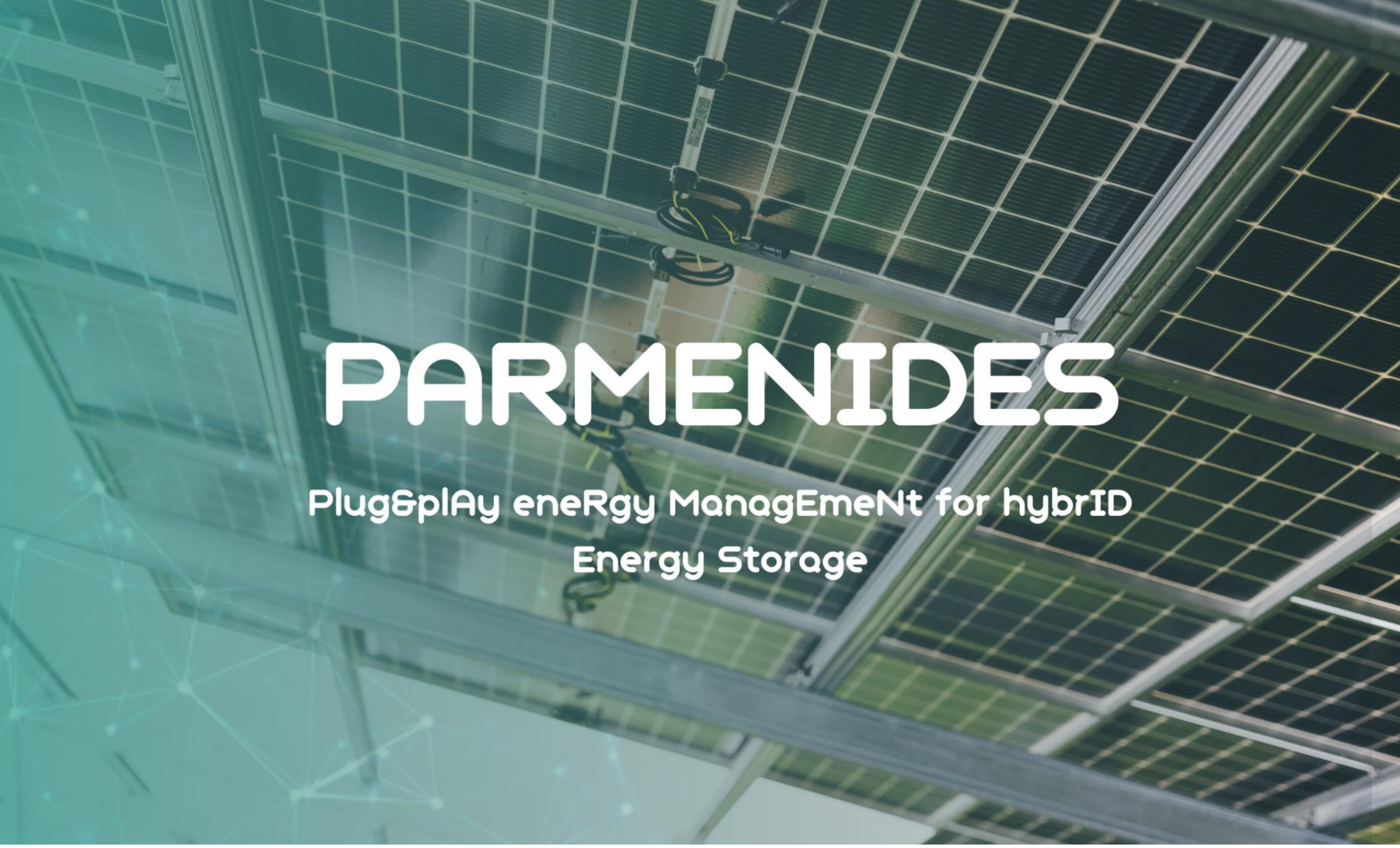


Deliverable D2.2

Use-case scenarios and requirements

Work Package 2

Disclaimer

The content of this deliverable reflects only the author's view. Neither the European Climate, Infrastructure and Environment Executive Agency (CINEA) nor the European Commission is responsible for any use that may be made of the information it contains.

Funded by the European Union's Horizon Europe programme under Grant Agreement nº 101096453

PARMENIDES

Grant agreement	101096453
Type of action	HORIZON-IA HORIZON Innovation Actions
Topic	HORIZON-CL5-2022-D3-01-10 Interoperable solutions for flexibility services using distributed energy storage
Starting date of project	01.01.2023
Project duration	36 months

Work package	WP2 – Requirements for energy communities
Related task	T2.2 – Use case definition and requirements analysis
Deliverable due date	M9 (30.09.2023)
Actual delivery date	M9 (30.09.2023)
Dissemination level	PU - Public
Deliverable responsible	KTH

Document Information

Document Version: 1.0

Revision / Status: Submission

All Authors/Partners

Name	Organisation
Lorenz Ray Payonga	KTH Royal Institute of Technology
Hatef Madani	KTH Royal Institute of Technology
Mark Stefan	AIT Austrian Institute of Technology
Jawad Kazmi	AIT Austrian Institute of Technology
Maria Aigner	ENS Energienetze Steiermark GmbH
Gregor Taljan	ENS Energienetze Steiermark GmbH

Document History

Revision	Content/changes	Resp. partner	Date
0.1	Initial version & and structure	AIT	07.08.2023
0.2	Use Case Draft	KTH	13.08.2023
0.3	Methodology	KTH	04.09.2023
0.4	Demonstrators	ENS, AIT, KTH	07.09.2023
0.5	Update use Cases	AIT, KTH	11.09.2023
0.6	Review and finalisation	ENS, AIT, KTH	15.09.2023
0.7	Finalisation	KTH, AIT	26.09.2023
1.0	Version for submission	KTH, AIT, ENS	28.09.2023

Document Approval

Final approval	Name	Resp. partner	Date
1.0	Mark Stefan	AIT	29.09.2023

Executive Summary

This document describes a number of use cases and scenarios which will be considered in PARMENIDES. 4 relevant use cases and 8 different use case scenarios have been identified, some of them will be implemented in the PARMENIDES pilots in Austria and Sweden, some of them will be tested only in the virtual environment. The use cases cover passive and active energy community participation as well as automated participation with human interaction and fully automated participation – aligned with USEF and 10 automation levels. The use cases are described by using the IEC 62559 template. Furthermore, an overview about the pilots is provided.

PARMENIDES

Table of contents

PARMENIDES

Abbreviations

Acronym	Description
aFRR	Automatic Frequency Restoration Reserve
BESS	Battery Energy Storage System
BMS	Building Management System
BRP	Balance Response Party
C & I	Commercial and Industry
CHP	Combined Heat and Power
DA	Day-Ahead
DER	Distributed Energy Resource
DF	Distributed Flexibility
DSF	Demand Side Flexibility
DSM	Demand Side Management
DSM	Demand Side Management
DSO	Distribution System Operator
EC	Energy Community
ECM	Energy Community Manager
EMS4HESS	Energy Management System for Hybrid Energy Storage Systems (Energy Community Energy Management System)
ESCO	Energy Supply Company
EV	Electric Vehicle
FCR	Frequency Containment Reserve
GCM	Grid Capacity Management
GWP	Global Warming Potential
HEMS	Home Energy Management System
HESS	Hybrid Energy Storage System
HSS	Hybrid Storage System
ICS	Information and Configuration System
ID	Intra-day
IEMD	Internal Electricity Market Directive
LiL	KTH Live-In Lab
mFRR	Manual Frequency Restoration Reserve
MID	Measuring Instruments Directive
PECO	PARMENIDES Energy Community Ontology
PV	Photovoltaic

Acronym	Description
RED	Renewable Energy Directive
RR	Replacement Reserve
RTP	Real Time Pricing
SGAM	Smart Grid Architecture Model
SM	Smart Meter
ToU	Time-of-Use
TSO	Transmission System Operator
USEF	Universal Smart Energy Framework
VLab	AIT Virtual Verification Laboratory
VPN	Virtual Private Network

1. Introduction

1.1. Scope

The aim of this document is to describe relevant use cases for PARMENIDES which will be implemented in the project. Some of the use cases will be demonstrated in the pilots in Austria and Sweden, some of the use cases will be implemented only in a virtual environment.

The use cases are described by using the IEC 62559-2 template and methodology as well as by consideration of the Universal Smart Energy Framework (USEF) and the Smart Grid Architecture Model (SGAM). This ensures a well-structured description of the use cases, including the involved actors, scenarios, sequence diagrams, system diagrams, etc. The use case descriptions will provide the baseline for all upcoming project activities and will support in further refinement and the pilot-specific architecture definition as well as in developing the PARMENIDES Energy Community Ontology (PECO) and the software components, such as the Energy Management system for Hybrid Energy Storage Systems (EMS4HESS), the Grid Capacity Management (GCM), and the Information and Configuration System (ICS) for energy communities and their customers.

In PARMENIDES 4 different high-level use cases are identified: (1) Passive Energy Community Customer Optimization, (2) Active Energy Community Participation, (3) Automated Energy Community Participation with Human Interaction, and (4) Fully Automated Energy Community Participation. Additionally, 8 applicable use case scenarios are identified and assigned to the use cases and pilots.

1.2. Structure of the document

On overview about the methodology is given in Section 2, describing the Universal Smart Energy Framework (USEF), the Smart Grid Architecture Model (SGAM) and the IEC 62559-2 methodology. In Section 3, an overview about the PARMENIDES pilots (Austria, Sweden, Virtual Environment) is given. Section 4 provides a detailed overview about the use cases, in particular automation levels, applicable scenarios, optimization features, and flexibility strategies are described; an overview about the actors, devices, and systems is given, followed by the use case details, based on the IEC template. Non-functional requirements as baseline for further refinement and the architecture design are provided in Section 5.

2. Methodology

2.1. Universal Smart Energy Framework (USEF)

The Universal Standard Energy Framework (USEF) is a common standard to build all smart energy products and services. Established by the USEF Foundation (founded 2014) made up of seven key players – ABB, Alliander, DNV, Essent, IBM Group, and Stedin – it has since come up with two versions: the initial public release in 2015 and the 2021 update. The latter has been aligned with the changes in the EU's Clean Energy Package (CEP), particularly the EU Directive 2019/944 on the common rules for the internal market for electricity [1]. It is in the CEP where the concept of energy communities (EC) was formally defined and intended to be transposed to constituent member states.

Although the USEF Foundation officially ended its activities in July 2021, the framework they created continues to be a valuable input in the structuring of an energy/electricity market that allows for flexibility services. According to the framework document, it "unlocks the value of flexible energy use by making it a tradeable commodity and by delivering the market structure and associated rules and tools required to make it work effectively." Additionally, it is intended to "fit on top of most energy market models, extending existing processes, to offer the integration of both new and existing energy markets" as well as to "offer fair market access and benefits to all stakeholders."

Among other publications of the USEF Foundation, the focus of this section are the USEF provisions in the 2021 update of "USEF: The Framework Explained" [2] that are relevant to the PARMENIDES Project. Of particular relevance is the USEF's guiding principle of a market-based flexibility activation in which the Aggregator holds a central role. In the context of ECs, the USEF states that ECs may either collectively reach out to Aggregators and negotiate the participation of its members (see Figure 1) or they can take the role of Aggregator and/or Energy Service Company (ESCo) themselves without being profit-driven (see Figure 2). They can assume the role of a flexibility retailer between its members and "Flexibility Requesting Parties" (FRPs), which can be the Distribution System Operator (DSO), the Transmission System Operator (TSO), and/or a separate Balance Responsible Party (BRP).

The USEF describes seven energy and flexibility services an EC can offer or make use of. These are (1) Services that increase energy awareness, (2) Services to facilitate the joint purchase and maintenance of (shared) assets, (3) Supply of (shared) energy, (4) Peer-to-Peer supply, and demand-side flexibility (DSF) services such as (5) optimization of individual Active Customers' energy profiles and (6) also of the EC as a whole (i.e., implicit DSF), and (7) the provision of explicit DSF services. Implicit DSF services ((5) and (6)) are often provided by ESCos, while explicit DSF services is allocated by the USEF for the Aggregator role. As mentioned earlier, an EC can assume both these roles. The ***PARMENIDES Energy Community Ontology (PECO)*** is tailored to ECs that do so. The DSFs are elaborated in the following paragraphs.

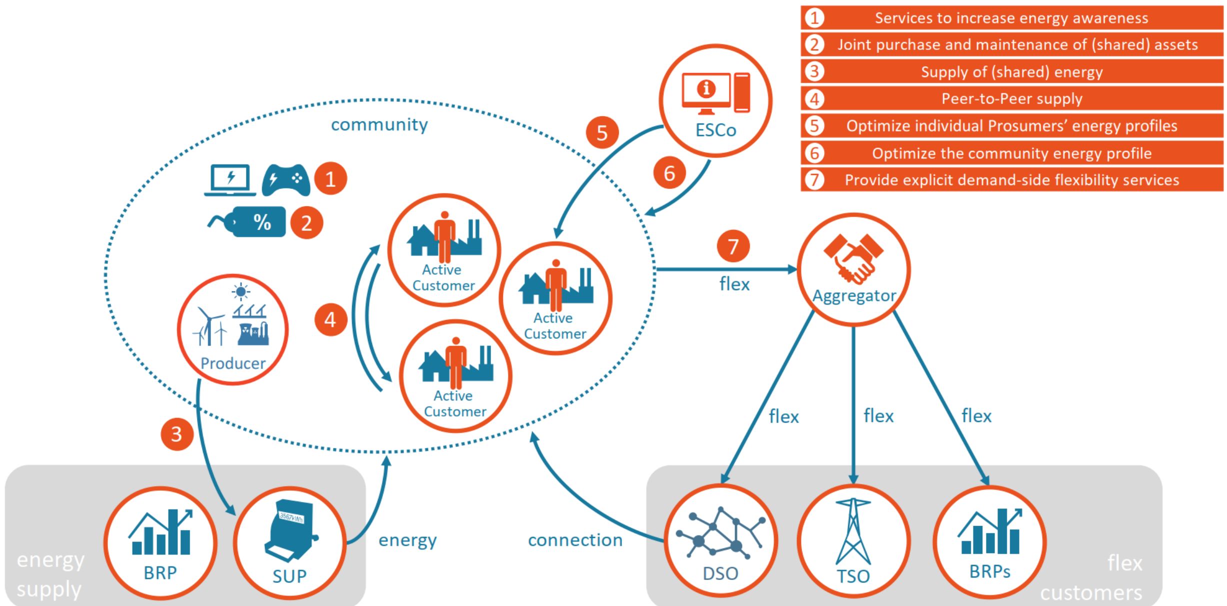


Figure 1: Energy and flexibility services for an EC and its members [2]

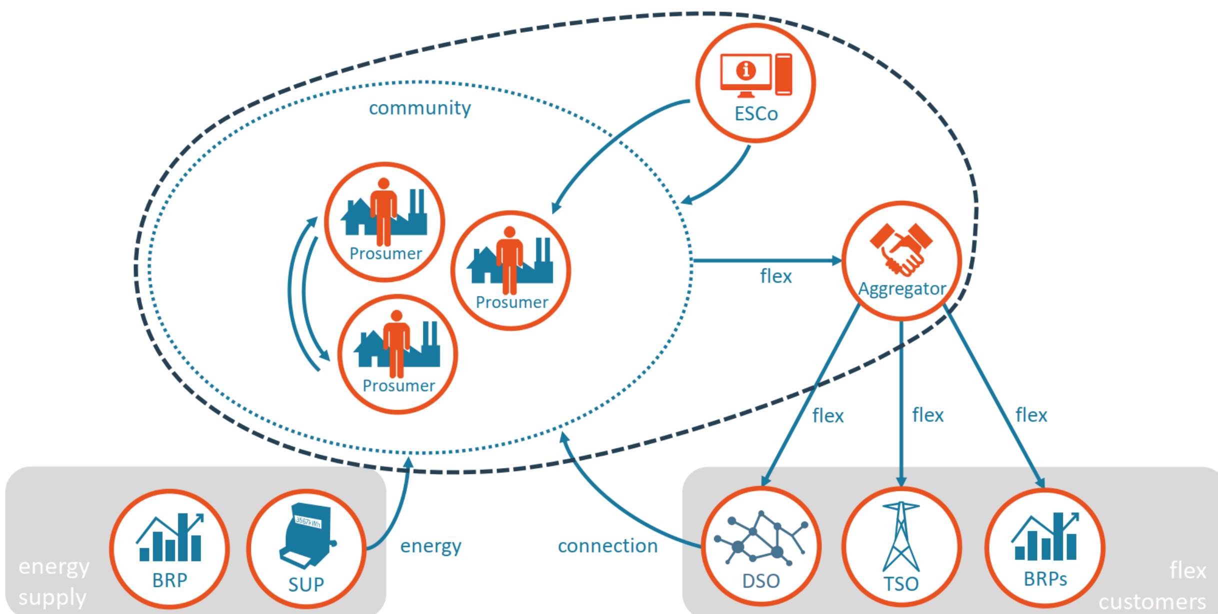


Figure 2: Illustration of the EC that takes on the role of both ESCo and Aggregator, thereby having the possibility to offer optimization for both implicit and explicit DSF services to its members [3]

Implicit DSF services include Time-of-Use (ToU) optimization, control of the maximum load (kW_{max} control), self-balancing services, and emergency power supply. Below are the corresponding USEF descriptions for Active Customers, which can also be extended to an aggregated EC profile:

1. **ToU Optimization:** Optimization based on load shifting from high-price intervals to low-price intervals (or vice versa in case of generation shifting), or even complete load shedding during periods with high prices. The time discrimination of ToU tariffs can vary; for example, peak/off-peak tariffs generally apply for 2 periods of time whereas Real Time Pricing (RTP) can have higher granularity e.g., hourly prices. This optimization requires that price schedules are known in advance (e.g., day-ahead). Using Distributed Flexibility (DF) for ToU optimization will lower the Active Customer's energy bill. ToU optimization is an implicit form of wholesale trading, with the Supplier as the trading party.
2. **kW_{max} Control:** Reducing the maximum load (peak shaving) that the Active Customer consumes within a predefined period (e.g., month, year), either through load or generation shifting, or shedding, with the objective to minimize grid fees. Current grid tariff schemes, especially for Commercial and Industrial (C&I) customers, often include a tariff component that is based on the Active Customer's maximum load (kW_{max}) and/or the connection capacity. Using DF to reduce the maximum load can reduce the grid component of the electricity bill for the Active Customer. Helping them avoid the one-off costs associated with a grid connection upgrade is another potential benefit.
3. **Self-balancing:** Typical for Active Customers who also generate electricity (e.g., through PV panels or CHP systems) and have flexible demand. Value is created through the difference in the prices for supply from the grid (buying) and feed-in to the grid (selling), including taxation. Note that self-balancing is not financially beneficial for Active Customers when national regulations allow for full administrative balancing (net-metering) of net load, and net generation, on an annual basis.
4. **Emergency Power Supply:** Emergency power supply during grid outages. Whether this is of sufficient value to the Active Customer depends mainly on the grid's reliability and the potential damage from a grid outage ('value of lost load'); this, in turn depends on the type of Active Customer (e.g., residential home, office building or hospital). Enabling the use of DF for islanding for emergency power supply may require additional investments, e.g., storage and synchronization systems.

Explicit DSF services include constraint management services, adequacy services, wholesale services, and balancing services. These services are made available when ECs agree to respond to BRP, DSO, or TSO requests to adjust their load or generation profile. It is the EC's Aggregator or the EC itself acting the role of an Aggregator that is responsible for activating these services. Thus, individual Active Customers cannot provide these services by themselves. Below are USEF descriptions for these services:

1. **Constraint Management Services:** Help the grid operators (TSO and DSO) to optimize grid operation using physical constraints, and impact on markets. Under this service category are voltage control, grid capacity management, congestion management, and controlled islanding and restoration.
2. **Adequacy Services:** Aim to increase security of supply by organizing sufficient long-term peak and non-peak generation capacity. Included in this service category are capacity markets, capacity payments, strategic reserves, and hedging.

3. **Wholesale Services:** Help BRPs to decrease sourcing costs (purchase of electricity) – mainly on Day-Ahead (DA) and Intraday (ID) markets - but also costs for sourcing through balancing mechanisms. Under this service category are day-ahead optimization, intraday optimization, self-balancing and passive balancing, and generation optimization.

4. **Balancing Services:** Services include all services specified by the TSO for frequency regulation. Included in this service category are frequency containment reserve (FCR), automatic frequency restoration reserve (aFRR), manual frequency restoration reserve (mFRR) and replacement reserve (RR).

Finally, the USEF recognizes four operating regimes, which are also referenced in the **PARMENIDES** project Use Cases. These are the Green (Normal Operations), Yellow (Capacity Management), Orange (Graceful Degradation), and Red (Power Outage) operating regimes. Figure 3 shows their descriptions from the perspective of the DSOs.

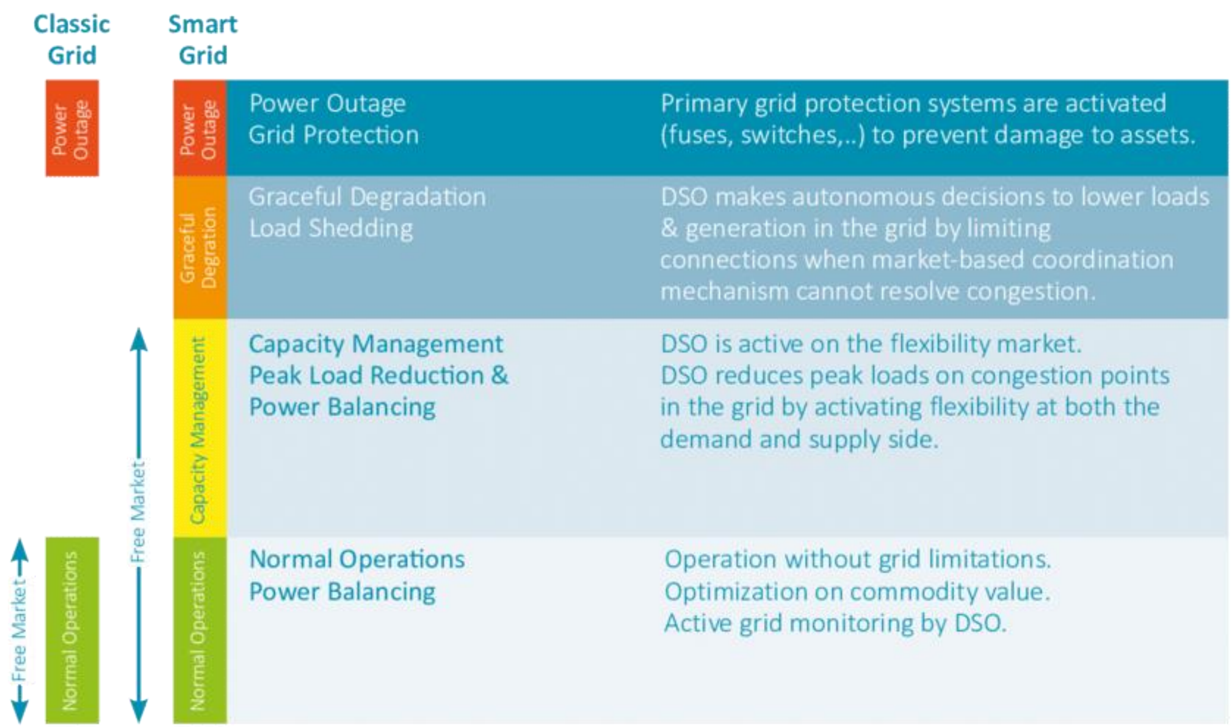


Figure 3: USEF Operating Regimes [2]

2.2. Smart Grid Architecture model (SGAM)

The SGAM (Smart Grid Architecture Model) [4] is a unified standard for smart grid use-case and architecture design. It enables to give a global view of the project by mapping the different actors and devices according to their energy grids domains (Generation, Transmission, Distribution, DER, and Customer premises) and their business zones (Market, Enterprise, Operation, Station, Field, and Process) – see Figure 4. Then, the different interoperability layers enable to focus on the exchanges between these actors (including devices) in different aspects:

- Business
- Functions
- Information (data exchanged)
- Communication (communication protocols)
- Components (physical devices)

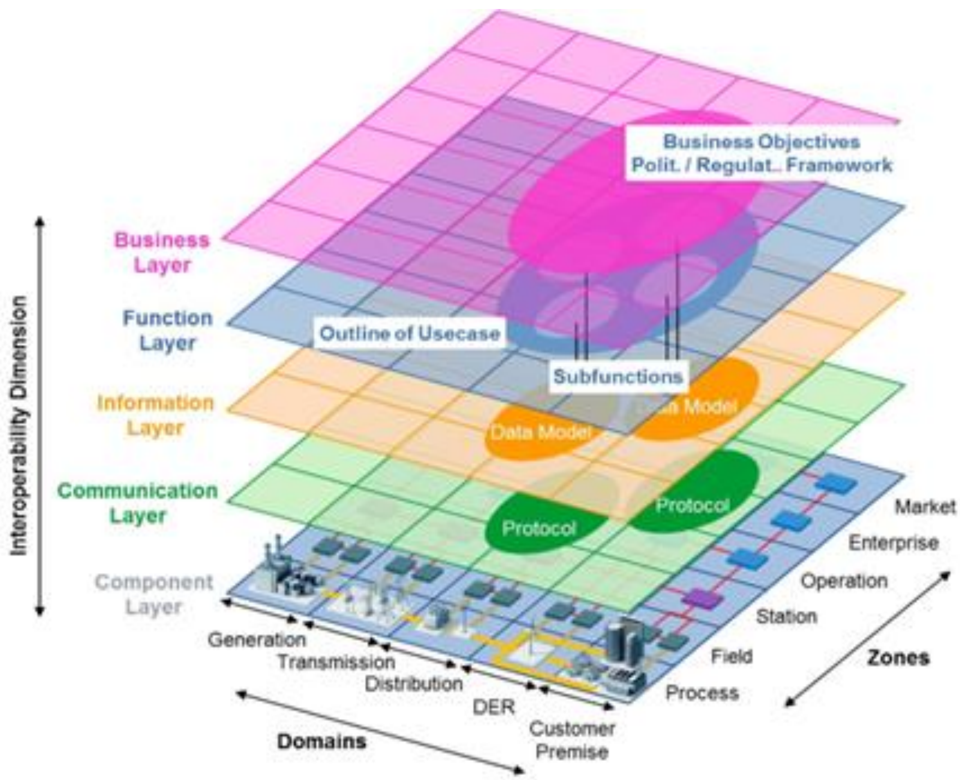


Figure 4: SGAM layers representation [4]

Within the **PARMENIDES** project, the SGAM framework will be used to define the architecture within WP3, but also to support and structure work in WP2.

2.3. The IEC 62559-2 Use Case Methodology

In PARMENIDES, the IEC 62559-2 standard [5] is used to describe the use-cases. It aims to set a methodology and a template for detailing a use case. It includes the description of objectives, actors, requirements (including KPI), and the relation between them. This template is designed for the definition of smart grid use cases, though it can be used as well for other energy systems and organizations, such as energy communities. It is therefore perfectly suitable for **PARMENIDES** use cases.

This template is divided into seven main parts, as detailed in Figure 5below:

- Description of the use case which defines the context and objectives.
- Diagrams of the use case.
- Technical details including the extensive description of all the actors.
- Step by step analysis of the use case which defines the main scenarios of the use case, and details for each of them the processes and relations between actors, step by step.
- Information exchanged.
- Requirements.

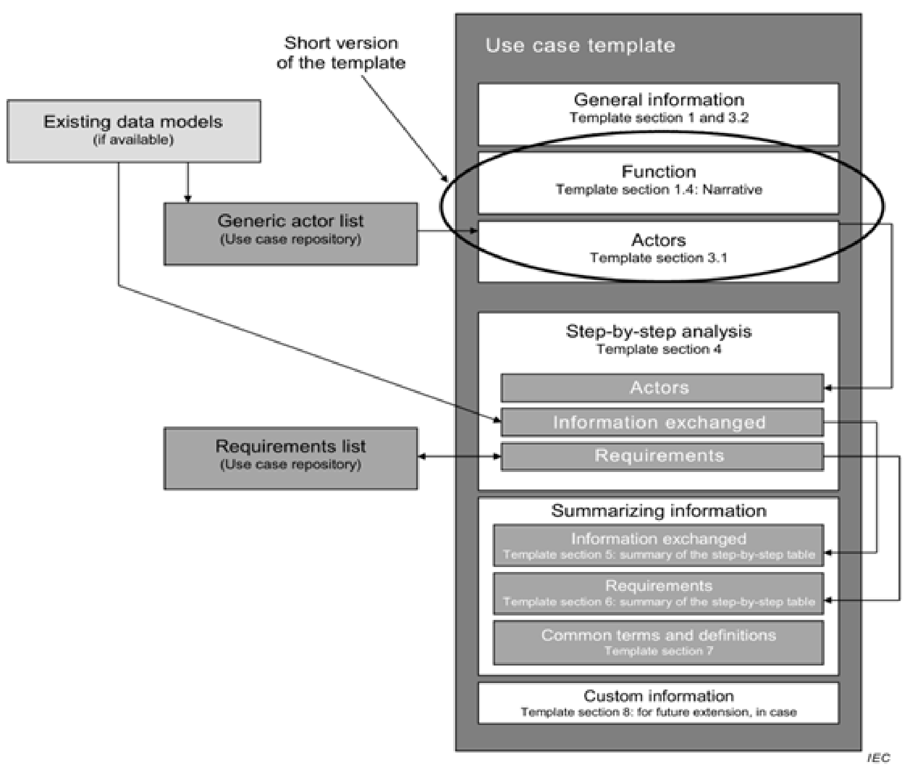


Figure 5: Overview of the IEC 62559-2 template

The use of this norm and associated methodology ensures a thorough analysis of the use-case, and the definition of all its elements. It moreover improves the replicability of the use-cases by making it easier for outsider to understand and compare to other use-cases.

3. Demonstrators

3.1. Austrian Pilot

The Austrian pilot consists of two different municipalities with very diverse characteristics and infrastructure. They are both located in the federal state of Styria (see Figure 6Figure 6), the distribution grid is operated by the local Distribution System Operator and project partner Energienetze Steiermark GmbH (ENS):

- **Demo AT-1:** Municipality of Gasen (8616 Gasen, Austria, population: ~900)
- **Demo AT-2:** Municipality of Heimschuh (8451 Heimschuh, Austria, population: ~2.000)

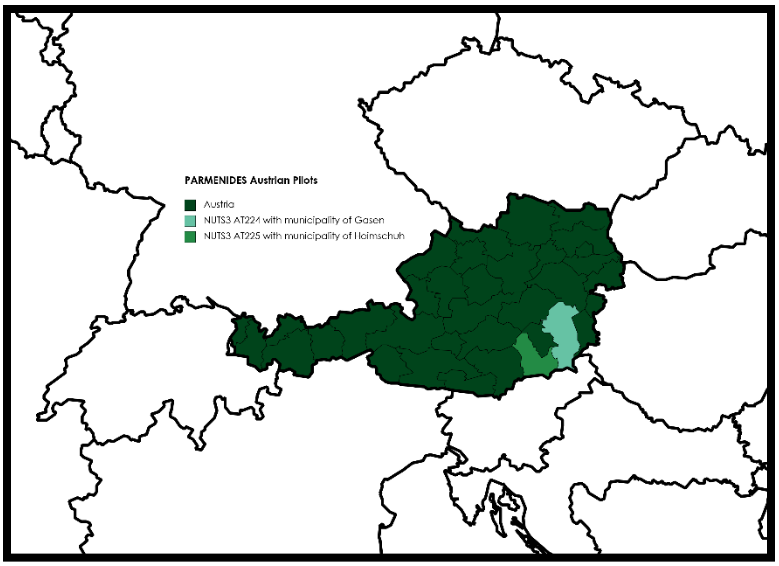


Figure 6: Location of Austrian pilots (NUT3)

Both Austrian municipalities have been equipped with hardware and software solutions in previous research projects (e.g., LEAFS, Blockchain Grid, CLUE). In **PARMENIDES**, it is planned to extend, merge, or replace the available solutions in order to be able to utilize the HESS (depending on the different storage technologies in the two municipalities) on the one hand, and to use ontologies as a knowledge base on the other hand. Different flexibility strategies with given priorities will be implemented and evaluated (see Section 4.1.4), whereas grid support will always have the highest priority and has to be ensured by a fully-automated system.

3.1.1 Demo AT-1 (Gasen)

A grid-friendly local energy community[1] with different storage technologies will be established in the municipality of Gasen. The HESS consists of:

- Battery energy storage system (BESS) with a charging/discharging power of 80 kW and a capacity of 140 kWh, see Figure 7.
- The usage of a hydrogen system (HSS) is foreseen in the project; technical aspects regarding installation conditions and compliance with required structural measures are in progress.
- One public charging station for electric vehicles with a nominal charging power of 22 kW.
- Private charging station for electric vehicles with a nominal charging power of 22 kW.

Figure 7: Xelectrix storage system (80 kW/140 kWh) in Gasen.

In total 4 residential homes, 1 restaurant, two public buildings as well as one district heating network with a total contractual power of 130 kW and approximately 135.000 kWh annual consumption will be considered. All customers are equipped with a Smart Meter for measuring consumption and production (in 15 minutes resolution) as well as an adapter for the Smart Meter to allow higher resolution (1 minute) and real-time communication of active and reactive power measurements. The adapter for the Smart Meter (Energy Live) does not provide voltage measurements. Therefore, additional hardware (Siemens PAC) will be used additionally at the customers (already available due to previous research project CLUE[2]). Additionally, two PAC devices are available within the transformer station – one measuring the relevant feeder, another one measuring the aggregated values of all feeders. Further PAC devices are needed for observability and will be installed during the pilot preparation. Nevertheless, A full observability is not needed – state estimation as part of the grid capacity management (GCM) will provide estimation values instead. The minimum number of additional grid measurements as well as their optimal placement will be determined as part of the pilot preparation. Furthermore, a weather station will be installed in order to increase

[1] It is not planned to establish a legal entity within the community. Nevertheless, the grid-friendly behaviour can be implemented for single customers and communities with the same infrastructure (hardware, software, ICT-infrastructure). Accounting will be done virtually (by considering the customers as part of a REC).

[2] https://project-clue.eu/

the quality of the generation and consumption forecasts by considering the actual local weather (including cloud movement).

3.1.2 Demo AT-2 (Heimschuh)

Similar to Demo AT-1, a grid-friendly community will be established in the municipality of Heimschuh. The HESS consists of the following storage systems:

- Battery energy storage system (BESS) with a charging/discharging power of 100 kW and a capacity of 100 kWh, see Figure 8.
- Private charging stations will be aligned with selected customers and installed during the project.

Figure 8: "Urban-box" with battery energy storage system (100 kW/100 kWh) in the municipality of Heimschuh.

In total, 23 PV systems with a total contractual power of 315 kW are installed on the considered branch of the concerned transformer station. 13 customers with a total contractual power of 135 kW and approx. 226.000 kWh annual consumption are participating in the current project. Due to the high penetration of PV systems, the grid is already at its absolute limits. Therefore, it has to be either reinforced or supported by smart solutions to optimally use the available capacity and use available (storage) flexibilities to comply with the limits. Similar to the other Austrian pilot, all customers are equipped with a Smart Meter (for power measurements); adapter for the Smart Meter to allow higher resolution (1 minute) and real-time communication of active and reactive power measurements will also be installed in Heimschuh. Already installed Siemens PAC devices will be used for voltage measurements and will be installed during the pilot preparation. A full observability is not needed – state estimation as part of the grid capacity management (GCM) will provide estimation values. The minimum number of additional grid measurements as well as their optimal placement will be determined as part of the pilot preparation.

3.2. Swedish Pilot

The Swedish pilot consists of a combination of physical and virtual laboratory set-ups to use the **PARMENIDES** ontologies. In particular, it is planned to leverage the capabilities of the KTH Live-in-Lab and the laboratory at the KTH Department of Energy Technology (EGI).

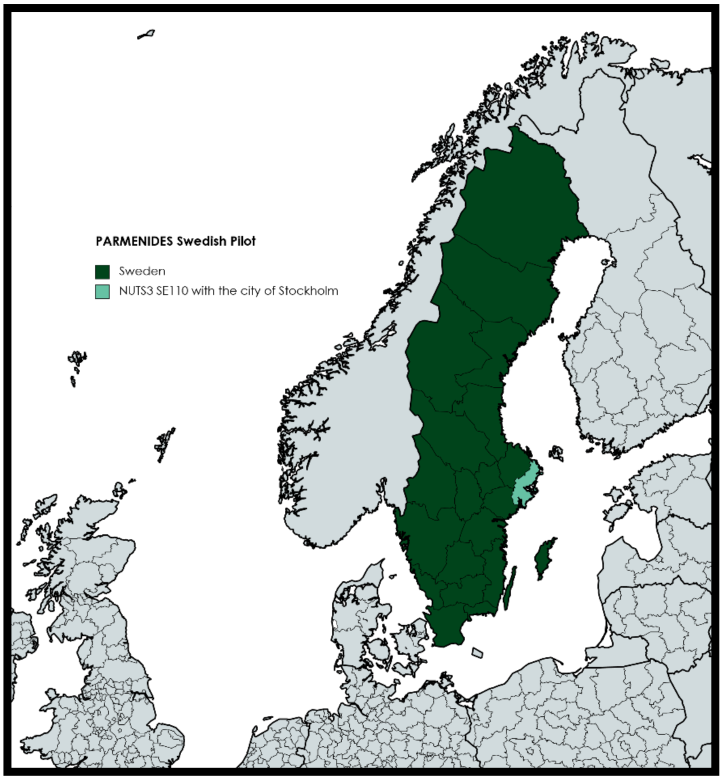


Figure 9: Location of Swedish pilot (NUTS3)

KTH Live-In Lab (LiL) is a platform comprising multiple testbeds for research and development within the real estate and construction sectors. It is designed to facilitate knowledge sharing between researchers and industry, being the link between research groups, facilitating contacts and helping arrange meetings between different research fields. The testbed is located in one of three plus-energy buildings at KTH Campus Valhallavägen. The premises have a total surface of 300 m² distributed on approximately 130 m² living space, 150 m² service space and a project office of about 20 m². It is equipped with the following systems and equipment that may be available for **PARMENIDES**:

- 4 apartments equipped with sensors (e.g., power meter, water flow meter, pressure sensors, occupancy sensors, light sensors, CO2 sensors, temperature sensors, humidity sensors) and actuators
- Schneider Electric building management system (BMS)
- Space heating (provided through an air handling unit)
- Sensible and latent heat storage facilities
- Ground source heat pump
- Seasonal storage facility
- Li-Ion batteries

Figure 10: (From left to right): Water tank, heat pump, and BMS at the KTH Live-in Lab.

The KTH Department of Energy Technology is equipped with a Climate Chamber as well as several storage facilities including sensible and latent heat storage, renewable energy, heating, and cooling systems, as well as models and digital twins which can be coupled with the hardware in a Hardware-in-the-Loop (HiL) environment.

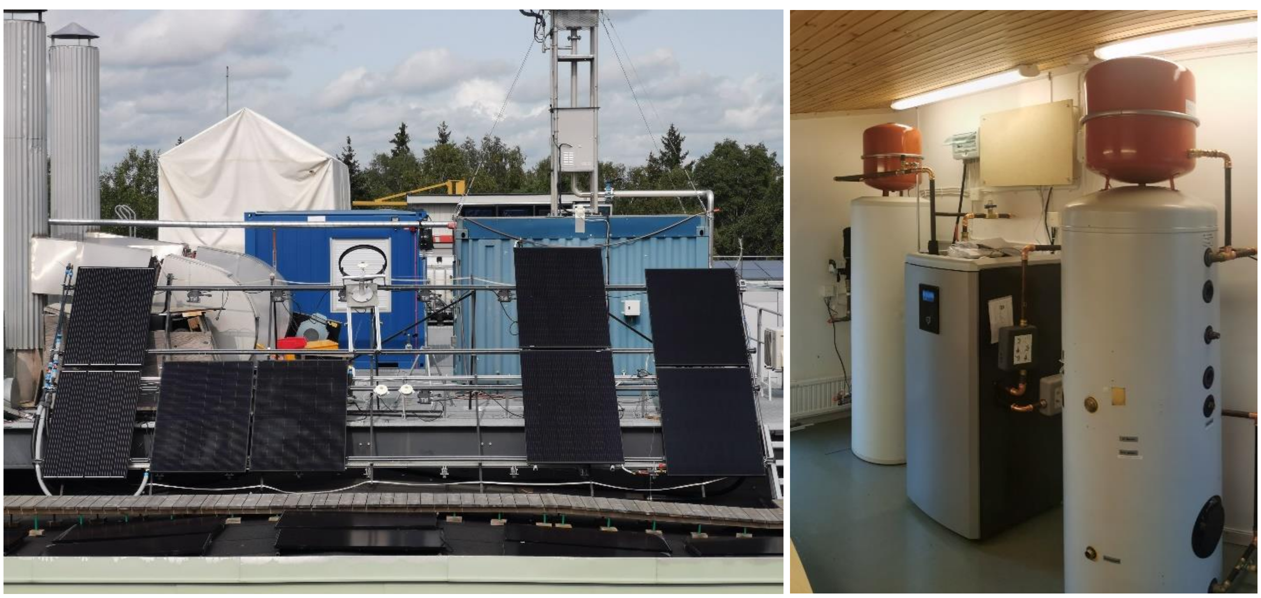


Figure 11: Photovoltaic thermal (PVT) panels and connected heat storage system at KTH Department of Energy Technology.

The intention is to pilot the **PARMENIDES** ontologies in a building perspective through combination of actual building data, energy community data, and distribution grid data, and physical and digital equipment and models in the lab environment. Laboratory experiments at the KTH EGI will be extended and validated at the KTH LiL to observe actual apartment resident response, as a proxy to EC Participants.

3.3. Virtual Environment

AIT Virtual Verification Laboratory (AIT VLab) [6] is a framework that includes a methodology and toolset for achieving a higher level (semantic and above) of interoperability (see Figure 12). It advocates defining a common view of the system first so that the functional objectives of the solution can be aligned with what needs to be implemented. It, further, helps in bridging the knowledge and understanding gap between the requirement and implementation teams. The framework, therefore, is equally beneficial for system architects, developers, and other stakeholders.

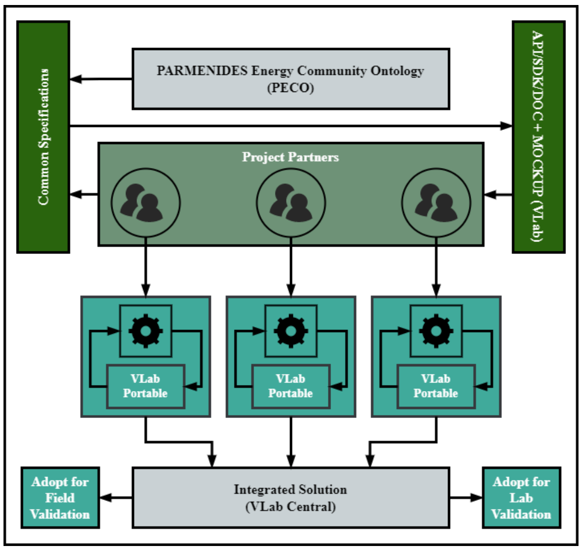


Figure 12: Interoperability-by-design principle for achieving a higher level of interoperability maturity.

A common specification of modules as well as the **PARMENIDES Energy Community Ontology (PECO)** will be used as a knowledge base for the AIT VLab toolset to automatically generate the data models, interfaces, and mock-ups of functional components to represent the participants and hardware and software components of different energy communities and their interactions. Based on the common specification, the project partners will develop their tools. A portable solution of AIT VLab will be provided to the project partners to allow a first integration of the developed modules. A central instance of AIT VLab will be hosted at AIT and access to the project partners will be granted through Virtual Private network (VPN). This centrally hosted environment will be used to integrate all developed modules and validate the interoperability of all components. This approach allows the integration of components and interoperability testing already during the development phase (and not after the modules have been developed). Therefore, bugs (related to interfaces and data models) can be identified early (before deployment and pilot demonstration) and thus, this approach could save many iterations, effort, and costs in the development and deployment process.

Furthermore, AIT VLab will enable the validation of different use cases, scenarios, optimization features, and flexibility strategies before deploying the developed solutions in the field and to test use cases which will not be deployed at all. Additionally, for post-pilot analysis, AIT VLab will be used to test the scalability and replicability of the solutions. In particular, other energy communities (than the Austrian and Swedish pilots) with various characteristics and operating conditions will be defined, as per region/country-specific regulations and will be tested and various deployment scales.

4. Use Cases

4.1. Definitions

4.1.1 Automation Levels

PARMENIDES Use Cases are described with respect to ten levels of automation and action selection defined by Parasuraman, Sheridan, and Wickens [7]. Since its publication in 2000 based on original work for air traffic control [8], it has become a widely cited framework in the field of automation in various fields. The ten levels are supposed to be applied in every stage of human information processing, which are (1) sensory processing (i.e., acquisition and registration of multiple sources of information), (2) perception/working memory (i.e., conscious perception, and manipulation of processed and retrieved information in working memory prior to the point of decision), (3) decision making (i.e., coming up of decisions based on prior cognitive processing), and (4) response selection (i.e., implementation of a response or action consistent with the decision choice). These are posited to be equivalent to the four system functions that can be automated, i.e., (1) information acquisition, (2) information analysis, (3) decision and action selection, and (4) action implementation, respectively.

In the context of the **PARMENIDES** Use Cases, the levels of automation assigned to each use case are applied in both the third (decision-making / action selection) and fourth (response selection / action implementation) stages. The levels are described below as they are applied in the **PARMENIDES** Use Cases.

Level 1 – Offers no assistance: Human must take all decisions and actions

The EMS4HESS collects all relevant data from available sensors and other information inputs, and communicates minimally processed data (e.g., summaries, billing information) to the EC Participant; but it is completely up to them to interpret their implications and act accordingly.

Level 2 – Offers a complete set of decision/action alternatives

The EMS4HESS collects all relevant data from available sensors and other information inputs, processes collected data to an extent possible, and communicates to the EC Participant all possible actions they may take, but does not do any filtering, prioritization, or make any recommendation. The EC Participant manually performs their preferred option or may choose to ignore them altogether.

Level 3 – Narrows the selection down to a few decision/action alternatives

The EMS4HESS collects all relevant data from available sensors and other information inputs, processes collected data to an extent possible, and communicates to the EC Participant a filtered set of possible actions they may take according to a set of criteria, preferences, and/or constraints they have predetermined. The EC Participant may perform their preferred option manually, ask the system to implement the chosen option (if applicable, depending on the Use Case), or choose to ignore them altogether.

Level 4 – Suggests one alternative

The EMS4HESS collects all relevant data from available sensors and other information inputs, processes collected data to an extent possible, and suggests to the EC Participant an option they may take according to a set of criteria, preferences, and/or constraints they have predetermined. The EC Participant may perform the option manually, request for another alternative, ask the system to implement the option (if applicable, depending on the Use Case), or choose to ignore them altogether.

Level 5 – Executes suggestion if the human approves

The EMS4HESS collects all relevant data from available sensors and other information inputs, processes collected data to an extent possible, and suggests to the EC Participant an option they may take according to a set of criteria, preferences, and/or constraints they have predetermined. The EMS4HESS is primed to implement this option but necessitates the approval of the EC Participant to proceed. Otherwise, the EMS4HESS resumes the status quo.

Level 6 – Allows the human a restricted time to veto before automatic execution

The EMS4HESS collects all relevant data from available sensors and other information inputs, processes collected data to an extent possible, and presents to the EC Participant an option it intends to take according to a set of criteria, preferences and/or constraints the EC Participant has predetermined. The EMS4HESS will implement this option by default but allows the EC Participant to prevent the implementation within a defined timeout period. If the implementation is vetoed, the EMS4HESS resumes the status quo.

Level 7 – Executes automatically, then necessarily informs the human

The EMS4HESS collects all relevant data from available sensors and other information inputs, processes collected data to an extent possible, and implements an option according to a set of criteria, preferences, and/or constraints the EC Participant has predetermined. The EMS4HESS will inform the EC Participant that the action was implemented. If the EC Participant does not like the consequences of such action, it can be undone to an extent possible, or they can modify the criteria, preferences, and/or constraints provided to the EMS4HESS.

Level 8 – Informs the human only if asked

The EMS4HESS collects all relevant data from available sensors and other information inputs, processes collected data to an extent possible, and implements an option according to a set of criteria, preferences, and/or constraints the EC Participant has predetermined. If specifically requested, the EMS4HESS will inform the EC Participant that the action was implemented. If the EC Participant does not like the consequences of such action, it can be undone to an extent possible, or they can modify the criteria, preferences, and/or constraints provided to the EMS4HESS.

Level 9 – Informs the human only if it (the computer) decides to

The EMS4HESS collects all relevant data from available sensors and other information inputs, processes collected data to an extent possible, and implements an option according to a set of criteria, preferences, and/or constraints the EC Participant has predetermined. The EMS4HESS will inform the EC Participant that the action was implemented according to predetermined/pre-programmed criteria. There will be a default set of criteria for informing the EC Participant, which they can modify accordingly. If the EC Participant does not like the consequences of the automated actions, they can modify the criteria, preferences, and/or constraints provided to the EMS4HESS.

Level 10 – Decides everything, acts autonomously, ignoring the human

The EMS4HESS collects all relevant data from available sensors and other information inputs, processes collected data to an extent possible, and implements an option according to a set of criteria, preferences, and/or constraints the EC Participant has predetermined. If the EC Participant does not like the consequences of the automated actions, they can modify the criteria, preferences, and/or constraints provided to the EMS4HESS.

4.1.2 Applicable Scenarios

Eight Scenarios are presented that apply to one or more **PARMENIDES** Use Cases. These Scenarios may occur depending on the prevailing circumstances of the grid (e.g., operating regime, as evaluated by the GCM/DSO), flexibility requests by the/a BRP, and EC Participants' identified preferences and constraints, among others. Scenarios that are available in lower-numbered Use Cases are carried over to the higher-numbered Use Cases. The Scenarios are (1) Energy Community Configuration, (2) Baseline Accounting, (3) Ex-post Energy Allocation, (4) Participant Optimization, (5) Participant Incentivization, (6) Participant Disregard, (7) Grid Friendliness, and (8) Grid Support. General descriptions are provided as follows:

Energy Community Configuration

An administrative process involving the configuration of EC including organizational aspects and prices. This may also include registration of EC Participants, including their preferences and constraints that may apply depending on the Use Case.

Baseline Accounting

Costs for customers (grid, energy, tax) are calculated without consideration of energy communities. This assumes that EC Participants are individual consumers/prosumers that do not benefit from any incentives, preferential pricing and tariffs, and optimization that are possible through aggregation. The outcome of baseline accounting shall serve as reference against which the results of any optimization will be compared.

Ex-post Energy Allocation

Costs for customers (grid, energy, tax) are calculated, and ECs with special prices and tariffs for internal energy accounting are considered. This does not entail any flexibility activation or optimization at any aggregation level but includes the potential benefit of distribution of preferential pricing and tariffs to EC Participants.

Participant Optimization

No flexibility activation is needed/recommended by GCM. Costs for customers (grid, energy, tax) are calculated, and ECs with special prices and tariffs for internal energy accounting are considered. Compared to the "Ex-post Energy Allocation" scenario, this accommodates the possibility of EC Participants further optimizing their energy consumption behavior either/both individually or/and collectively in order to achieve their goals (see *Optimization Features*). In Use Cases with automation (i.e., UC 3 and 4), this implies that participant preferences and constraints are considered top priority in optimization outcomes. This Scenario is most applicable in the Green (Normal Operation) USEF operating regime but not feasible during the Orange (Graceful Degradation) and Red (Power Outage) regimes.

Participant Incentivization

Manual flexibility activation by the EC Participants, based on recommendations and incentives provided by the DSO. Costs for customers (grid, energy, tax) are calculated, and energy communities with special prices and tariffs as well as incentives for flexibility activation for internal energy accounting are considered. This Scenario is most applicable in the Yellow (Capacity Management) USEF operating regimes but not feasible during the Orange (Graceful Degradation) and Red (Power Outage) regime.

Participant Disregard

Manual flexibility activation would be possible by the EC Participants, based on recommendations and incentives provided by the DSO but participant is not responding to the recommendations. Costs for customers (grid, energy, tax) are calculated, and energy communities with special prices and tariffs, no incentives for flexibility activation considered.

Grid Friendliness

GCM is providing power limits due to the grid situation which have to be considered. In this Scenario, grid requirements are prioritized over EC Participant preferences. This Scenario is most applicable in the Yellow (Capacity Management) or Orange (Graceful Degradation) USEF operating regimes but not feasible during the Red (Power Outage) USEF operating regime.

Grid Support

GCM is providing set-points for HESS due to the grid situation which must be implemented. In this Scenario, grid requirements prevail over EC Participant preferences. This is applicable only in the Orange (Graceful Degradation) and Red (Power Outage) USEF operating regimes. Grid Support has the highest priority in the control scheme.

Remark: When implementing the respective use cases, it is ensured that this does not impair the distribution system operations. Systems such as GCM and EMS4HESS support the assurance of resilient grid operation and enable the integration of additional renewable energy sources through intelligent control and activation of existing HESS flexibilities. Critical grid situations will be simulated only in the virtual environment and will not impact grid operation.

4.1.3 Optimization Features

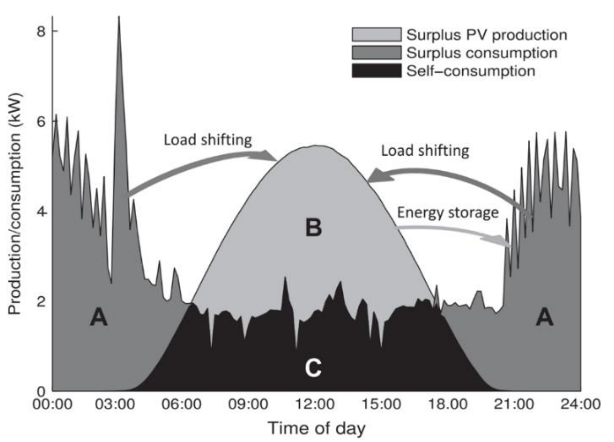
In asserting that there is no one-size-fits-all optimization, and acknowledging that there are multiple optimization pathways, **PARMENIDES** intends to implement two categories of optimization: (1) Supply-Demand Management and (2) Preference Optimization. The first category covers an energy utilization priority, under which are (a) Self-consumption Optimization and (b) Self-sufficiency Maximization. Whereas the second category leans toward personal/behavioral preferences by the EC Participant, which includes (a) Cost Optimization, (b) Environmental Impact Reduction, and (c) Comfort Maximization. These are further detailed below.

Supply-Demand Management

With the increasing number of Active Users (also known as "prosumers") in the EU, more and more households are recognizing the potential of renewable energy [9]. Although it is ideal that a household is able to take advantage of whatever energy it generates from their own RE assets or have them cover their total energy demand, it is difficult to achieve. The metrics of *self-consumption* and *self-sufficiency* are defined for this matter and are illustrated and elaborated below.

Self-consumption Optimization

The Self-consumption Optimization feature aims to find a suitable combination of load management and energy storage such that the EC Participant will maximize the use of on-site generation whenever it is available (in real-time or through storage discharge phase) and minimize surplus. Whenever on-site generation is insufficient, this optimization feature will aim to reallocate loads to times when grid electricity costs are low. When on-site generation has unavoidable surplus, this optimization feature will aim to feed electricity into the grid when grid electricity prices are high, assuming the presence of energy storage.



$$\text{Self-consumption} = \frac{C}{B+C}$$

$$\text{Self-sufficiency} = \frac{C}{A+C}$$

Figure 13: Schematic outline of daily net load (A+C), net generation (B+C) and absolute self-consumption (C) in a building with on-site PV. It also indicates the function of the two main options (load shifting and energy storage) for increasing the self-consumption [10].

Self-sufficiency Maximization

The Self-sufficiency Optimization feature aims to find a suitable combination of load management and energy storage such that the electricity demand of the EC Participant will be covered by on-site generation either or both in real-time or/and through storage discharge. While maximizing the use of on-site generation and minimizing surplus are potential consequences of this optimization feature, the priority is for the energy demand to be covered by energy generated on-site. Thus, less emphasis is placed on modifying load profiles and minimizing surplus generation. Whenever on-site generation is insufficient, this optimization feature will aim to reallocate loads to times when grid electricity costs are low. When on-site generation has surplus, this optimization feature will aim to feed electricity into the grid when grid electricity prices are high, assuming the presence of energy storage.

Preference Optimization

Along with conventional energy supply-demand management-based optimization, a novelty in PARMENIDES is opening the possibility of prioritizing EC Participants' individual preferences. These preferences will appear subjective from the perspective of EC Participants, while the EMS4HESS will try to achieve an optimal set up where these are met as satisfactorily as possible, without compromising technical constraints and limitations, and while accounting for variation in the preferences of other EC Participants. Constraints may include the size and quantity of controllable/shiftable loads, regular and shiftable consumption schedules, actual shiftable load from the grid and community level, grid balancing considerations, weather (in relation to its effects on RE generation and building heating/cooling requirements), electrical and heating storage capacities, and electrical infrastructure capacities and operational limits, among others.

Cost Optimization

Prioritizes the achievement of the lowest cost of energy possible, subject to constraints and preferences set by the EC Participant and the EC Management. In the case of electricity, this will be a combination of accounting for grid electricity prices and tariffs, cost of stored electricity, and selling price of electricity (if grid feed-in is allowed), among others. Deviations in comfort levels and use of non-renewable electricity are acceptable.

Environmental Impact Reduction

Prioritizes the reduction of environmental impact in terms of kg-CO2 equivalent (i.e., global warming potential, GWP), subject to constraints and preferences set by the EC Participant and the EC Management. This will be based on the accounting of the energy supply mix consumed in real-time from the grid, other fuels, or as stored in energy storage equipment. A low-GWP energy mix shall be prioritized over costs and comfort levels.

Comfort Maximization

Prioritizes the maximization of thermal comfort based on the consistent achievement of desired temperature and humidity set-points, subject to constraints and preferences set by the EC Participant and the EC Management. The set-point may be fixed by the EC Participant or a machine-learned set-point based on reinforced system configuration. This optimization disregards energy costs and characteristics of energy supply, in favor of maximum comfort levels.

4.1.4 Flexibility Strategies

Three high-level flexibility strategies are reflected in the **PARMENIDES** Use Cases. These are (1) Passive Exploitation, (2) Active Exploitation, and (3) Exploration/Exploitation Trade-off. The level of EC Participants' control or input varies depending on the flexibility strategy employed, as integrated in the specific Use Cases. These strategies are described below.

Passive exploitation

HESS is used to maximize the flexibility without considering any preference from end-users.

Active exploitation

HESS is used to maximize the flexibility, end-users are allowed to choose between different modes, such as "economy mode" (aiming for cost optimization), "comfort mode" (highest comfort, lowest flexibility), and "environment mode" (lowest GWP). Selection of the preferred mode is allowed only once within a predefined period (e.g., once a year and depending on the envisaged contract liabilities).

Exploration/Exploitation Trade-off

HESS is used to maximize the flexibility, end -users are allowed to choose between different modes, such as "economy mode" (aiming for cost optimization), "comfort mode" (highest comfort, lowest flexibility), and "environment mode" (lowest CO2 emissions). Selection of the preferred mode is allowed at any moment, based on own preferences or external signals (e.g., monetary incentives for providing local flexibility). A combination of (dynamically changing or static) choices of the modes (considered as *social constraints*), technical characteristics about the available technologies (considered as *technical constraints*), and other information such as prices and tariffs (considered as *economic constraints*) as well as information about the EC Participants, relation between EC Participants, and relation to other stakeholders (considered as *classes* and *relations*) provide the required information for the ontology.

4.2. PARMENIDES System

4.2.1 System Overview

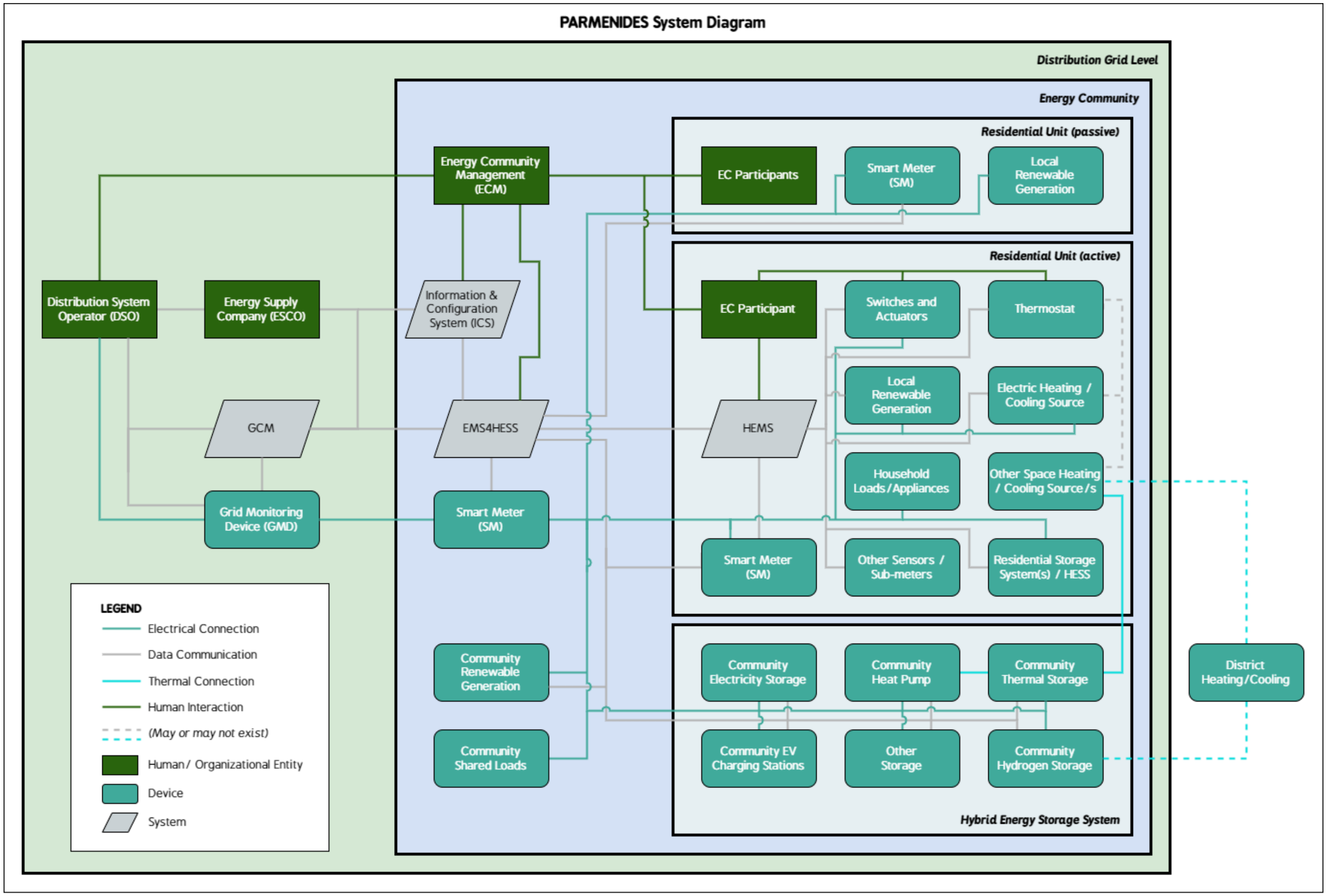


Figure 14: PARMENIDES System Diagram

4.2.2 Actors, devices, and systems

PARMENIDES aims to develop an ontology (WP3, **PARMENIDES Energy Community Ontology, PECO**) to provide a knowledge base for different aggregation levels in energy systems, focusing on buildings, customers, and energy communities. The developed ontology will support different flexibility strategies and use cases and ensure semantic interoperability.

The ontology will be designed to support the PARMENIDES use cases with different time resolutions (from seconds to seasons) and on different aggregation levels – see the PARMENIDES system overview in Figure 14. It covers the Residential Unit, the Energy Community, as well as the Distribution Grid and supports different flexibility strategies including the utilization of Hybrid Energy Storages Systems (HESS) as a virtual representation of different storages technologies, whereas the relevant characteristics (e.g., technical parameters such as maximum charging/discharging power, storage capacity, charging/discharging/storage efficiency) are part of the ontologies.

Besides the representation of storage technologies, information about energy community participants, their behaviours, and components including their relation will be part of the ontology, providing a standardized vocabulary of the domain of energy communities. This further includes technical, economic, regulatory, behavioural, and social constraints which have to be considered in operation. To support several HESS and energy community-related use cases, a new generation of innovative Energy Management Systems (EMS4HESS) will be developed (WP4). This system will be capable of using the ontology as a knowledge base as well as providing abilities to infer extended information. The EMS4HESS will support the implementation of the PARMENIDES use cases.

Distribution Grid Level

The system boundary in PARMENIDES is the Distribution Grid – in particular, the low voltage distribution grid including the transformer station (the medium voltage network is not part of the project). Nevertheless, PECO as well as the software systems can be extended to higher voltage levels. The following actors, devices, and systems will be considered in the use cases and thus, in the PECO and software development.

The primary objective of **Distribution System Operators (DSO)** is to ensure the reliable and efficient operation of the electricity distribution system. The DSOs aim to maintain a high level of reliability in the distribution system, ensuring that electricity is delivered to consumers. The DSOs are responsible for the day-to-day operation and control of the distribution grid. They have to balance the electricity supply and demand within their distribution area, managing voltage levels, power flows, and system stability. Especially the violation of voltage bands is often caused by the feed in of several PVs simultaneously. In the Austrian Pilots therefore a grid-supporting battery storage is part of the project in each region and is hence considered in the Grid Capacity Management (GCM).

In this project a **Grid Capacity Management (GCM)** system will be developed, trained, and deployed in the specific pilots. This GCM consists of a machine-learned model for Distribution System State Estimation (DSSE) as well as for load flow determination. The training of this module will be done in advance by using instantiated PARMENIDES Energy Community Ontology (PECO), generated data from comprehensive offline simulations, as well as historical measurement data. All possible flexibility scenarios provided by the available HESS as well as generation and consumption scenarios will be considered in the training process. Depending on the grid situation and the use case, the GCM provides recommendations, set-points, or power limitations for the HESS in order to avoid peaks and thus, avoid voltage and thermal violations in the distribution grid. **Grid Monitoring Devices (GMD)** will be used for measuring the grid state (voltage, power) and thus, to support the low voltage grid observability (together with measurements at the energy community connection point (if available/applicable) and customer measurements (if available/applicable) and the DSSE). Measurement values will be used as input data for GCM in operation.

The **Energy Supply Company (ESCO)** is a business entity that provides energy-related services and products to customers. Although energy communities and prosumers may generate energy, contracts with ESCOs will still be needed for residual energy provision (and its accounting).

Energy Community

Energy communities (EC) are associations of people, companies, or organizations that aim to generate, consume, and share energy in a decentralized manner. These communities typically aim to promote local energy production, use renewable energy sources, and advance the energy transition.

In an energy community, multiple participants can operate their own renewable energy generation systems, such as solar arrays, wind turbines, or biomass plants. The energy generated is then used within the community and can be shared or sold among the members. This allows participants to become less dependent on traditional energy suppliers and reduce their energy costs. In addition, energy communities can also implement energy efficiency measures, promote energy conservation, and coordinate the use of energy storage devices such as batteries. By working together within the community, resources and expertise can be pooled to create an efficient and sustainable energy cycle. Energy communities can take a variety of forms, from local citizens' initiatives to cooperatives to commercial or industrial collaborations. They play an increasingly important role in decentralized energy supply and help to reduce greenhouse gas emissions and promote renewable energies.

The **Energy Community Management (ECM)** stands for and optional entity and represents a group of participants that exercise control over the operations of the Energy Community and is responsible for all administrative processes.

Energy communities consist of a minimum number of **EC Participants** (depending on the national implementation of the EU directives), they can either be passive consumers – **Residential Unit (passive)** – or active consumers/prosumers with flexibilities – **Residential Unit (active)**.

In **PARMENIDES**, it is assumed that ECs can own their own and operate their own assets, **such Community Renewable Generation** (e.g., community PV). Additionally, it is considered that **Community Shared Loads** (e.g., lighting or elevators in a building community). Besides the GMDs in the low voltage distribution grid, **Smart Meter (SM**, and specific adapters**)** are considered as optional metering device (e.g., at the grid connection point for a building energy community).

The main system of the energy community is the **EMS4HESS** – an energy management system which considers limitations provided by the grid (in particular, by the GCM) and is capable of optimizing and controlling the utilization of the **Hybrid Energy Storage System (HESS)** as well as providing flexibility information to active customers. All relevant information about the community and its customers (e.g., technical, economic, and social constraints, as part of the PECO) are provided by **the Information & Configuration**

System (ICS) and considered in the calculation of flexibility strategies; information about flexibility activation will be sent back to the ICS and provided to the customers by a User Interface (UI).

Residential Unit

As mentioned above, the energy community customers can be passive or active **EC Participants**. In both cases, **Smart Meter** (**SM**; or comparable metering devices) are needed for measuring the energy flows. Active customers may have different equipment such as **Home Energy Management System (HEMS)** to control **Residential Storage Systems/HESS, Electric Heating / Cooling Sources**, or other **Switches and Actuators**, to retrieve information and measurement data from **Thermostats, Smart Meters** or **Other Sensors / Sub-meters**. Furthermore, local **Renewable Generation** may be available for both, for active and passive customers.

The **HEMS** (or Building Energy Management System, BEMS, or Customer Energy Management System, CEMS) is the main component on a local level. It is responsible for the optimization on the customer level, based on customer preferences and by consideration of provided information coming from the EMS4HESS.

Obviously, a clear hierarchy for energy management is established in PARMENIDES. GMC provides the technical framework conditions from the distribution grid that must be taken into account in any case. The following hierarchical level is the energy community, operated and optimized by the EMS4HESS. Finally, the residential units are operated and optimized by the HEMS.

Hybrid Energy Storage System

The **Hybrid Energy Storage System (HESS)** is a virtual representation of different storage technologies, whereas the relevant characteristics (e.g., technical parameters such as maximum charging/discharging power, storage capacity, efficiency) are part of the ontologies. The **EMS4HESS** will be capable of using the ontology as a knowledge base as well as providing abilities to infer extended information and to utilize the available flexibilities. Major storage technologies which will be considered in PARMENIDES are electrical (e.g., batteries), thermal (including heat pump), chemical (e.g., hydrogen), and mechanical storage, as well as EV charging stations, depending on the availability of the technologies in the participating pilot sites.

Optionally, some of the storage devices might be connected to a **District Heating Network** (e.g., residential space heating or the community hydrogen storage system) but will not be considered in PARMENIDES.

Pilot-specific implementation

In the PARMENIDES pilots, the focus will be on the following boundaries:

- *The Austrian pilots in Gasen and Heimschuh will be equipped with GCM and EMS4HESS (see Section 3.1), whereas no active customers will be considered. Parts will be tested or validated within the virtual environment in parallel to the pilot.*
- *The Swedish pilot in Stockholm will be a combination of physical and virtual laboratory set-ups, which will be validated in a multi-apartment building that may act as an energy community, equipped with a EMS4HESS (on the building level) as well as HEMS for different apartments.*

A detailed overview of the pilot-specific architecture and the respective instantiation of the System Diagram will be developed in Task 3.1 and provided in Deliverable D3.1.

4.3. Use Case Overview

Table 1 provides an overview about the Automation Levels, the Optimization Features, and the Flexibility Strategies and how they can be applied to the four PARMENIDES Use Cases.

Table 1: PARMENIDES Use Cases, Automation Levels, Optimization Features, and Flexibility Strategies.

	Use Case	***1. Passive***	***2. Active***	***3. Automated with human inputs***	***4. Fully Automated***
	Automation Level				
1	Offers no assistance: human must take all decisions and actions				
2	Offers a complete set of decision/action alternatives				
3	Narrows the selection down to a few decision/action alternatives				
4	Suggests one alternative				
5	Executes suggestion if the human approves				
6	Allows the human a restricted time to veto before automatic execution				
7	Executes automatically, then necessarily informs the human				
8	Informs the human only if asked				
9	Informs the human only if it (the computer) decides to				
10	Decides everything, acts autonomously, ignoring the human				
	Optimization Features				
1	Supply-Demand Management: Self-consumption optimization				
2	Supply-Demand Management: Self-sufficiency maximization				
3	Preference Optimization: Cost optimization				
4	Preference Optimization: Environmental impact reduction				
5	Preference Optimization: Comfort maximization				
	Flexibility Strategies				
1	Passive Exploitation				
2	Active Exploitation				
3	Exploitation/Exploration Trade-off				

4.4. Applicable Scenarios for PARMENIDES Use Cases (Overview)

Table 2 provides an overview about the scenarios and how they can be applied to the four PARMENIDES Use Cases.

Table 2: Applicable Scenarios for PARMENIDES Use Cases.

Use Case	Scenario	Name	Administrative process	Flexibility available	Manual flexibility activation	Automated flexibility activation	Automated lim-itations	Standard accounting	Community ac-counting
1	1.1	Energy Community Configuration	Yes	N/a	N/a	N/a	N/a	N/a	N/a
1	1.2	Baseline Accounting	No	No	No	No	No	Yes	No
1	1.3	Ex-post Energy Allocation	No	No	No	No	No	No	Yes
2	2.1	Participant Optimization	No	Yes	No	No	No	No	Yes
2	2.2	Participant Incentivization	No	Yes	Yes	No	No	No	Yes
2	2.3	Participant Disregard	No	Yes	Not used	No	No	No	Yes
3	3.1	1.2 Baseline Accounting	No	No	No	No	No	Yes	No
3	3.2	2.1 Participant Optimization	No	Yes	No	No	No	No	Yes
3	3.3	2.2 Participant Incentivization	No	Yes	Yes	No	No	No	Yes
3	3.4	Grid-Friendliness	No	Yes	Yes	No	Yes	No	Yes
4	4.1	1.2 Baseline Accounting	No	No	No	No	No	Yes	No
4	4.2	2.1 Participant Optimization	No	Yes	No	No	No	No	Yes
4	4.3	2.2 Participant Incentivization	No	Yes	Yes	No	No	No	Yes
4	4.4	3.4 Grid-Friendliness	No	Yes	Yes	No	Yes	No	Yes
4	4.5	Grid-Support	No	Yes	No	Yes	Yes	No	Yes

4.5. Use Case Actors

Table 3 provides a summary of the actors used in the PARMENIDES Use Cases.

Table 3: UC1/UC2/UC3/UC4 - Actors

Actors							
Actor name	***Actor type***	***Actor description***	***UC1***	***UC2***	***UC3***	***UC4***	***Further information***
Distribution System Operator (DSO)	Role	According to the IEMD: "a natural or legal person who is responsible for operating, ensuring the maintenance of and, if necessary, developing the distribution system in a given area and, where applicable, its interconnections with other systems, and for ensuring the long-term ability of the system to meet reasonable demands for the distribution of electricity". Moreover, the DSO is responsible for regional grid access and grid stability, integration of renewables at the distribution level and regional load balancing.	Yes	Yes	Yes	Yes	
Energy Supply Company (ESCO)	Role	An entity that offers contracts for the supply of energy to a consumer (the supply contract). Within this role, he will initiate DSM activities NOTE: In some countries referred to as Retailer	Yes	Yes	Yes	Yes	
Smart Meter (SM)	System	The metering end device is a combination of the following meter-related functions from the Smart Metering reference architecture: • Metrology functions including the conventional meter display (register or index) that are under legal metrological control. When under metrological control, these functions shall meet the essential requirements of the MID; • One or more additional functions not covered by the MID. These may also make use of the display; • Meter communication functions	Yes	Yes	Yes	Yes	UC1: No real-time communication or (high-resolution) measurements is needed for the passive use case. Ex-post provision of data is sufficient.
EMS4HESS	System	Energy Management System (EMS) that interfaces across the three aggregation levels (i.e., distribution grid, energy community, and residential unit) and specializes in controlling, managing, and optimizing systems that involve multiple energy storage technologies (i.e., Hybrid Energy Storage Systems, HESS). It seeks to facilitate flexibility management while considering grid requirements and constraints, and customer preferences and limitations, among others. Basic functions include data acquisition, analysis, and reporting.	Yes	Yes	Yes	Yes	UC1: HESS utilization is not part of this use case. EMS is used for accounting only. UC3: Has to consider power limits from GCM and manual flexibility requestion/activations from customers. UC4: Has to consider power limits from GCM and manual flexibility requestion/activations from customers.

Actors							
Actor name	***Actor type***	***Actor description***	***UC1***	***UC2***	***UC3***	***UC4***	***Further information***
EC Participant	Role	Participant of an energy community, whether as defined by EU directives and/or the respective Member State implementations, or by the energy community itself.	Yes	Yes	Yes	Yes	
EC Manager	Role	Person/s and/or entity/ies that collectively exercise control over an energy community, as defined by EU directives and/or the respective Member State implementations, or by the energy community itself, or those authorized to perform day-to-day management of the energy community operations	Yes	Yes	Yes	Yes	
Grid Capacity Management (GCM)	System	System consisting of a machine-learned model for Distribution System State Estimation (DSSE) as well as for load flow determination. It can provide recommendations for power reduction for energy community participants or set-points and/or power limitations for all flexible devices (e.g., charging/discharging power) in order to avoid peaks and thus, avoid voltage and thermal violations in the distribution grid for a given set of input values (e.g., measurement values on selected nodes).	No	Yes	Yes	Yes	UC2: Provides only recommendations and incentives. UC3: Provides power limits. UC4: Provides set-points.
Grid Monitoring Device (GMD)	Device	Monitors different grid parameters and values of an electrical grid and sends data (including but not limited to real-time electrical measurements) to the GCM	No	Yes	Yes	Yes	
Information and Configuration System (ICS)	System	System or application that maintains reusable participant and community information inputs to the EMS4HESS, including but not limited to residential load characteristics, number of occupants in residential units, time-use profiles and must-run appliances, optimization preferences, pre-set configurations, and relevant historical data. It also acts as an intermediary for information sent from the DSO and/or Supplier	No	Yes	Yes	Yes	
Hybrid Energy Storage System (HESS)	System	A system of multiple distributed energy storage technologies, which may include electric batteries, thermal storage, mechanical storage, hydrogen storage, and water storage with heat pumps, among others. It leverages the complementary characteristics of each technology to improve overall system performance, energy utilization, and flexibility.	No	Yes	Yes	Yes	

PARMENIDES

4.6. PARMENIDES Use Case 1 – Passive Energy Community Customer Optimization

Table 4: UC1 - Name of the use case

Use case identification		
ID	***Area/Domain/Zone(s)***	***Name of the use case***
1	Area: Energy system Domains: Distribution, DER, Customer Premise Zones: Operation, Station, Field	**Passive Energy Community Customer Optimization**

Table 5: UC1 - Scope and objective of use case

Scope and objectives of the use case	
Scope	General scope: • Energy community is a "community of place", i.e., with participants in close proximity to one another, connected to a common grid/microgrid • Energy community is connected to the distribution grid, either as a separate entity or as a DSO in itself (depending on jurisdiction) • Three aggregation levels are considered: (1) Distribution Grid, (2) Energy Community, and (3) Residential Unit • Limited to a single energy vector outside of an energy community's boundary (e.g., if energy is electricity-based, the heating domain is considered as an actor or as a source) • Intended to be flexible and scalable, regardless of national implementation of EU directives • The energy community is collectively considered as an active customer (also known as "prosumer"), but may include non-prosumer participants • Generally, more applicable to Energy Communities with Active Customers • Use case diagrams are described for the primary systems within each boundary, i.e., GCM for the DSO (not applicable for this use case), EMS4HESS for the energy community, and HEMS for the residential unit Pilot-specific scope: • Austria: Renewable energy community in a low-voltage distribution grid • Sweden: Renewable energy community in a multi-user building
Objective(s)	• **Objective 1: Preference (Cost) Optimization** ○ Satisfaction of EC Management and EC Participants' optimization goals, particularly cost minimization and self-consumption maximization

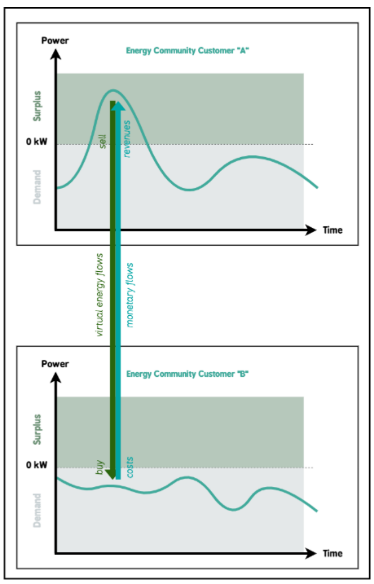
Table 6: UC1 - Narrative of use case

Narrative of use case
Short description
The "Passive" Use Case is implemented in both the EMS4HESS and HEMS. The EMS4HESS constantly monitors the energy data sent from the HEMS, the flexibility profile of the HESS, and signals from the DSO/Supplier. There is no intent to activate flexibility, so energy data is only used to calculate relevant charges and allocate fees as needed. Any available flexibility cannot be dispatched/activated in a short period, and any optimization is done ex-post, depending on EC Management and individual participants' appreciation of billed energy consumption. As the **main objective is cost optimization**, it can be done ex-ante through joint purchase agreements, supply and/or sale from shared energy assets, and peer-to-peer sharing of generated electricity. The EC Management takes on an administrative role to leverage the combined demand to be given preferential electricity rates and/or take advantage of economies of scale in the purchase of shared electricity generation and/or storage assets.

Complete description

Distribution Grid
The DSO cannot activate flexibility from the EC. During the orange (graceful degradation) and red (power outage) operating regimes recognized by USEF, the DSO can only perform load shedding or implement power outages when market-based coordination mechanisms cannot resolve congestion and/or to prevent damage to assets.

Energy Community
The EMS4HESS constantly monitors the energy data sent from the Participants' HEMS, the flexibility profile of the HESS, and signals from the DSO/Supplier. Although the EC and multiple participants can operate their own renewable energy generation systems, (e.g., solar arrays, wind turbines, or biomass plants), the energy generated is used within the community, shared, and/or sold among themselves to achieve high levels of self-consumption and/or self-sufficiency. This allows participants to become less dependent on traditional energy suppliers and reduce their energy costs. Despite the availability of energy storage equipment, there is no intent to activate flexibility, so energy data are only used to calculate relevant charges and allocate fees as needed. Any available flexibility cannot be dispatched/activated in a short period, and any optimization is done ex-post, depending on EC Management and individual participants' appreciation of billed energy consumption. During the orange (graceful degradation) and red (power outage) operating regimes recognized by USEF, the EC cannot leverage the aggregated demand and flexibility potential of its Participants to avoid load shedding or power outages. If onsite generation and/or HESS are available, their capability to support and/or optimize demand in these situations cannot be ascertained.



Energy Management Systems (EMS) are software solutions designed to monitor, control, and optimize energy generation, consumption, and storage in energy communities.
EMS continuously collects (near) real-time data about local energy generation, consumption, and storage utilization. This can be done using smart meters or any other collection device.
The system analysis the current situation and manages the energy flows within the community aiming to fulfil specific objectives, such as cost-minimization or self-consumption optimization. It can also reduce peak loads by scheduling or targeting consumers. Furthermore, the EMS can increase the usage of locally available renewable energy. For example, it can prioritize self-consumption, sell the surplus to the grid, or temporarily store the energy in storage systems. Additionally, the system manages the use of hybrid energy storage systems to store surplus energy and release it when needed. This can increase self-sufficiency and reduce grid feed-in. For optimizing the energy flows, data analysis and forecasting models are used to predict future energy demand and generation. Finally, the system supports transparent and equitable distribution of energy costs within the energy community. It records the energy consumption of each participant and generates appropriate billing statements.
Energy management systems play an important role in the efficient use of renewable energy and the optimization of energy flow within energy communities. They enable better control and management of the energy system, contribute to energy savings, and support the transition to a sustainable energy supply.

In this use case, no active components are considered. Thus, the EMS is responsible for the determination of community-internal (virtual) energy flows as well as for calculating the related financial transactions.
The figure above shows the aggregated power profiles (e.g., measured by the Smart Meter at the grid connection point) of customers "A" and "B". In times of higher generation than consumption of customer "A", the surplus can be sold[3] to customer "B" who has a demand simultaneously. For optimizing the energy transactions and thus, the monetary flows, energy prices within the community, energy prices for transactions with the supplier, (reduced) grid fees and taxes must be considered.

Residential Unit
The HEMS monitors energy consumption and other energy consumption-related parameters based on available sensors. These data are sent to the EMS4HESS without feedback. The EC Participant can view summaries of energy consumption profiles and billing information through the HEMS dashboard but is free to decide on what to do with the provided information. If the EC Participant has its own residential generation (e.g., solar PV) and/or energy storage, these may be activated by the Participant independently from the EMS4HESS.

[3] Selling energy in this case refers to energy allocation and accounting without any impact on the physical energy flows. The allocation and accounting are done ex-post (e.g., at the end of the accounting period)

Table 7: UC1 - Key performance indicators

<table>
<tr><th colspan="4">Key performance indicators</th></tr>
<tr><th>ID</th><th>Name</th><th>Description</th><th>Reference to objectives</th></tr>
<tr><td rowspan="2">1</td><td rowspan="2">Community-related KPIs</td><td>Community costs (without energy community)
Scenario: Baseline Accounting
• Total community costs without consideration of any benefits or incentives including energy costs, grid fees, other fees and taxes.
• Monthly
• Absolute (€)

Community costs (with energy community)
Scenario: Ex-post energy allocation
• Total community costs, considering benefits and incentives from the energy community.
• Monthly
• Absolute (€)

Community cost savings (with energy community)
Scenario: Ex-post energy allocation
• Cost savings through participation in the energy community.
• Monthly
• Absolute (€), relative (%)</td><td>01: Preference optimization (Costs)</td></tr>
<tr><td>Community generation
Scenario: Ex-post energy allocation
• Aggregated local generation within the community.
• Monthly
• Absolute (kWh)

Community consumption
Scenario: Ex-post energy allocation
• Aggregated local consumption within the community.
• Monthly
• Absolute (kWh)

Community transactions
Scenario: Ex-post energy allocation
• Aggregated allocated energy/energy transactions within the energy community.
• Monthly
• Absolute (kWh), relative to total generation (%), relative to total consumption (%)</td><td>01: Preference optimization (Self-consumption)</td></tr>
</table>

<table>
<tr>
<td rowspan="2">2</td>
<td rowspan="2">Customer-related KPIs</td>
<td>Customer costs (without energy community)
Scenario: Baseline Accounting
Total customer costs without consideration of any benefits or incentives including energy costs, grid fees, other fees and taxes
Monthly
Absolute (€) (min, max, average, median, quartile)
Customer costs (with energy community)
Scenario: Ex-post energy allocation
Total customer costs, considering benefits and incentives from the energy community including energy costs, grid fees, other fees and taxes, penalties, incentives, etc.
Monthly
Absolute (€) (min, max, average, median, quartile)
Customer cost savings (with energy community)
Scenario: Ex-post energy allocation
Customer costs savings through participation in the energy community including energy costs, grid fees, other fees and taxes, penalties, incentives, etc.
Monthly
Absolute (€), relative (%) (min, max, average, median, quartile)</td>
<td>01: Preference optimization (Costs)</td>
</tr>
<tr>
<td>Customer generation
Scenario: Ex-post energy allocation
Local generation per community participant
Monthly
Absolute (kWh) (min, max, average, median, quartile)
Customer consumption
Scenario: Ex-post energy allocation
Local consumption per community participant
Monthly
Absolute (kWh) (min, max, average, median, quartile)
Customer transactions
Scenario: Ex-post energy allocation
Allocated energy per community participant
Monthly
Absolute (kWh), relative to own generation (%), relative to own consumption (%)</td>
<td>01: Preference optimization (Self-consumption)</td>
</tr>
</table>

Table 8: UC1 - Use case conditions

Use case conditions
Assumptions & Prerequisites
• Automation Level 1: Offers no assistance • Energy community may have renewable generation and/or storage facilities (community or independent) but are not integrated into an energy management system (EMS) • Real-time operation is not necessary • Data for calculating flows is needed for ex-post energy allocation. • Smart meters and functional ICT infrastructure for data gathering are present. • No forecasts needed or available • No grid aspects are considered • Price information must be available (energy price within the community, for external transactions, grid fees and taxes, reductions, etc.) • Participants have provided consent for the access, storage, and use of data for the purposes of energy use accounting and potential optimization

Table 9: UC1 - Further information to the use case for classification/mapping

Classification information
Relation to the other use cases
Ex-post energy allocation and accounting is part of all other PARMENIDES use cases Use Case 2 (Active), Use Case 3 (Automated with human inputs), Use Case 4 (Fully Automated) are extensions of this use case
Level of depth
High-level UC
Prioritization
-
Generic, regional or national relation
Relevant to PARMENIDES pilots with energy communities within one distribution grid as well as for the virtual environment. Can be applied to other countries and communities as well by considering the prerequisites and the same assumptions. Accounting (DSO, ESC, EC) in sequence diagram shows the Austrian implementation (DSO and ESC bills could be merged).
Nature of the use case
Technical
Further keywords for classification
Cost optimization

Table 10: UC1 - Overview of scenarios

Scenario conditions						
No.	***Scenario name***	***Scenario description***	***Primary actor***	***Triggering event***	***Pre-condition***	***Post-condition***
1.1	Energy Community Configuration	Configuration of energy community including organisational aspects and prices	Energy Community Management	Once (Establishment), on demand	No energy community established, or configuration changes needed	Energy community established with up-to-date configuration
1.2	Baseline Accounting	Costs for customers (grid, energy, tax) are calculated without consideration of energy communities	EMS4HESS	Monthly accounting	SM is available at the customer. SM data can be requested once a month.	Electricity allocation is done. Total costs are calculated, and bills are sent.
1.3	Ex-post Energy Allocation	Costs for customers (grid, energy, tax) are calculated, and energy communities with special prices and tariffs for internal energy accounting are considered	EMS4HESS	Monthly accounting	SM is available at the customer. SM data can be requested once a month. Internal pricing is defined, and reduced grid fees are defined (if applicable)	Electricity allocation is done. Total costs are calculated, and bills are sent.

Remark (valid for all use cases): The is no influence on the accounting for EC Participants. All bills in the project are calculated virtually for use case evaluation only.

4.7. PARMENIDES Use Case 2 – Active Energy Community Participation

Table 11: UC2 - Name of the use case

Use case identification		
ID	***Area/Domain/Zone(s)***	***Name of the use case***
2	Area: Energy system Domains: Distribution, DER, Customer Premise Zones: Operation, Station, Field	**Active Energy Community Participation**

Table 12: UC2 - Scope and objective of use case

Scope and objectives of the use case	
Scope	General scope: • Energy community is a "community of place", i.e., with participants in close proximity to one another, connected to a common grid/microgrid • Energy community is connected to the distribution grid, either as a separate entity or as a DSO in itself (depending on jurisdiction) • Three aggregation levels are considered: (1) Distribution Grid, (2) Energy Community, and (3) Residential Unit • Limited to a single energy vector outside of an energy community's boundary (e.g., if energy is electricity-based, the heating domain is considered as an actor or as a source) • Intended to be flexible and scalable, regardless of national implementation of EU directives • The energy community is collectively considered as an active customer (also known as "prosumer"), but may include non-prosumer participants • Generally more applicable to Energy Communities with Active Customers • Use case diagrams are described for the primary systems within each boundary, i.e., GCM for the DSO, EMS4HESS for the energy community, and HEMS for the residential unit Pilot-specific scope: • Austria: Renewable energy community in a low-voltage distribution grid • Sweden: Renewable energy community in a multi-user building

Objective(s)	• **Objective 1: Preference Optimization**
	  ○ Satisfaction of EC Management and EC Participants' optimization goals, which include but are not limited to: self-consumption or self-sufficiency maximization and cost minimization
	• **Objective 2: Flexibility Activation**
	  ○ Fulfill flexibility activation requests to be as close to the target flexibility as possible to support grid balance requirements and avoid power outages
	• **Objective 3: Timely Response**
	  ○ Respond to flexibility activation requests as quickly as possible

Table 13: UC2 - Narrative of use case

Narrative of use case
Short description
The "Active" Use Case is implemented in the GCM System, EMS4HESS, and HEMS. The GCM system monitors grid and asset utilization and flexibility potential based on data received from grid monitoring devices and the EC's HESS and calculates load flow, estimates missing grid and asset parameters, forecasts, and recommendations and incentives. The EMS4HESS constantly monitors the energy data sent from the HEMS, the flexibility profile of the HESS, and signals from the DSO/Supplier. A DSO/Supplier or GCM signal triggers the EMS4HESS to generate insights to send to respective EC Participants to act on, based on the EC Management's system priorities, which may be maximizing self-consumption, self-sufficiency, or other custom metrics. There is an intent to activate flexibility albeit manually and on the prerogative of the EC Management and individual EC Participants. Thus, the outcome of any flexibility activation requests, incentivization, and intended optimization may only be appreciated ex-post, as far as any implicit distributed flexibility (e.g., time-of-use optimization, in-home self-balancing, peak shaving, emergency power supply) can deliver. In addition to potential economic benefits from joint purchase, supply and/or sale from shared energy assets, and peer-to-peer sharing of generated electricity, the EC can enable the provision of explicit demand-side flexibility services through manual and voluntary response to BRP, DSO, or TSO requests and incentives.
Complete description
Distribution Grid The DSO and/or Supplier can activate flexibility from the EC through coordination with the EC Management (manual flexibility activation). The GCM system shall determine the actual and future grid utilization, which will indicate potential grid-efficient behavior (e.g., for peak reduction, set points/limitations, avoidance of voltage and thermal violations), including recommended benefits and/or incentives for Participants. It consists of a machine-learned model for Distribution System State Estimation (DSSE) as well as for load flow determination based on simulations and historical measurement data. The DSO does not need active interaction with the GCM System in operation, only grid constraints (e.g., allowed voltage band) and incentives must be deposited. Information about the grid utilization/state and requested flexibility will be sent to the ICS. However, there is no possibility of directly controlling the assets of EC Participants, aside from counting on their response to recommendations and incentives. During the orange (graceful degradation) and red (power outage) operating regimes recognized by USEF, the DSO can only perform load shedding or implement power outages when market-based coordination mechanisms cannot resolve congestion and/or to prevent damage to assets. During the yellow (capacity management) and green (normal operations) operating regimes, the DSO/Supplier can send flexibility activation requests and market signals to and incentivize grid-efficient operations of the EC. Although flexibility may be activated, there will be some degree of uncertainty due to the manual and voluntary nature of activation. **Energy Community** The EMS4HESS constantly monitors the energy data sent from the HEMS, the flexibility profile of the HESS, and signals from the DSO/Supplier. A DSO/Supplier or GCM signal triggers the EMS4HESS to generate insights to send to respective EC Participants to act on, based on the EC Management's system priorities, which may be maximizing self-consumption, self-sufficiency, or other custom metrics. There is an intent to activate flexibility albeit manually and on the prerogative of the EC Management and individual EC Participants. Thus, the outcome of any flexibility activation requests, incentivization, and intended optimization may only be appreciated ex-post, as far as any implicit distributed flexibility (e.g., time-of-use optimization, in-home self-balancing, peak shaving, emergency power supply) can deliver. There is no possibility of directly controlling the assets of EC Participants, aside from counting on their response to recommendations and incentives. Some of the available flexibility may be dispatched/activated in a short period but without certainty, considering that the Participants are expected to take action by themselves if they choose to. During the orange (graceful degradation) and red (power outage) operating regimes recognized by USEF, the EC may be able to leverage the aggregated demand and flexibility potential of its Participants to avoid load shedding or power outages, as long as the EC Management acts strategically on the insights generated by the EMS4HESS. The EC may also be able to contribute to peak load reduction and power balancing during the yellow (capacity management) and green (normal operations) operating regimes as long as the EC Management and individual EC Participants respond favorably to DSO/Supplier signals and incentives. **Residential Unit** The HEMS monitors energy consumption and other energy consumption-related parameters based on available sensors. These data are sent to the EMS4HESS for processing along with HESS profiles and DSO/Supplier signals. The EC Participant can view

summaries of energy consumption profiles and billing information through the HEMS dashboard but is free to decide on what to do with the provided information, especially when there are announcements or requests for flexibility activation. If the EC Participant has its own residential generation (e.g., solar PV) and/or energy storage, these may be activated by the Participant independently from the EMS4HESS.

Table 14: UC2 - Key performance indicators

<table>
<tr><th colspan="4">Key performance indicators</th></tr>
<tr><th>ID</th><th>Name</th><th>Description</th><th>Reference to objectives</th></tr>
<tr><td rowspan="2">1</td><td rowspan="2">Community-related KPIs</td><td>Community costs (with energy community and incentivization)
Scenario: Participant Incentivization
• Total community costs, considering benefits and incentives from the energy community including incentives for manual flexibility activation.
• Monthly
• Absolute (€)

Community cost savings (with energy community)
Scenario: Participant Incentivization
• Cost savings through participation in the energy community including incentives for manual flexibility activation.
• Monthly
• Absolute (€), relative (%)</td><td>01: Preference optimization (Costs)</td></tr>
<tr><td>Community generation
Scenario: Participant Incentivization
• Aggregated local generation within the community.
• Monthly
• Absolute (kWh)

Community consumption
Scenario: Participant Incentivization
• Aggregated local consumption within the community.
• Monthly
• Absolute (kWh)

Community transactions
Scenario: Participant Incentivization
• Aggregated allocated energy/energy transactions within the energy community with consideration of manual flexibility activation.
• Monthly
• Absolute (kWh), relative to total generation (%), relative to total consumption (%)</td><td>01: Preference optimization (Self-consumption)</td></tr>
</table>

1	Community-related KPIs	***Community flexibility request*** **Scenario: Participant Incentivization** • Total number of flexibility requests within the community • Monthly/daily • Absolut (1) ***Community flexibility activation*** **Scenario: Participant Incentivization** • Total number of manual flexibility activations with the community • Monthly/daily • Absolut (1) and relative (%) to flexibility request ***Community peak power reduction*** **Scenario: Participant Incentivization** • Reduced peak power of the community due to flexibility activation (compared to forecasted peak power) • Monthly/daily • Absolut (kW) and relative (%)	02: Flexibility activation
2	Customer-related KPIs	***Customer costs (without energy community)*** **Scenario: Baseline Accounting (UC1, Scenario 1.2)** • Customer costs without consideration of any benefits or incentives • Monthly • Absolute (€) (min, max, average, median, quartile) ***Customer costs (with energy community)*** **Scenario: Participant Incentivization** • Customer costs, considering benefits and incentives from the energy community including incentives for manual flexibility activation. • Monthly • Absolute (€) (min, max, average, median, quartile) ***Customer cost savings (with energy community)*** **Scenario: Participant Incentivization** • Customer cost savings through participation in the energy community including incentives for manual flexibility activation • Monthly • Absolute (€), relative (%) (min, max, average, median, quartile)	01: Preference optimization (Costs)
		Customer generation **Scenario: Participant Incentivization** • Local generation per community participant • Monthly • Absolute (kWh) (min, max, average, median, quartile) ***Customer consumption*** **Scenario: Participant Incentivization** • Local consumption per community participant • Monthly • Absolute (kWh) (min, max, average, median, quartile) ***Customer transactions*** **Scenario: Participant Incentivization** • Allocated energy per community participant with consideration of manual flexibility activation • Monthly • Absolute (kWh), relative to own generation (%), relative to own consumption (%)	01: Preference optimization (Self-consumption)

2	Customer-related KPIs	***Customer flexibility request*** **Scenario: Participant Incentivization** • Number of flexibility requests per community participant • Monthly/daily • Absolut (1) (min, max, average, median, quartile) ***Customer flexibility activation*** **Scenario: Participant Incentivization** • Number of manual flexibility activations per community participant • Monthly/daily • Absolut (1) and relative (%) to flexibility request (min, max, average, median, quartile) ***Customer peak power reduction*** **Scenario: Participant Incentivization** • Reduced peak power due to flexibility activation (compared to forecasted peak power) per community participant • Monthly/daily • Absolute (kW) and relative (%) (min, max, average, median, quartile)	02: Flexibility activation
3	Asset-related KPIs	***Flexibility activation response time*** **Scenario: Participant Incentivization** • Time between the request for flexibility and the manual fulfilment/activation of the requested flexibility (if measurable)	03: Timely Response

Table 15: UC2 - Use case conditions

Use case conditions
Assumptions & Prerequisites
• Automation Level 2: Offers a complete set of decision/action alternatives • Automation Level 3: Narrows the selection down to a few decision/action alternatives • Automation Level 4: Suggests one alternative • Real-time operation is necessary (monitoring and providing recommendations) • Data for calculating flows is needed for ex-post energy allocation. • Working ICT infrastructure for data gathering and provision of recommendations is needed. • Components with flexibility activation potential are available • Activation is done manually by the community participant • Forecasts and grid state estimation needed • Grid aspects considered, recommendations and incentives based on actual and future grid situation • Price information must be available (energy price within the community, for external transactions, grid fees and taxes, reductions, etc.) • Participants have provided consent for the access, storage, and use of data for the purposes of energy use accounting and potential optimization

Table 16: UC2 - Further information to the use case for classification/mapping

Classification information
Relation to the other use cases
This use case is based on Use Case 1 (Passive) and extended by the manual activation of available flexibilities.
Level of depth
High-level UC
Prioritization
-
Generic, regional or national relation
Relevant to PARMENIDES pilots with energy communities within one distribution grid as well as for the virtual environment. Can be applied to other countries and communities as well by considering the prerequisites and the same assumptions. Accounting (DSO, ESC, EC) in sequence diagram shows the Austrian implementation (DSO and ESC bills could be merged).
Nature of the use case
Technical
Further keywords for classification
Grid capacity management, manual flexibility activation, grid-efficiency

Table 17: UC2 - Overview of scenarios

Scenario conditions						
No.	***Scenario name***	***Scenario description***	***Primary actor***	***Triggering event***	***Pre-condition***	***Post-condition***
2.1	Participant Optimization	No flexibility activation is needed/recommended by GCM. Costs for customers (grid, energy, tax) are calculated, and energy communities with special prices and tariffs for internal energy accounting are considered	EMS4HESS	Every x minutes for flexibility activation. Monthly accounting	GMD is available within the grid, capacity management is available, no recommendations are calculated by GCM due to the grid situation. SM is available at the customer. SM data can be requested once a month. Internal pricing is defined, and reduced grid fees are defined (if applicable)	Electricity allocation is done. Total costs are calculated, and bills are sent.
2.2	Participant Incentivization	Manual flexibility activation by the energy community participants, based on recommendations and incentives provided by the DSO. Costs for customers (grid, energy, tax) are calculated, and energy communities with special prices	GCM, EMS4HESS	Every x minutes for flexibility activation. Monthly accounting	GMD is available within the grid, capacity management is available, and recommendations and incentives are calculated by GCM due to the grid situation. SM is available at the customer. SM data can be requested once a month.	Flexibility might be activated manually by the EC Participants. Electricity allocation is done. Total costs (including the consideration of incentives) are calculated, and bills are sent.

		and tariffs as well as incentives for flexibility activation for internal energy accounting are considered			Internal pricing is defined, and reduced grid fees are defined (if applicable)	
2.3	Participant Ignorance	Manual flexibility activation would be possible by the energy community participants, based on recommendations and incentives provided by the DSO but participant is not responding to the recommendations. Costs for customers (grid, energy, tax) are calculated, and energy communities with special prices and tariffs, no incentives for flexibility activation considered.	GCM, EMS4HESS	Every x minutes for flexibility activation. Monthly accounting	GMD is available within the grid, capacity management is available, and recommendations and incentives are calculated by GCM due to the grid situation. SM is available at the customer. SM data can be requested once a month. Internal pricing is defined, and reduced grid fees are defined (if applicable)	Flexibility activation is not done by the EC Participants. Electricity allocation is done. Total costs (without incentives) are calculated, and bills are sent.

Remark (valid for all use cases): The is no influence on the accounting for EC Participants. All bills in the project are calculated virtually for use case evaluation only.

4.8. PARMENIDES Use Case 3 – Automated Energy Community Participation with Human Inputs

Table 18: UC3 - Name of the use case

Use case identification		
ID	***Area/Domain/Zone(s)***	***Name of the use case***
2	Area: Energy system Domains: Distribution, DER, Customer Premise Zones: Operation, Station, Field	**Automated Energy Community Participation with Human Inputs**

Table 19: UC3 - Scope and objective of use case

Scope and objectives of the use case	
Scope	General scope: • Energy community is a "community of place", i.e., with participants in close proximity to one another, connected to a common grid/microgrid • Energy community is connected to the distribution grid, either as a separate entity or as a DSO in itself (depending on jurisdiction) • Three aggregation levels are considered: (1) Distribution Grid, (2) Energy Community, and (3) Residential Unit • Limited to a single energy vector outside of an energy community's boundary (e.g., if energy is electricity-based, the heating domain is considered as an actor or as a source) • Intended to be flexible and scalable, regardless of national implementation of EU directives • The energy community is collectively considered as an active customer (also known as "prosumer"), but may include non-prosumer participants • Generally more applicable to Energy Communities with Active Customers • Use case diagrams are described for the primary systems within each boundary, i.e., GCM for the DSO, EMS4HESS for the energy community, and HEMS for the residential unit Pilot-specific scope: • Austria: Renewable energy community in a low-voltage distribution grid • Sweden: Renewable energy community in a multi-user building

Objective(s)	• **Objective 1: Preference Optimization**
	  ○ Satisfaction of EC Management and EC Participants' optimization goals, which include but are not limited to: self-consumption or self-sufficiency maximization, cost minimization, comfort maximization, and environmental impact reduction
	• **Objective 2: Flexibility Activation**
	  ○ Fulfill flexibility activation requests to be as close to the target flexibility as possible to support grid balance requirements and avoid power outages
	• **Objective 3: Timely Response**
	  ○ Respond to flexibility activation requests as quickly as possible
	• **Objective 4: System Accuracy**
	  ○ Come up with models, predictions, and implementations that reflect the actual situation/requirements of the stakeholders

PARMENIDES

Table 20: UC3 - Narrative of use case

Narrative of use case
Short description
The "Automated with Human Inputs" Use Case is implemented in the GCM System, EMS4HESS, and HEMS. The GCM system monitors grid and asset utilization and flexibility potential based on data received from grid monitoring devices and the EC's HESS and calculates load flow, estimates missing grid and asset parameters, forecasts, and recommendations and incentives. The EMS4HESS constantly monitors the energy data sent from the HEMS, the flexibility profile of the HESS, and signals from the DSO/Supplier. A DSO/Supplier triggers the EMS4HESS via GCM signal to explore optimization pathways based on preferences and constraints provided by the Participants and the EC Management. If called for, the EMS4HESS will also operate within the constraints/limits set by the DSO/Supplier. Without DSO/Supplier signals, the EMS4HESS shall still constantly explore optimization pathways based on the same constraints and preferences and shall inform the Participants whenever an optimization opportunity is available. Using trade-off exploration based on optimization considerations, the EMS4HESS simplifies its insights and sends only options to the Participants through HEMS notifications. Any implementation of an optimization activity has to be confirmed by the Participants unless they choose automatic implementation based on their pre-provided preferences. The outcome of any flexibility activation requests, incentivization, and intended optimization may be appreciated almost real-time, as far as any implicit distributed flexibility (e.g., time-of-use optimization, in-home self-balancing, peak shaving, emergency power supply) can deliver. In addition to potential economic benefits from joint purchase, supply and/or sale from shared energy assets, and peer-to-peer sharing of generated electricity, the EC can enable the provision of explicit demand-side flexibility services through automated and coordinated response to BRP, DSO, or TSO requests and incentives.
Complete description
Distribution Grid The DSO and/or Supplier can activate flexibility from the EC by sending requests and signals to the ICS. The GCM system shall determine the actual and future grid utilization, which will indicate potential grid-efficient behavior (e.g., for peak reduction, set points/limitations, avoidance of voltage and thermal violations), including recommended benefits and/or incentives for Participants. It consists of a machine-learned model for Distribution System State Estimation (DSSE) as well as for load flow determination based on simulations and historical measurement data. The DSO does not need active interaction with the GCM System in operation, only grid constraints (e.g., allowed voltage band) and incentives must be deposited. Information about the grid utilization/state and requested flexibility will be sent to the ICS. Although the GCM System cannot directly control the assets of EC Participants, its intentions or recommendations can be implemented by the EMS4HESS, especially during yellow (capacity management), orange (graceful degradation), and red (power outage) operating regimes recognized by USEF. During the yellow and green (normal operations) operating regimes, the DSO/Supplier can send flexibility activation requests and market signals to and incentivize grid-efficient operations of the EC. In response to this, the EMS4HESS shall explore optimization pathways that will maximize incentives while ensuring that the preferences and constraints set by the EC Participants and Management are respected. **Energy Community** The EMS4HESS constantly monitors the energy data sent from the HEMS, the flexibility profile of the HESS, and signals from the DSO/Supplier. A DSO/Supplier or GCM signal triggers the EMS4HESS to explore optimization pathways based on preferences and constraints provided by the Participants and the EC Management. If called for, the EMS4HESS will also operate within the constraints/limits set by the DSO/Supplier/GCM. Without DSO/Supplier signals, the EMS4HESS shall still constantly explore optimization pathways based on the same constraints and preferences and shall inform the Participants whenever an optimization opportunity is available. Using trade-off exploration based on optimization considerations, the EMS4HESS simplifies its insights and sends only options to the Participants through HEMS notifications. Any implementation of an optimization activity has to be confirmed by the Participants unless they choose automatic implementation based on their pre-provided preferences. The EMS4HESS can directly control the controllable assets of EC Participants, which, ideally should involve their heavy loads like heating/cooling and lighting; provided that the Participants confirm any of the optimization options provided by the EMS4HESS through the HEMS. Shared generation and storage systems (HESS) are also directly controllable by the EMS4HESS and integrated into the individual HEMS of Participants. Thus, the available flexibility may be dispatched/activated in a short period. During the orange (graceful degradation) and red (power outage) operating regimes recognized by USEF, the EC may be able to leverage the aggregated demand and flexibility potential of its Participants to avoid load shedding or power outages, as long as most of the Participants agree to implement any of the optimization options provided by the EMS4HESS. The EC may

also be able to contribute to peak load reduction and power balancing during the yellow (capacity management) and green (normal operations) operating regimes. **Residential Unit** The HEMS monitors energy consumption and other energy consumption-related parameters based on available sensors (e.g., thermostat, occupancy sensors). These data are sent to the EMS4HESS for processing along with HESS profiles and DSO/Supplier signals. The EC Participant can view summaries of energy consumption profiles and billing information through the HEMS dashboard. Additionally, the Participants can indicate their information and optimization preferences through the HEMS, which may include but are not limited to must-run units/loads, flexibility/time-use schedules, comfortable temperature and humidity set points, energy cost targets, and environmental impact preferences. These pieces of information are then sent to the ICS and shall be ready for access by the EMS4HESS to explore any trade-offs and optimization opportunities. When there is a need to optimize or explore optimization options, the EMS4HESS processes data from the ICS along with other inputs and system constraints (e.g., set by the EC Management, DSO/Supplier through the GCM System; prevailing circumstances). Simplified optimization options are sent to participants and are displayed on their HEMS dashboards. Once they confirm a choice, the EMS4HESS sends control signals to the HEMS to perform control of the Participants' controllable assets. The implementation of flexibility activation will vary by Participant..

Table 21: UC3 - Key performance indicators

Key performance indicators			
ID	***Name***	***Description***	***Reference to mentioned use case objectives***
1	Community-related KPIs	***Community costs (with energy community and incentivization)*** **Scenario: Grid-Friendliness** • Total community costs, considering benefits and incentives from the energy community including incentives for manual flexibility activation (within provided limits). • Monthly • Absolute (€) ***Community cost savings (with energy community)*** **Scenario: Grid-Friendliness** • Cost savings through participation in the energy community including incentives for manual flexibility activation (within provided limits). • Monthly • Absolute (€), relative (%)	01: Preference optimization (Costs)

		Community generation **Scenario: Grid-Friendliness** • Aggregated local generation within the community. • Monthly • Absolute (kWh) ***Community consumption*** **Scenario: Grid-Friendliness** • Aggregated local consumption within the community. • Monthly • Absolute (kWh) ***Community transactions*** **Scenario: Grid-Friendliness** • Aggregated allocated energy/energy transactions within the energy community with consideration of manual flexibility activation (within provided limits). • Monthly • Absolute (kWh), relative to total generation (%), relative to total consumption (%)	01: Preference optimization (Self-consumption)
		Community flexibility request **Scenario: Grid-Friendliness** • Total number of flexibility requests (number of provided limits) within the community • Monthly/daily • Absolut (1)	02: Flexibility activation
2	Customer-related KPIs	***Customer costs (without energy community)*** **Scenario: Baseline Accounting (UC1, Scenario 1.2)** • Customer costs without consideration of any benefits or incentives • Monthly • Absolute (€) (min, max, average, median, quartile) ***Customer costs (with energy community)*** **Scenario: Grid-Friendliness** • Customer costs, considering benefits and incentives from the energy community including incentives for manual flexibility activation (within provided limits). • Monthly • Absolute (€) (min, max, average, median, quartile) ***Customer cost savings (with energy community)*** **Scenario: Grid-Friendliness** • Customer cost savings through participation in the energy community including incentives for manual flexibility activation (within provided limits). • Monthly • Absolute (€), relative (%) (min, max, average, median, quartile)	01: Preference optimization (Costs)

		Customer generation **Scenario: Grid-Friendliness** • Local generation per community participant • Monthly • Absolute (kWh) (min, max, average, median, quartile) ***Customer consumption*** **Scenario: Grid-Friendliness** • Local consumption per community participant • Monthly • Absolute (kWh) (min, max, average, median, quartile) ***Customer transactions*** **Scenario: Grid-Friendliness** • Allocated energy per community participant with consideration of manual flexibility activation (within provided limits) • Monthly • Absolute (kWh), relative to own generation (%), relative to own consumption (%)	01: Preference optimization (Self-consumption)
2	Customer-related KPIs	***Customer flexibility request*** **Scenario: Grid-Friendliness** • Number of flexibility requests (number of provided limits) per community participant • Monthly/daily • Absolut (1) (min, max, average, median, quartile) ***Incremented contracted power*** **Scenario: Grid-Friendliness** • The amount of additional power (kW; compared to the contractual power) which is possible due to the utilization of customer HESS. E.g., a customer is allowed to charge with 11/22 kW instead of 4 kW (contractual power) due to the low grid utilization. • Monthly/daily • Absolute (kW) and relative (%) (min, max, average, median, quartile) ***Customer limitation*** **Scenario: Grid-Friendliness** • The amount of (generation/consumption) power which is reduced by the GCM • Monthly/daily • Absolute (kW) and relative (%) (min, max, average, median, quartile)	02: Flexibility activation
3	Asset-related KPIs	***Shifted HESS energy*** **Scenario: Grid-Friendliness** • The amount of energy that is shifted from/to the HESS. • Monthly/daily • Absolute (kW)	02: Flexibility activation
		Thermal comfort **Scenario: Grid-Friendliness** • Measured in Predicted Mean Vote (PMV) and Predicted Percentage of Dissatisfied (PPD) of the building inhabitants/prosumers during instances of peak shaving that impact comfort levels. ***Global warming potential*** **Scenario: Grid-Friendliness** • Indicator of environmental impact, calculated in terms of kg-CO2 equivalent vs. baseline scenario of full grid electricity consumption	01: Preference Optimization

		Flexibility activation response time **Scenario: Grid-Friendliness** • Time between the request for flexibility and the fulfilment/activation of the requested flexibility	03: Timely Response
		Model performance **Scenario: Grid-Friendliness** • A performance metric or metrics that compare the System's predictions against actual outcomes. Additionally, this may also be a comparison of the percentage of instances when the System's recommended option is chosen by the user. Indicators may include accuracy and regression tests.	04: System Accuracy

Table 22: UC3 - Use case conditions

Use case conditions
Assumptions & Prerequisites
• Automation Level 3: Narrows the selection down to a few decision/action alternatives • Automation Level 4: Suggests one alternative • Automation Level 5: Executes suggestion if the human approves • Automation Level 6: Allows the human a restricted time to veto before automatic execution • Reliable real-time operation is necessary (monitoring, providing limits, implementation of limits) • Data for calculating flows is needed for ex-post energy allocation. • Working ICT infrastructure for data gathering, provision of limits, and flexibility activation is needed. • Components with flexibility activation potential, i.e., controllable assets, are available • Possible to apply split-supply model (i.e., separation of controllable and non-controllable assets) or separation of flexibility activation and energy supply • Activation is done automatically by the EMS4HESS-based objective while ensuring GCM limits compliance • Forecasts and grid state estimation needed • Grid aspects considered, limitations based on actual and future grid situation • Price information must be available (energy price within the community, for external transactions, grid fees and taxes, reductions, etc.) • Participants have provided consent for the access, storage, and use of data and control of controllable assets for the purposes of energy use accounting and potential optimization

Table 23: UC3 - Further information to the use case for classification/mapping

Classification information
Relation to the other use cases
This use case is based on Use Case 1 (Passive) and Use Case 2 (Active) and is extended by the automated activation of available flexibilities. Automated flexibility activation for grid-friendly behaviour has the highest priority
Level of depth
High-level UC
Prioritization
Automated flexibility activation (implementation of limits) has the highest priority
Generic, regional or national relation
Relevant to PARMENIDES pilots with energy communities within one distribution grid as well as for the virtual environment. Can be applied to other countries and communities as well by considering the prerequisites and the same assumptions. Accounting (DSO, ESC, EC) in sequence diagram shows the Austrian implementation (DSO and ESC bills could be merged).

Nature of the use case
Technical
Further keywords for classification
Grid capacity management, automated flexibility activation, grid-friendliness

Table 24: UC3 - Overview of scenarios

Scenario conditions						
No.	***Scenario name***	***Scenario description***	***Primary actor***	***Triggering event***	***Pre-condition***	***Post-condition***
3.1	Same as Scenario 1.2 Baseline Accounting					
3.2	Same as Scenario 2.1 Participant Optimization					
3.3	Same as Scenario 2.2 Participant Incentivization					
3.4	Grid-Friendliness	GCM is providing power limits due to the grid situation which have to be considered.	GCM, EMS	Every x minutes for flexibility activation.	GMD is available within the grid, capacity management is available, and power limits are calculated by GCM due to the grid situation SM is available at the customer. USEF grid operating regime is yellow (capacity management) or orange (graceful degradation)	Flexibility is activated with the consent of the EC Participants in compliance with provided grid limits. Electricity allocation is done.

Remark (valid for all use cases): The is no influence on the accounting for EC Participants. All bills in the project are calculated virtually for use case evaluation only.

4.9. PARMENIDES Use Case 4 – Fully Automated Energy Community Participation

Table 25: UC4 - Name of the use case

Use case identification		
ID	***Area/Domain/Zone(s)***	***Name of the use case***
2	Area: Energy system Domains: Distribution, DER, Customer Premise Zones: Operation, Station, Field	**Fully Automated Energy Community Participation**

Table 26: UC4 - Scope and objective of use case

Scope and objectives of the use case	
Scope	General scope: • Energy community is a "community of place", i.e., with participants in close proximity to one another, connected to a common grid/microgrid • Energy community is connected to the distribution grid, either as a separate entity or as a DSO in itself (depending on jurisdiction) • Three aggregation levels are considered: (1) Distribution Grid, (2) Energy Community, and (3) Residential Unit • Limited to a single energy vector outside of an energy community's boundary (e.g., if energy is electricity-based, the heating domain is considered as an actor or as a source) • Intended to be flexible and scalable, regardless of national implementation of EU directives • The energy community is collectively considered as an active customer (also known as "prosumer"), but may include non-prosumer participants • Generally more applicable to Energy Communities with Active Customers • Use case diagrams are described for the primary systems within each boundary, i.e., GCM for the DSO, EMS4HESS for the energy community, and HEMS for the residential unit Pilot-specific scope: • Austria: Renewable energy community in a low-voltage distribution grid • Sweden: Renewable energy community in a multi-user building

Objective(s)	• **Objective 1: Preference Optimization**
	  ○ Satisfaction of EC Management and EC Participants' optimization goals, which include but are not limited to: self-consumption or self-sufficiency maximization, cost minimization, comfort maximization, and environmental impact reduction
	• **Objective 2: Flexibility Activation**
	  ○ Fulfill automated flexibility activation requests to achieve the target flexibility to support grid balance requirements and avoid power outages
	• **Objective 3: Timely Response**
	  ○ Respond to flexibility activation requests as quickly as possible
	• **Objective 4: System Accuracy**
	  ○ Come up with models, predictions, and implementations that reflect the actual situation/requirements of the stakeholders

Table 27: UC4 - Narrative of use case

Narrative of use case
Short description
The "Full Automation" Use Case is implemented in the GCM System, EMS4HESS, and HEMS. The GCM system monitors grid and asset utilization and flexibility potential based on data received from grid monitoring devices and the EC's HESS and calculates load flow, estimates missing grid and asset parameters, forecasts, and recommendations and incentives. The EMS4HESS constantly monitors the energy data sent from the HEMS, the flexibility profile of the HESS, and signals from the DSO/Supplier. A DSO/Supplier or GCM signal triggers the EMS4HESS to explore optimization pathways based on preferences and constraints provided by the Participants and the EC Management. If called for, the EMS4HESS will also operate within the constraints/limits set by the DSO/Supplier. Without DSO/Supplier signals, the EMS4HESS shall still constantly explore optimization pathways based on the same constraints and preferences. Using trade-off exploration based on optimization considerations, the EMS4HESS automatically implements the most optimal option based on the respective Participants' predetermined preferences and constraints. Participants can track any implemented flexibility activity through the HEMS and can modify their preferences through it. The EMS4HESS does not require Participants' consent before activating flexibility. The outcome of any flexibility activation requests, incentivization, and intended optimization may be appreciated almost real-time, as far as any implicit distributed flexibility (e.g., time-of-use optimization, in-home self-balancing, peak shaving, emergency power supply) can deliver. In addition to potential economic benefits from joint purchase, supply and/or sale from shared energy assets, and peer-to-peer sharing of generated electricity, the EC can enable the provision of explicit demand-side flexibility services through automated and coordinated response to BRP, DSO, or TSO requests and incentives.
Complete description
Distribution Grid The DSO and/or Supplier can activate flexibility from the EC by sending requests and signals to the ICS. The GCM system shall determine the actual and future grid utilization, which will indicate potential grid-efficient behavior (e.g., for peak reduction, set points/limitations, avoidance of voltage and thermal violations), including recommended benefits and/or incentives for Participants. It consists of a machine-learned model for Distribution System State Estimation (DSSE) as well as for load flow determination based on simulations and historical measurement data. The DSO does not need active interaction with the GCM System in operation, only grid constraints (e.g., allowed voltage band) and incentives must be deposited. Information about the grid utilization/state and requested flexibility will be sent to the ICS. Although the GCM System cannot directly control the assets of EC Participants, its intentions or recommendations can be implemented by the EMS4HESS, especially during yellow (capacity management), orange (graceful degradation), and red (power outage) operating regimes recognized by USEF. During the yellow and green (normal operations) operating regimes, the DSO/Supplier can send flexibility activation requests and market signals to and incentivize grid-efficient operations of the EC. In response to this, the EMS4HESS shall explore optimization pathways that will maximize incentives while ensuring that the preferences and constraints set by the EC Participants and Management are respected. **Energy Community** The EMS4HESS constantly monitors the energy data sent from the HEMS, the flexibility profile of the HESS, and signals from the DSO/Supplier. A DSO/Supplier or GCM signal triggers the EMS4HESS to explore optimization pathways based on preferences and constraints provided by the Participants and the EC Management. If called for, the EMS4HESS will also operate within the constraints/limits set by the DSO/Supplier/GCM. Without DSO/Supplier signals, the EMS4HESS shall still constantly explore optimization pathways based on the same constraints and preferences. Using trade-off exploration based on optimization considerations, the EMS4HESS automatically implements the most optimal option based on the respective Participants' predetermined preferences and constraints. Participants can track any implemented flexibility activity through the HEMS and can modify their preferences through it. The EMS4HESS does not require Participants' consent before activating flexibility. The EMS4HESS can directly control the controllable assets of EC Participants, which, ideally should involve their heavy loads like heating/cooling and lighting. This happens without the need for the Participants' consent. Shared generation and storage systems (HESS) are also directly controllable by the EMS4HESS and integrated into the individual HEMS of Participants. Thus, the available flexibility may be dispatched/activated in a short period. During the orange (graceful degradation) and red (power outage) operating regimes recognized by USEF, the EC may be able to leverage the aggregated demand and flexibility potential of its Participants to avoid load shedding or power outages. The EC may also be able to contribute to peak load reduction and power balancing during the yellow (capacity management) and green (normal operations) operating regimes. **Residential Unit**

The HEMS monitors energy consumption and other energy consumption-related parameters based on available sensors (e.g., thermostat, occupancy sensors). These data are sent to the EMS4HESS for processing along with HESS profiles and DSO/Supplier signals. The EC Participant can view summaries of energy consumption profiles and billing information through the HEMS dashboard. Additionally, the Participants can indicate their information and optimization preferences through the HEMS, which may include but are not limited to must-run units/loads, flexibility/time-use schedules, comfortable temperature and humidity set points, energy cost targets, and environmental impact preferences. These pieces of information are then sent to the ICS and shall be ready for access by the EMS4HESS to explore any trade-offs and optimization opportunities.

When there is a need to optimize or explore optimization options, the EMS4HESS processes data from the ICS along with other inputs and system constraints (e.g., set by the EC Management, DSO/Supplier through the GCM System; prevailing circumstances). Based on the most optimal option, the EMS4HESS sends control signals to the HEMS to perform control of the Participants' controllable assets. Participants can track any implemented flexibility activity through the HEMS and can modify their preferences through it. The implementation of flexibility activation will vary by Participant.

Table 28: UC4 - Key performance indicators

Key performance indicators			
ID	***Name***	***Description***	***Reference to mentioned use case objectives***
1	Community-related KPIs	***Community costs (with energy community and incentivization)*** **Scenario: Grid-Support** • Total community costs, considering benefits and incentives from the energy community including incentives for automated set-point implementation. • Monthly • Absolute (€) ***Community cost savings (with energy community)*** **Scenario: Grid-Support** • Cost savings through participation in the energy community including incentives for automated set-point implementation. • Monthly • Absolute (€), relative (%)	01: Preference optimization (Costs)
		Community generation **Scenario: Grid-Support** • Aggregated local generation within the community. • Monthly • Absolute (kWh) ***Community consumption*** **Scenario: Grid-Support** • Aggregated local consumption within the community. • Monthly • Absolute (kWh) ***Community transactions*** **Scenario: Grid-Support** • Aggregated allocated energy/energy transactions within the energy community with consideration of automated set-point implementation. • Monthly • Absolute (kWh), relative to total generation (%), relative to total consumption (%)	01: Preference optimization (Self-consumption)

1	Community -related KPIs	***Community flexibility request*** **Scenario: Grid-Support** • Total number of automated flexibility activations. • Monthly/daily • Absolut (1)	02: Flexibility activation
2	Customer-related KPIs	***Customer costs (without energy community)*** **Scenario: Baseline Accounting (UC1, Scenario 1.2)** • Customer costs without consideration of any benefits or incentives • Monthly • Absolute (€) (min, max, average, median, quartile) ***Customer costs (with energy community)*** **Scenario: Grid-Support** • Customer costs, considering benefits and incentives from the energy community including incentives for automated set-point implementation. • Monthly • Absolute (€) (min, max, average, median, quartile) ***Customer cost savings (with energy community)*** **Scenario: Grid-Support** • Customer cost savings through participation in the energy community including incentives for automated set-point implementation. • Monthly • Absolute (€), relative (%) (min, max, average, median, quartile)	01: Preference optimization (Costs)
		Customer generation **Scenario: Grid-Support** • Local generation per community participant • Monthly • Absolute (kWh) (min, max, average, median, quartile) ***Customer consumption*** **Scenario: Grid-Support** • Local consumption per community participant • Monthly • Absolute (kWh) (min, max, average, median, quartile) ***Customer transactions*** **Scenario: Grid-Support** • Allocated energy per community participant with consideration of automated set-point implementation. • Monthly • Absolute (kWh), relative to own generation (%), relative to own consumption (%)	01: Preference optimization (Self-consumption)

2	Customer-related KPIs	***Customer flexibility request*** **Scenario: Grid-Support** • Number of automated flexibility activations. • Monthly/daily • Absolut (1) (min, max, average, median, quartile) ***Incremented contracted power*** **Scenario: Grid-Support** • The amount of additional power (kW; compared to the contractual power) which is possible due to the utilization of customer HESS. E.g., a customer is allowed to charge with 11/22 kW instead of 4 kW (contractual power) due to the low grid utilization. • Monthly/daily • Absolute (kW) and relative (%) (min, max, average, median, quartile) ***Customer limitation*** **Scenario: Grid-Support** • The amount of (generation/consumption) power which is reduced by the GCM. • Monthly/daily • Absolute (kW) and relative (%) (min, max, average, median, quartile)	02: Flexibility activation
3	Asset-related KPIs	***Shifted HESS energy*** **Scenario: Grid-Support** • The amount of energy that is shifted from/to the HESS. • Monthly/daily • Absolute (kW)	02: Flexibility activation
		Thermal comfort **Scenario: Grid-Support** • Measured in Predicted Mean Vote (PMV) and Predicted Percentage of Dissatisfied (PPD) of the building inhabitants/prosumers during instances of peak shaving that impact comfort levels. ***Global warming potential*** **Scenario: Grid-Support** • Indicator of environmental impact, calculated in terms of kg-CO2 equivalent vs. baseline scenario of full grid electricity consumption	01: Preference Optimization
		Flexibility activation response time **Scenario: Grid-Support** • Time between the request for flexibility and the fulfilment/activation of the requested flexibility	03: Timely Response
		Model performance **Scenario: Grid-Support** • A performance metric or metrics that compare the System's predictions against actual outcomes. Additionally, this may also be a comparison of the percentage of instances when the System's recommended option is chosen by the user. Indicators may include accuracy and regression tests.	04: System Accuracy

Table 29: UC4 - Use case conditions

Use case conditions
Assumptions & Prerequisites
• Automation Level 7: Executes automatically, then necessarily informs the human • Automation Level 8: Informs the human only if asked • Automation Level 9: Informs the human only if it (the computer) decides to • Automation Level 10: Decides everything, acts autonomously, ignoring the human • Reliable real-time operation is necessary (monitoring, providing limits, implementation of limits) • Data for calculating flows is needed for ex-post energy allocation. • Working ICT infrastructure for data gathering and provision of set-points is needed. • Components with flexibility activation potential, i.e., controllable assets, are available • Possible to apply split-supply model (i.e., separation of controllable and non-controllable assets) or separation of flexibility activation and energy supply • Activation is done automatically by the EMS4HESS by implementing the GCM set-points • Forecasts and grid state estimation needed • Grid aspects considered, limitations based on actual and future grid situation • Price information must be available (energy price within the community, for external transactions, grid fees and taxes, reductions, etc.) • Participants have provided consent for the access, storage, and use of data and control of controllable assets for the purposes of energy use accounting and potential optimization

Table 30: UC4 - Further information to the use case for classification/mapping

Classification information
Relation to the other use cases
This use case has the highest priority and supports the resilient grid operation. Therefore, full automation is necessary, any manual human interaction is not possible, and no further flexibility activation is possible when facing grid issues. Use Case 1 (Passive) provides the baseline for accounting. Use Case 2 (Active) and Use Case 3 (Automated with human inputs) can follow with lower priority when no grid support is needed.
Level of depth
High-level UC
Prioritization
This use case has the highest priority. Others can follow with lower priority.
Generic, regional or national relation
Relevant to PARMENIDES pilots with energy communities within one distribution grid as well as for the virtual environment. Can be applied to other countries and communities as well by considering the prerequisites and the same assumptions. Accounting (DSO, ESC, EC) in sequence diagram shows the Austrian implementation (DSO and ESC bills could be merged).
Nature of the use case
Technical
Further keywords for classification
Grid capacity management, automated flexibility activation, grid-support

Table 31: UC4 - Overview of scenarios

Scenario conditions						
No.	***Scenario name***	***Scenario description***	***Primary actor***	***Triggering event***	***Pre-condition***	***Post-condition***
4.1	Same as Scenario 1.2 Baseline Accounting					
4.2	Same as Scenario 2.1 Participant Optimization					
4.3	Same as Scenario 2.2 Participant Incentivization					
4.4	Same as Scenario 3.4 Grid-Friendliness					
4.5	Grid-Support	GCM is providing set-points for HESS due to the grid situation which must be implemented.	GCM, EMS4HESS	Every x minutes for flexibility activation.	GMD is available within the grid, capacity management is available, and set-points are calculated by GCM due to the grid situation SM is available at the customer. USEF grid operating regime is orange (graceful degradation) or red (power outage)	Flexibility is activated automatically by EMS4HESS by implementing the provided set-points. Electricity allocation is done.

Remark (valid for all use cases): The is no influence on the accounting for EC Participants. All bills in the project are calculated virtually for use case evaluation only.

4.10.Common References

In the following table, a summary of relevant references related to the PARMENIDES Use Cases is provided.

Table 32: Relevant References

References					
No.	***Reference type***	***Name***	***Author***	***Impact on use cases***	***Reference***
1	Article	Energy community ex-post electricity allocation algorithm based on participants' preferences	Berndadette Fina (AIT)	Medium	[11]
2	Article	Ex-Post Electricity Algorithm Allocation for Energy Communities	Bernadette Fina (AIT)	Medium	[12]
3	Legislation	Directive (EU) 2019/944 of the European Parliament and of the Council of 5 June 2019 on common rules for the internal market for electricity and amending Directive 2012/27/EU	European Parliament, & Council of the European Union	High	[1]
4	Legislation	Directive (EU) 2018/2001 of the European Parliament and of the Council of 11 December 2018 on the promotion of the use of energy from renewable sources (recast)	European Parliament, & Council of the European Union	High	[13]
5	Guidelines	USEF: The Framework Explained (Initial Public Release 2 November 2015; Update 25 May 2021)	USEF Foundation	High	[2]
6	Guidelines	The Harmonised Electricity Market Role Model (version: 2022-01)	ebIX, EFET, ENTSO-E	Medium	[14]
7	Guidelines	Use Case Collection, Management, Repository, Analysis and Harmonization' (SGCG/M490/E_Smart Grid Use Cases Management Process)	CEN-CENELEC-ETSI	Medium	[15]
8	Guidelines	Smart Grid Reference Architecture	CEN-CENELEC-ETSI	High	[4]
9	Article	A Model for Types and Levels of Human Interaction with Automation	Raja Parasuraman et al	Medium	[7]
10	Article	Mapping of Energy Communities in Europe: Status Quo and Review of Existing Classifications	Maksym Koltunov et al	Low	[16]
11	Article	Beyond Individual Active Customers: Citizen and Renewable Energy Communities in the European Union	Nicolò Rosetto	Low	[17]
12	Article	Three-Phase Unbalanced Optimal Power Flow Using Holomorphic Embedding Load Flow Method	Bharath-Varsh Rao et al (AIT)	Medium	[18]
13	Article	Stratified Control Applied to a Three-Phase Unbalanced Low Voltage Distribution Grid in a Local Peer-to-Peer Energy Community	Bharath-Varsh Rao et al (AIT)	High	[18]
14	Article	Optimal capacity management applied to a low voltage distribution grid in a local peer-to-peer energy community	Bharath-Varsh Rao et al (AIT)	High	[19]

4.11. Use Case Selection for PARMENIDES Pilots

Table 33 gives an overview about the PARMENIDES Use Case scenarios and where they are planned to be implemented – some scenarios will be tested in the pilots, some scenarios will be implemented in AIT Vlab for KPI evaluation and comparison, and some scenarios will be tested only in the virtual environment. Furthermore, the virtual environment allows to simulate test situations in the frame of the project.

Remark: The is no influence on the accounting for project participants.

Table 33: Overview about the planned scenarios to be implemented in the pilots and Vlab.

Use Case Scenarios	Austrian Pilot	Swedish Pilot	Virtual Environment
Energy Community Configuration[4]	No	No	No
Baseline Accounting	For KPI evaluation	For KPI evaluation	For KPI evaluation
Ex-post Energy Allocation	For KPI evaluation	For KPI evaluation	For KPI evaluation
Participant Optimization	No	Yes	Yes
Participant Incentivization	No (Project INNOnet[5])	Yes	Yes
Participant Disregard	No	Yes	Yes
Grid Friendliness	Yes	No	Yes
Grid Support	Yes	No	Yes

[4] The legal establishment is not planned to be done in the pilots.

[5] The Austrian research project "**INNOnet**" (Interaktive Netzoptimierung und Netztarife, ID FO999894848) runs in parallel to PARMENIDES and addresses innovative grid tariffs and the incentivization of grid customers in case of grid friendly behaviour. A regular exchange between the two projects takes place. AIT is coordinating the project, ENS and Siemens (as subcontractor for pilot infrastructure) are project partners.

5. Requirements

A detailed overview about the pilot-specific implementation of the use cases will be elaborated in task T3.1 and provided in Deliverable D3.1, including a detailed description of the respective non-functional requirements. Table 34 provides an overview about relevant non-functional requirements which will be evaluated.

Table 34: Overview about relevant non-functional Requirements.

Description	Category	Possible Values
Number of Information Producers	Configuration Issues	One Two to a few Few to a hundred Hundreds to thousands Thousands to millions Significantly varied in different implementations Changes frequently Other________________
Number of Information Receivers	Configuration Issues	One Two to a few Few to a hundred Hundreds to thousands Thousands to millions Significantly varied in different implementations Changes frequently Other________________
Distance between entities	Configuration Issues	A few meters A few kilometers Many kilometers Many hundreds of kilometers Varies and/or is not relevant
Location of Information Producer	Configuration Issues	Control room operation Depot operation Corporate building Building Substation Field outside substation Domestic customer site Industrial customer site Commercial customer site Another corporation Mobile Changes frequently Other________________
Location of Information Receiver	Configuration Issues	Control room operation Depot operation Corporate building Building Substation Field outside substation

Description	Category	Possible Values
		Domestic customer site Industrial customer site Commercial customer site Another corporation Mobile Changes frequently Other________________
Communication configuration	Configuration Issues	WAN LAN HAN Other________________
Communication media	Configuration Issues	Any Landline preferred Wireless possible Wireless required Other________________
Communication ownership	Configuration Issues	Any Utility-owned Jointly-owned Commercially provided Internet Other________________
Communication bandwidth	Configuration Issues	<2400 bps 2.4-56 kbps 56 kbps - 5 Mbbps 10 Mbps-100 Mbps 100 Mbps - 1 Gbps >1 Gbps Other________________
Data exchange methods	Configuration Issues	Any Master-slave Peer-to-peer Client-server Publish-subscribe Through database Ad hoc Other________________
Communication access services requirements	Configuration Issues	Any or all Request-response Periodic reporting Report-by-exception Control command Select-before-operate Set parameter values Query for data by name Subscribe Broadcast Multi-cast Data discovery

PARMENIDES

Description	Category	Possible Values
		Use of data sets Query to find location of data Query to determine what data is available (discovery) Execute application Establish and end association Logging Journaling Remote restart Remote reconfiguration Remote diagnosis Other________________
Data exchange pattern	Configuration Issues	Data flow is <10% of bandwith available Data flow is >10% but less than 50% of bandwith available Data flows patterns basically even Data flows include high volume bursts Other________________
Growth	Configuration Issues	2x number of participating devices - Over the next 5 years 10x number of participating devices - Over the next 5 years 100x number of participating devices - Over the next 5 years
Commonly used communication protocol	Configuration Issues	*Include here the communication protocols used for the infor-mation exchange. This relates to the Communication Layer in SGAM.*
Commonly used data model	Configuration Issues	*Include here the data models used for the information ex-change. This relates to the Information Layer - Canonical Data Model view in SGAM.*
Relative maturity of current implementation	Configuration Issues	Very mature and widely implemented Moderately mature Fairly new Future, no systems, no interactions
Existence of legacy systems	Configuration Issues	Many legacy systems Some legacy systems Few legacy systems Extensive changes will be needed for full system functionality Moderate changes will be needed Few changes will be needed No changes will be needed
Communication paradigm	Configuration Issues	One-on-one One-to-many Many-to-many Multi-drop Ad hoc Other________________
Operation mode of Information Producer	Configuration Issues	Manual Automatic Manual&Automatic
Operation mode of Information Receiver	Configuration Issues	Manual Automatic Manual&Automatic

Description	Category	Possible Values
Elapsed time response requirements for exchanging data	Quality of Service (QoS) Issues	1-4 milliseconds 4-10 milliseconds Less than 1 second 1-2 seconds 10 seconds More than 10 seconds No specific response requirements Other_______________
Contractual timelines for exchanging data is required	Quality of Service (QoS) Issues	Within 1 second Within 1 minute Within 5 minutes Within some longer time: No specific contractual timeliness is required Other_______________
Availability of information flows	Quality of Service (QoS) Issues	99.9999% + availability - Allowed outage: 1/2 second per year 99.999% + availability - Allowed outage: 5 minutes per year 99.99% + availability - Allowed outage: 1 hour per year 99.9% + availability - Allowed outage: 9 hours per year 99% + availability -Allowed outage: 3.5 days per year 90% + availability - Allowed outage: 1 month per year Less than 90% Continuous availability not required so long as downtime is scheduled Continuous availability not required but must be available at specific times or under specific conditions No specific availability is required Other_______________
Precision of data requirements	Quality of Service (QoS) Issues	100% accurate >0.5% variance >1% variance >5% variance Not relevant Other_______________
Accuracy of data requirements	Quality of Service (QoS) Issues	Requires quality flag indicating at least normal and not normal Age of data needs to be knowable Time skew of data must be known Adequate accuracy can be assumed Accuracy of data not an issue Other_______________
Frequency of data exchanges	Quality of Service (QoS) Issues	Essentially continuous Every few milliseconds Every few seconds Periodicity greater than a few seconds Upon event Upon request Random Sparse Other_______________

Description	Category	Possible Values
Eavesdropping: Ensuring confidentiality, avoiding illegitimate use of data, and preventing unauthorized reading of data, is:	Security Issues	Crucial Quite important Not particularly important Detection that a security violation was attempted is crucial Other_______________
Information integrity violation: Ensuring that data is not changed or destroyed is:	Security Issues	Crucial Quite important Not particularly important Detection that a security violation was attempted is crucial Other_______________
Authentication: Masquerade and/or spoofing: Ensuring that data comes from the stated source or goes to authenticated receiver is:	Security Issues	Crucial Quite important Not particularly important Detection that a security violation was attempted is crucial Other_______________
Repudiation: Ensuring that the source cannot deny sending the data or that the receiver cannot deny receiving the data is:	Security Issues	Crucial Quite important Not particularly important Detection that a security violation was attempted is crucial Other_______________
Replay: Ensuring that data cannot be resent by an unauthorized source is:	Security Issues	Crucial Quite important Not particularly important Detection that a security violation was attempted is crucial Other_______________
Information theft: Ensuring that data cannot be stolen or deleted by an unauthorized entity is:	Security Issues	Crucial Quite important Not particularly important Detection that a security violation was attempted is crucial Other_______________
Denial of Service: Ensuring unimpeded access to data is:	Security Issues	Crucial Quite important Not particularly important Detection that a security violation was attempted is crucial Other_______________
This data exchange has the following requirements with respect to proof of conformance and/or non-repudiation with contractual agreements:	Security Issues	Logging of all information exchanged during this interaction is required Logging of only key information is required Logging of the source, destination, requesting application, and requesting user of information exchanges is required, but not the data itself Other_______________
Authentication and Access Control mechanisms commonly used	Security Issues	Private (secret) key encryption Public key encryption (e.g. SSL/TLS) Certificate

Description	Category	Possible Values
with this data exchange		Shared secret Kerberos Access control through database security mechanisms Bilateral data access control tables Other_______________
Network security measures commonly used with this data exchange	Security Issues	Virtual Private Networks (VPNs) VLAN segregation Physical network separation Network management such as SNMP or CMIP Firewalls with Access Control Lists and/or proxy servers One-way communications assurance Other_______________
Procedural security measures commonly used with this data exchange	Security Issues	Audits Security policies with procedures to follow Other_______________
Other security measures commonly used with this data exchange	Security Issues	Dial-back moderns Time stamping, logging, and data records Non-repudiation techniques Backup Defence in depth Least access privileges Other_______________
Type of source data	Data Management Issues	Source data was directly measured Source data was previously automatically stored in a database Source data was previously manually entered in a database Source data was calculated or output by an application Other_______________
Correctness of source data	Data Management Issues	Source data is always correct (e.g. by definition) Source data is usually correct Source data is often not correct (incorrectly entered, out of date, not available) Source data is rarely correct Correctness of source data is not relevant Other_______________
Up-to-date management	Data Management Issues	Received data must be up-to-date within seconds of source data changing Received data must be up-to-date within minutes of source data changing Received data must be up-to-date within hours of source data changing Received data does not need to be up-to-data if source data changes Other_______________
Management of large volumes of data that are being exchanged	Data Management Issues	Major part of step involves handling large volumes of data Some part of step involves handling large volumes of data No part of step involves handling large volumes of data Other_______________

Description	Category	Possible Values
Data consistency and synchronization management across systems	Data Management Issues	Second-by-second synchronization Minute-by-minute synchronization Day-by-day synchronization No synchronization Other_______________
Management of timely access to data by multiple different users	Data Management Issues	Contractual/required time windows for multiple access are less than one second Contractual/required time windows for multiple access are within seconds Contractual/required time windows for multiple access are within tens of seconds Contractual/required time windows for multiple access are within minutes Timely access by multiple users is not relevant Other_______________
Validation of data exchanges	Data Management Issues	All data must be validated on each data exchange Data must include quality codes to indicate its validity Data from different sources must be validated against each other Data mapping of data item names is required for data from different sources Data can be assumed as valid (or validity checking is handled elsewhere) Data is usually not validated Data cannot be validated Validity of data is not relevant Other_______________
Management of accessing different types of data to be exchanged	Data Management Issues	Each data exchange could entail different types of data (e.g. query a database) Numbers or types of data being exchanged are changed or updated every few minutes Numbers or types of data being exchanged are changed or updated every few hours Numbers or types of data being exchanged are changed or updated every few days or weeks Numbers or types of data being exchanged are rarely changed or updated Not relevant Other_______________
Management of data across organizational boundaries	Data Management Issues	Data exchanges go across organizational boundaries Data exchanges go across departmental boundaries Data exchanges go across boundaries between system developed by different vendors Data exchanges are within one vendor's system Not relevant Other_______________
Transaction integrity required (backup and rollback capability)	Data Management Issues	Data exchanges require the ability to rollback to previous data states Data exchanges require full backup for immediate "failover" to

PARMENIDES

Description	Category	Possible Values
		a second source of data Data exchanges require backup of crucial data for "cold" failo-ver Data exchanges do not require rollback or backup Other________________
Transaction integrity required (backup and rollback capability)	Data Management Issues	Standard computer formats (e.g. binary, integers and floating pt, files) Standard serial tranfer formats (e.g. DNP, Mobdus, LonTalk, BACnet) Graphics formats HTML-based XML-based CSV Standardized data objects Exchange of unstructured or special-format data (e.g. text, doc-uments, oscillographic data) must be supported Any formats are acceptable Other________________
Management of data formats in data ex-changes	Data Management Issues	The same data exchanged between different applications have the same formats Conversion of data formats is automatically handled by each application Conversion of data formats is handled by Enterprise Service Bus (ESB) Conversion of data formats is handled by a "converter" at Infor-mation Producer site Conversion of data formats is handled by a "converter" at Infor-mation Receiver site Other________________
Naming of data items	Data Management Issues	The data items have the same name in all the applications (no need to match names) Matching of names is handled by Enterprise Service Bus (ESB) Matching of names is handled by a "converter" at Information Producer Matching of names is handled by a "converter" at Information Receiver Other________________
Management across different implementa-tions	Data Management Issues	Types of data being exchanged can vary significantly in different implementations Types of data being exchanged vary very little in different im-plementations Other________________
Data exchange maintenance in which a human changes or updates what is to be exchanged	Data Management Issues	Data exchanges require maintenance every few hours Data exchanges require maintenance every few days Data exchanges require maintenance every few weeks or months Data exchanges rarely require maintenance Other________________

Description	Category	Possible Values
Database maintenance in which a human changes or updates what is in the database	Data Management Issues	Database requires maintenance every few hours Database requires maintenance every few days Database requires maintenance every few weeks or months Database rarely require maintenance Other_______________
Data maintenance effort: human versus automation	Data Management Issues	Data maintenance involves significant human time and manual data entries Data maintenance is patially automated byt involves some human time and manual data entries Data maintenance is mostly automated buy requires occasional intervention Data maintenance is (or can be if so authorized) completely automated (e.g. Live Update of Virus, Microsfot Updates) Other_______________
Data security classification	Data Management Issues	
Data owner specification	Data Management Issues	
Others	Other Constraints	Political, legal, financial, or just very specific to a particular step. For instance, one step may involve data received from another utility that requires special handling: format conversions or manual intervention. This is a catch-all for such special issues.

References

[1] European Parliament, & Council of the European Union, "Directive (EU) 2019/944 of the European Parliament and of the Council of 5 June 2019 on common rules for the internal market for electricity and amending Directive 2012/27/EU," 2019.

[2] H. de Heer, M. von der Laan and A. S. Armenteros, "USEF: The Framework Explained," 2021.

[3] E. Klaassen and M. van der Laan, "USEF White Paper: Energy and Flexibility Services for Citizens Energy Communities," 2019.

[4] CEN-CENELEC-ETSI Smart Grid Coordination Group, "Smart Grid Reference Architecture," 2012.

[5] International Electrotechnical Commission (IEC), "IEC 62559-2:2015: Use case methodology - Part 2: Definition of the templates for use cases, actor list and requirements list," 2015.

[6] J. Kazmi, M. Stefan and M. Farré, "An Interoperability-by-Desing Approach for Designing Smart Grid Solutions," in *27th International Conference on Electricity Distribution (CIRED)*, Rome, Italy.

[7] R. Parasuraman, T. Sheridan and C. Wickens, "A model for types and levels of human interaction with automation," *IEEE transactions on systems, man, and cybernetics. Part A, Systems and humans : a publication of the IEEE Systems, Man, and Cybernetics Society,* pp. 286-297, 2000.

[8] C. D. Wickens, A. S. Mavor, R. Parasuraman and J. P. McGee, The Future of Air Traffic Control: Human Operators and Automation, National Academies Press, 1997.

[9] European Environment Agency, "Energy prosumers in Europe : citizen participation in the energy transition," Publications Office of the European Union, 2022.

[10] R. Luthander, J. Widén, D. Nilsson and J. Palm, "Photovoltaic self-consumption in buildings: A review," *Applied Energy,* vol. 142, pp. 80-94, 2015.

[11] B. Fina, "Energy community ex-post electricity allocation algorithm based on participants' preferences," *Energy Reports,* vol. 9, pp. 3822-3836, 2023.

[12] B. Fina, "Ex-Post Electricity Algorithm Allocation for Energy Communities," in *Proceedings of the EEM22 University of Ljubljana*, 2022.

[13] European Parliament, & Council of the European Union, "Directive (EU) 2018/2001 of the European Parliament and of the Council of 11 December 2018 on the promotion of the use of energy from renewable sources," 2018.

[14] ebIX, EFET and ENTSO-E, "The Harmonised Electricity Market Role Model," 2022.

[15] CEN-CENELEC-ETSI Smart Grid Working Group Sustainable Processes, “Use Case Collection, Management, Repository, Analysis and Harmonization (SGCG/M490/E_Smart Grid Use Cases Management Process),” 2012.

[16] M. Koltunov, S. Pezzutto, A. Bisello, G. Lettner, A. Hiesl, W. van Sark, A. Louwen and E. Wilczynski, “Mapping of Energy Communities in Europe: Status Quo and Review of Existing Classifications,” *Sustainability,* vol. 10, no. 15, 2023.

[17] N. Rossetto, “Beyond Individual Active Customers: Citizen and Renewable Energy Communities in the European Union,” *IEEE Power and Energy Magazine,* vol. 21, no. 4, pp. 36-44, 2023.

[18] B.-V. Rao, F. Kupzog and M. Kozek, “Three-Phase Unbalanced Optimal Power Flow Using Holomorphic Embedding Load Flow Method,” *Sustainability,* vol. 11, no. 6, 2019.

[19] B.-V. Rao, M. Stefan, T. Brunnhofer, R. Schwalbe, R. Karl, F. Kupzog, G. Taljan, F. Zeilinger, P. Stern and M. Kozek, “Optimal capacity management applied to a low voltage distribution grid in a local peer-to-peer energy community,” *International Journal of Electrical Power & Energy Systems,* vol. 134, 2022.

[20] B.-V. Rao, M. Stefan, R. Schwalbe, R. Karl, F. Kupzog and M. Kozek, “Stratified Control Applied to a Three-Phase Unbalanced Low Voltage Distribution Grid in a Local Peer-to-Peer Energy Community,” *Energies,* vol. 14, no. 11, 2021.

6. Annex

6.1. Use Case Details

6.1.1 PARMENIDES Use Case 1 – Passive Energy Community Customer Optimization

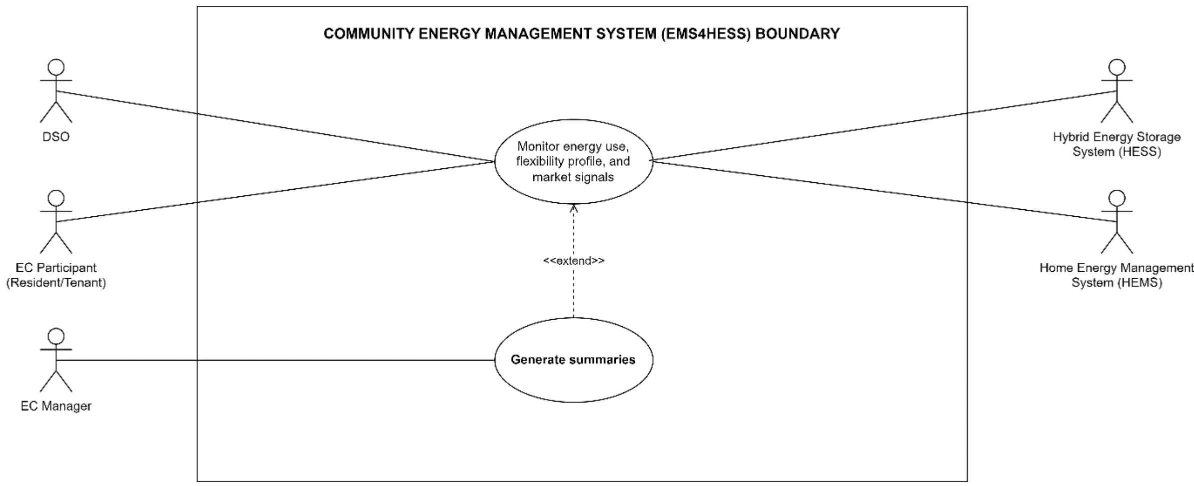


Figure 15: Use Case Diagram - Community Energy Management System (EMS4HESS) Boundary

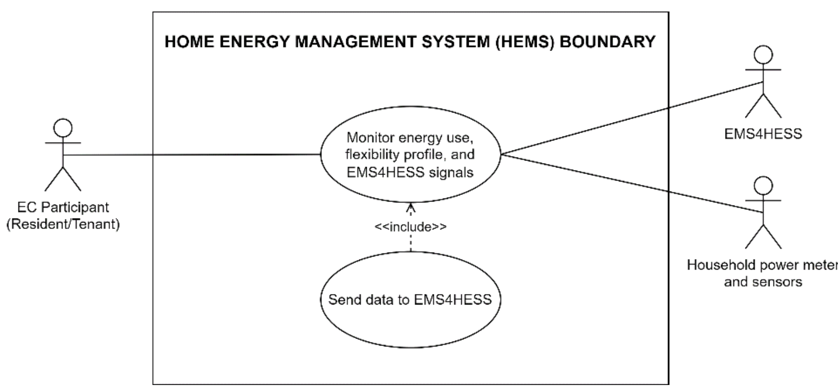


Figure 16: Use Case Diagram – Home Energy Management System (HEMS) Boundary

Table 35: UC1 - Steps – Scenarios: Scenario 1.1 (Energy Community Configuration)

Scenario					
Scenario name		***Energy Community Configuration***			
Step No.	***Event Name of process/activity***	***Description of process/activity***	***Service***	***Information producer (actor)***	***Information receiver (actor)***
01	Request participation	EC Manager requests the participation of a customer	GET	EC Manager	EC Participant
02	Confirm participation	EC Participant confirms participation	REPORT	EC Participant	EC Manager
03	Discuss/agree on community configuration	EC Manager and EC Participant discuss/agree on community configuration	GET	EC Manager	EC Participant
04	Discuss/agree on community configuration	EC Manager and EC Participant discuss/agree on community configuration	REPORT	EC Participant	EC Manager
05	Register community	EC Manager registers the community at the DSO	REPORT	EC Manager	DSO
06	Update configuration	Initialize/Update the community configuration	REPORT	EC Manager	ICS

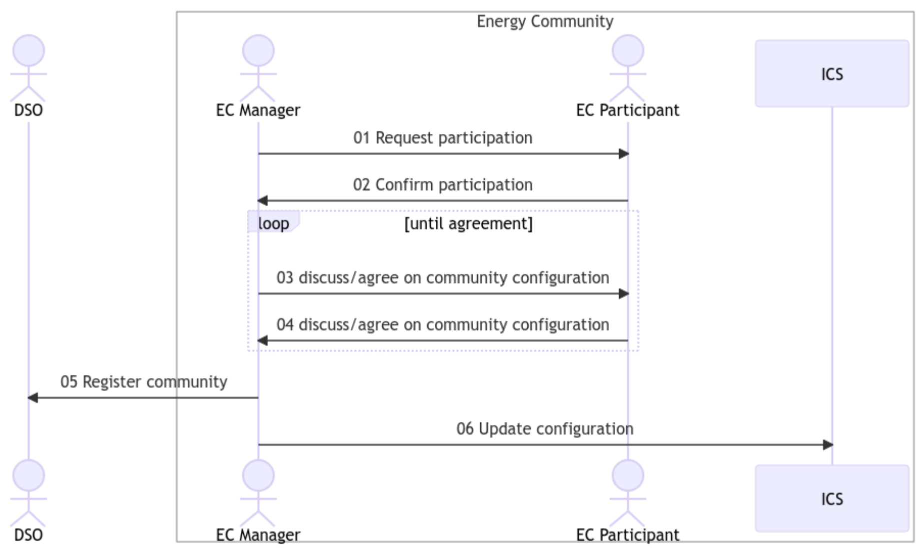


Figure 17: UC1 – Sequence diagram – Scenario 1.1 (Energy Community Configuration)

Table 36: UC1 - Steps – Scenarios: Scenario 1.2 (Baseline Accounting)

Scenario					
Scenario name		***Baseline Accounting***			
Step No.	***Event Name of process/activity***	***Description of process/activity***	***Service***	***Information producer (actor)***	***Information receiver (actor)***
01	Request consumption data	DSO requests consumption data from SM	GET	DSO	SM
02	Reply consumption data	SM replies with the requested consumption data	REPORT	SM	DSO
03	Calculate grid bill	DSO calculates the grid bill based on consumption data	EXECUTE	DSO	DSO
04[6]	Send grid bill	DSO sends the grid bill to the customer	REPORT	DSO	EC Participant
05	Send consumption data	DSO sends the consumption data to the ESCO	REPORT	DSO	ESCO
06	Calculate energy bill	ESCO calculates the energy costs based on the received consumption data	EXECUTE	ESCO	ESCO
07	Send energy bill	ESCO sends the energy bill to the customer	REPORT	ESCO	EC Participant

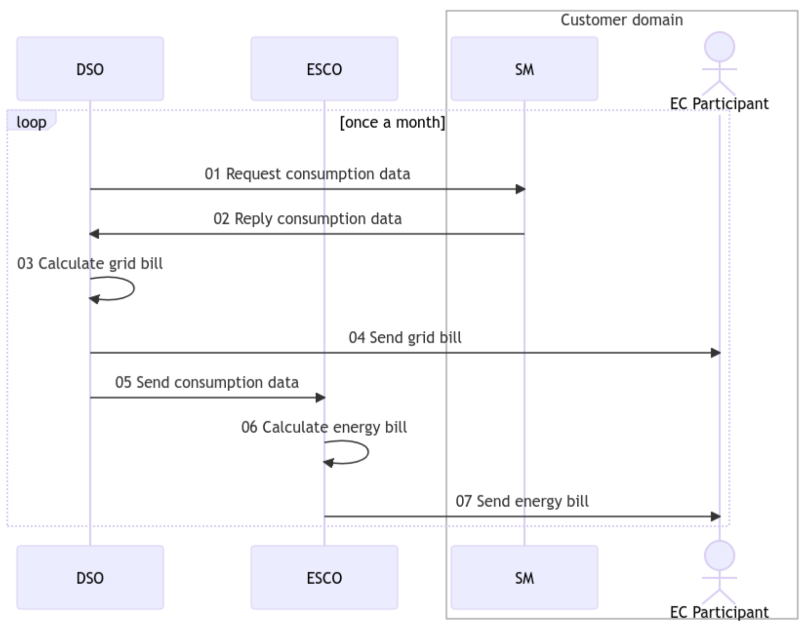


Figure 18: UC1 – Sequence diagram – Scenario 1.2 (Baseline Accounting)

[6] This step can be either done separately or can be combined with 07 (one bill with grid costs and energy costs provided by the ESC).

PARMENIDES

Table 37: UC1 - Steps – Scenarios: Scenario 1.3 (Ex-post Energy Allocation)

Scenario					
Scenario name		***Ex-post Energy Allocation***			
Step No.	***Event Name of process/activity***	***Description of process/activity***	***Service***	***Information producer (actor)***	***Information receiver (actor)***
1	Request consumption data	DSO requests consumption data from SM	GET	DSO	SM
2	Reply consumption data	SM replies with the requested consumption data	REPORT	SM	DSO
3	Calculate energy allocation	DSO calculates the community-internal and external ex-post allocation of energy	EXECUTE	DSO	DSO
4	Calculate grid bill	DSO calculates the grid bill based on the calculated energy allocation	EXECUTE	DSO	DSO
5[7]	Send grid bill	DSO sends the grid bill to the customer	REPORT	DSO	Customer
6	Send external allocation data	DSO sends the external energy allocation to the ESCO	REPORT	DSO	ESCO
7	Calculate external energy bill	ESCO calculates the energy costs based on the received external energy allocation	EXECUTE	ESCO	ESCO
8	Send external energy bill	ESCO sends the external energy bill to the customers	REPORT	ESCO	Customer
9	Send internal allocation data	DSO sends the community internal allocation to the EMS4HESS	REPORT	DSO	EMS4HESS
10	Calculate internal energy bill	EMS4HESS calculates the community-internal energy bill based on the received energy allocation	EXECUTE	EMS4HESS	EMS4HESS
11	Send internal energy bill	EMS4HESS sends the internal energy bill to the customers	REPORT	EMS4HESS	Customer

[7] This step can be either done separately or can be combined with 08 (one bill with grid costs and energy costs provided by the ESC).

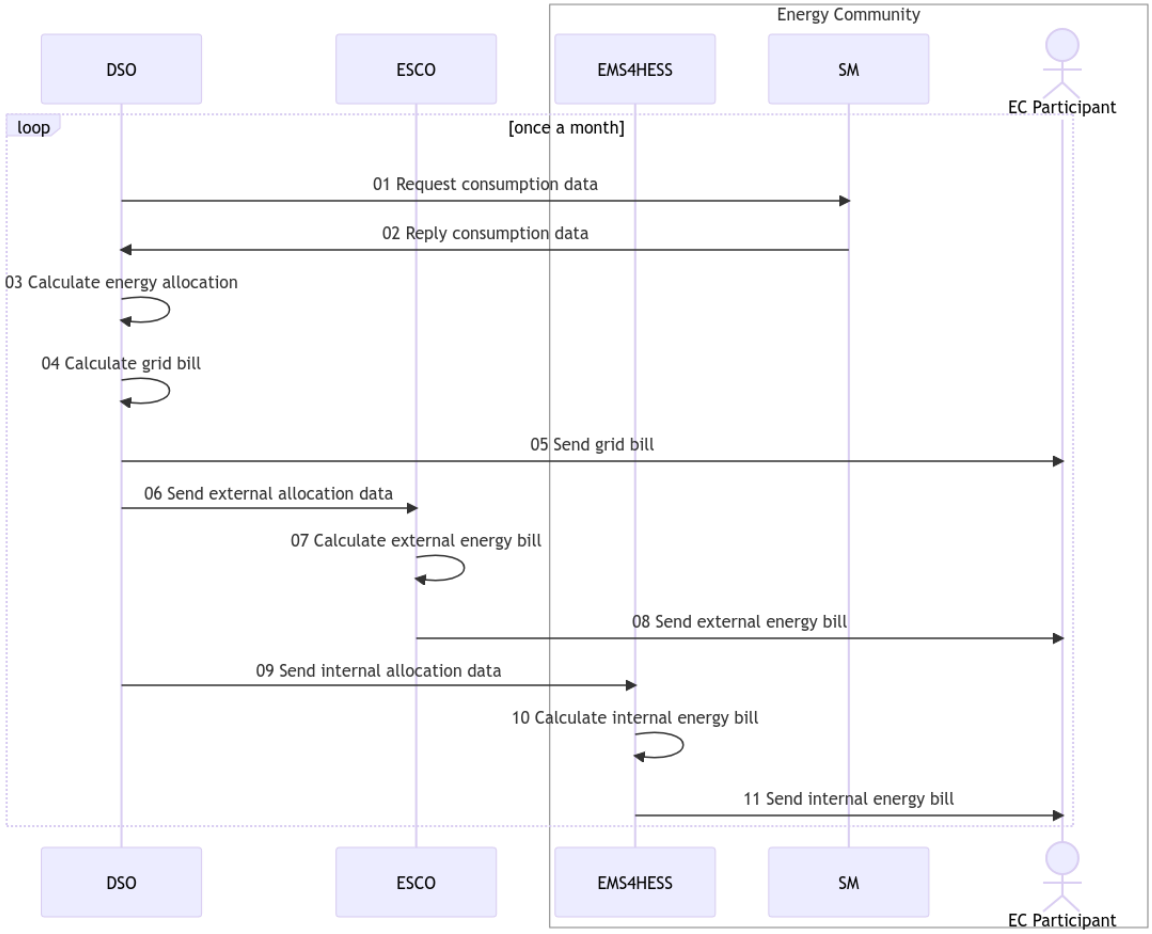


Figure 19: UC1 – Sequence diagram – Scenario 1.3 (Ex-post Energy Allocation)

6.1.2 PARMENIDES Use Case 2 – Active Energy Community Participation

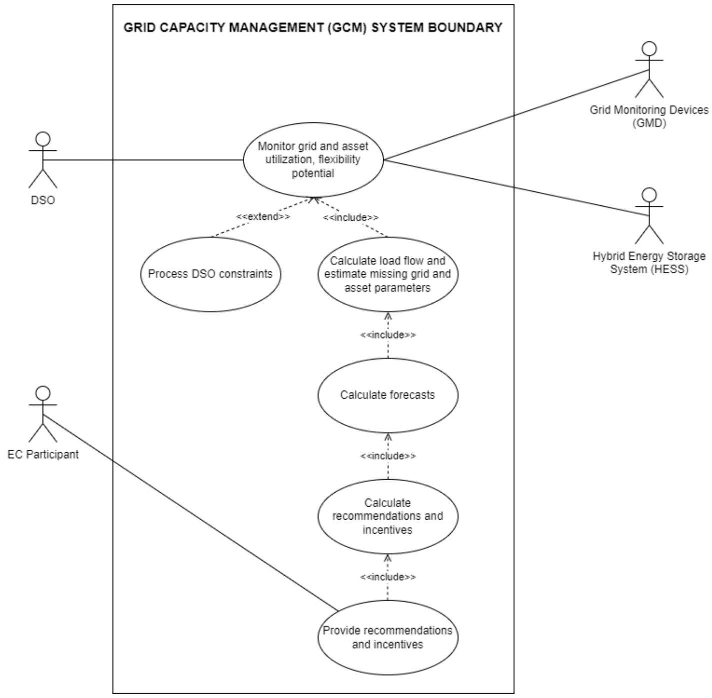


Figure 20: Use Case Diagram - Grid Capacity Management (GCM) boundary

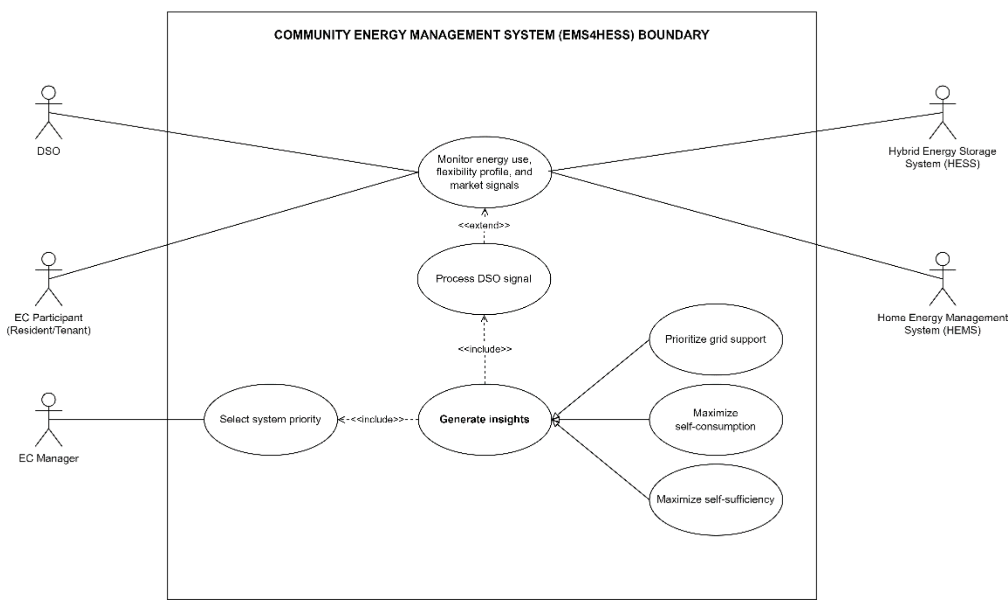


Figure 21: Use Case Diagram - Community Energy Management System (EMS4HESS) boundary

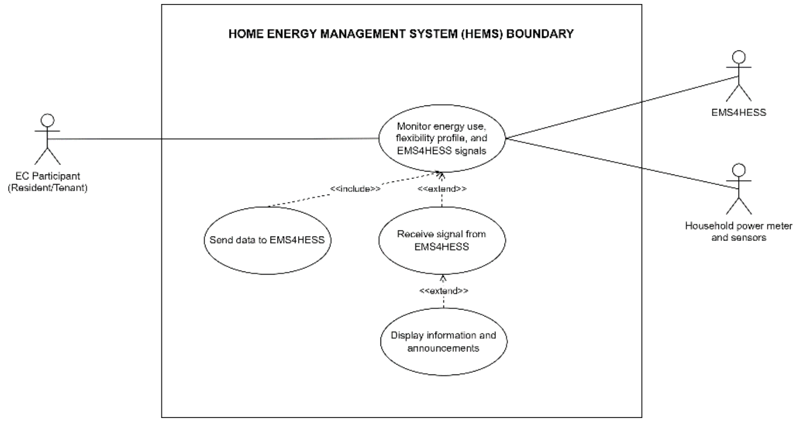


Figure 22: Use Case Diagram – Home Energy Management System (HEMS) boundary

Table 38: UC2 - Steps – Scenarios: Scenario 2.1 (Participant Optimization)

Scenario					
Scenario name		***Participant Optimization***			
Step No.	***Event Name of process/activity***	***Description of process/activity***	***Service***	***Information producer (actor)***	***Information receiver (actor)***
01	Request measurement	GCM requests measurement from the grid	GET	GCM	GMD
02	Reply measurement	GMD replies with the requested measurement data	REPORT	GMD	GCM
03	Request consumption data	GCM requests consumption data from SM	GET	GCM	SM
04	Reply consumption data	SM replies with the requested consumption data	REPORT	SM	GCM
05	Request state information	GCM requests state information from HESS	GET	GCM	HESS
06	Reply state information	HESS replies with state information	REPORT	HESS	GCM
07	Calculate recommendations	GCM calculated grid state, needed flexibility, and derives recommendations and incentives (no flexibility activation needed)	EXECUTE	GCM	GCM
08	Provide systems state	GCM provides information about the system state to ICS	REPORT	GCM	ICS
09	Display system state	ICS displays the current system state	EXECUTE	ICS	ICS
10	Request consumption data	DSO requests consumption data from SM	GET	DSO	SM
11	Reply consumption data	SM replies with the requested consumption data	REPORT	SM	DSO
12	Calculate energy allocation	DSO calculates the community-internal and external ex-post allocation of energy	EXECUTE	DSO	DSO
13	Calculate grid bill	DSO calculates the grid bill based on the calculated energy allocation	EXECUTE	DSO	DSO

14[8]	Send grid bill	DSO sends the grid bill to the customer	REPORT	DSO	EC Participant
15	Send external allocation data	DSO sends the external energy allocation to the ESCO	REPORT	DSO	ESCO
16	Calculate external energy bill	ESCO calculates the energy costs based on the received external energy allocation	EXECUTE	ESCO	ESCO
17	Send external energy bill	ESCO sends the external energy bill to the customers	REPORT	ESCO	EC Participant
18	Send internal allocation data	DSO sends the community internal allocation to the EMS4HESS	REPORT	DSO	EMS4HESS
19	Calculate internal energy bill	EMS4HESS calculates the community internal energy bill based on the received energy allocation	EXECUTE	EMS4HESS	EMS4HESS
20	Send internal energy bill	EMS4HESS sends the internal energy bill to the customers	REPORT	EMS4HESS	EC Participant

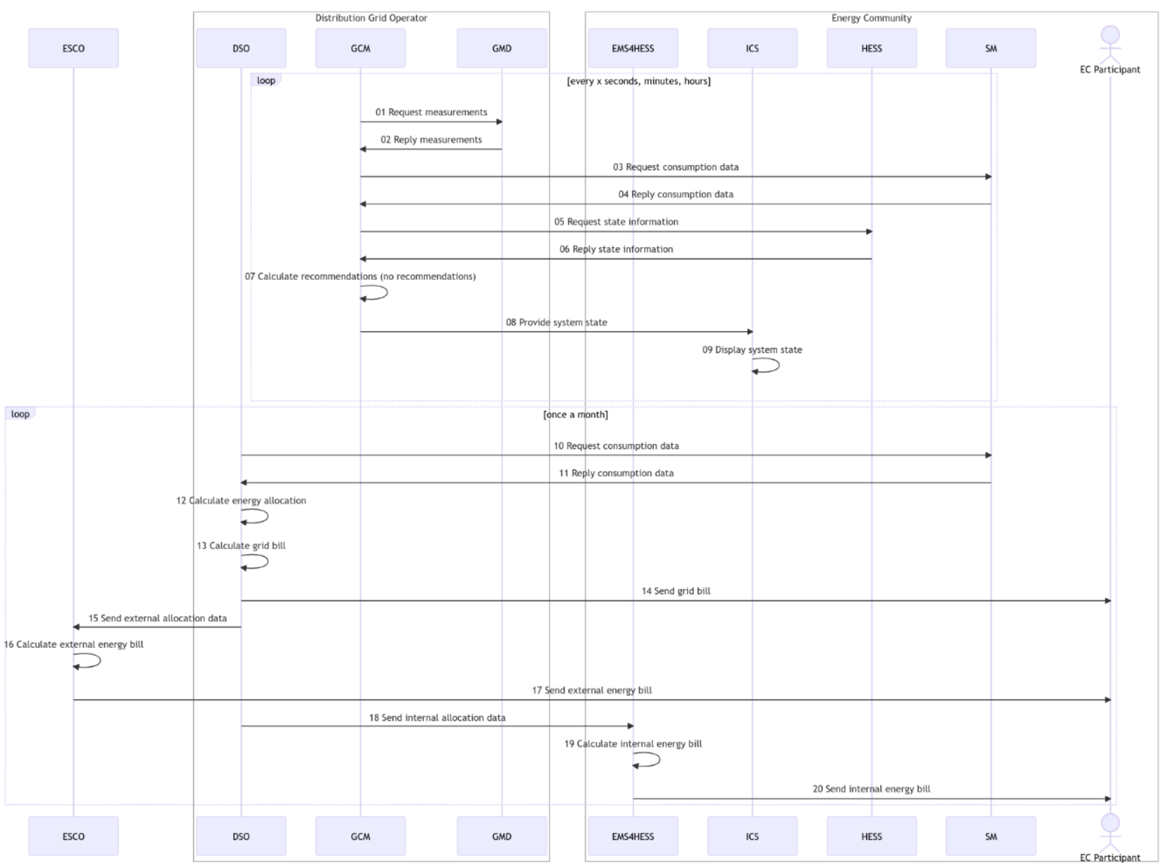


Figure 23: Sequence diagram – Scenario 2.1 (Participant Optimization)

[8] This step can be either done separately or can be combined with 07 (one bill with grid costs and energy costs provided by the ESC).

Table 39: UC2 - Steps – Scenarios: Scenario 2.2 (Participant Incentivization)

Scenario					
Scenario name		***Participant Incentivization***			
Step No.	***Event Name of process/activity***	***Description of process/activity***	***Service***	***Information producer (actor)***	***Information receiver (actor)***
01	Request measurement	GCM requests measurement from the grid	GET	GCM	GMD
02	Provide measurement	GMD replies with the requested measurement data	REPORT	GMD	GCM
03	Request consumption data	GCM requests consumption data from SM	GET	GCM	SM
04	Reply consumption data	SM replies with the requested consumption data	REPORT	SM	GCM
05	Request state information	GCM requests state information from HESS	GET	GCM	HESS
06	Reply state information	HESS replies with state information	REPORT	HESS	GCM
07	Calculate recommendations	GCM calculated grid state, needed flexibility, and derives recommendations and incentives	EXECUTE	GCM	GCM
08	Provide systems state	GCM provides information about the system state to ICS	REPORT	GCM	ICS
09	Display system state	ICS displays the current system state	EXECUTE	ICS	ICS
10	Flexibility recommendation	GCM provides recommendations and incentives to Customer	REPORT	GCM	EC Participant
11	Manual activation	EC Participant manually activates the flexibility	EXECUTE	EC Participant	HESS
12	Request consumption data	DSO requests consumption data from SM	GET	DSO	SM
13	Reply consumption data	SM replies with the requested consumption data	REPORT	SM	DSO
14	Calculate energy allocation	DSO calculates the community-internal and external ex-post allocation of energy	EXECUTE	DSO	DSO
15	Calculate grid bill	DSO calculates the grid bill based on the calculated energy allocation and incentives due to flexibility activation	EXECUTE	DSO	DSO
16[9]	Send grid bill	DSO sends the grid bill to the customer	REPORT	DSO	EC Participant
17	Send external allocation data	DSO sends the external energy allocation to the ESCO	REPORT	DSO	ESCO
18	Calculate external energy bill	ESCO calculates the energy costs based on the received external energy allocation	EXECUTE	ESCO	ESCO
19	Send external energy bill	ESCO sends the external energy bill to the customers	REPORT	ESCO	EC Participant

[9] This step can be either done separately or can be combined with 07 (one bill with grid costs and energy costs provided by the ESC).

20	Send internal allocation data	DSO sends the community internal allocation to the EMS4HESS	REPORT	DSO	EMS4HESS
21	Calculate internal energy bill	EMS4HESS calculates the community internal energy bill based on the received energy allocation	EXECUTE	EMS4HESS	EMS4HESS
22	Send internal energy bill	EMS4HESS sends the internal energy bill to the customers	REPORT	EMS4HESS	EC Participant

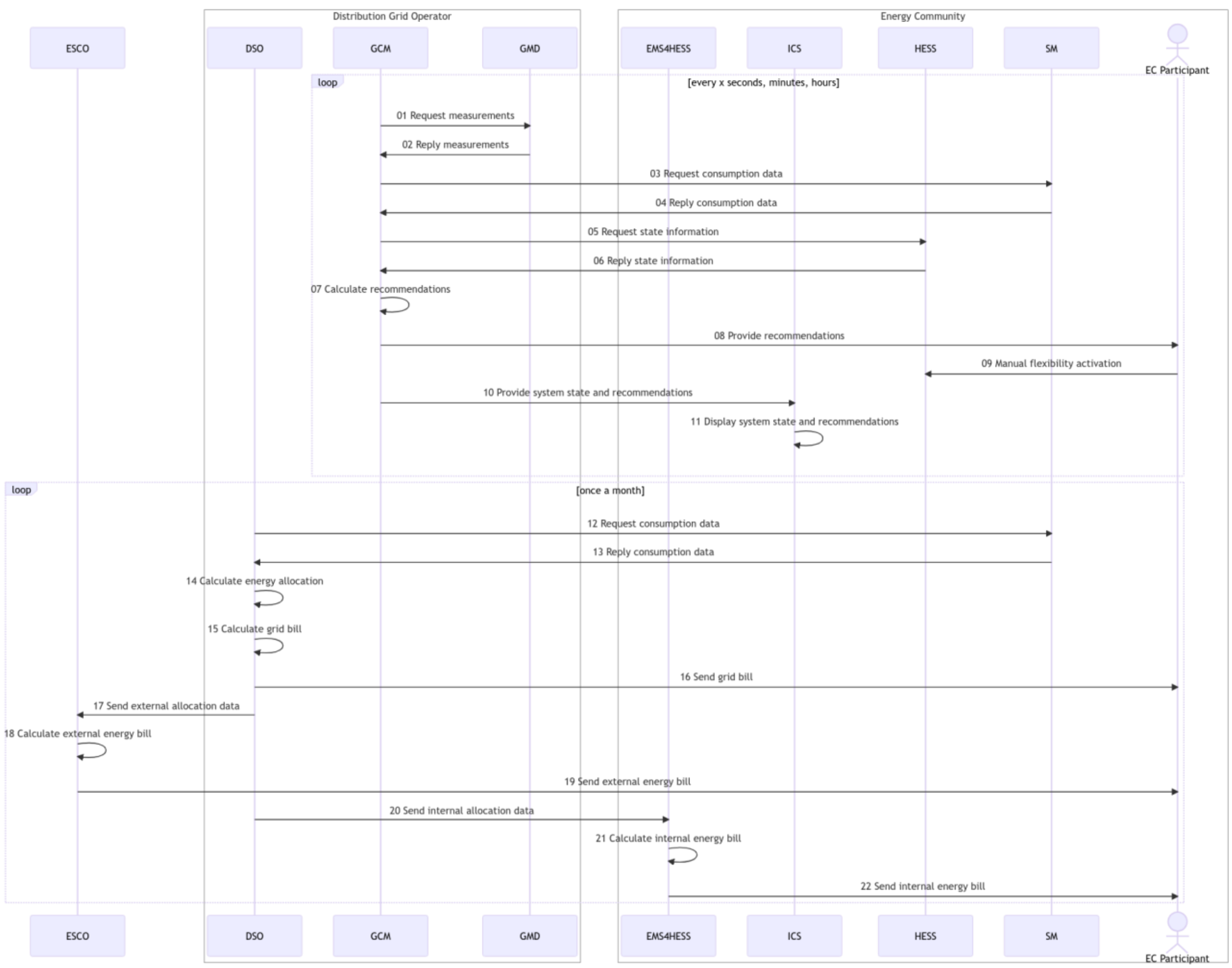


Figure 24: Sequence diagram – Scenario 2.2 (Participant Incentivization)

Table 40: UC2 - Steps – Scenarios: Scenario 2.3 (Participant Disregard)

Scenario					
Scenario name		***Participant Disregard***			
Step No.	***Event Name of process/activity***	***Description of process/activity***	***Service***	***Information producer (actor)***	***Information receiver (actor)***
01	Request measurement	GCM requests measurement from the grid	GET	GCM	GMD
02	Provide measurement	GMD replies with the requested measurement data	REPORT	GMD	GCM
03	Request consumption data	GCM requests consumption data from SM	GET	GCM	SM
04	Reply consumption data	SM replies with the requested consumption data	REPORT	SM	GCM
05	Request state information	GCM requests state information from HESS	GET	GCM	HESS
06	Reply state information	HESS replies with state information	REPORT	HESS	GCM
07	Calculate recommendations	GCM calculated grid state, needed flexibility, and derives recommendations and incentives	EXECUTE	GCM	GCM
08	Provide systems state	GCM provides information about the system state to ICS	REPORT	GCM	ICS
09	Display system state	ICS displays the current system state	EXECUTE	ICS	ICS
10	Flexibility recommendation	GCM provides recommendations and incentives to Customer	REPORT	GCM	EC Participant
11	No flexibility activation	EC Participant does not activate the flexibility	EXECUTE	EC Participant	EC Participant
12	Request consumption data	DSO requests consumption data from SM	GET	DSO	SM
13	Reply consumption data	SM replies with the requested consumption data	REPORT	SM	DSO
14	Calculate energy allocation	DSO calculates the community-internal and external ex-post allocation of energy	EXECUTE	DSO	DSO
15	Calculate grid bill	DSO calculates the grid bill based on the calculated energy allocation, no incentives due to missing flexibility activation	EXECUTE	DSO	DSO
16[10]	Send grid bill	DSO sends the grid bill to the customer	REPORT	DSO	EC Participant
17	Send external allocation data	DSO sends the external energy allocation to the ESCO	REPORT	DSO	ESCO
18	Calculate external energy bill	ESCO calculates the energy costs based on the received external energy allocation	EXECUTE	ESCO	ESCO
19	Send external energy bill	ESCO sends the external energy bill to the customers	REPORT	ESCO	EC Participant

[10] This step can be either done separately or can be combined with 07 (one bill with grid costs and energy costs provided by the ESC).

PARMENIDES

20	Send internal allocation data	DSO sends the community internal allocation to the EMS4HESS	REPORT	DSO	EMS4HESS
21	Calculate internal energy bill	EMS4HESS calculates the community internal energy bill based on the received energy allocation	EXECUTE	EMS4HESS	EMS4HESS
22	Send internal energy bill	EMS4HESS sends the internal energy bill to the customers	REPORT	EMS4HESS	EC Participant

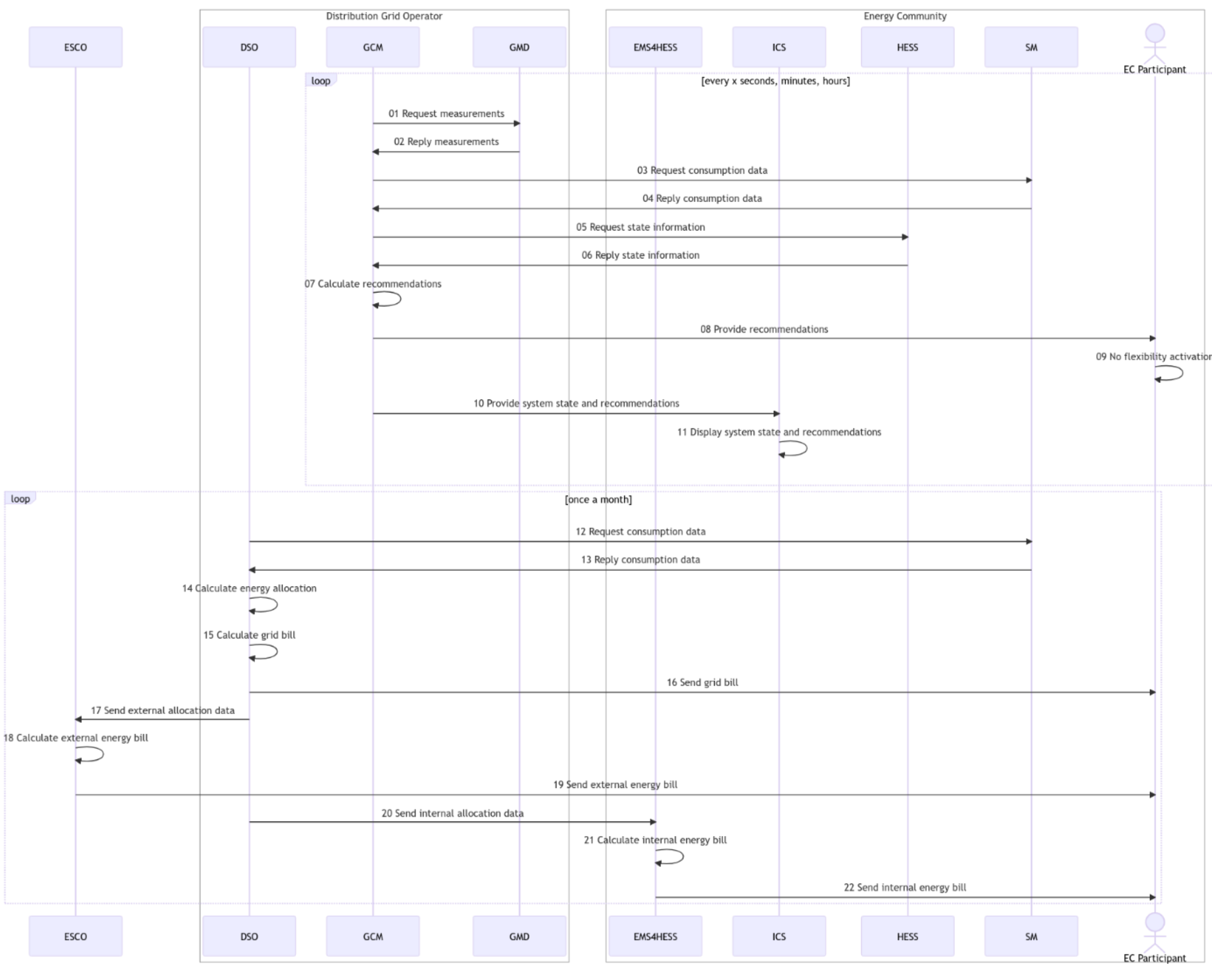


Figure 25: Sequence diagram – Scenario 2.3 (Participant Disregard)

6.1.3 PARMENIDES Use Case 3 – Automated Energy Community Participation with Human Inputs

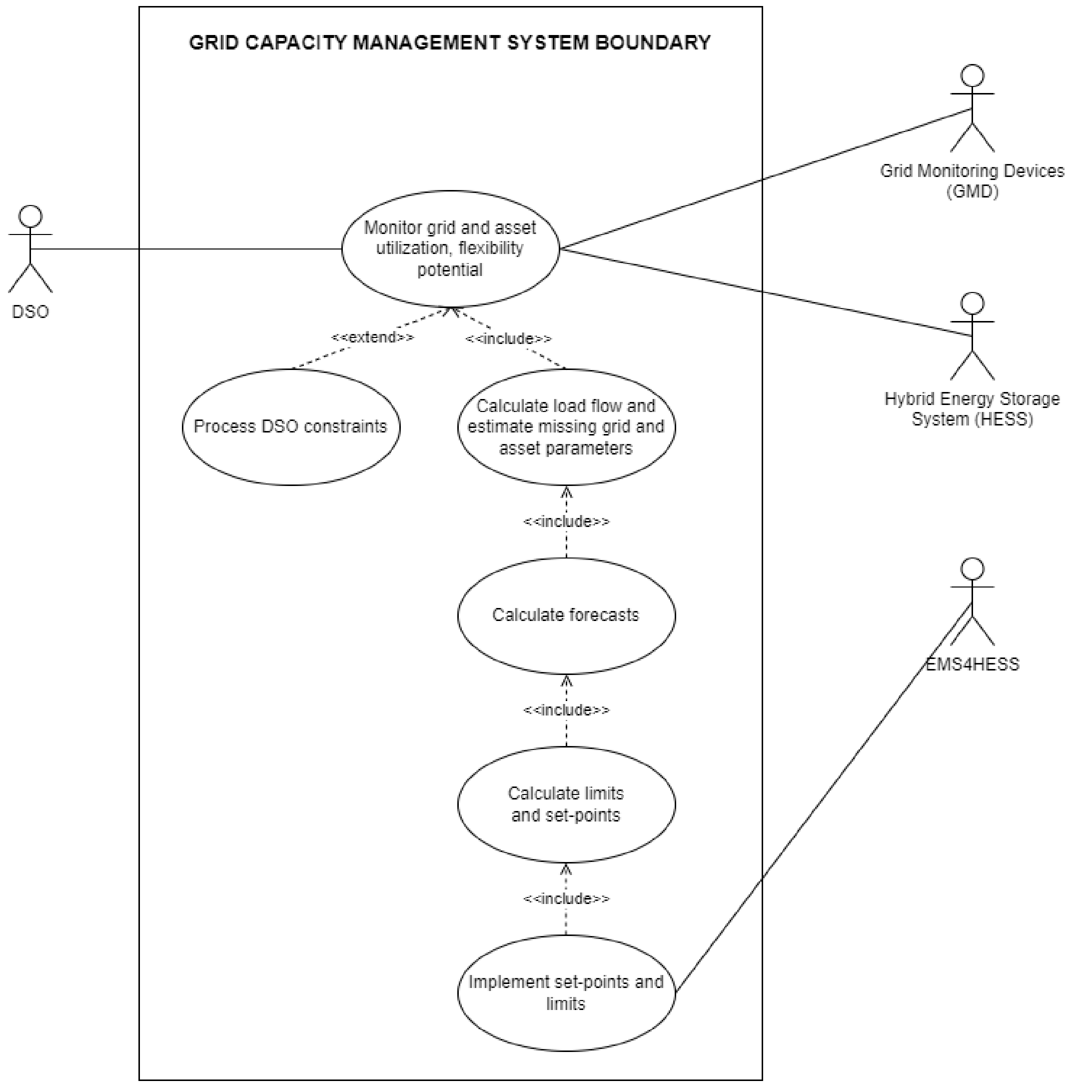


Figure 26: Use Case Diagram - Grid Capacity Management (GCM) boundary

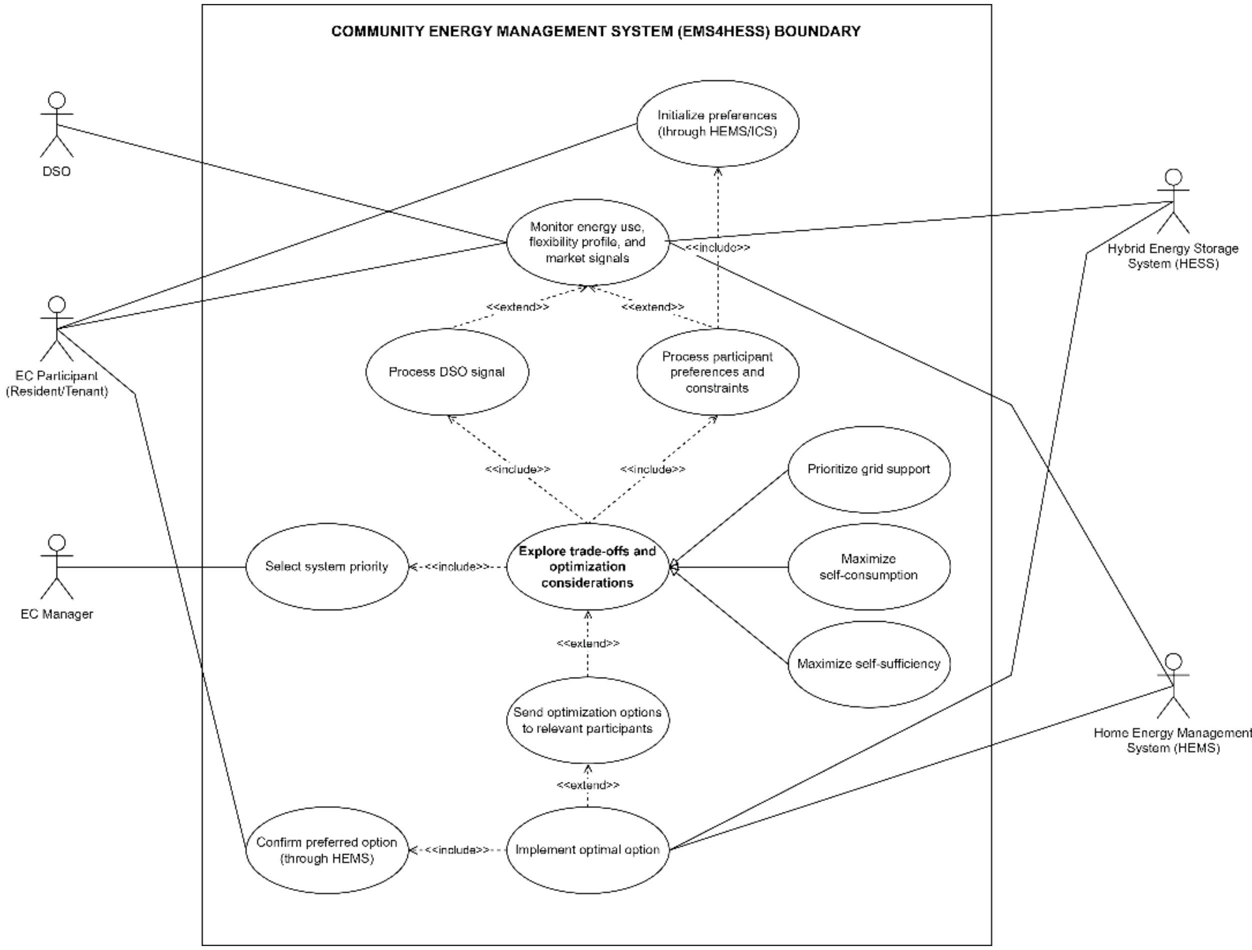


Figure 27: Use Case Diagram - Community Energy Management System (EMS4HESS) boundary

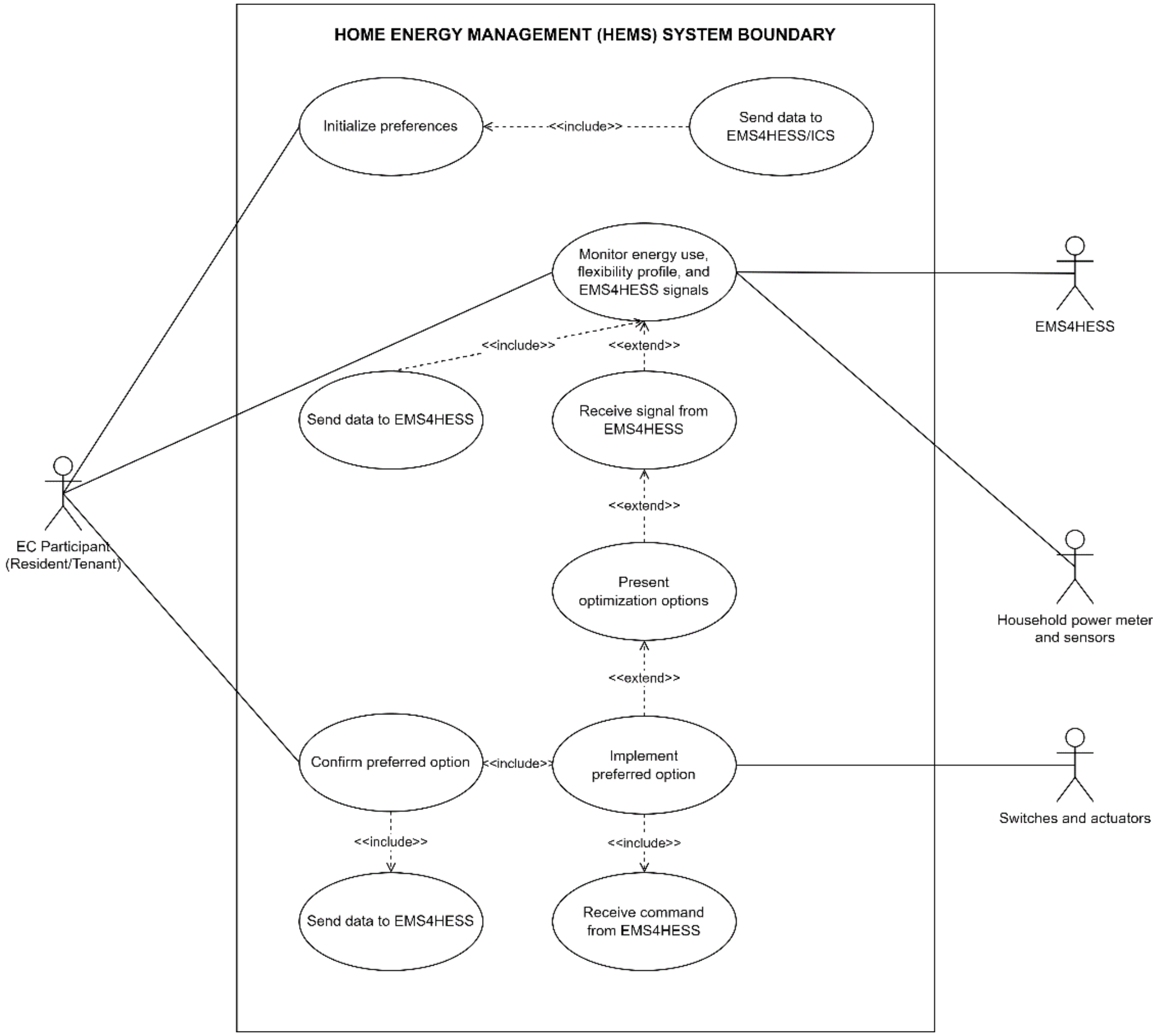


Figure 28: Use Case Diagram – Home Energy Management System (HEMS) boundary

Table 41: UC3 - Steps – Scenarios: Scenario 3.4 (Grid Friendliness)

Scenario					
Scenario name		***Grid Friendliness***			
Step No.	***Event Name of process/activity***	***Description of process/activity***	***Service***	***Information producer (actor)***	***Information receiver (actor)***
01	Request measurement	GCM requests measurement from the grid	GET	GCM	GMD
02	Provide measurement	GMD replies with the requested measurement data	REPORT	GMD	GCM
03	Request consumption data	GCM requests consumption data from SM	GET	GCM	SM
04	Reply consumption data	SM replies with the requested consumption data	REPORT	SM	GCM
05	Request state information	GCM requests state information from HESS	GET	GCM	HESS
06	Reply state information	HESS replies with state information	REPORT	HESS	GCM
07	Calculate power limits	GCM calculated grid state and power limits	EXECUTE	GCM	GCM
08	Provide power limits	GCM sends power limits to EMS4HESS	REPORT	GCM	EMS4HESS
09	Forward power limits	EMS4HESS forwards the power limits to be displayed at ICS	REPORT	EMS4HESS	ICS
10	Display power limits	ICS displays the power limits	EXECUTE	ICS	ICS
11	Manual flexibility activation request	EC Participants requests the activation of flexibility	REPORT	EC Participant	HEMS
12	Forward customer flexibility activation request	HEMS forwards the request to the EMS4HESS	REPORT	HEMS	EMS4HESS
13	Calculate flexibility activation	EMS4HESS calculates the flexibility potential based on customer request and power limits	EXECUTE	EMS4HESS	EMS4HESS
14	Request flexibility activation	EMS4HESS sends the flexibility requestion to the HESS	REPORT	EMS4HESS	HESS
15	Implement flexibility request	HESS implements the received request	EXECUTE	HESS	HESS
16	Provide limits and customer request	EMS4HESS provides information limits and flexibility requests to ICS	REPORT	EMS4HESS	ICS
17	Display limits and customer request	ICS displays limits and flexibility requestions	EXECUTE	ICS	ICS
18	Request consumption data	DSO requests consumption data from SM	GET	DSO	SM
19	Reply consumption data	SM replies with the requested consumption data	REPORT	SM	DSO
20	Calculate energy allocation	DSO calculates the community-internal and external ex-post allocation of energy	EXECUTE	DSO	DSO
21	Calculate grid bill	DSO calculates the grid bill based on the calculated energy allocation	EXECUTE	DSO	DSO

22[11]	Send grid bill	DSO sends the grid bill to the customer	REPORT	DSO	EC Participant
23	Send external allocation data	DSO sends the external energy allocation to the ESCO	REPORT	DSO	ESCO
24	Calculate external energy bill	ESCO calculates the energy costs based on the received external energy allocation	EXECUTE	ESCO	ESCO
25	Send external energy bill	ESCO sends the external energy bill to the customers	REPORT	ESCO	EC Participant
26	Send internal allocation data	DSO sends the community internal allocation to the EMS4HESS	REPORT	DSO	EMS4HESS
27	Calculate internal energy bill	EMS4HESS calculates the community internal energy bill based on the received energy allocation	EXECUTE	EMS4HESS	EMS4HESS
28	Send internal energy bill	EMS4HESS sends the internal energy bill to the customers	REPORT	EMS4HESS	EC Participant

[11] This step can be either done separately or can be combined with 07 (one bill with grid costs and energy costs provided by the ESC).

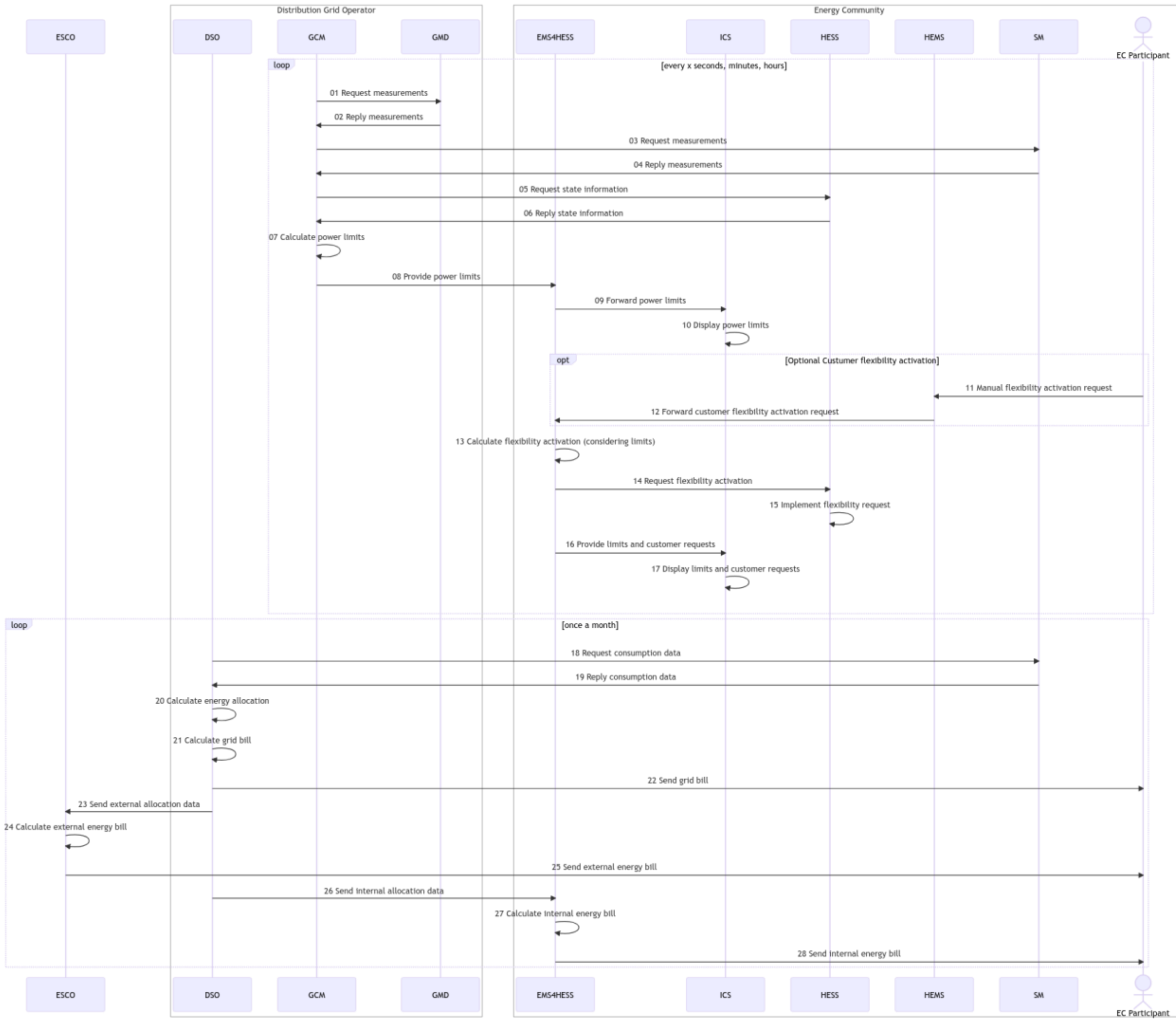


Figure 29: Sequence diagram – Scenario 2 (Grid Friendliness)

6.1.4 PARMENIDES Use Case 4 – Fully Automated Energy Community Participation

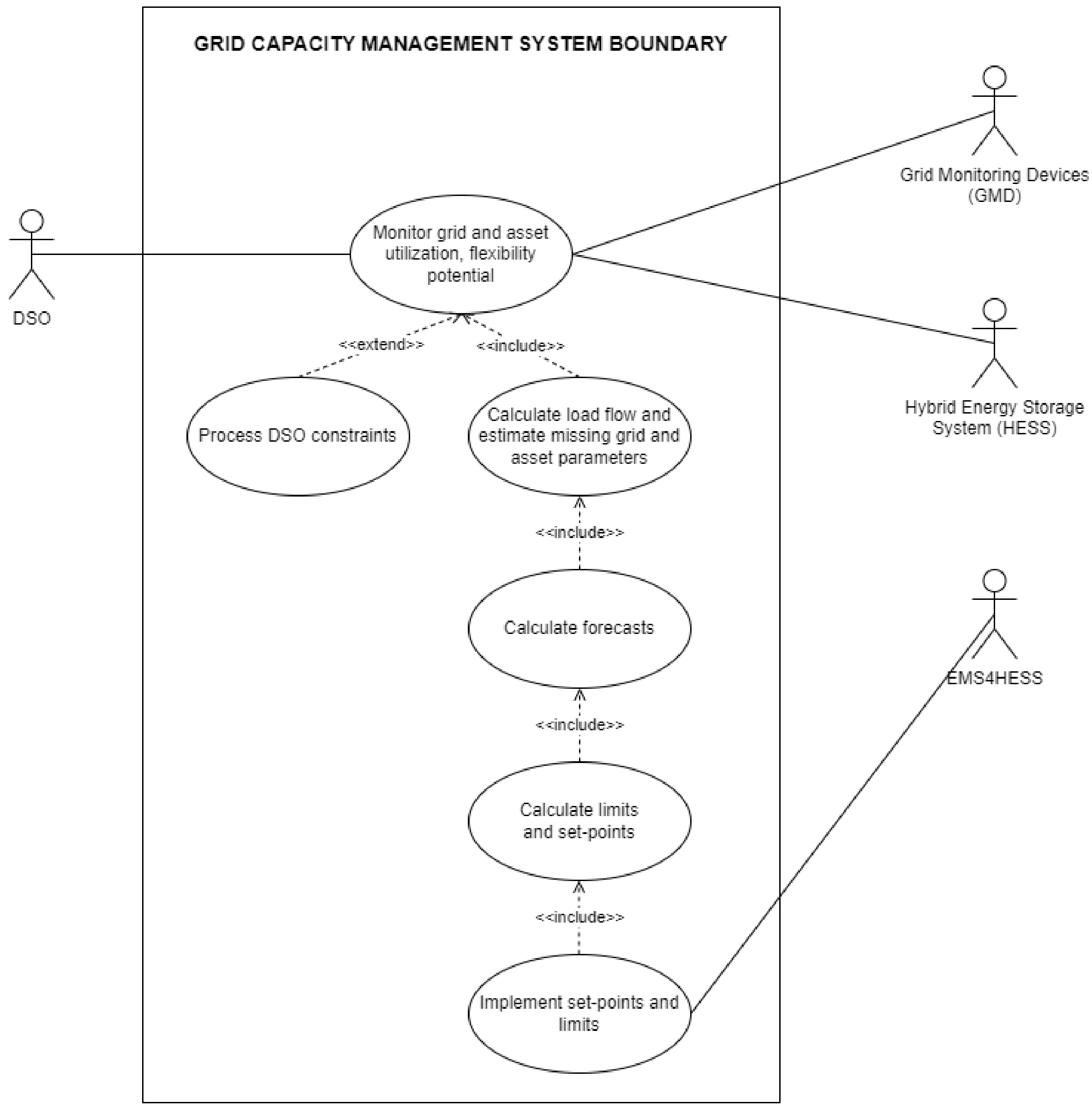


Figure 30: Use Case Diagram - Grid Capacity Management (GCM) boundary

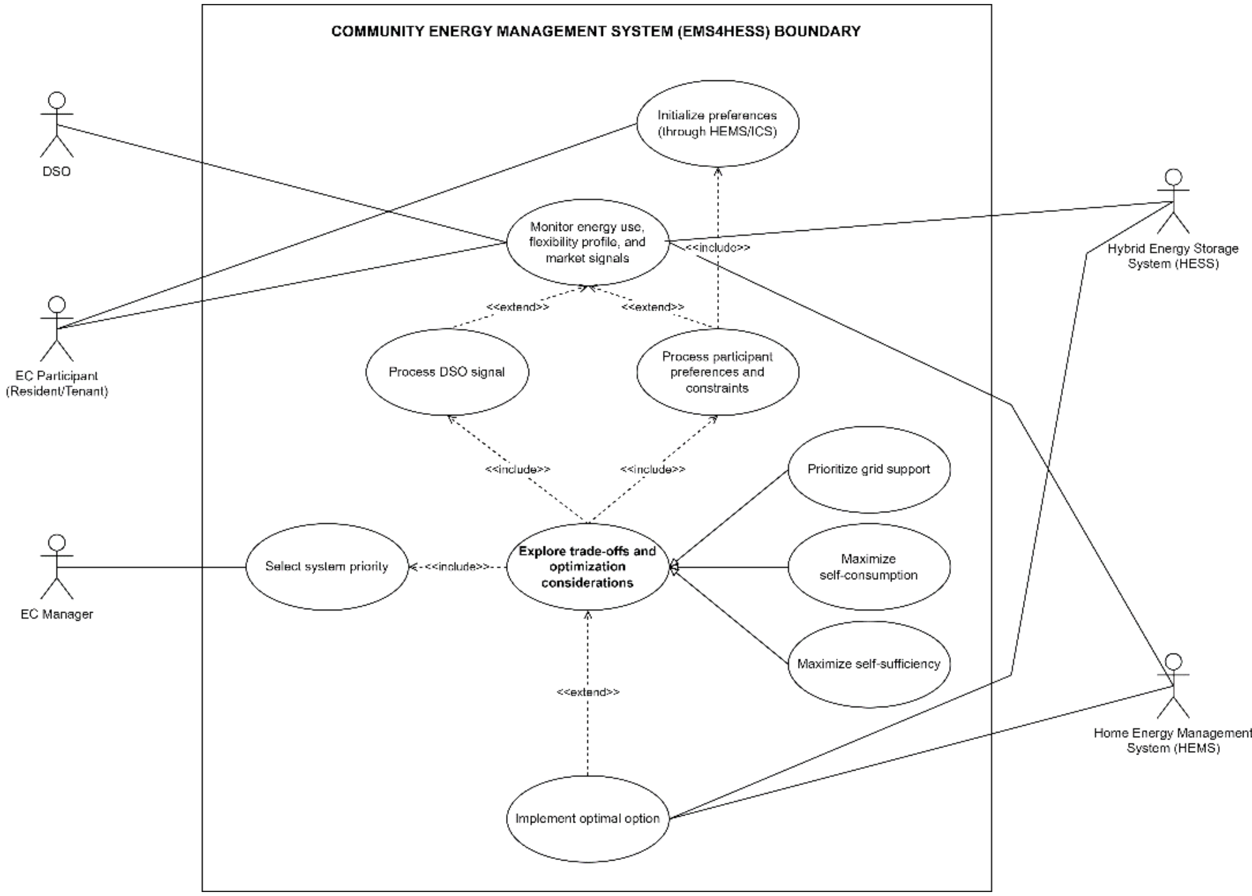


Figure 31: Use Case Diagram - Community Energy Management System (EMS4HESS) boundary

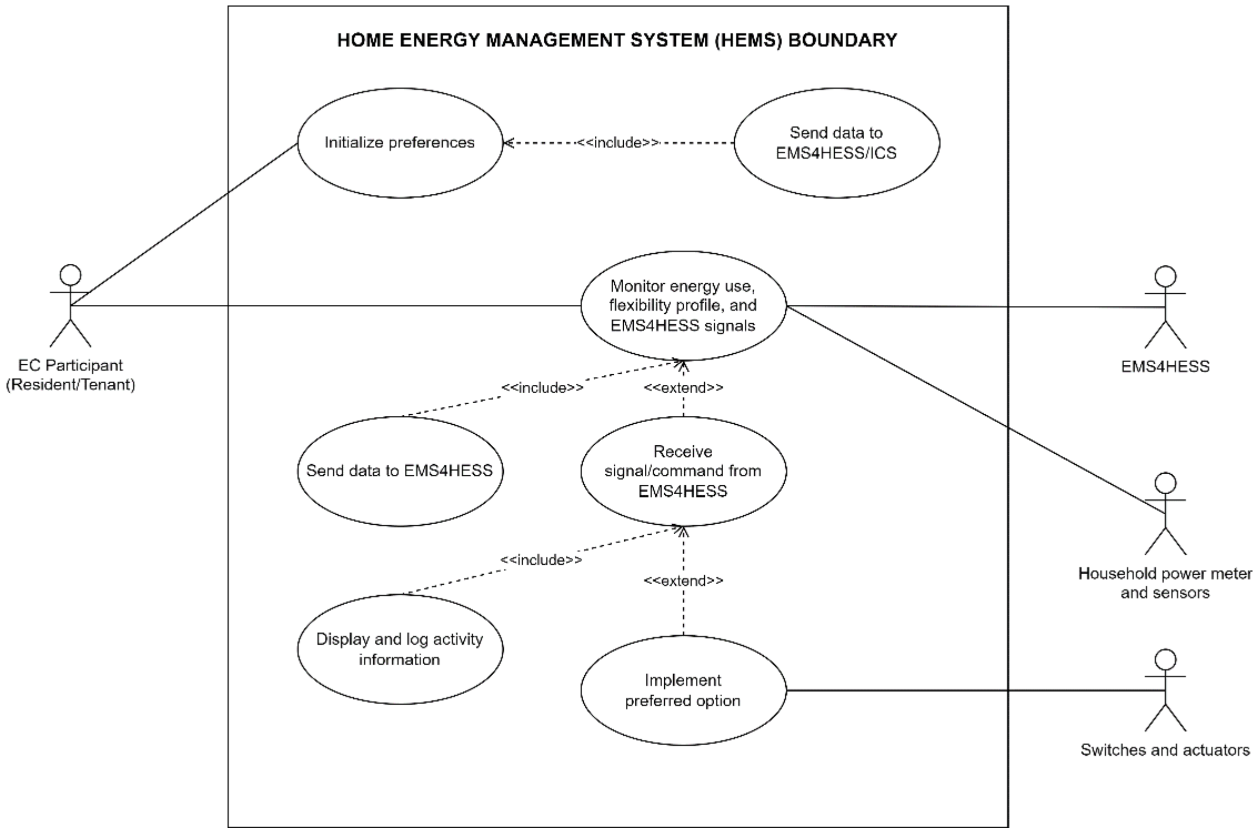


Figure 32: Use Case Diagram – Home Energy Management System (HEMS) boundary

Table 42: UC4 - Steps – Scenarios: Scenario 4.5 (Grid Support)

Scenario					
Scenario name		***Grid Support***			
Step No.	***Event Name of process/activity***	***Description of process/activity***	***Service***	***Information producer (actor)***	***Information receiver (actor)***
01	Request measurement	GCM requests measurement from the grid	GET	GCM	GMD
02	Provide measurement	GMD replies with the requested measurement data	REPORT	GMD	GCM
03	Request consumption data	GCM requests consumption data from SM	GET	GCM	SM
04	Reply consumption data	SM replies with the requested consumption data	REPORT	SM	GCM
05	Request state information	GCM requests state information from HESS	GET	GCM	HESS
06	Reply state information	HESS replies with state information	REPORT	HESS	GCM
07	Calculate set-points	GCM calculates grid state and set-points	EXECUTE	GCM	GCM
08	Provide set-points	GCM sends set-points to EMS4HESS	REPORT	GCM	EMS4HESS

09	Forward set-points	EMS4HESS forwards the set-points to be displayed at ICS	REPORT	EMS4HESS	ICS
10	Display set-points	ICS displays the power limits	EXECUTE	ICS	ICS
11	Request implementation of set-points	EMS4HESS sends a request to HESS to implement the set-points	REPORT	EMS4HESS	HESS
12	Implement set-points	HESS implements the received set-points	EXECUTE	HESS	HESS
13	Request consumption data	DSO requests consumption data from SM	GET	DSO	SM
14	Reply consumption data	SM replies with the requested consumption data	REPORT	SM	DSO
15	Calculate energy allocation	DSO calculates the community-internal and external ex-post allocation of energy	EXECUTE	DSO	DSO
16	Calculate grid bill	DSO calculates the grid bill based on the calculated energy allocation	EXECUTE	DSO	DSO
17[12]	Send grid bill	DSO sends the grid bill to the customer	REPORT	DSO	EC Participant
18	Send external allocation data	DSO sends the external energy allocation to the ESCO	REPORT	DSO	ESCO
19	Calculate external energy bill	ESCO calculates the energy costs based on the received external energy allocation	EXECUTE	ESCO	ESCO
20	Send external energy bill	ESCO sends the external energy bill to the customers	REPORT	ESCO	EC Participant
21	Send internal allocation data	DSO sends the community internal allocation to the EMS4HESS	REPORT	DSO	EMS4HESS
22	Calculate internal energy bill	EMS4HESS calculates the community internal energy bill based on the received energy allocation	EXECUTE	EMS4HESS	EMS4HESS
23	Send internal energy bill	EMS4HESS sends the internal energy bill to the customers	REPORT	EMS4HESS	EC Participant

[12] This step can be either done separately or can be combined with 07 (one bill with grid costs and energy costs provided by the ESC).

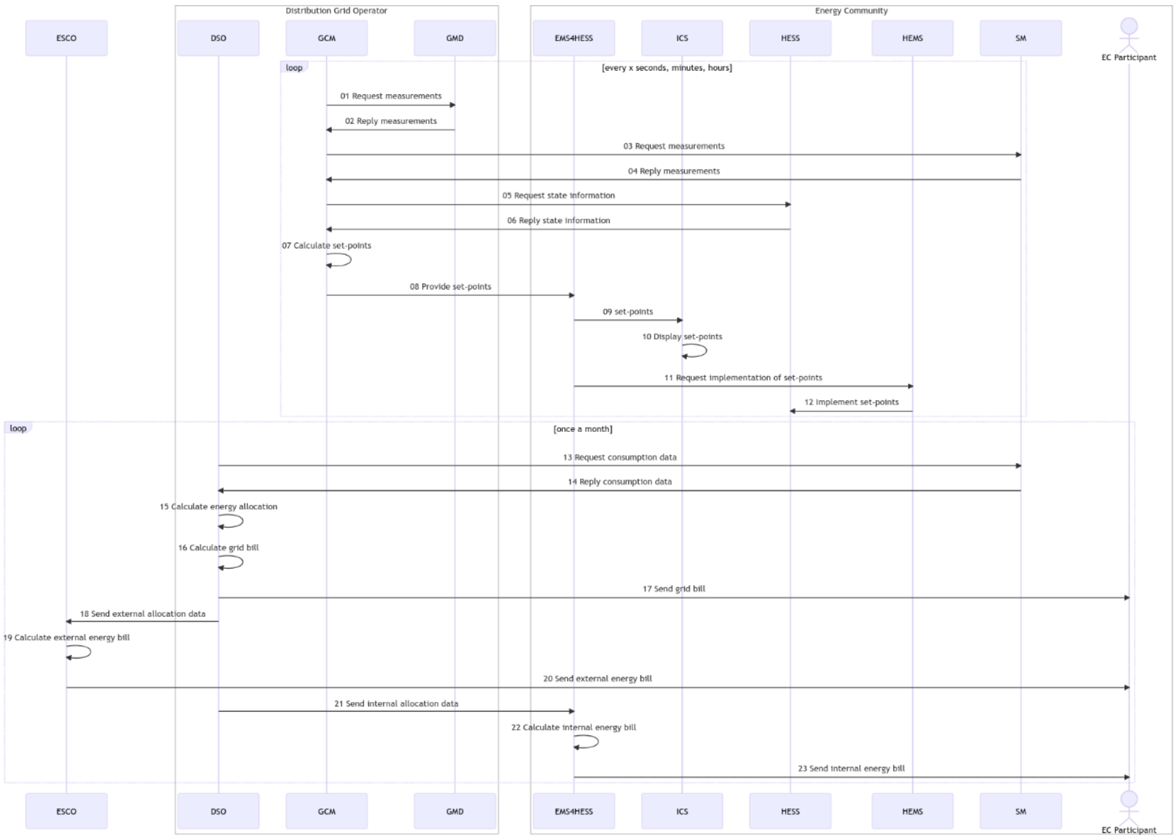


Figure 33: Sequence diagram – Scenario 4.5 (Grid-Support)

PARMENIDES

6.2. List of Figures

6.3. List of Tables

PARMENIDES

PARMENIDES

Plug&plAy eneRgy ManagEmeNt for hybrID Energy Storage