules, and the functionality associated by its Identifier. In it can be found the description and the name of each of these functionalities.

Table 18: Modules' interoperability table.

Demanding Module As a demanding module partner, please introduce the module identifier	Demanded Module As a demanded module partner, please introduce the demanded module identifier	Functionality associated Identifier of the functionality associated to the data interchanged between modules
M1	M4	M1.02
M2	M1	M1.02
M2	M9	TwinTEP.09
M2	M3	Neighbourhood.Flex.02
M2	M4	H&T-EMS.02
M3	M2	Consumer.Flex.03
M3	M7	TwinEV.12; TwinEV.11
M3	M9	TwinTEP.09
M3	M4	H&T-EMS.02
M4	M2/M3	Consumer.Flex.02; Neighbourhood.Flex.02
M4	M9	TwinTEP.12
M4	M1	M1.02

M5/M4	M4/M5	H&T.X
M5	M2	Consumer.Flex.03
M5	M3	Neighbourhood.Flex.02
M6	M5	DERMgmt.01
M7	M3	TwinEV.11
M7	M5	TwinEV.11
M8	M3-M4	SocialNetwork.01-05
M8	M4	SocialNetwork.02-03
M8	M5	SocialNetwork.07
M9	M4	H&T-EMS.02
M9	M5	DERMgmt.02; DERMgmt.01
M9	M7	TwinEV.12

Annex 3. Definition of common messages interchanged.

To add information regarding the schema messaging

The above messages indicate in the previous section are listed here:

Table 19: Common messages interchanged

Message Message name and description	Subject Message subject	Data Description of the JSON with the data interchanged
Notification: Error {MOD} has generated an error during its execution	{MOD}.notify.error	{ "code": integer (HTTP code 400-599, referenced here), "message": string (human readable string) } <i>For instance: {</i> "code": 500, "message": "Too many requests. Re-starting module" }
Notification: Status {MOD} wants to notify its status	{MOD}.notify.status	{ "code": integer(HTTP code: 100-299, referenced here), "message": string (human readable string) } <i>For instance: {</i> "code": 202, "message": "Module back to normal" }
Notification: Database changed {MOD} has inserted, modified or deleted entities	{MOD}.notif.dbChanged	{ "timestamp": string (ISO Date of the operation), "dataset": string (collection/table/dataset that has changed) "action": string (INSERT/UPDATE/DELETE) "amount": string (ONE/MANY)

<p>in/from the Suite5 storage system/database</p>		<pre> "extra": string (other important information) } For instance: { "timestamp": 2021-02-25T23:40:45.123Z, "dataset": "forecasting" "action": "INSERT" "amount": "ONE" "extra": "id=YHDGE3HETFDy" } </pre>
<p>Synchronization {MOD} needs to synchronize with one or several modules</p>	<p>{MOD}.synchronization</p>	<pre> { "timestamp": string (ISO Date of the operation), "type": string (type/reason for synchronization), "destination": array[string] (array of affected modules) } For instance: { "timestamp": 2021-02-25T23:40:45.123Z, "type": "restart", "destination": ["M2", "M3"] } </pre>
<p>Data request {MOD} needs information from {MOD2}</p>	<p>{MOD}.request.{MOD2}</p>	<pre> { "operation": string (request type identifier), "keyId": string (identifier used for the response) "params": accorded format for the request between related partners } For instance: { "operation": "get_forecast", "keyId": "EUND/efg3G" "params": "period=24h" } </pre>
<p>Data response {MOD} responds to a request from {MOD2}</p>	<p>{MOD}.response.{MOD2}</p>	<pre> { "keyId": string (same identifier as the data request message which sourced this response) "response": string (JSON) } </pre>

		<p><i>For instance, (in response to example of previous row):</i> { <i>"keyId": "EUND/efg3G"</i> <i>"response": [23.4, 33.0, 30.0, ... 45.9]</i> }</p>
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Annex 4. Definition of messages related to modules

A4.1. Consumer Comfort/Well-being Module

The list of messages for this module are:

Table 20: List of messages in Consumer Comfort/Well-being module

Message name and description	Subject Message subject	Payload Message itself
<p>Data request</p> <p>M1 needs information from M4</p>	M1.request.M4	<pre>{ "operation": String [request type identifier], "keyId": String [identifier used for the response] "params": accorded format for the request between related partners }</pre> <p><i>For instance: {</i></p> <pre> "operation": "indoor temperature", "keyId": "EUND/efg3G" "params": { userID="1", "period=24h" }</pre> <p><i>}</i></p> <p><i>For instance: {</i></p> <pre> "operation": "indoor humidity", "keyId": "EUND/efg3G" "params": { userID="1", "period=24h" }</pre> <p><i>}</i></p>
<p>Data response</p> <p>M4 responds to a request from M1</p>	M4.response.M1	<pre>{ "keyId": String (same identifier as the data request message which sourced this response) "response": String (JSON) }</pre> <p><i>For instance, (in response to example of previous row): {</i></p> <pre> "keyId": "EUND/efg3G" "response": [23.4, 22.0, 23.0, ... 22.9]</pre>

		<pre> } For instance, (in response to example of previous row): { "keyId": "EUND/efg3G" "response": [55.4, 55.0, 52.0, ... 57.9] } </pre>
--	--	---

A4.2. Consumer demand flexibility profiling Module

This module does not send specific messages, but common messages.

A4.3. Neighbourhood demand flexibility profiling Module

This module does not send specific messages, but common messages.

A4.4. Home & Tertiary real-time Energy monitoring

Table 21: List of messages in Home & Tertiary real-time Energy monitoring

Message Message name and description	Subject Message subject	Payload Message itself
Data Request Short description of the message	M4.Timeseries.MonitorData	[<pre> { "id": 0, "referenceDateFrom": "2021-06-25T16:07:37.696Z", "referenceDateTo": "2021-06-25T16:07:37.696Z", "energy": 0, "reactiveEnergy": 0, "minVoltage": 0, "maxVoltage": 0, "vendorMeter": { "vendorMeterId": "string", "channel": "string" } } </pre>

		<pre> } }]</pre>
<p>Data response Possible message for the real VS optimal users energy behaviour</p>	<p>M4.Timeseries. EnergyBehaviour</p>	<pre> { "id": 0, "assetId": 0, "discomfort": 0, "status": "SOLVED/UNSOLVED", "result": { "optimizationReferenceId": 0, "canonicalOffpeakCost": 0, "realFlexCost": 0, "optimizedFlexCost": 0, "optimizedCycleTimes": [{ "assetReferenceId": 0, "nodeName": "string", "canonicalCost": 0, "optimizedCost": 0, "optimizedCycleTimes": { "additionalProp1": [{ "from": 0, "to": 0 }], "additionalProp2": [{ "from": 0, "to": 0 }], "additionalProp3": [{ "from": 0, "to": 0 }] } }] } }</pre>

		<pre>], "powerDistributions": { "additionalProp1": [{ "from": 0, "to": 0, "power": 0 }], "additionalProp2": [{ "from": 0, "to": 0, "power": 0 }], "additionalProp3": [{ "from": 0, "to": 0, "power": 0 }] } } } </pre>
--	--	---

A4.5. DER management Module

For this module, messages use the following data structures:

- String: String, serial of characters.
- Float: Real value.
- ISODate: String representing a date with format [ISO Date](#).
- Timeseries: JSON containing the value of local res in an interval of time:

```

{
  "start": ISODate (when the period starts),
  "end": ISODate (when the period ends),
  "value": Float (share of local res)
}

```

The messages are:

Table 22: List of messages in DER management Module

Message Message name and description	Subject Message subject	Payload Message itself
Notification: Share of local Energy M5 sends information about the predicted share of local RES in the grid	<i>M5.notif.predictedShareOfLocalEnergy</i>	<pre>{ "timestamp": ISODate (calculation time), "longitude": Float, "latitude" : Float, "city": String (name of the city, e.g., Benetutti), "country": String (country, e.g., Italy), "unit": String (unit of measurement -> here percent) "curve": array of Timeseries }</pre>
Notification: Predicted energy demand M5 sends information about the predicted local energy demand	<i>M5.notif.predictedEnergyDemand</i>	<pre>{ "timestamp": ISODate (calculation time), "longitude": Float, "latitude" : float, "city": String (name of the city, e.g., Benetutti), "country": String (country, e.g., Italy), "unit": String (unit of measurement -> here kWh or MWh) "curve": array of Timeseries }</pre>
Notification: Predicted RES energy production M5 sends information about the	<i>M5.subject.notif.predictedRES EnergyProduction</i>	<pre>{ "timestamp": ISODate (calculation time), "longitude": Float, "latitude" : Float, "city": String (name of the city, e.g., Benetutti), "country": String (country, e.g., Italy), }</pre>

<u>predicted local res production</u>		<pre>"unit": String (unit of measurement -> here kWh or MWh) "curve": array of Timeseries }</pre>
Notification: Consumer DR Signal M5 sends information about the local DR-Signal (if directly used by HEMS)	<i>M5.notif.consumerDRSignal</i>	<pre>{ "timestamp": ISODate (calculation time), "longitude": Float, "latitude" : Float, "city": String (name of the city, e.g., Benetutti), "country": String (country, e.g., Italy), "unit": String (unit of measurement -> here unitless) "curve": array of Timeseries }</pre>

A4.6. Risk Management and event handling Module

Table 23: List of messages in Risk Management and event handling module

Message Message name and description	Subject Message subject	Payload Message itself
Notification: Anomaly Detection of anomalies in the energy patterns	<i>{M6}.{notif}.{anlomag}</i>	<pre>{ "id": 0, "referenceDateFrom": "2021-06-25T16:07:37.696Z", "referenceDateTo": "2021-06-25T16:07:37.696Z", "longitude": Float, "latitude" : Float, "city": String "country": String (country, e.g., Italy), "Event": array of Timeseries }</pre>

A4.7. TwinEV Module

For this module, the messages use the following data structures:

- Boolean: true/false.
- String: String, serial of characters.
- Float: Real value.
- ISODate: string representing a date with format [ISO Date](#).
- Period: JSON with information about energy imported or exported in a period of time. It is composed by:

```
{
  "start": ISODate (when the period starts),
  "end": ISODate (when the period ends),
  "eImported": Float (energy imported from grid)
  "eExported": Float (energy exported to grid if V2G is available)
}
```

The messages are:

Table 24: List of messages in TwinEV module

Message Message name and description	Subject Message subject	Payload Message itself
Notification: Future charging curves M7 sends the estimated charging curves for a future charging session.	<i>M7.notif.future_charging_curve</i>	<pre>{ "timestamp": ISODate (when the operation will start), "charging_station": String (charging station identifier), "vehicle": String (vehicle identifier), "V2G": Boolean (if vehicle supports V2G functionality), "curve_default": array of Period (estimated charging curve related to default charge), "curve_green": array of Period (estimated charging curve related to "green" charge), "curve_faster": array of Period (estimated charging curve related to "faster" charge), "curve_cheaper": array of Period (estimated charging curve related to "cheaper" charge), }</pre>
Notification: Charging curve	<i>M7.notif.charging_curve</i>	<pre>{</pre>

<p>M7 sends information about the charging curve for a charging session</p>		<pre> "timestamp": ISODate (when the operation starts), "charging_station": String (charging station identifier), "vehicle": String (vehicle identifier), "V2G": Boolean (vehicle supports V2G functionality) "curve": array of Period (curve calculated for this session) } </pre>
<p>Notification: New restrictions to the grid</p> <p>M7 sends the restrictions for the grid, configured by the DSO</p>	<p><i>M7.notif.dso_restrictions</i></p>	<pre> { "start": ISODate (when restrictions become valid), "end": ISODate (when restrictions become invalid), "V2G": Boolean (needs to use V2G when possible), "max": Float (Maximal power to be supplied by the charging points), "min": Float (Minimal power to be supplied by the charging points) } </pre>
<p>Notification: new eVehicle user</p> <p>M7 notifies a new user with electric vehicle.</p>	<p><i>M7.notif.new_eVehicle</i></p>	<pre> { "timestamp": ISODate (creation date), "user": String (user identifier), "vehicle": String (vehicle identifier), "storage": String (collection/storage system where related data is stored) "register": String (identifier of the register containing the data) } </pre>
<p>Notification: Removed eVehicle user</p> <p>M7 notifies that has removed a user with electric vehicle</p>	<p><i>M7.notif.remove_eVehicle</i></p>	<pre> { "timestamp": ISODate (removing date), "user": String (user identifier), "vehicle": String (vehicle identifier) } </pre>

<p>Notification: New charging point</p> <p>M7 notifies a new charging point belonging to a charging station</p>	<p><i>M7.notif.future_charging_curve</i></p>	<pre>{ "timestamp": ISODate (creation date), "CP": String (charging point identifier), "CS": String (charging station identifier), "storage": String (collection/storage system where related data is stored) "register": String (identifier of the register containing the data) }</pre>
<p>Notification: Charging point removed</p> <p>M7 notifies that has removed a charging point belonging to a charging station</p>	<p><i>M7.notif.dso_restrictions</i></p>	<pre>{ "timestamp": ISODate (removing date), "CP": String (charging point identifier), "CS": String (charging station identifier) }</pre>

A4.8. Social Network Module

For this module, the messages use the following data structures:

- Boolean: true/false.
- String: String, serial of characters.
- Float: Real value.
- ISODate: string representing a date with format [ISO Date](#).
- SinglePeriod: JSON with information about periods of time. It is composed by:


```
{
  "start": ISODate (when the period starts),
  "end": ISODate (when the period ends)
}
```
- EnergyPeriod: JSON with information about energy imported and exported in each period of time. It is composed by:


```
{
  "start": ISODate (when the period starts),
  "end": ISODate (when the period ends),
  "eImported": Float (energy imported from grid)
  "eExported": Float (energy exported to grid if V2G is available)
}
```

- ChargePeriod: JSON with information about charge in each period of time. It is composed by:

```
{
  "start": ISODate (when the period starts),
  "end": ISODate (when the period ends),
  "eCharge": Float (energy used)
  "eDischarge": Float (energy exported to grid if discharging)
}
```

- Recommendation: JSON with information about a challenge:

```
{
  "start": ISODate (when the period starts),
  "end": ISODate (when the period ends),
  "description": String (challenge description),
  "target": Float (challenge target)
}
```

- Consumer: JSON with information about a consumer:

```
{
  "user": String (consumer identifier),
  "location": String (user location)
}
```

- Reward: JSON with information about a reward:

```
{
  "reward": String (reward identifier)
  "description": String (reward description)
}
```

- Setting: JSON containing a setting:

```
{
  "setting": String (setting identifier)
  "description": String (setting description)
  "value": String (setting value)
}
```

The messages are:

Table 25: List of messages in Social Networking module

Message Message name and description	Subject Message subject	Payload Message itself
Data request M8 needs information from M3-4	M8.request.M4	Depending on the request, the message will be one of these JSONs: <pre> { "operation": String ("get_gener_forecast"), "keyId": String("EUND/efg3G"), "assetId": String (e.g., "PV1"), "Period": array of SinglePeriod, "forecast": array of Float (values in kWh) } { "operation": String ("get_smart-meter_load"), "keyId": String ("EUND/efg3G"), "meteringPointId": string(e.g., House1), "Period": array of SinglePeriod, "energyMeter": array of Float (energy in kWh) } { "operation": String ("get_current_load"), "keyId": String("EUND/efg3G"), "timestamp": ISODate, "device": String (device identifier) "smart": Boolean (smart device) } { "operation": String ("get_smartDevices_schedules"), "keyId": String("EUND/efg3G"), "userID": String (e.g., "House1"), "device": String (device identifier), "Period": array of SinglePeriod, "curve": array of Float } </pre>
Data request	M8.request.M5	Depending on the request, the message will be one of these JSONs:

<p>M8 needs information from M5</p>		<pre>{ "operation": String("get_EV_chargingStatus"), "keyId": String("EUND/efg3G"), "charging_station": String (charging station identifier), "vehicle": String (vehicle identifier), "V2G": Boolean (vehicle supports V2G functionality) "curve": array of EnergyPeriod (per each period of time, the energy imported-exported) }</pre> <pre>{ "operation": String("get_BESS_status"), "keyId": String("EUND/efg3G") "BESSid": String (battery identifier), "curve": array of ChargePeriod (per each period of time, the energy imported-exported) }</pre>
<p>Notification: Consumers Recommendations M8 sends information about recommendations on neighbouring consumers for energy challenge</p>	<p><i>M8.notif.consumers_rec</i></p>	<pre>{ "timestamp": ISODate, "neighbourhood": String (neighbourhood identifier), "consumer": String (consumer identifier), "recs": array of Recommendation (challenge target per each period of time) }</pre>
<p>Notification: Neighbourhood Users M8 sends information about set of potential candidate users from the</p>	<p><i>M8.notif.neighbourhood_users</i></p>	<pre>{ "timestamp": ISODate (when the operation starts), "neighbourhood": String (neighbourhood identifier), "consumers": array of Consumer (per each neighbourhood) }</pre>

neighbourhood (recommendations)		
Notification: User Rewards M8 sends information about user rewards via 'TwinERGY Points' or badges	<i>M8.notif.user_rewards</i>	{ "timestamp": ISODate (when the operation starts), "user": String (user identifier), "type": Boolean (TwinERGY Points or badges), "points": Float (TwinERGY Points), "rewards": array of Rewards (for each user) }
Notification: User Settings M8 sends information about user configuration file for selected consumption settings	<i>M8.notif.user_configuration_settings</i>	{ "timestamp": ISODate (when the operation starts), "user": string (user identifier), "settings": array of Setting (for each user) }

A4.9. Transactive Energy Module

Table 26: List of messages in Transactive Energy Module

Message name and description	Subject	Payload
Message subject	Message subject	Message itself
Notification: Error code <i>Expectation that prosumers and devices</i>	<i>M9.notif.error</i>	{ "timestamp": string (ISO Date when the message is broadcasted), "code": integer (HTTP code 400-599, referenced here), }

<p><i>joining the TwinERGY network are also broadcasted via the NAT server.</i></p>		<pre> "message": string (human readable string) } TEM custom error code messages { "code": 409, "message": "Prosumer account already exists" "Device already exists" "Device already has an existing prosumer relation" "Device already has an existing consortium relation" "Prosumer is already a member of the consortium" "Prosumer account does not exist" "Device does not exist" "Consortium does not exist" "No data available for date range" "Transaction destination unknown" } </pre>
<p>Notification: Forecasting of LEM price TEM broadcasts the total transacted energy for a specific period</p>	<p><i>M9.notif.forecast.lem_price</i></p>	<pre> { "timestamp": string (ISO Date when the message is broadcasted), "lem_ID": string (LEM identifier), "price_kwh": array of Period (96 price values) "dso_price": array of Period (96 price values) } </pre>
<p>Data Request</p>	<p><i>M5.notif.predictedShareOfLocalEnergy</i> <i>M5.notif.predictedEnergyDemand</i></p>	

M9 needs information from M5	<i>M5.subject.notif.predictedRESEnergyProduction M5.notif.consumerDRSignal</i>	
Data Request M9 needs information from M4	<i>Pending messaging from STAM which is relying on the pilot site equipment</i>	
Data Request M9 needs information from Digital Twins		

