System Architecture

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Statement of Originality

This deliverable contains original unpublished work except where clearly indicated otherwise.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

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Executive summary

This present document is D4.4 "System's architecture" of the TwinERGY project, funded by the European Commission's Innovation and Networks Executive Agency (CINEA) under its Horizon 2020 Research and Innovation programme (H2020). This deliverable presents the results related to the architecture of the products and use cases during the TwinERGY project. The deliverable is focused on the results of the work carried out under Task 4.4 "System's Architecture Design", that develops an open, secure, and flexible customer-centric architecture mapped on the European SGAM framework [1]. This deliverable is developed under WP4 that targets the development of an interoperable, secure, and flexible architecture which considers active buildings, increased electrical vehicles presence, energy storage and Demand Response to optimize the functionality for all actors, including the end-user. The proposed architecture will also consider local neighbourhood transactions for energy delivery and other aggregated services. Furthermore, the development of this architecture will take, as a basis, already developed architectures in H2020 funded projects such as NOBEL GRID [2] and WISEGRID [3]. The purpose of the delivery within the context of TwinERGY is twofold:

- The **adaptation of the requirements of stakeholders** in the diverse TwinERGY environments and its scenarios development based on the detailed decomposition of the different Use Cases development and the profound understanding of their requirements and
- The **development of an open, secure, and flexible customer-centric architecture** that will allow the optimal utilization of the interconnections in a scenario of high penetration of renewables, increased energy storage and demand response campaigns. The solution will be integrated in the existing active buildings and cooperatives structures.

To provide a consistent and systematic approach of the modelling of the use cases and the description of the TwinERGY architecture, the Smart Grid Architecture Model (SGAM) framework is used. This methodology is a powerful framework that allows the unified modelling of the different Use Cases by its implementation in different layers. The lowest SGAM layer (Component Layer) would describe the physical layer of the grid, including the system equipment, protection infrastructure and network devices. The Communication Layer is then referred to the different protocols and mechanisms used for the information exchange between the model entities. The information layer, deals with the information objects and data models exchanged between Use Case (UC) actors/function, followed by the Function Layer, which refers to the UC different functionalities.

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1. Introduction

1.1. Scope of the document

The deliverable is focused on the results of the work carried out under Task 4.4 "System's Architecture Design", that develops an open, secure, and flexible customer-centric architecture, which will be mapped on the European SGAM framework. This deliverable is developed under WP4 that targets the development of an interoperable, secure, and flexible architecture, which considers active buildings and cooperatives to increase high renewable penetration, increased electrical vehicles presence, energy storage and Demand Response to optimize the functionality for all actors, including the end-user. The proposed architecture will also consider local neighbourhood transactions for energy delivery and other aggregated services. Furthermore, the development of this architecture will take as a basis already developed architectures in H2020 funded projects such as NOBEL GRID [2] and WISEGRID [3].

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1.2. Structure of the deliverable

The document is structured as follows. Section 2. Objectives will deeply analyse the objectives that this deliverable intends to address. The Smart Grid Architecture Model (SGAM) framework, that is used for the modelling of the Use Cases and for the proposed architecture for TwinERGY, is described in detail in Section 3. Smart Grid Reference Architecture. Regarding Section 4. Overview of TwinERGY Use Cases and Actors, an overview of TwinERGY participating actors alongside the TwinERGY high-level Use Cases are presented. Sections 5. HLUC 1: Home Energy Management through 13. HLUC09.

Consumer Engagement in Demand Response Programs Utilizing Digital Twin Prediction Capabilities for Dynamic VPPs, the deliverable presents extensively describe the architecture of the use cases according to the SGAM framework. The Use Case relations with other Use Cases as well as their representation using the Component, Communication, Function, and Business Layers are presented alongside the underlying communication and their technologies. 14. Conclusions will provide a brief conclusion on the work performed within this task and its outcomes. Additionally, to the content developed in the different sections, Annex I will expose the complete definition of the different 9 Use Cases studied in TwinERGY, as a further evolution of the UC already introduced in T2.2 "Stakeholders Requirements".

1.3. Abbreviation list

Table 1: Acronym list

Acronym	Full Name
1D	One dimension
CIM	Computation Independent Model
DER	Distributed Energy Resource
DER	Distributed Energy Resources
DSO	Distributed System Operator
HEMS	Home Energy Management System
HLUC	High Level Use Case
ICT	Internet and Communication Technologies
PIM	Platform Independent Model
PSI	Platform Specific Implementation
PSM	Platform Specific Model
PUC	Primary Use Case
PV	Photovoltaic
RA	Reference Architecture

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RES	Renewable Energy System
RTU	Remote Terminal Unit
SG	Smart Grid
SUC	Secondary Use Case
TEM	Transactive Energy Module
UC	Use Cases

2. Objectives

WP4 "Methodological framework and Architecture design" is expected to develop a system methodology that can analyse behavioural attitudes and classify segment end-customers. In the TwinERGY methodology, this WP is reflected in the Designing Thinking Phase, in which a more detailed uptake is developed, to come up with solutions to address the needs of the different user groups, defined in the number of Use Cases selected per each pilot site. This basis will be used as a first step for the upcoming Innovation Lab Phase, in which the operation of the prototypes identified can be rolled out, tested, and improved in a real-life setting. In order to perform this task, the TwinERGY Project identifies nine different Use Cases, that will allow the project partners to test the operation, accuracy and effectiveness of the technical and non-technical solutions, that will be addressed to meet the needs of the different user groups. In TwinERGY, the High-Level Use Cases (HLUC) identified are the following:

- Home Energy Management
- RES generation in domestic and tertiary buildings
- Grid capacity enhancement utilizing e-mobility
- Prosumer's empowerment in Local Energy Trading Markets
- Enhance grid flexibility through DER Management
- Consumer's engagement in Demand Side Management Programs utilizing feedback mechanisms
- Consumer's engagement in demand response programs utilizing a socio-economic context
- Consumer's engagement in demand response programs utilizing a socio-economic context
- Consumer's engagement in demand response programs utilizing personalized comfort/health-oriented services
- Consumer's Engagement in Demand Response Programs Utilizing Digital Twin Prediction Capabilities for Dynamic VPPs

Projects requirements (especially architectural and functional requirements) are factors that impose restrictions on the definition of the architecture. Additionally, new requirements might emerge from the detailed architecture. That is the reason behind the breakdown structure of each one of the, already defined, High Level Use Cases (HLUC) into different Primary Use Cases and Secondary Use Cases, where the level of abstraction can be lowered and the linkage of the systems and components to the different scenarios can be facilitated. These HLUC were firstly introduced within Task 2.2 "Stakeholder

Requirements". Nevertheless, in T4.4 and in this deliverable, these HLUCs are addressed in greater detail, in order to focus them to the SGAM methodology, that has been applied to develop the system architecture.

To enable a structured analysis of the different Use Cases, the SGAM (Smart Grid Architecture Methodology) is the methodology used to address this objective. The SGAM methodology will serve as a model of the architecture of the smart grid system from the point of view of relationships between, and interactions among systems, components, and assets that cooperate towards offering the functionalities described in High Level Use Cases (HLUC), Primary Use Cases (PUC) and Secondary Use Cases (SUC). Significantly, the SGAM methodology also reduces the of the produced model, so that it can be sub-divided into the different architectural aspects: **Business Architecture** (business models/processes), **Functional Architecture** (functional SG characteristics), **Information Architecture** (data modelling and interfaces applicable in SGAM model), **Communication Architecture** (elimination of communication standard gaps). An introductory explanation of this methodology is explained later in this document.

This deliverable will be written based on the modelled architecture, which has been created based on the contributions of the different project participants within Task 4.4 "System architecture design". Partners have been periodically asked to submit information requested to fulfil the different diagrams. These diagrams have been created using the software Sparx Enterprise Architecture [4]. This tool will facilitate the representations of the different HLUCs, PUCs and SUCs, based on the preliminary analysis of each of their needs. Alongside the development of the deliverable, screenshots of the different diagrams created will be posted so that they can reflect the architecture that has been created. The different screenshots will be classified into the different layers from which the SGAM Methodology is composed: Function Layer, Component Layer, Communication Layer, Information Layer (specified as well with a Canonical Data Model Diagram alongside a Standard and Information Object Diagram) and Business Layer. Additionally, both an activity and a sequence diagram will complement the architectural description of each of the PUC and SUC presented. At the end of this document, an Annex will provide the description of each HLUC that the TwinERGY project contemplates.

3. Smart Grid Reference Architecture

3.1. Overview

The Reference Architecture concept (RA) is used to provide an abstract schema of a standard architecture. It constitutes the foundations upon which the development process should be based. In the world of Smart Grids (SG), many different models are employed in order to describe the different aspects of the grid functionality and its involved stakeholders. The model developed process should be dictated by strict rules, to result in the production of simple models, capable of describing the overall picture of a Smart Grid. Furthermore, low-level details (e.g., different aspects of SG functionality or the architectural design) should also be provided by the model. Many models that have been developed in the past few years have been characterized as "obsolete", a fact that encourages the design of flexible, maintainable, and upgradable models [5].

The design process of SG-RA should be performed carefully, in order to comply with already established standards. At first, consistency with the M/490 conceptual model [5] is recommended aiming at the production of a universal schema, able to provide a clear view on SG domains, zones, and layers. The inclusion of the NIST Conceptual Model [6] is also important since it can cover most of the grid aspects of interest and decrease the complexity of different (UC) models. Additionally, due to the huge penetration of Distributed Energy Resource (DER) in smart grids during the recent years, the proper adjustments must be performed regarding this domain.

Different RA models could be distinguished to achieve a clear differentiation between them. It should be accompanied with a recommendation, providing general guidelines to simplify the modelling process as well as making it friendlier for the average user. Additionally, the methodology should be tested thoroughly, through modelling a wide variety of UC, so that defects can be detected. The elaboration of RA should be compatible with already existing standards. However, continuous technological advancement in the micro-grid structure, in conjunction with the integration of ICT and market domain, requires a more sophisticated, multidimensional architectural structure. In order to allow the participation of all stakeholders involved, the SG RA was based upon the RA of mandate M/490. In the following sections, three different components are included: the European Conceptual Model (Section 3.2. The European Conceptual Model), the Smart Grid Architecture Model (SGAM) Framework (Section 3.3. The Smart Grid Architecture Model Framework) and the Reference Architecture Viewpoints (Section 3.4. Model-Driven Architecture Specification using the SGAM Toolbox).

3.2. The European Conceptual Model

The European Conceptual Model is based on the NIST Smart Grid conceptual model: a framework for discussing the characteristics, uses, requirements and standards for a SG [6]. It is based upon 3 basic general concepts: loose coupling (enabling transactions without elaborate pre-arrangement), layered systems (a collection of functions providing services to the layer above and receiving from the layers below) and shallow integration (not keeping knowledge of the managed configured components). In this framework, seven different domains are identified (Bulk Generation, Transmission, Distribution, Customers, Operations, Markets and Service Providers). These are related to the most fundamental SG processes. The communication and energy flows between them are also provided, as presented in Figure 1: NIST Conceptual Model.

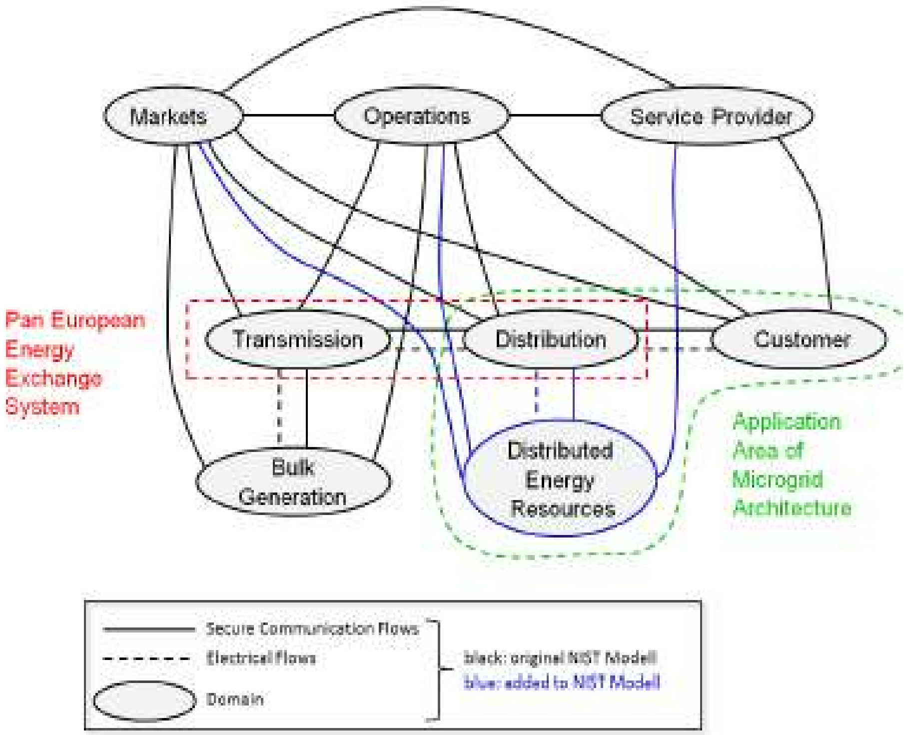

Figure 1: NIST Conceptual Model

Even though this model has proven to be quite useful over the years, lately it may not be characterized as a completely satisfactory modelling framework. This is due to the lack of discrimination mechanisms between the Distributed Energy Resource (DER) and the Bulk Generation and Customers domain, each of them is accompanied by various economic and technical details. More specifically, as far as the DER domain is concerned, the introduction of prosumers has modified the classical production-consumption model, demanding support of dynamic role switching. These modifications have been applied to the NIST model, constituting the European Conceptual Model [1].

The European Conceptual Model consists of four main domains, each of them containing subdomains, associated with different actors and functions. The Operations domain includes the system metering, transmission, and distribution operations, as well as the physical equipment involved (transformers, switches, transmission/distribution lines, etc.). In the Grid Users domain, the actors dealing with bulk generation, storage and consumption of electricity are included (the DER subdomain is also included here). These two domains (operations, grid users) address the more technical part of the system (generation and distribution of electricity and ICT actors). To describe the transaction processes of electricity produced and their services provided, two more domains are presented: Energy Services actors responsible for the flexibility operations of the system, which would guarantee its total balance in terms of electricity and secondly, the Market domain actors associated with the economical aspect of the grid. Figure 2: European Conceptual Model depicts the proposed architecture already explained.

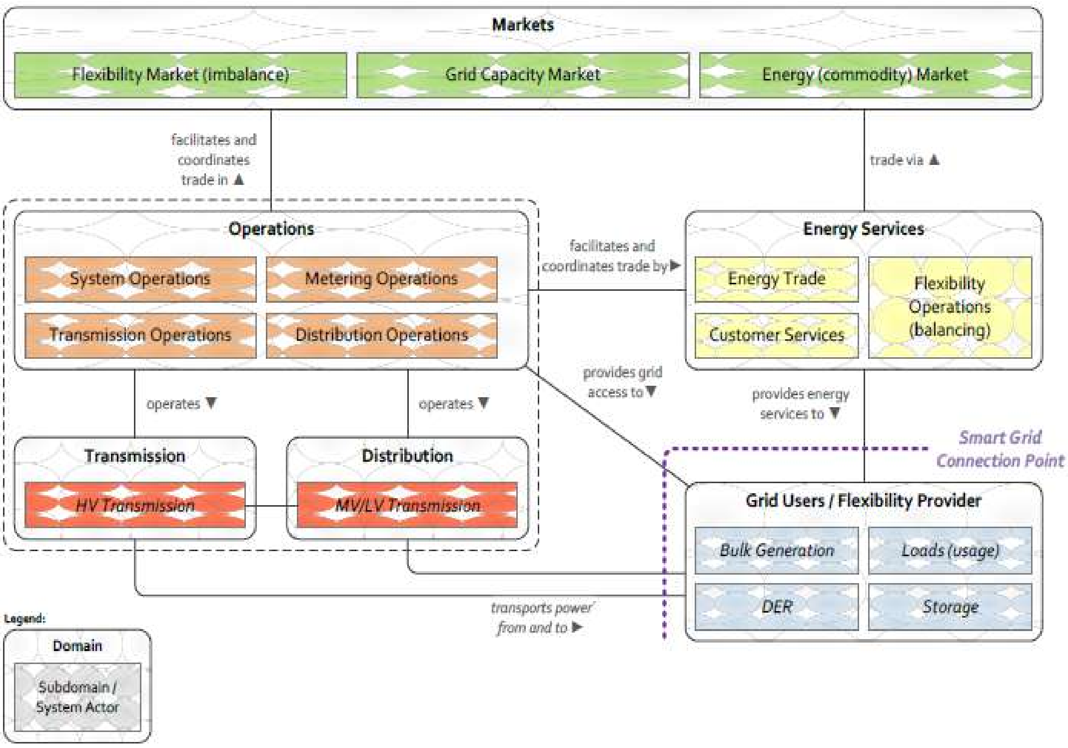

Figure 2: European Conceptual Model

3.3. The Smart Grid Architecture Model Framework

The modelling process of different smart grid's functionality can prove to be proven quite a challenge, considering the number of actors and systems involved. Proposed by CENELEC-CEN-ETSI, The Smart Grid Architecture Model (SGAM) framework is an architectural structure which provides a safe and systematic way of modelling and analysing different SG scenarios, without disrupting the smooth operation of the individual processes [5].

The role of the different actors involved can be clearly defined, while the outcome of the process should consist of an analytical model where UC details are depicted. While every UC can be analysed from many different perspectives, the coherency of the whole process is guaranteed through the tight and analytic communication flows between the different SGAM layers, zones, and the different domains. While an UC scenario is being modelled, three main categories interoperate between each other (Organizational, Informational and Technical). Additionally, cross-cutting issues are also taken under consideration, under those the relationships between them are being described. Figure 3: Interoperability categories describes perfectly what has been already described [5].

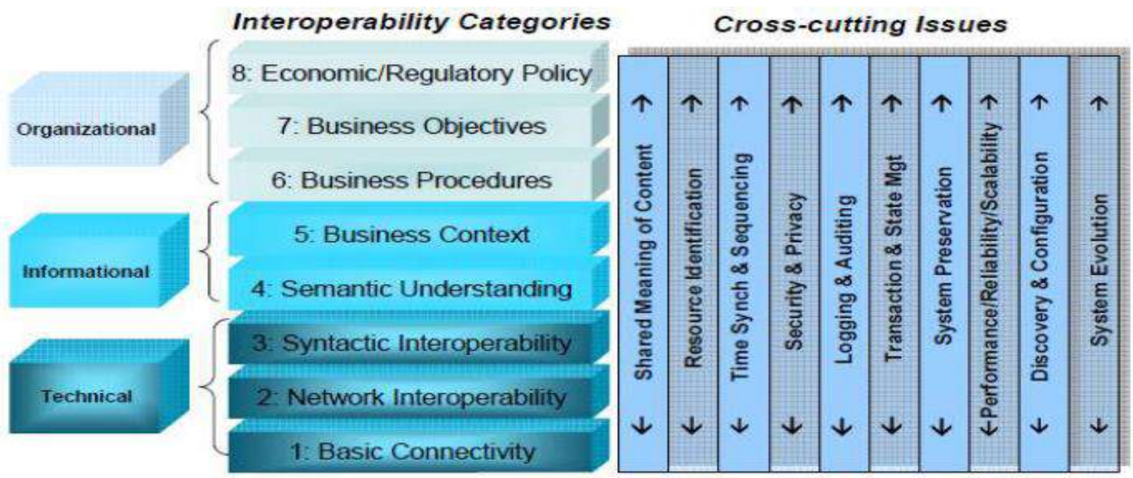

Figure 3: Interoperability categories

Regarding the SGAM methodology, five different "levels" encapsulate the various functionalities associated with typical SG operational periods and are associated to the first dimension (1D) of the three-dimensional SGAM modelling framework. Figure 4: SGAM mapping of Interoperability categories into layers depicts the classification of the different SGAM Layers according to the Interoperability categories [5].

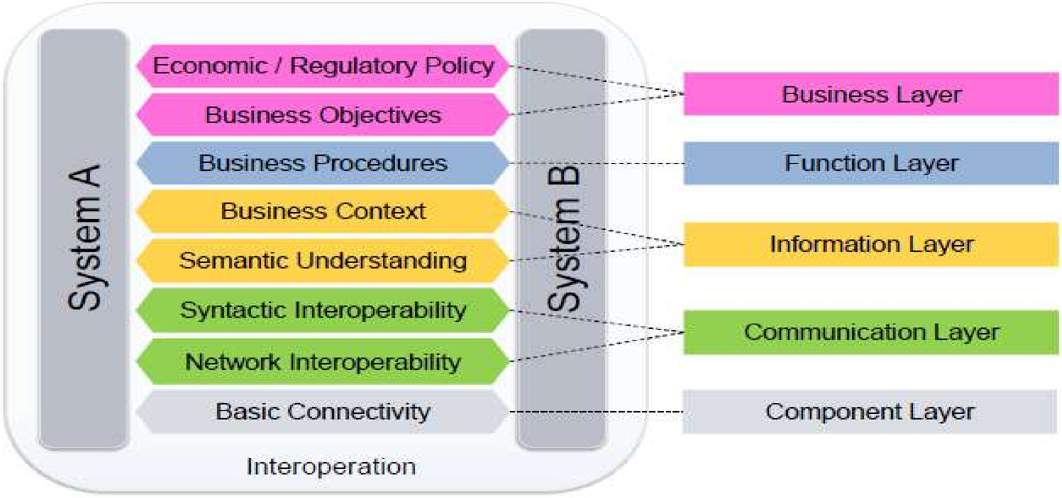

Figure 4: SGAM mapping of Interoperability categories into layers

Starting from the lowest SGAM layer (**Component Layer**), it describes the physical layer of the grid, which includes the system equipment, protection infrastructure and network devices. Next, the **Communication Layer** indicates the protocols and mechanisms used for the exchange of information between the model entities. The **Information Layer** deals with the information objects and data models exchanged between UC actors/functions, followed by the **Function Layer** which refers to the UC different functionalities. Finally, the **Business Layer** models the business logic of the UC scenarios, through the involved market partners, business objectives, goals, and restrictions. This last layer comes with a great degree of peculiarity.

As a result, this model complies with already existing standards that will allow the proper mapping of roles and actors, as well as their interactions. The Harmonized Electricity Market Role Model by ENTSO-E [7], EFET [8] and ebIX [9] seems like a very promising candidate since it can fit in all European electricity markets. During this step, the usage of the HEM-RM of ENTSO-E, EFET and ebIX is strongly recommended in order to model properly each Use Case scenario.

The SGAM Layers are merged with a two-dimensional plane (Figure 5: The smart grid plane) resulting to the final, complete structure of the framework. The SG plane could be described as a double axis area: electrical processes (domains) and the information management viewpoints (zones) involved in each UC. In terms of the domains, firstly, the **Bulk Generation** domain, which refers to the substantial generation of electricity. This is followed by the **Transmission** domain, that involves the complete infrastructure and organization processes for the transportation of the energy produced. The **Distributed Energy Resource** domain is differentiated from the **Distribution** domain since the former refers to the DER connected to the distribution grid (3kW – 10.000 kW). Finally, the **Customer Premises** refers to the prosumers involved in the UC.

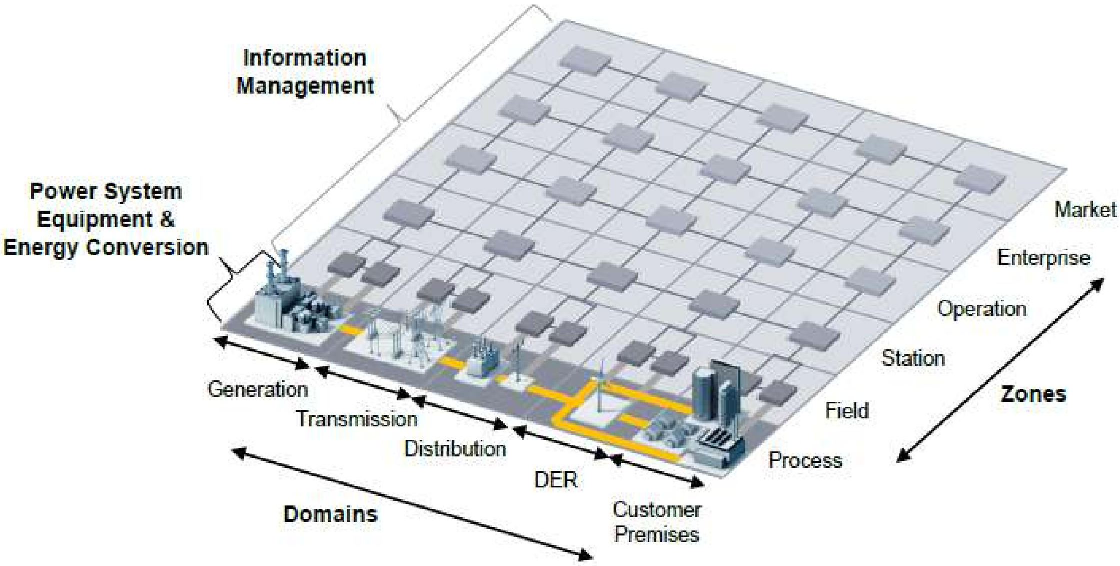

Figure 5: The smart grid plane

Regarding the zones, hierarchically there are six of them at the Smart Grid Plane, which are designed to support the framework coherency by following a similar conceptual pattern. The first zone, known as **Process zone**, refers to the transformation of energy and the physical equipment involved. Next comes the **Field zone** (protection, control and monitor equipment), which is followed by the **Station zone**, succeeded in turn by the **operation zone** (control of operation systems). Moving onto the business aspect of a UC, the **Enterprise and Market zone** refer to the commercialization of the total amount of electricity produced and distributed. The SGAM framework is a combination of the concept of interoperability layers and the smart grid plane. This merge results in a model which spans in three different dimensions:

- Domain
- Interoperability (layer)
- Zone

Consisting of the five interoperability layers, the SGAM framework allows the representation of the different entities and relationships in the context of smart grid domains, information management, hierarchies and consideration of different interoperability aspects. Figure 6: SGAM framework depicts the already mentioned architecture.

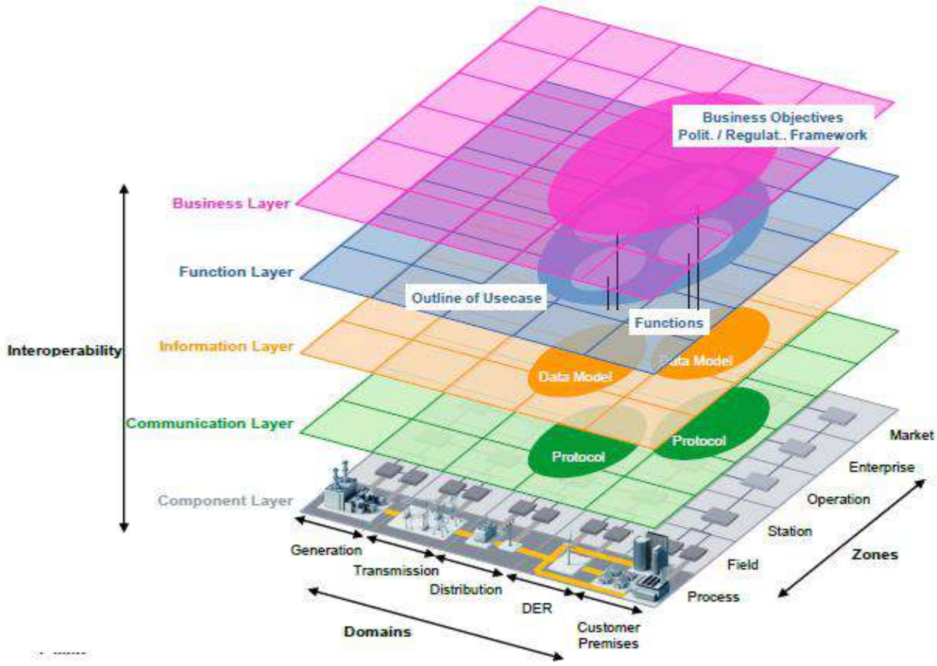

Figure 6: SGAM framework

3.4. Model-Driven Architecture Specification using the SGAM Toolbox

The abstract architectural concepts presented in the previous sections provide the general, as well as theoretical, concept of the SGAM framework. The more practical aspect of the modelling process incorporates UC into the SGAM framework is actualized through the SGAM Toolbox [10]. This useful tool provides a simple and structured way of combining the available information to extract a unified model, distributed to the different parts of the framework. The hierarchical structure of the toolbox is presented below (Figure 7: SGAM Toolbox architecture):

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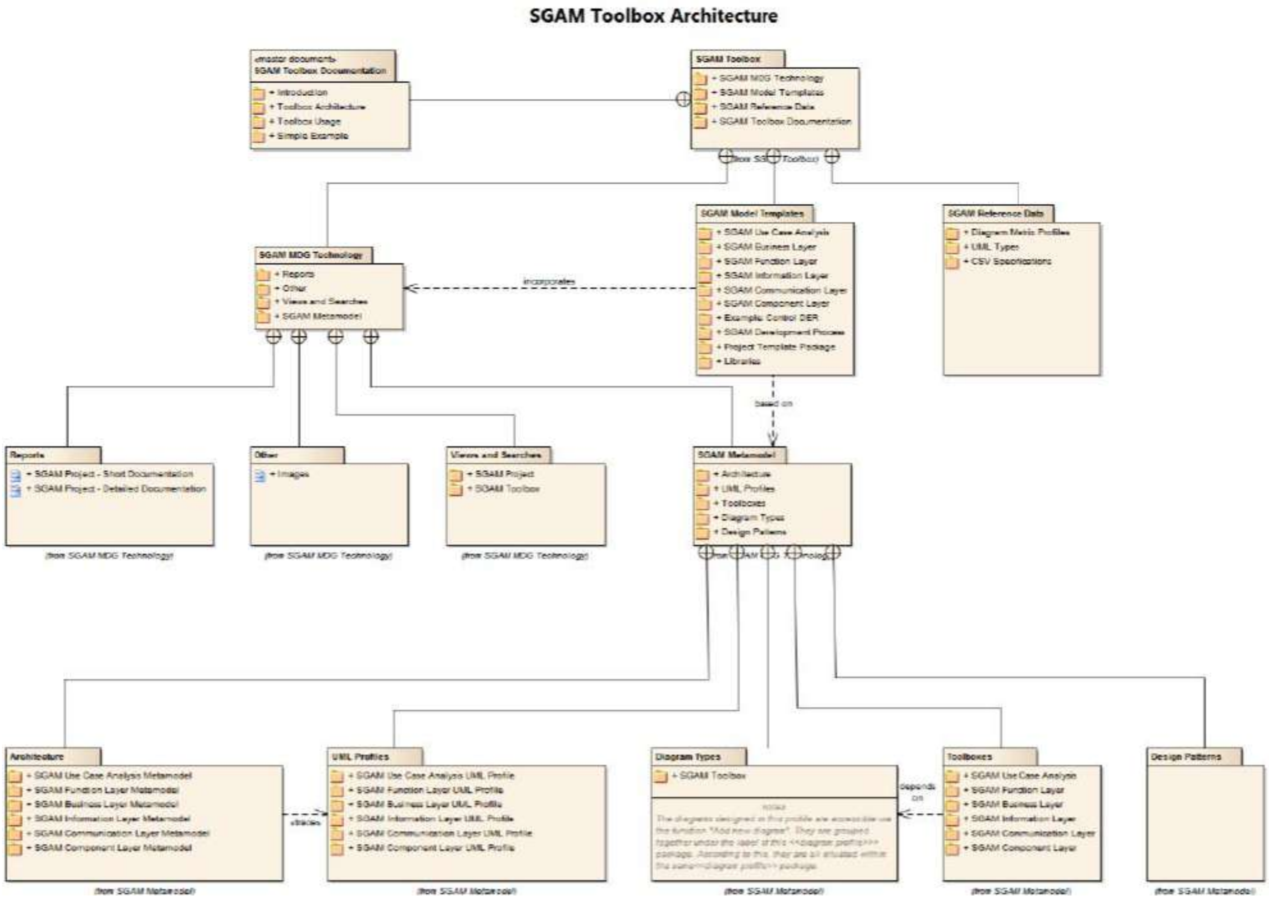

Figure 7: SGAM Toolbox architecture

There are three basic components that are aggregated into the SGAM Toolbox: the SGAM MDG Technology (connected to Enterprise Architect to provide additional toolboxes, UML profiles and other modelling resources), the SGAM Model Templates (UC analysis and SGAM Layers) and the SGAM Reference Data (providing information regarding the Model Import/Export). The core component of the framework, the SGAM Metamodel is aggregated to the MDG Technologies which is the basis of the Model Templates (Figure 8: SGAM Metamodel).

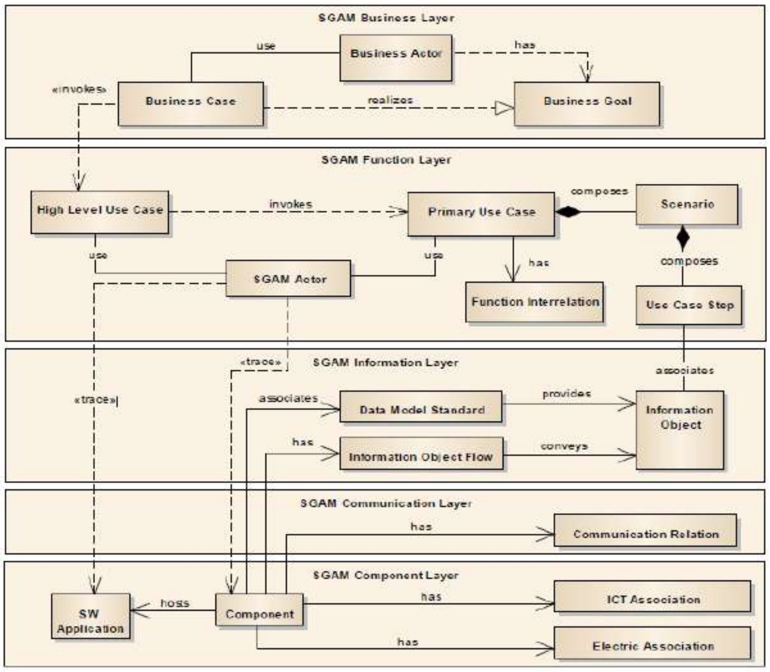

Figure 8: SGAM Metamodel

In the **component layer**, the different components (protection devices, cable lines, ICT associated components, etc) are presented in this layer. These components need to interoperate with each other, while complying with the standards and specific protocols of the market. The **communication layer** takes care of these procedures, providing an intermediate stage where the components' behaviour is transformed into information that the actors and functions can use. In the **Information layer** the objects are defined through data models allowing the information flow to the level above. The objects designed at this stage, are used to compose the Primary Use Case (PUC) scenarios, which are called by the High-Level Use Case (HLUC), in the **Function layer**. Furthermore, at this stage, a general description of the actors and the roles involved is also provided. To add more clarification on it, it is worth mentioning that a PUC is composed by a number of different Secondary Use Cases (SUC). Moving onto the **Business layer**, HLUCs are requested by the Business case, involving the actors necessary to realize the business goals that have been defined.

There is a need to transform UC into objects compatible with the SGAM toolbox, possessing certain SGAM characteristics. In order to initially develop the SGAM, a System Analysis Phase is performed. The UC is examined, so that the information needed (objectives, UC diagram, actors, type, preconditions, assumptions, steps, information exchanged, requirement) is present. This phase results in the elaboration of a Computation Independent Model (CIM). Once it is completed, the process continues with the elaboration of the System Architecture Phase, in which the rest of the SGAM layers

(Information, Communication, Component) are produced. This results in a Platform Independent Model (PIM). Once these two Models are created, the last step in the SGAM creation is the Design & Implementation phase, where the systems are designed, using engineering methods. In this stage, both a Platform Specific Model (PSM) and a Platform Specific Implementation (PSI) are produced. Figure 9: SGAM development process introduces the steps that have been already mentioned.

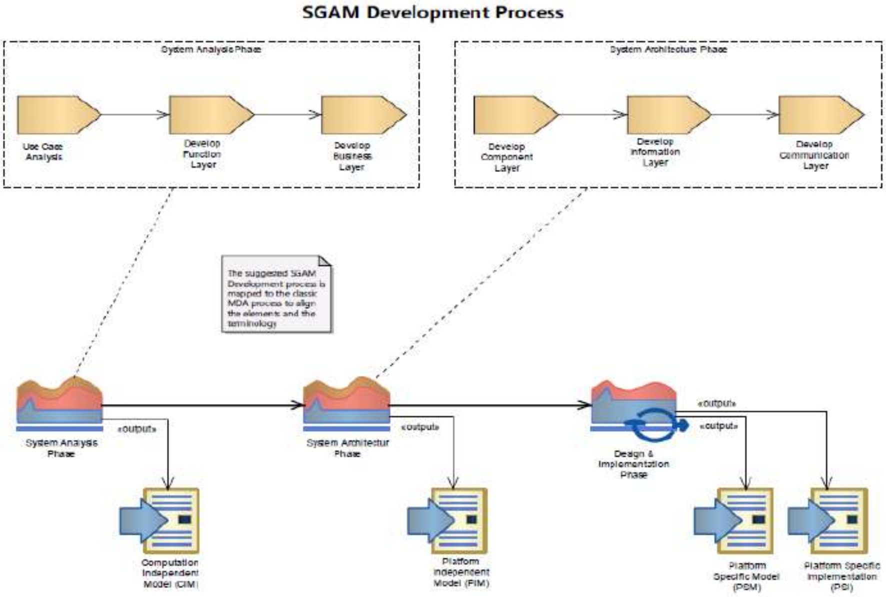

Figure 9: SGAM development process

3.5. The Smart Grid Architecture concepts in TwinERGY

The architectural concepts describing the functionality of a Smart Grid (SG) should be clearly defined. The field of Smart Grids has been increasing its complexity since there are many stakeholder entities with diverse roles. The description of the equipment involved, used to generate the information (that will be later transformed into useful data for the UC modelling process) should also cope with strict architectural rules, analysed from an engineering, as well as a computational viewpoint. Addressing the SG from the business aspect, the detailed description of actors and functions implemented is also needed so as to encapsulate market entities involved. However, there is need for restrictions to reduce the complexity of the final produced model. Considering the aforementioned, the Joint Working Group for Standards for the Smart Grids (JWG-SG 2011) [5] recommendations has proposed the following architectural aspects: **Business Architecture** (business models/processes), **Functional Architecture** (functional SG characteristics), **Information Architecture** (data modelling and interfaces applicable in SGAM model), **Communication Architecture** (elimination of communication standard gaps).

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4. Overview of TwinERGY Use Cases and Actors

4.1. Actors

Table 2: TwinERGY Actors

Actor Name	Description
Aggregator	Energy service provider which can increase or moderate the electricity consumption of a group of consumers according to total electricity demand on the grid
Authority	Role which provides public power utilities with access to advanced resources and technology systems so they can respond competitively in the changing energy markets
Charging Point	Element in the grid that allows a user to re charge the battery installed in the electric vehicle after parking it. It can be private, public or semi-public.
Comfort – Wellbeing Module	Module in TwinERGY that implements a wireless device for monitorization of physiological signals, extraction of the various vital signs and transmission of them to a platform, where environmental metrics are also used for determining the user's comfort
Community Battery Storage	Set of batteries that are common to a pilot site. They store the energy that is generated by the Photovoltaic Panels while it is not used
Community Planner	Role which drives community priorities around energy with a view to increasing efficiency, reducing emissions, and driving economic development.
Consumer	Business or residential consumer of electric generation service, located within the territorial jurisdiction of a government aggregator;
Consumer Demand Flexibility Profiling Module	Module in TwinERGY in charge of calculating the potential flexibility at dwelling level.
Core Data Management Platform	TwinERGY data platform for batch and real-time data ingestion, management and curation. It includes all the services needed to communicate with the platform
Digital Twin Platform	TwinERGY interoperability platform based on NATS, used for the communication among the modules in TwinERGY

Energy Asset/Appliance	Energy consuming elements whose electric consumption can be monitored and maybe remotely controlled.
Energy Supplier	A company that provides electricity, gas, etc. to homes and businesses
ENTSO-E	European Network of Transmission System Operators, representing 42 electricity transmission system operators (TSOs) from 35 countries across Europe, thus extending beyond EU borders.
Environmental Sensor	Connected objects capable of providing various types of information: location, position, the individual's movements and contextual elements which can be compared to data collected via sensors embedded on or implanted in the individual, including the validation of alarms, like in the case of falls.
EV Owner	Owner (driver) of an electrical vehicle
eVehicle	Electrical vehicle
Grid Access Provider	A party responsible for providing access to the grid through an Accounting Point for energy consumption or production by the Party Connected to the Grid. The Grid Access Provider is also responsible for creating and terminating Accounting Points.
Grid Metering Point	Element in the electric network where energy products are measured or computed.
Home & Tertiary real-time energy monitoring module	Module in TwinERGY that corresponds with a user-friendly building Energy Management system, supporting consumers to manage self-consumption, increasing residential awareness and demand side management programs
Home Battery Storage	Each element in a dwelling used for storing energy generated by a photo-voltaic panel installed also at the house
Home Metering Point	Element in a house where metrics of generation and consumption of energy at home are registered
Meter Operator	A party responsible for installing, maintaining, testing, certifying and decommissioning physical meters.
Metered Data Collector	A party responsible for meter reading and quality control of the reading.

Neighbourhood Demand Flexibility Profiling Module	Module in TwinERGY in charge of calculating the potential flexibility at community level.
Physiological sensor	Type of sensor that can measure one or different metrics in the individuals, such as: blood pressure, amount of glucose in the blood, electrocardiograms, electroencephalograms, etc.
Producer	A party that generates electricity
PV Panel	Photo-voltaic panel. Assembled set of modules which are mounted in a framework. These modules use sunlight as a source of energy to generate direct current electricity.
RES Integration & DER Management Module	Module in TwinERGY focused on measuring of metrics in the grid and calculation of grid status in real time, being the detection of bottlenecks one of its main tasks.
Resource Aggregator	A party that aggregates resources for usage by a service provider for energy market services.
Social Network Module	TwinERGY platform including these tools: i) Comparison of energy use between different neighbourhoods ii) Social competition / community rewards including playful challenges and competitions to enhance consumers' participation and engagement.
Social Network Interface	Graphical User Interface where end-users can interact with Social Network Module
System Operator	A party responsible for operating, ensuring the maintenance of and, if necessary, developing the system in each 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 or transmission of electricity.
Transactive Energy Blockchain	Blockchain settlements model for supporting of the evolving Transactive Energy platform.
Transactive Energy Platform	Module in TwinERGY that allows consumers to earn tokens with their energy IoT devices in energy management programs, solves the public-vs-private Blockchain debate holding back blockchain solutions

	for electric utilities, and opens the energy market to millions of micro-energy prosumers.
TwinEV Dashboard	Interface in TwinEV Module which allows to configure services offered by the module.
TwinEV Module	Module in TwinERGY that provide high-value services to users of electric vehicles, such as minimum charging prices and maximum green electricity supply, as well as different kind of grid services
Weather Forecast Service	External API where some services related to prediction and metric of weather are offered.
Wind Farm	Group of wind turbines in the same location used to produce electricity

4.2. Use Cases

The HLUC were created to address the different project objectives. Annex I: High Level Use Cases provides a detailed explanation of them, alongside their PUCs and SUCs:

- HLUC01. Home Energy Management
  - Demonstrate the energy management of residential consumer premises and their ability to monitor and control electrical loads taking into account PV generation and energy storage. The aim is to maximize self-consumption and self-sufficiency.
- HLUC02. RES generation in domestic and tertiary buildings
  - Its goal is to create further sources and infrastructures to increase the RES share in public and private buildings. It aims at minimising energy costs for the end user alongside the overall carbon emissions produced by the community. Moreover, the use of local RES supporting the infrastructure is expected to be maximised.
- HLUC03. Grid capacity enhancement utilizing e-mobility
  - Analyse the potential implementation of electromobility to use EVs as a distributed asset in the benefit of grid performance. It is expected to offer ancillary services to the DSO, the development of a smart charging scheme for EV owners and the participation of EV batteries in flexible energy markets.
- HLUC04. Prosumer's empowerment in local energy trading markets
  - Provide solutions to Transactive Energy Use Cases enabling grid decentralization and democratization. This will aid in balancing the grid as well as increasing the quality and reliability of it. The Transactive Energy Module, based on Hybrid Blockchain technologies will be used to solve optimization problems.

- **HLUC05. Enhance grid flexibility through DER Management**
  - The congestion management will be operated and tested within this HLUC. Different forecasts for loads and RES production will be tested to measure combined network data in order to calculate the network status in real time.
- **HLUC06. Consumer's engagement in Demand Side Management Programs Utilizing feedback mechanisms**
  - The scope of this use case is limited to feedback-based demand-side intervention strategies applied at the residential level. It describes how the DSO and/or Retailer provides a feedback mechanism in a context that is relevant to the needs of the households, and thereby increases residential awareness and engagement to demand side management programs in order to: Increase residential demand flexibility and decrease residential energy use.
- **HLUC07. Consumer's engagement in demand response programs utilizing a socio-economic context**
  - Enable Social context drivers for energy-related behaviour changes, by utilization of social interactions and cultural values to influence energy exchanges between households, and consumer attitudes towards benefit and comfort.
- **HLUC08. Consumer's engagement in demand response programs utilizing personalized comfort/health-oriented services**
  - Demonstrate innovative approaches to obtain consumers' realistic comfort / wellbeing level with minimum intervention. The utilization of low-cost wearable devices through which specific physiological data can be unobtrusively obtained, and advance unsupervised classification techniques comprise an appropriate combination to accurately depict consumers' comfort / wellbeing level. By accurately depicting this level the consumers become predictable energy wise and pertinent personalized feedback notifications can be provided to them.
- **HLUC09. Consumer's Engagement in Demand Response Programs Utilizing Digital Twin Prediction Capabilities for Dynamic VPPS**
  - The focus of consumer engagement in the demand response programs that utilise the digital twins of the TwinERGY pilot sites will be a human-machine interface in the form of an online interactive dashboards. Bespoke dashboards will be created for each of the pilot sites, the design of which will be informed by their specific requirements.

Twinergy has received funding from the European Union's Horizon 2020 research and innovation programme under grant agreement No. 957736

5. HLUC 1: Home Energy Management

5.1. PUC01.01. Increase the building observability - Data gathering from the home monitoring system

5.1.1. Use Case Description

The monitoring system on edge will send the raw data directly to the TwinERGY Storage System which will collect the data with the same data format for each pilot. The Home & Tertiary Real-time Energy Monitoring Module can perform various data aggregation features and share them through the TwinERGY interoperability platform. For instance, it can send back the energy data with hourly detail (e.g., kWh). Depending on the energy monitoring devices on edge, the data collected are:

- Datetime reference
- Active energy
- Reactive energy
- Voltage
- Frequency

The goal is to achieve the max monitoring granularity inside the building:

- Building power demand
- Power lines demand
- Single appliance power demand
- PV production
- Energy storage state of charge

The indoor monitoring is going to integrate the following sensors:

- Temperature
- Humidity
- CO_2
- Luminance
- Noise

The data will be available through a public API in the module, so they are available for the DSO and they can be managed from the other modules. Whenever available, a feature related to the detection of anomalies in the appliances power consumption will be embedded. Moreover, some of the data will be shown in the GUI in order to increase the end-user's awareness about their energy patterns.

5.1.2. SGAM Function Layer

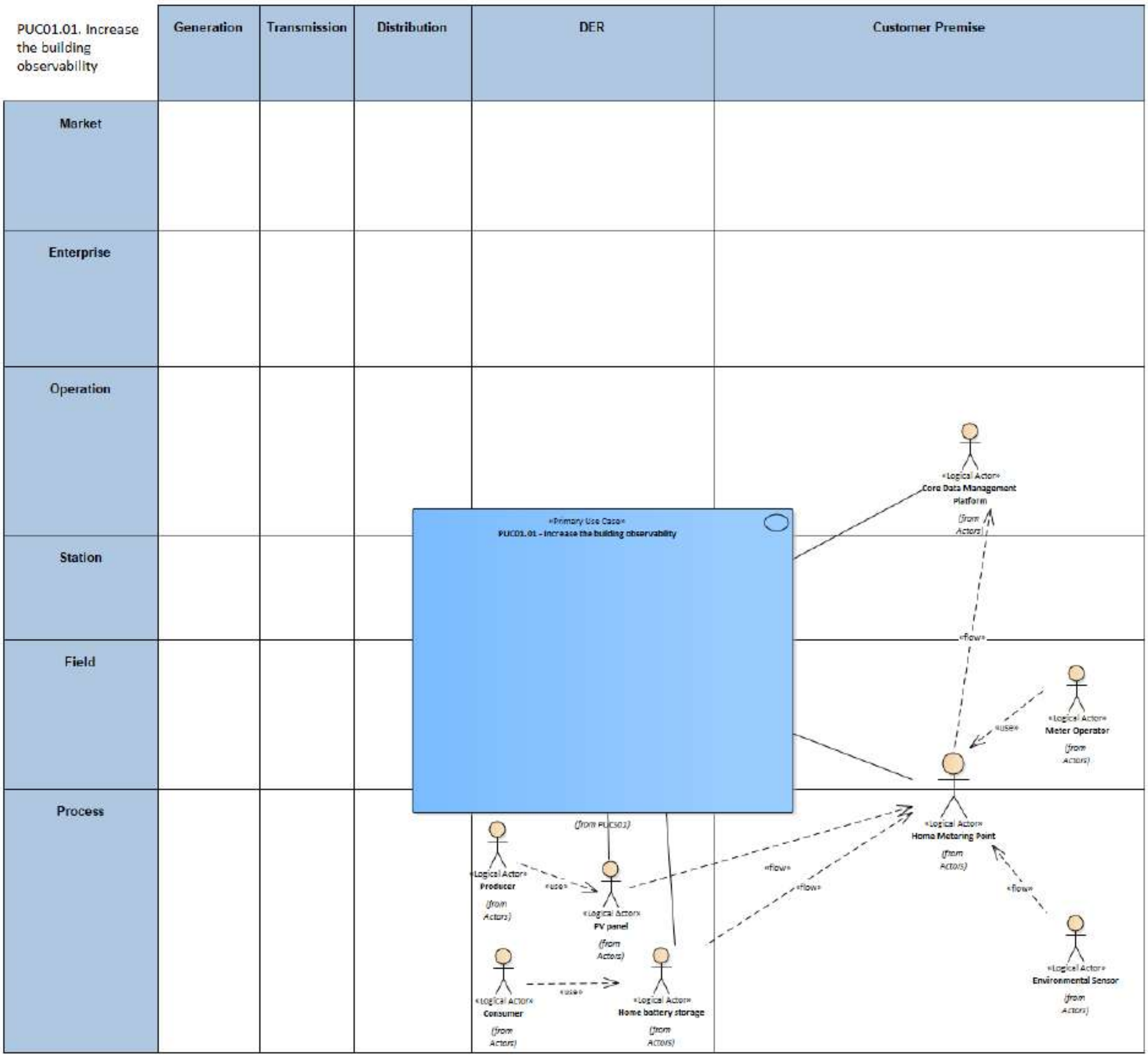

Figure 10: SGAM Function Layer PUC01.01

Table 3: List of Actors Involved PUC01.01

Actor Name	Actor Type
Producer	Logical actor role
Consumer	Logical actor role
PV Panel	Device
Home Battery Storage	Device
Home Metering Point	Device

Meter Operator	Device
Core Data Management Platform	Application

5.1.3. SGAM Component Layer

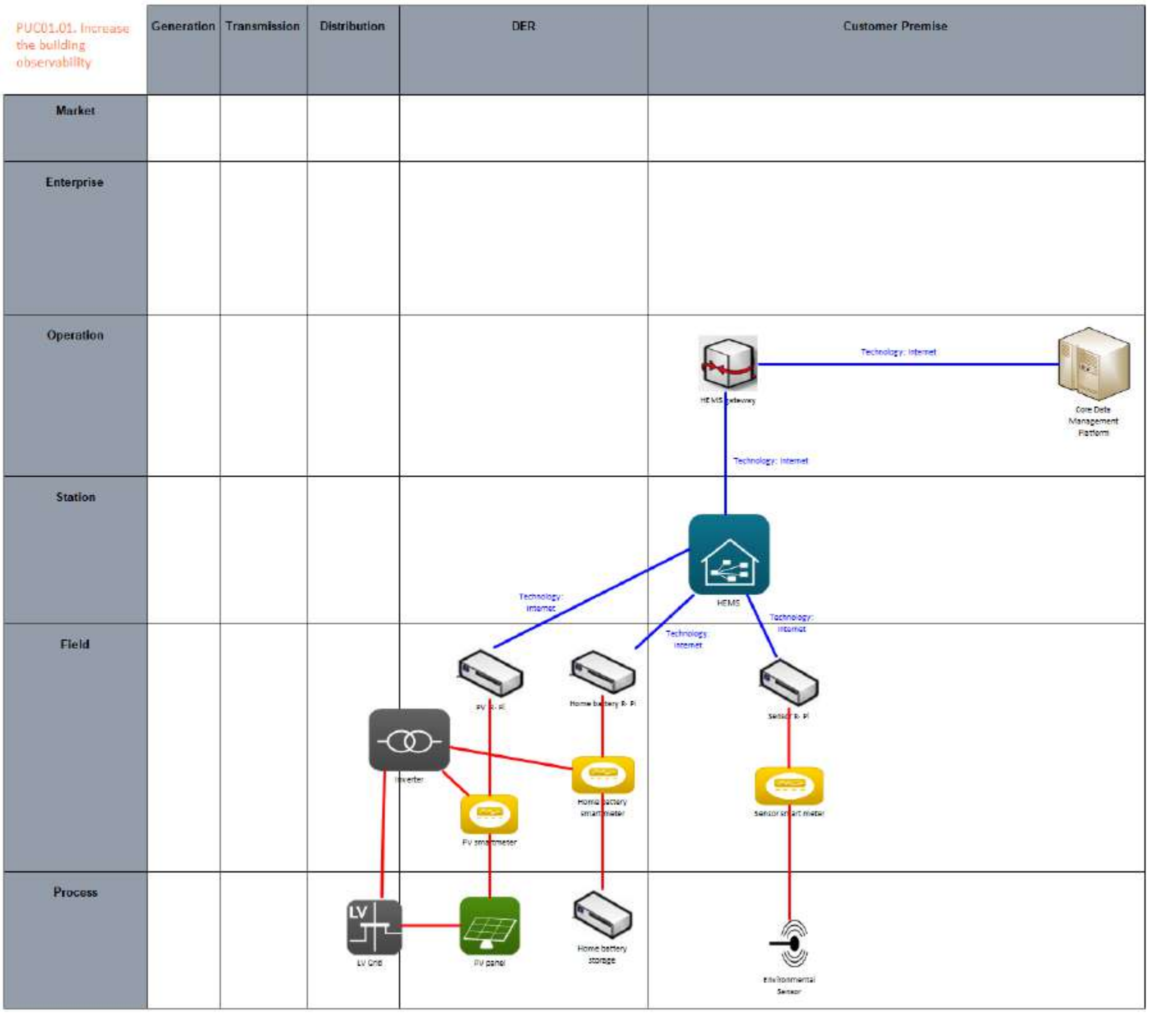

Figure 11: SGAM Component Layer PUC01.01

Table 4: List of Components Participating in the PUC01.01

Component	Component Type
LV Grid	Physical asset
PV Panel	Physical asset
Home Battery Storage	Physical asset

Inverter	Physical asset
PV Smart Meter	Physical asset
Home Battery Smart Meter	Physical asset
Sensor Smart Meter	Physical asset
Raspberry Pi	Physical asset
Environmental Sensor	Physical asset
HEMS	External Application
HEMS Gateway	External application
Core Data Management Platform	TwinERGY application

5.1.4. SGAM Communication Layer

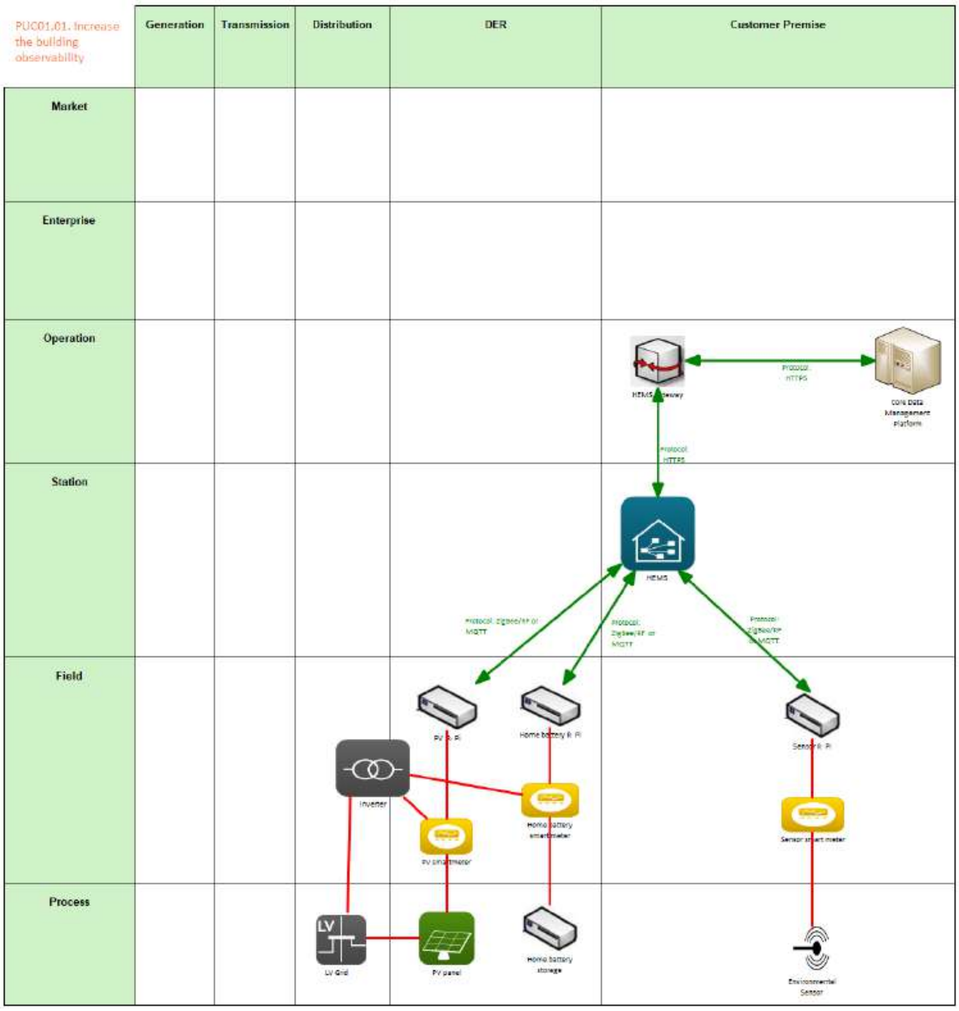

Figure 12: SGAM Communication Layer PUC01.01

Twinergy has received funding from the European Union's Horizon 2020 research and innovation programme under grant agreement No. 957736

Table 5: List of Communication technologies involved in PUC01.01

Communication Technology	Description
ZigBee/RF	Protocol IEEE 802.15.4, designed to communicate data through noisy RF environments. This standard operates on the physical radio specification and operates in unlicensed bands including 2.4 GHz, 900 MHz and 868 MHz.
MQTT	MQ Telemetry Transport. It is an open OASIS standard and an ISO recommendation (ISO/IEC 20922) over TCP/IP, being a lightweight, publish-subscribe network protocol that transports messages between devices.
HTTPS	HyperText Transfer Protocol Secure. It is an extension of the Hypertext Transfer Protocol (HTTP), used for secure communication over a computer network. In HTTPS, the communication protocol is encrypted using Transport Layer Security (TLS) or, formerly, Secure Sockets Layer (SSL). The protocol is therefore also referred to as HTTP over TLS, or HTTP over SSL.

5.1.5. SGAM Information Layer

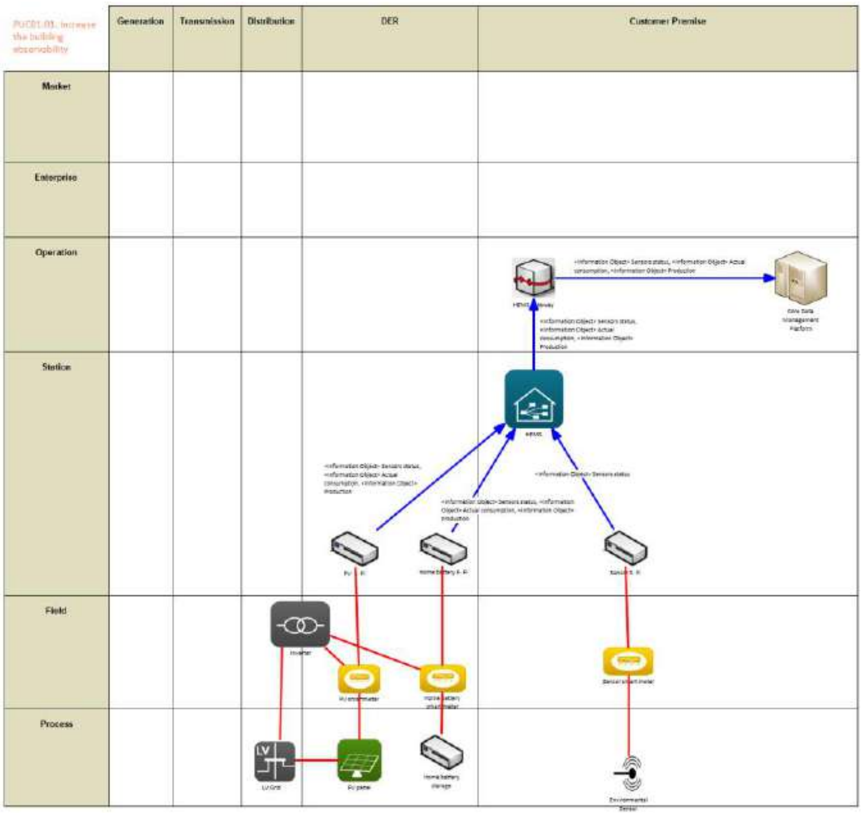

Figure 13: SGAM Information Layer PUC01.01

5.1.6. Canonical Data Model

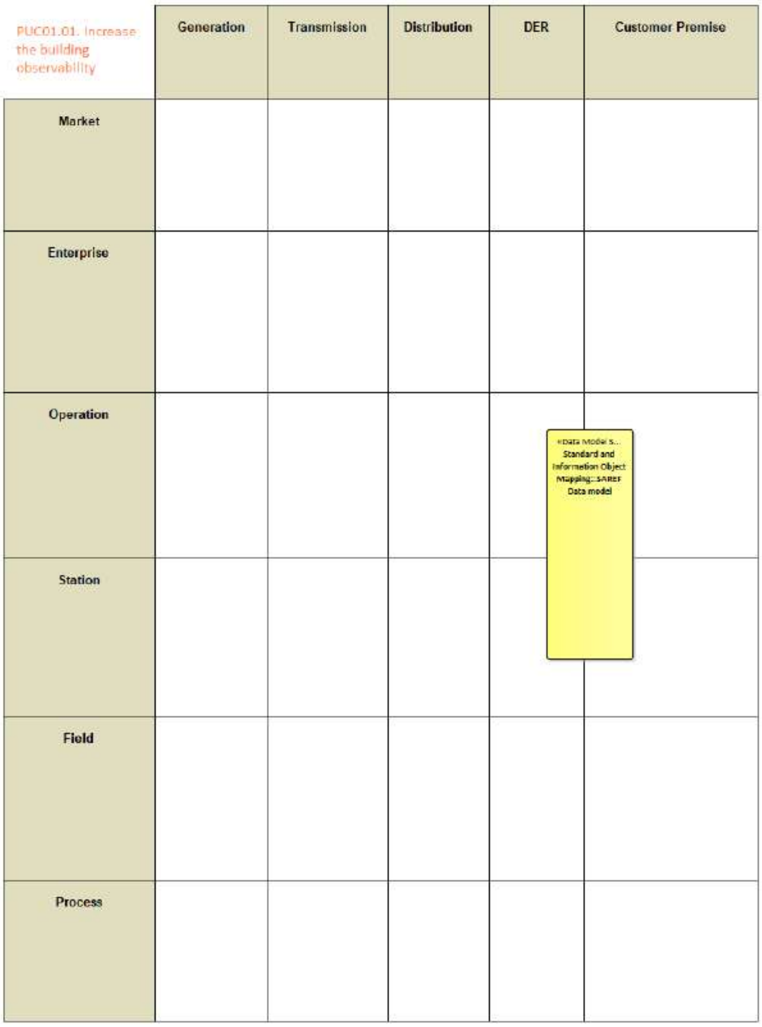

Figure 14: SGAM Canonical Data Model PUC01.01

Table 6: List of Data Models PUC01.01

Data Models
SAREF Data Model

5.1.7. Standards and Information Object Mapping

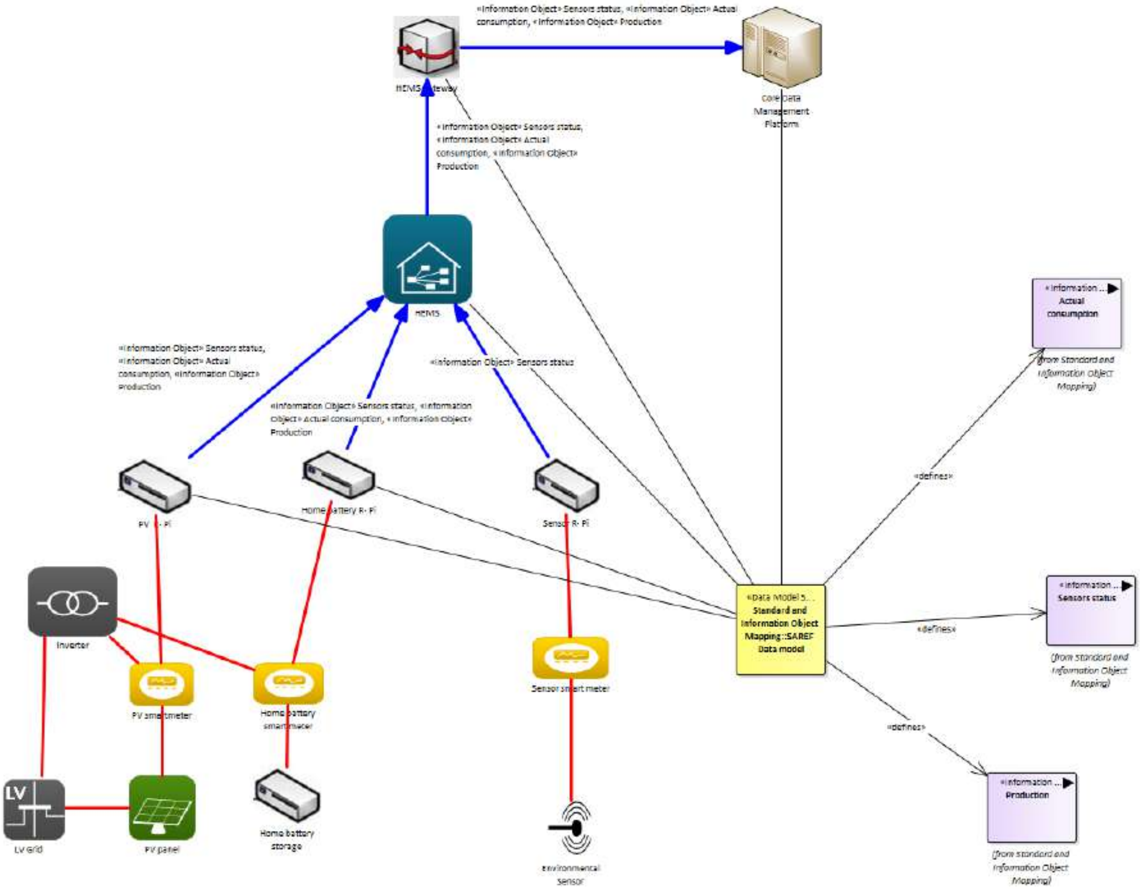

Figure 15: SGAM Standards and Information Object Mapping PUC01.01

Table 7: List of Information Objects PUC01.01

Information Objects	Data Models
Sensor status	SAREF data model
Actual consumption	SAREF data model
Production	SAREF data model

5.1.8. Activity Diagram

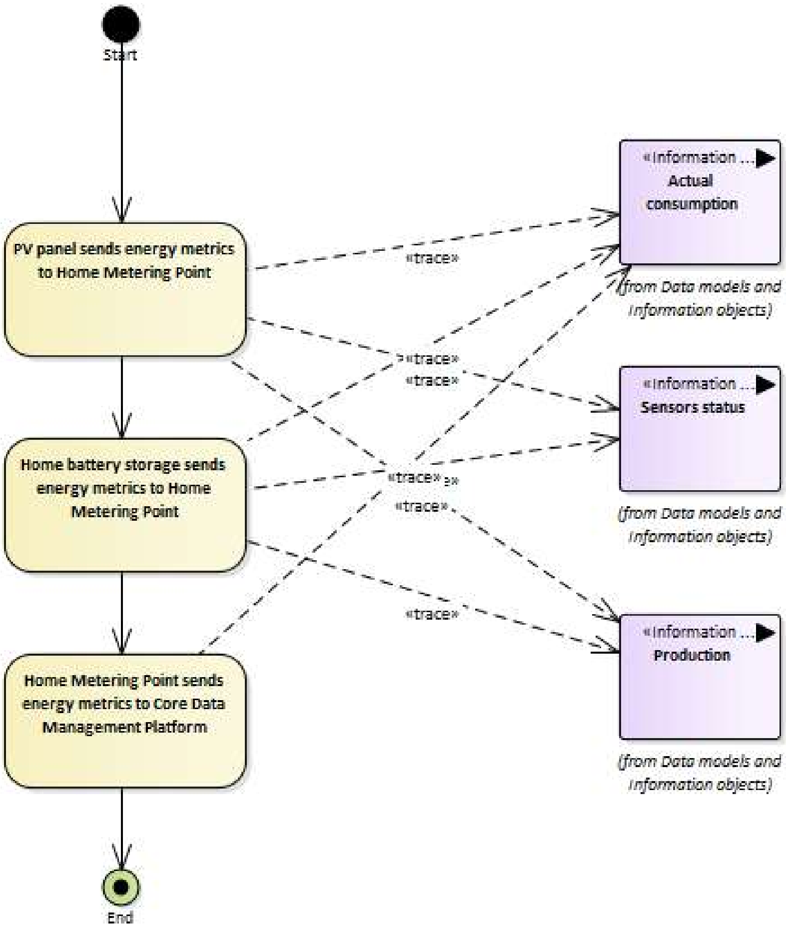

Figure 16: SGAM Activity Diagram PUC01.01

5.1.9. Sequence Diagram

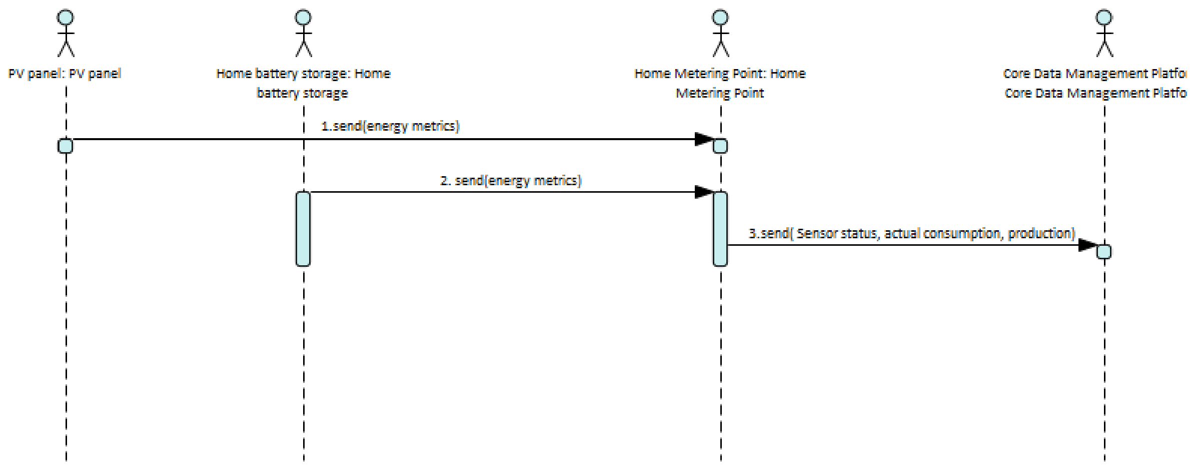

Figure 17: SGAM Sequence Diagram PUC01.01

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5.2. PUC01.02. Data analysis. Behavioural rules analysis, minimization of the energy costs and increase the self-consumption from PV

5.2.1. Use Case Description

Depending on the specific facility typology and in the users' habits, The Home & Tertiary Real-time Energy Monitoring Module can shape the usage patterns for each of them. The first step consists into getting of all the needed information from the TwinERGY Storage System passing through the Interoperability Platform. Some information related to the consumers and the buildings are also stored in the Digital Twin so that it is necessary to reach them passing through iSCAN and the interoperability Platform and then to the H&T EMS Module. electrical appliances inventory. Secondly, Facility energy assets information (e.g., PV sources, energy storages, ...). In third place, the energy demand identified through historical data and/or utility bills are regarded.

5.2.2. SGAM Function Layer

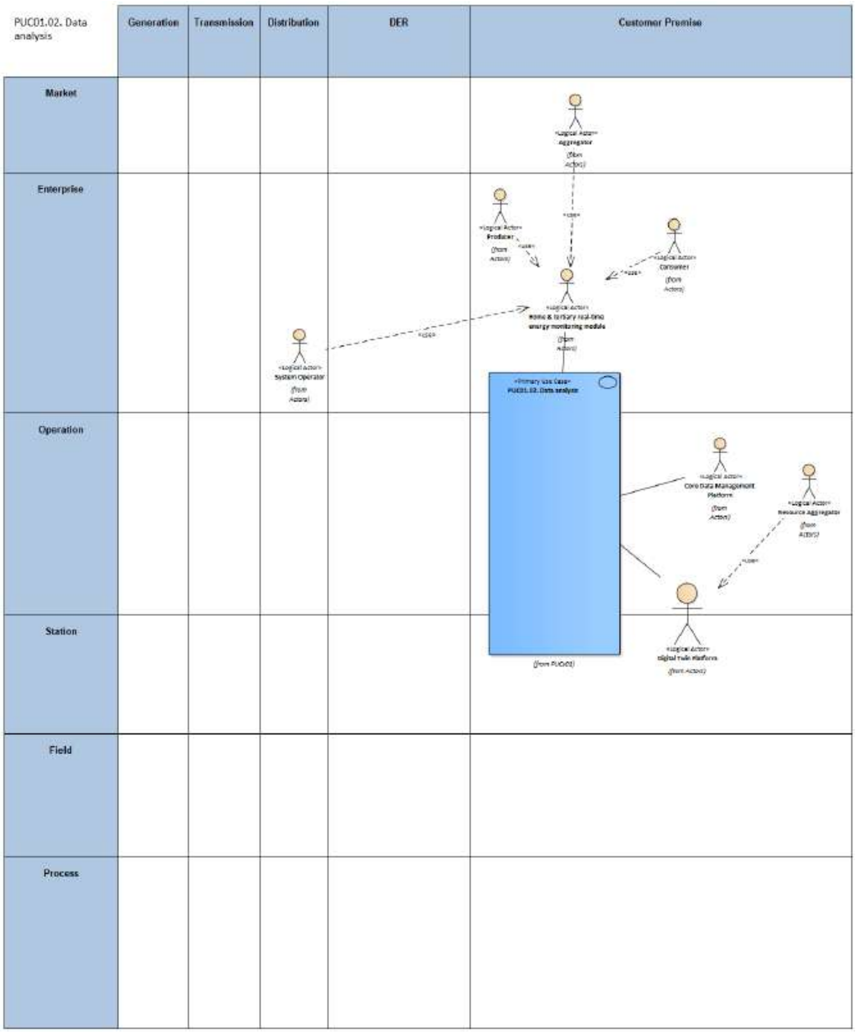

Figure 18: SGAM Function Layer PUC01.02

Twinergy has received funding from the European Union's Horizon 2020 research and innovation programme under grant agreement No. 957736

Table 8: List of Actors Involved PUC01.02

Actor Name	Actor Type
System Operator	Organization
Producer	Logical actor role
Aggregator	Logical actor role
Consumer	Logical actor role
Home & Tertiary real-time energy monitoring module	Application
Core Data Management Platform	Application
Resource Aggregator	Logical actor role
Digital Twin Platform	Application

5.2.3. SGAM Component Layer

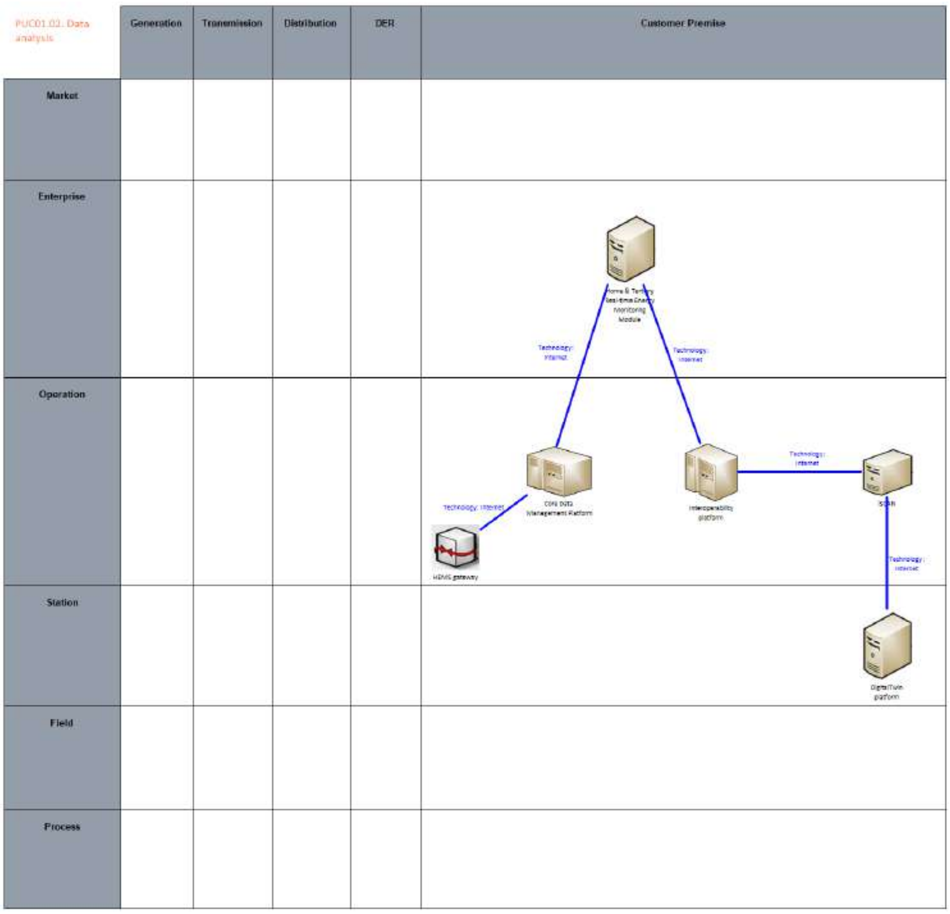

Figure 19: SGAM Component Layer PUC01.02

Table 9:List of Components PUC01.02

Component	Component Type
HEMS gateway	External Application
Core Data Management Platform	TwinERGY application
Home & Tertiary Real-time Energy Monitoring Module	TwinERGY application
Interoperability Platform	TwinERGY application
iSCAN	External Application
Digital Twin Platform	TwinERGY application

5.2.4. SGAM Communication Layer

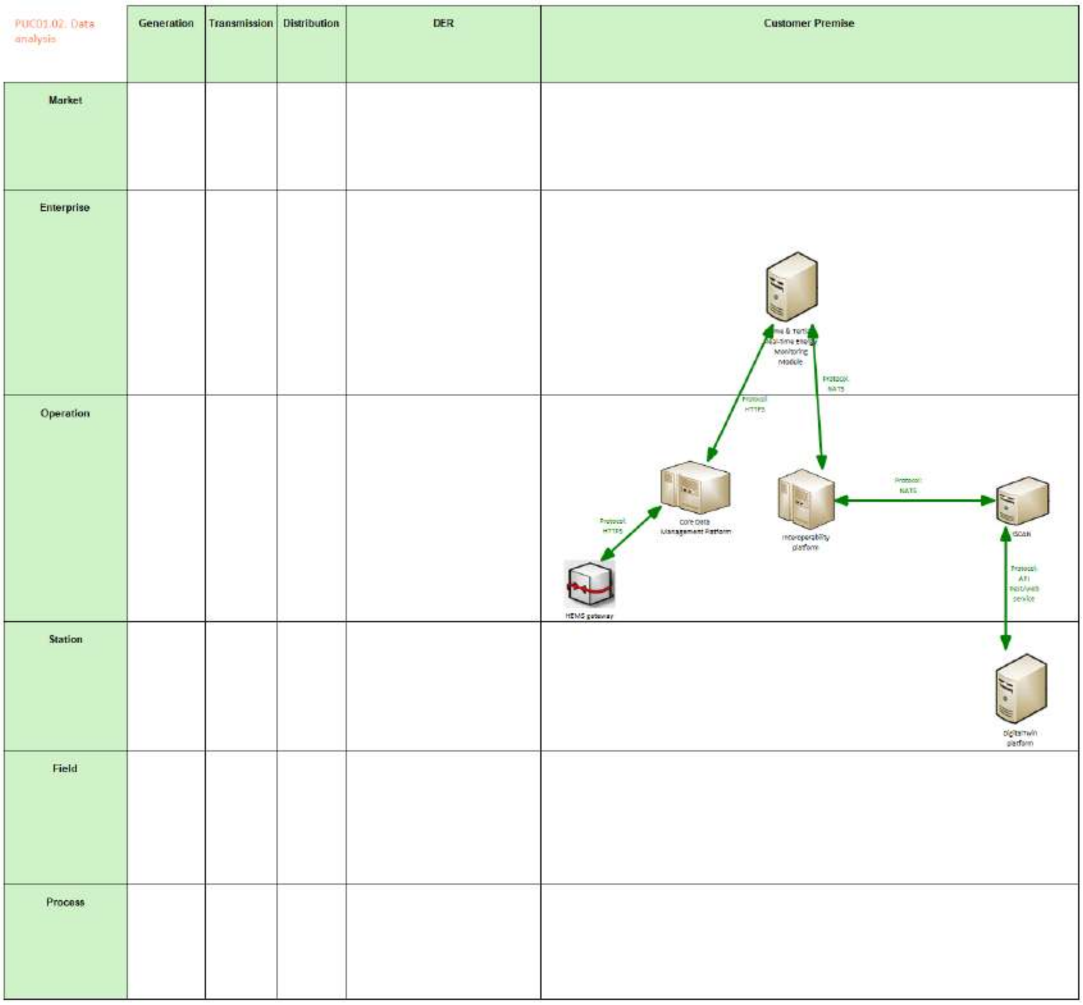

Figure 20: SGAM Communication Layer PUC01.02

Table 10:List of Communication technologies involved in PUC01.02

Communication Technology	Description
HTTPS	HyperText Transfer Protocol Secure. It is an extension of the Hypertext Transfer Protocol (HTTP), used for secure communication over a computer network. In HTTPS, the communication protocol is encrypted using Transport Layer Security (TLS) or, formerly, Secure Sockets Layer (SSL). The protocol is therefore also referred to as HTTP over TLS, or HTTP over SSL.
NATS	Protocol of messaging that enables the exchange of messages among computer applications and services, not depending on the network location.
API REST	Application Programming Interface for REpresentational State Transfer. API is a software intermediary that allows two applications to talk to each other, whilst REST is an architectural style for distributed hypermedia systems, working stateless. Both define a set of distributed resources accessible and manipulable through a set of public functions.

5.2.5. SGAM Information Layer

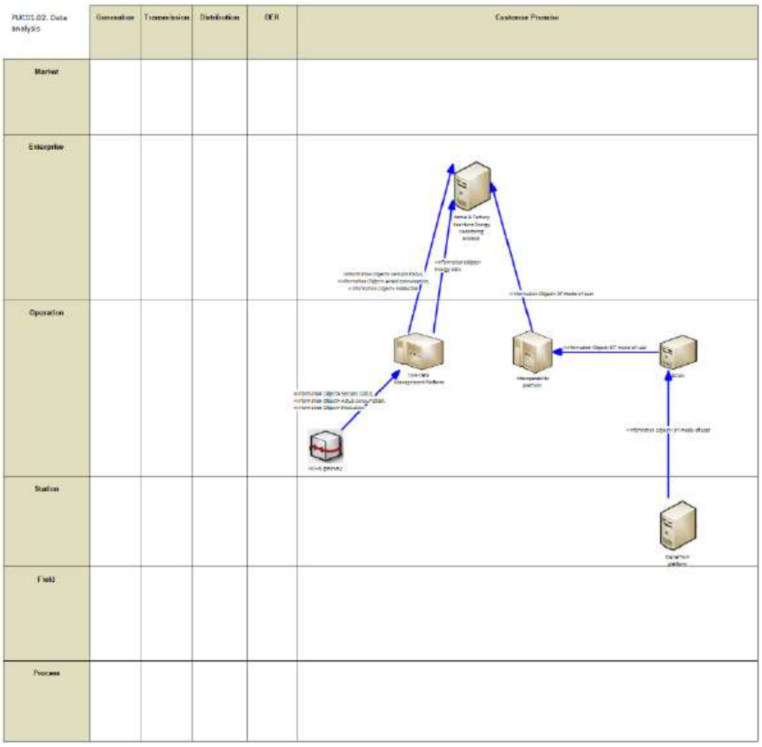

Figure 21: SGAM Information Layer PUC01.02

Twinergy has received funding from the European Union's Horizon 2020 research and innovation programme under grant agreement No. 957736

5.2.6. Canonical Data Model

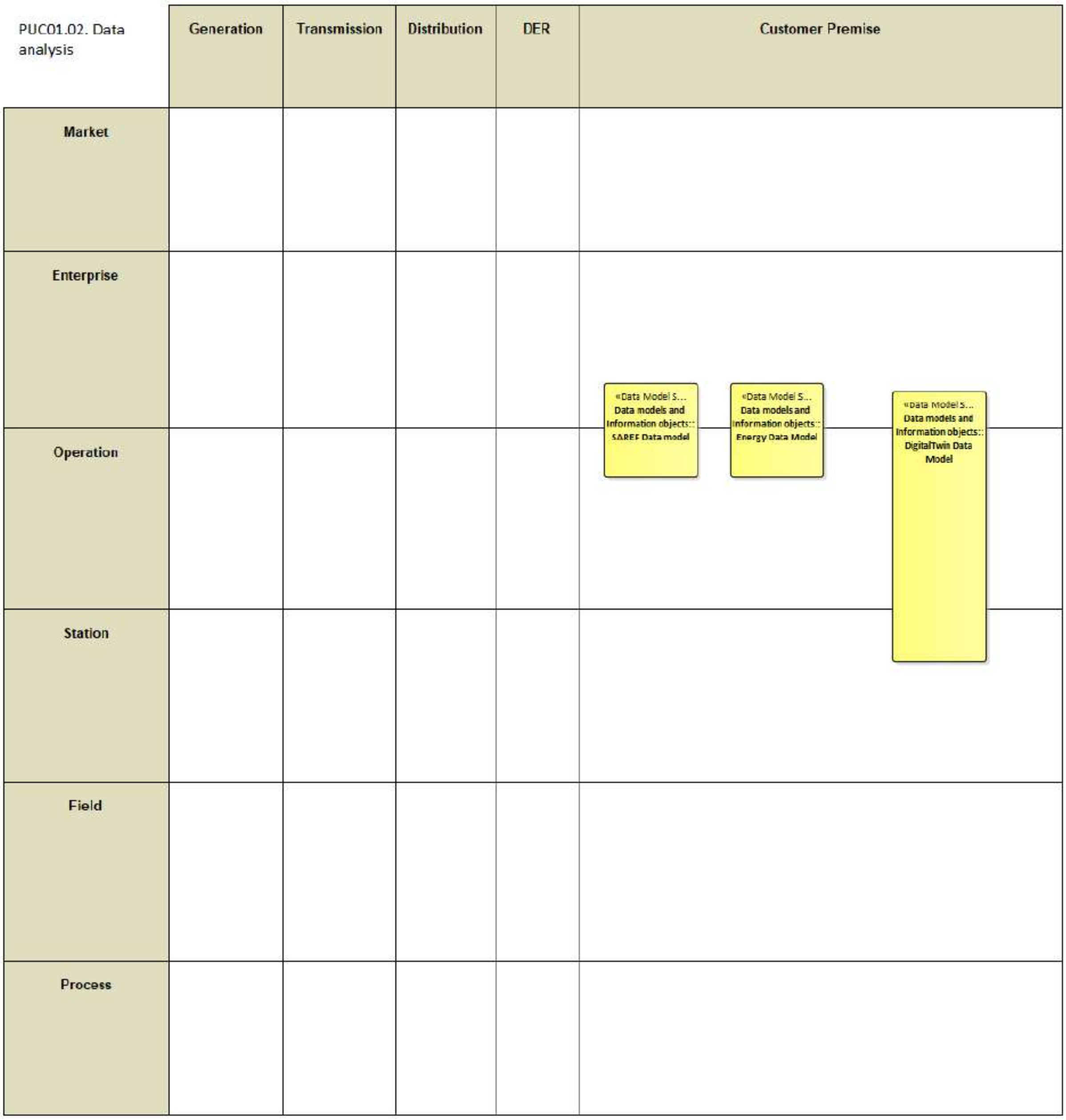

Figure 22: SGAM Canonical Data Model PUC01.02

Table 11: List of Data Models PUC01.02

Data Models
SAREF Data Model
Energy Data Model
Digital Twin Data Model

5.2.7. Standards and Information Object Mapping

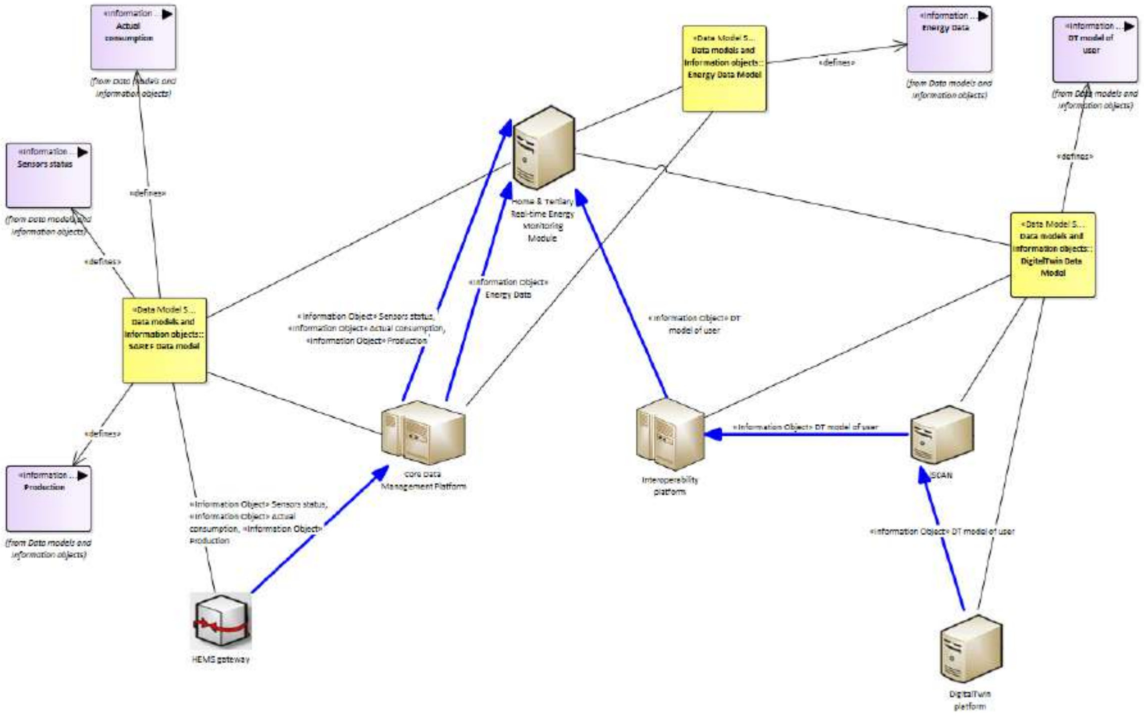

Figure 23: SGAM Standards and Information Object Mapping PUC01.02

Table 12: List of Information Objects PUC01.02

Information Objects	Data Models
Actual consumption	SAREF Data model
Sensor status	SAREF Data model
Production	SAREF Data model
Energy data	Energy Data model
DT model of user	Digital Twin data model

5.2.8. Activity Diagram

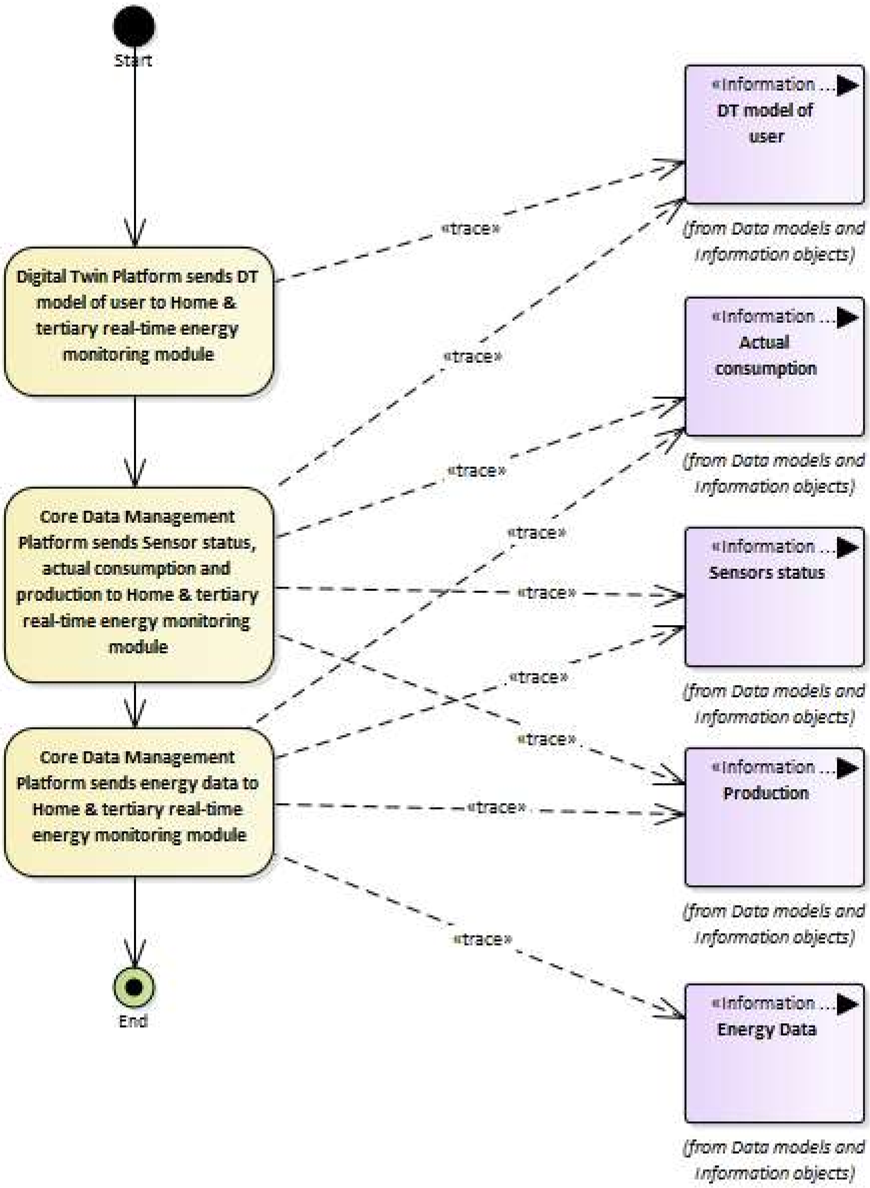

Figure 24:SGAM Activity Diagram PUC01.02

5.2.9. Sequence Diagram

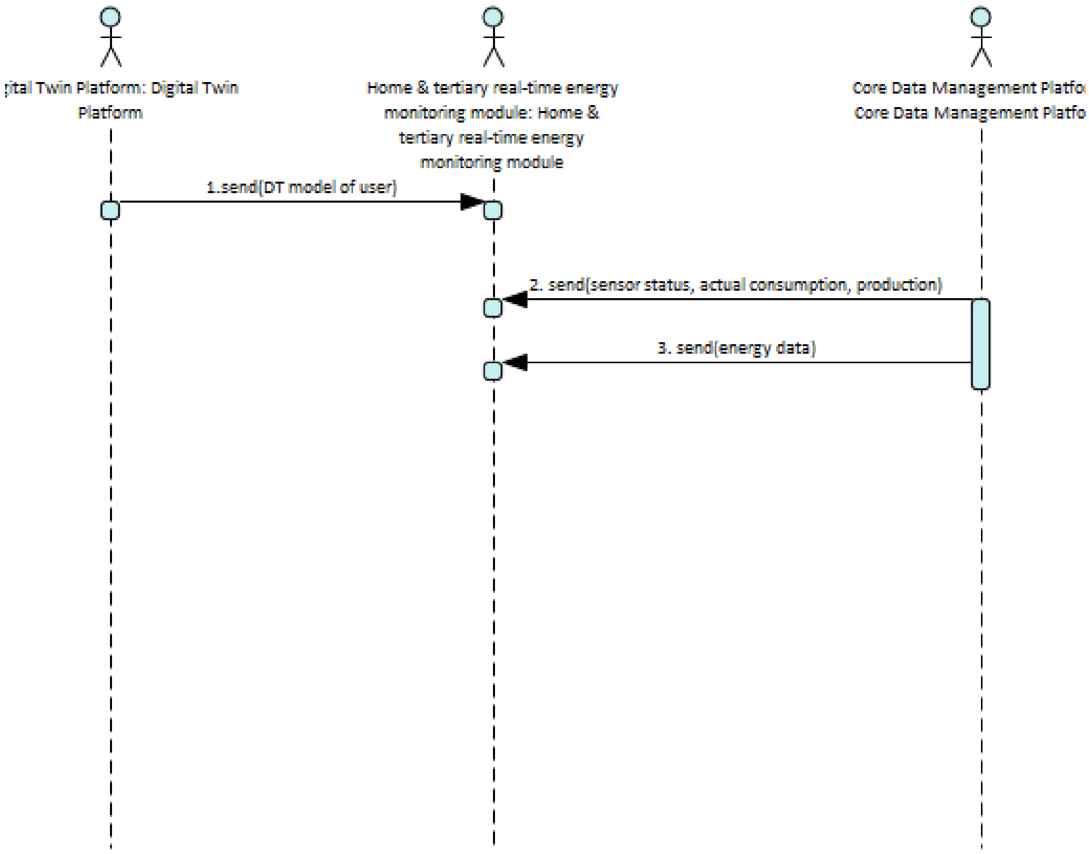

Figure 25: SGAM Sequence Diagram PUC01.02

5.3. PUC01.03. Optimal flexibility management system - Analysis of the optimal electrical appliances flexibility management

5.3.1. Use Case Description

The optimization algorithm, placed in the Home & Tertiary Real-time Energy Monitoring module, will find the best solution to control/suggest the smart plugged appliances.

To do that, the optimal scheduling developed in the Consumer Demand Flexibility Profiling Module, installed in the Digital Twin Platform (through the iSCAN platform) will pass through the Interoperability Platform and then to the Home & Tertiary Real-time Energy Monitoring module. Similarly, the forecast PV generation algorithms located in RES Integration & DER Management Module will feed the flexibility optimization algorithm and Consumer Demand Flexibility Profiling Module.

In order to do that, the optimization algorithm requires as input:

- The electrical appliances inventory
- The user behavioural model

- The PV forecast
- The energy contract information and costs provided by a DT service
- The energy storage state of charge

The output will be shown in the module GUI, in order to inform the users about the consequence of their Demand Response (DR) action and the influence they can reach in terms of:

- Reduction of the energy consumption
- Reduction of the costs
- Reduction of the CO2 footprint

This use case starts when a user installs the Home & Tertiary Real-time Energy Monitoring Module. The steps to complete this are the following ones:

1. Energy monitoring of the main electrical appliances and power lines
2. Energy monitoring of the main indoor parameters (Temperature and Humidity)
3. Evaluate the energy contribution of the PV and storage systems
4. Improve self-consumption
5. Use of electrical load flexibility management considering dynamic tariffs (calculated by the Transactive Energy Module) to minimize energy cost to the end user
6. Difference between the real energy pattern and the optimal pattern suggested, that will be shaped in a GUI belonging to the Home & Tertiary Real-time Energy Monitoring Module.

Whenever is possible, the bills checking function will be implemented, in order to ensure the correct matching between the energy costs released by the energy provider and the one calculated from the measurement of the Home Energy Monitoring System (HEMS).

5.3.2. SGAM Function Layer

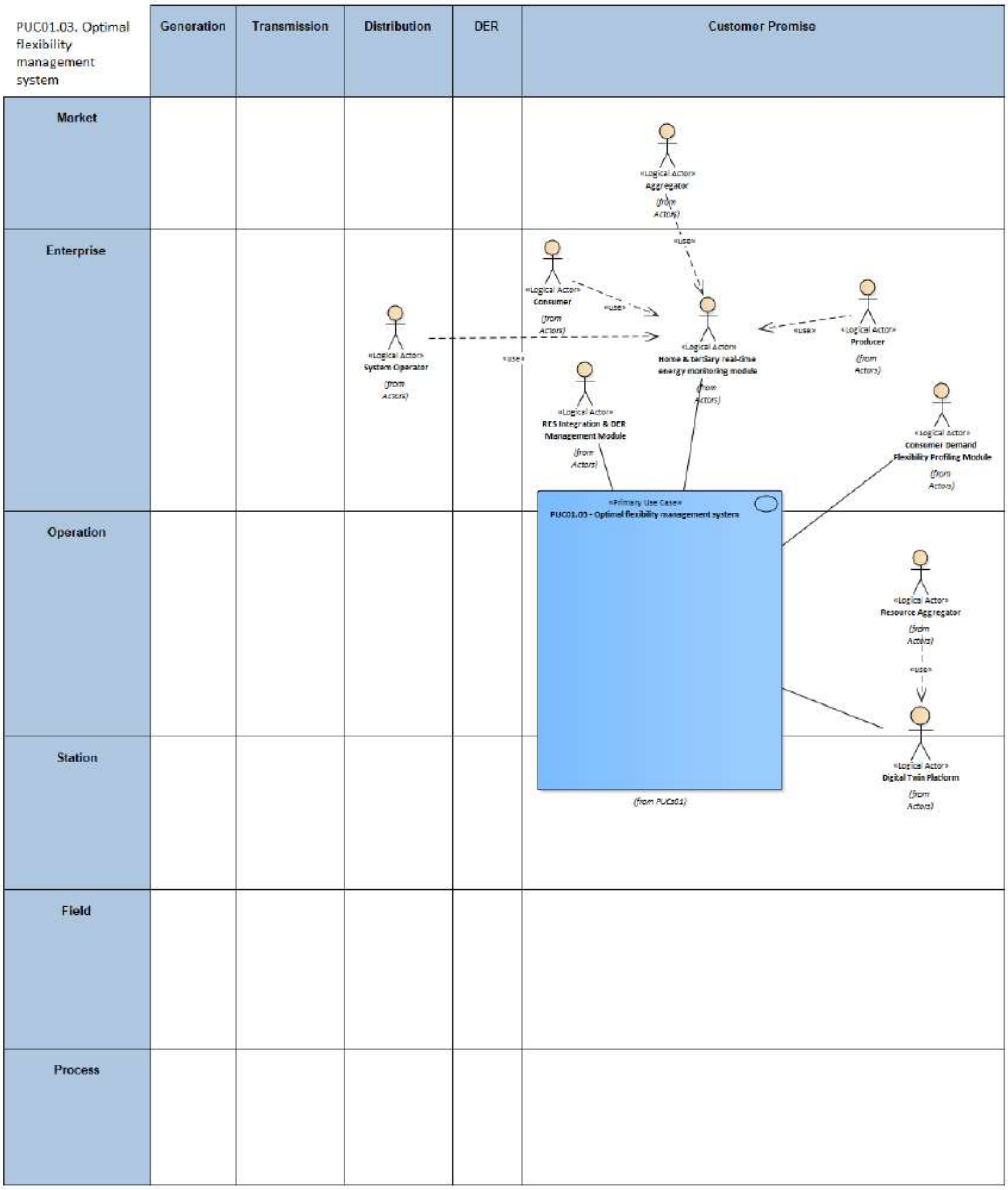

Figure 26: SGAM Function Layer PUC01.03

Table 13: List of Actors Involved PUC01.03

Actor Name	Actor Type
System Operator	Organization
Consumer	Logical actor role

RES Integration & DER Management Module	Application
Aggregator	Logical actor role
Home & Tertiary real-time energy monitoring module	Application
Producer	Logical actor role
Consumer Demand Flexibility Profiling Module	Application
Resource Aggregator	Logical actor role
Digital Twin Platform	Application

5.3.3. SGAM Component Layer

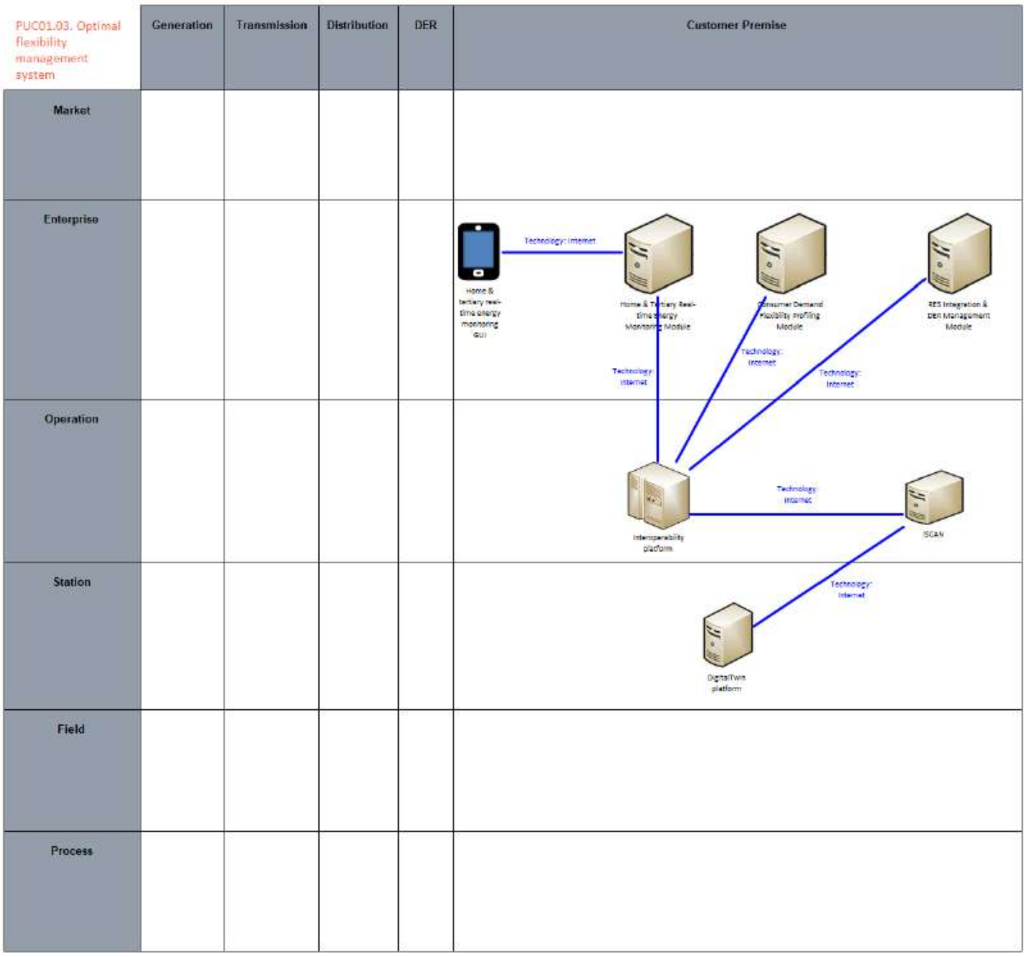

Figure 27: SGAM Component Layer PUC01.03

Table 14: List of Components PUC01.03

Component	Component Type
Home & tertiary real-time energy monitoring GUI	TwinERGY application
Home & Tertiary Real-time energy Monitoring Module	TwinERGY application
Consumer Demand Flexibility Profiling Module	TwinERGY application
RES Integration & DER Management Module	TwinERGY application
Interoperability platform	TwinERGY application
iSCAN	External application
Digital Twin Platform	TwinERGY application

5.3.4. SGAM Communication Layer

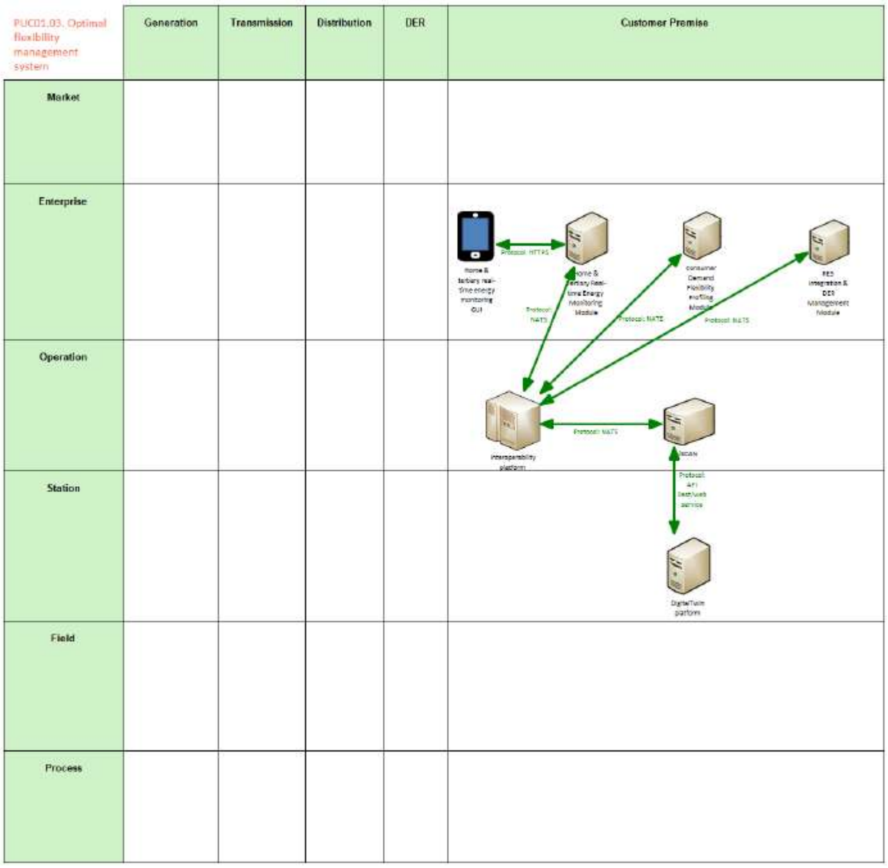

Figure 28: SGAM Communication Layer PUC01.03

Table 15: List of Communication technologies involved in PUC01.03

Communication Technology	Description
NATS	Protocol of messaging that enables the exchange of messages among computer applications and services, not depending on the network location.
HTTPS	HyperText Transfer Protocol Secure. It is an extension of the Hypertext Transfer Protocol (HTTP), used for secure communication over a computer network. In HTTPS, the communication protocol is encrypted using Transport Layer Security (TLS) or, formerly, Secure Sockets Layer (SSL). The protocol is therefore also referred to as HTTP over TLS, or HTTP over SSL.
API Rest	Application Programming Interface for REpresentational State Transfer. API is a software intermediary that allows two applications to talk to each other, whilst REST is an architectural style for distributed hypermedia systems, working stateless. Both define a set of distributed resources accessible and manipulable through a set of public functions.

5.3.5. SGAM Information Layer

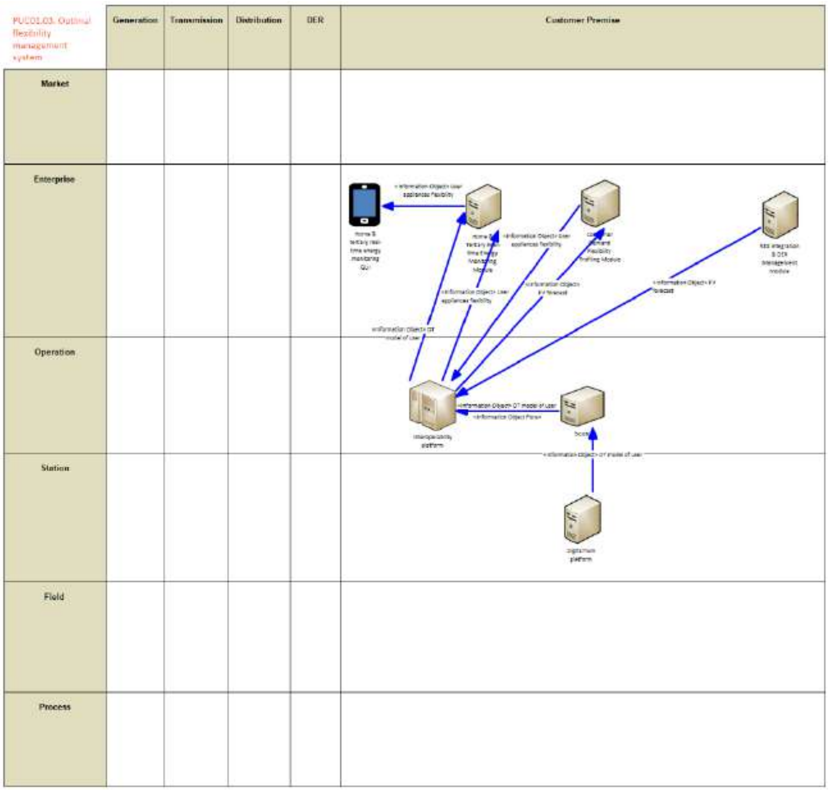

Figure 29: SGAM Information Layer PUC01.03

5.3.6. Canonical Data Model

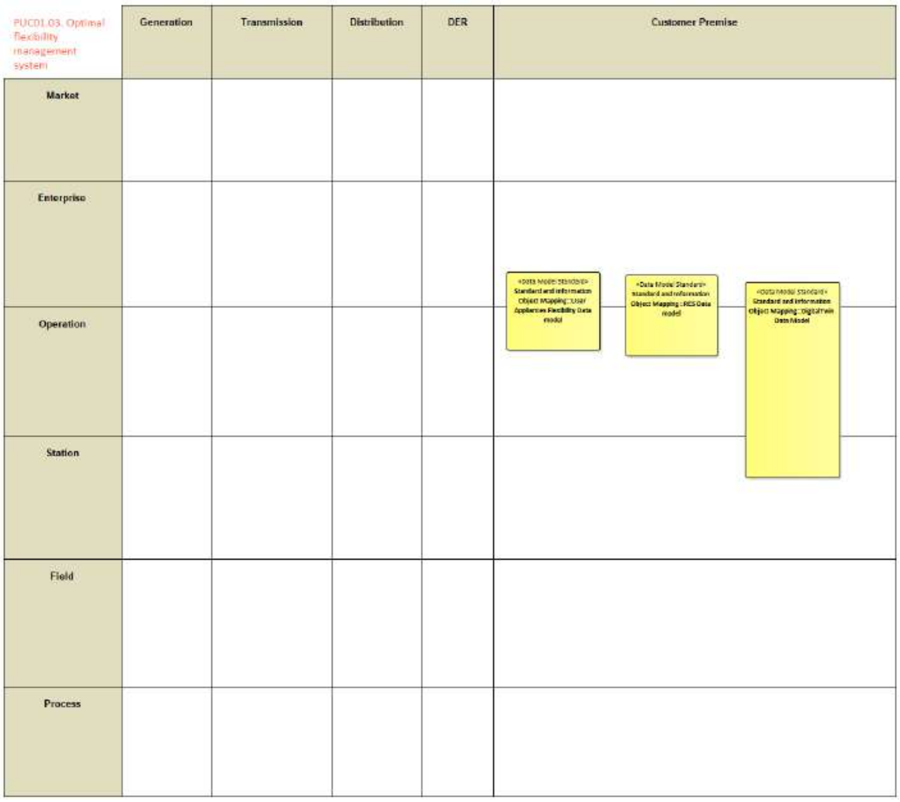

Figure 30: SGAM Canonical Data Model PUC01.03

Table 16: List of Data Models PUC01.03

Data Models
SAREF Data Model
Energy Data Model
Digital Twin Data Model

5.3.7. Standards and Information Object Mapping

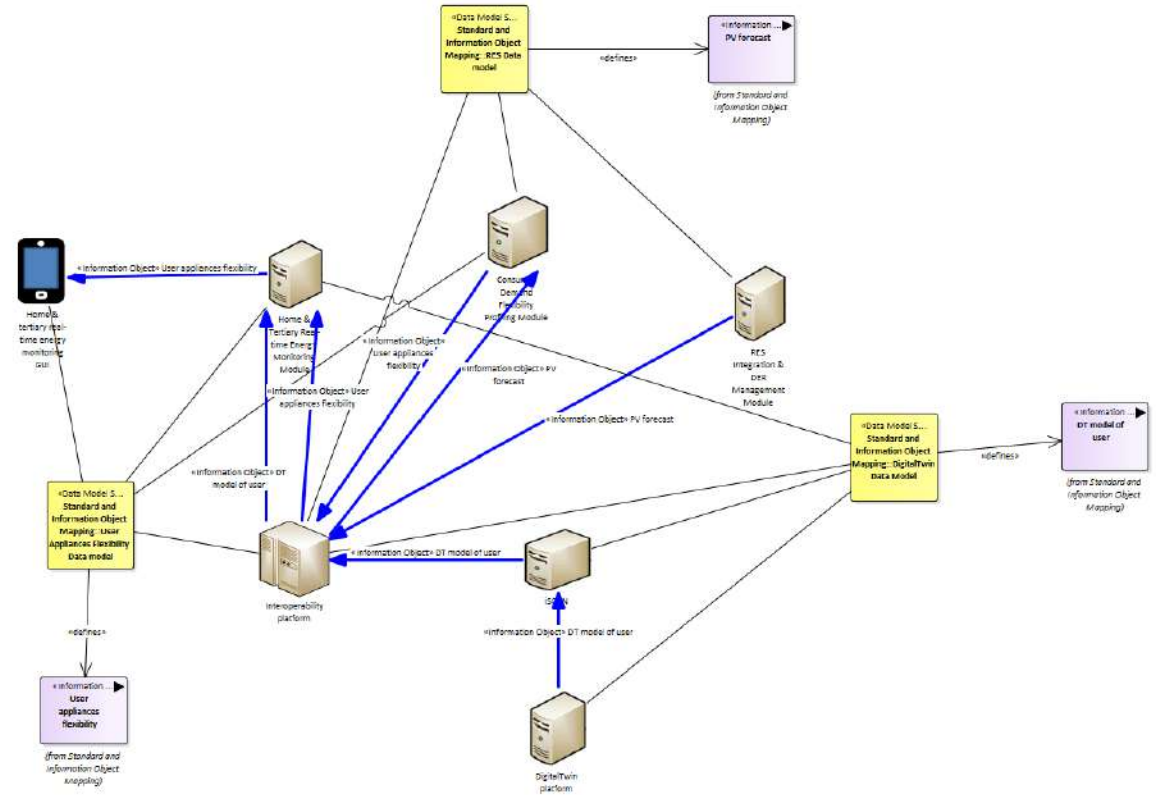

Figure 31: SGAM Standards and Information Object Mapping PUC01.03

Table 17: List of Information Objects PUC01.03

Information Objects	Data Models
User appliances flexibility	User Appliances Flexibility Data Model
PV forecast	RES data model
DT model of user	Digital Twin Data Model

5.3.8. Activity Diagram

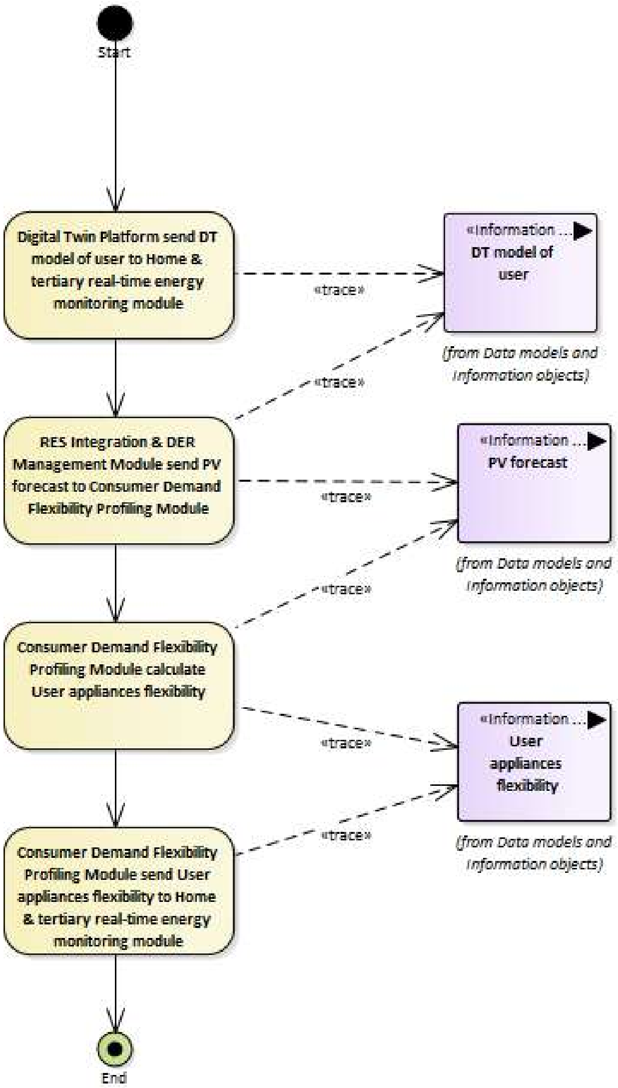

Figure 32: SGAM Activity Diagram PUC01.03

5.3.9. Sequence Diagram

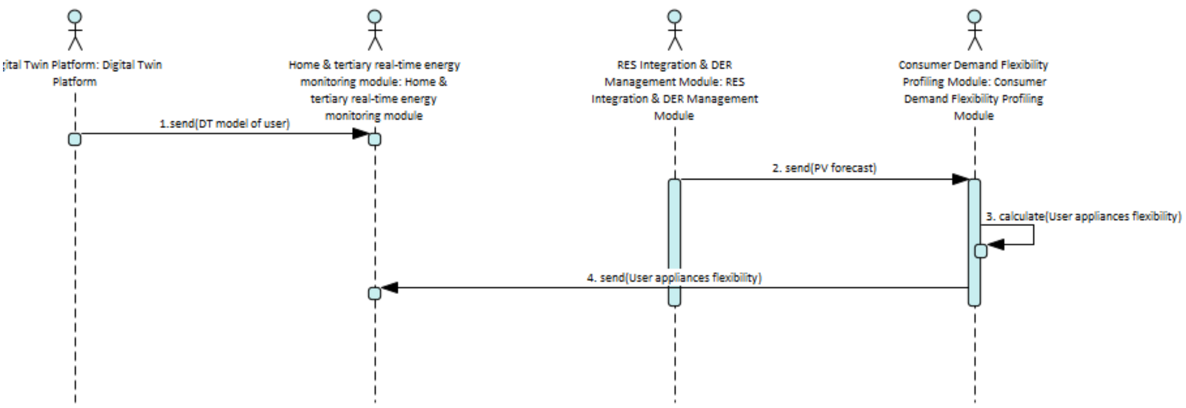

Figure 33: SGAM Sequence Diagram PUC01.03

5.4. PUC01.04. Control of the smart devices

5.4.1. Use Case Description

Depending on the appliances' typology, it is possible to perform different level of control from the GUI in the Home & Tertiary real-time energy monitoring module.

The focus is on the remote control of the smart plugs linked to the main electrical load. They monitor the devices power consumption and can operate their switch ON/OFF.

Also, some other module, such as the Transactive module can request the switch ON/OFF of the smart plugs.

The focus will rely on:

- Smart plugged appliances
- Smart HVAC

For those appliances whose are already smart enough for the remote control and the rest APIs are available, also their control will be targeted.

5.4.2. SGAM Function Layer

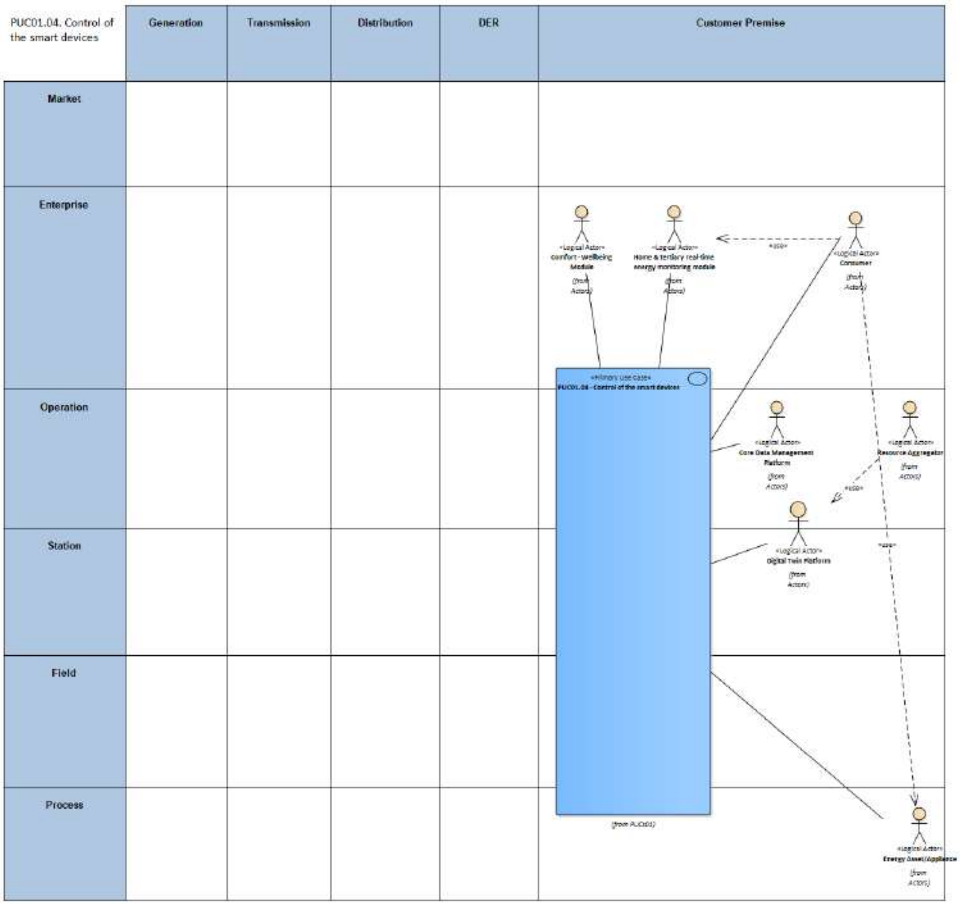

Figure 34: SGAM Function Layer PUC01.04

Table 18: List of Actors Involved PUC01.04

Actor Name	Actor Type
Comfort – Wellbeing Module	Application
Home & Tertiary real-time energy monitoring Module	Application
Consumer	Logical actor role
Core Data Management Platform	Application
Resource Aggregator	Logical actor role
Digital Twin Platform	Application
Energy Asset/Appliance	Device

5.4.3. SGAM Component Layer

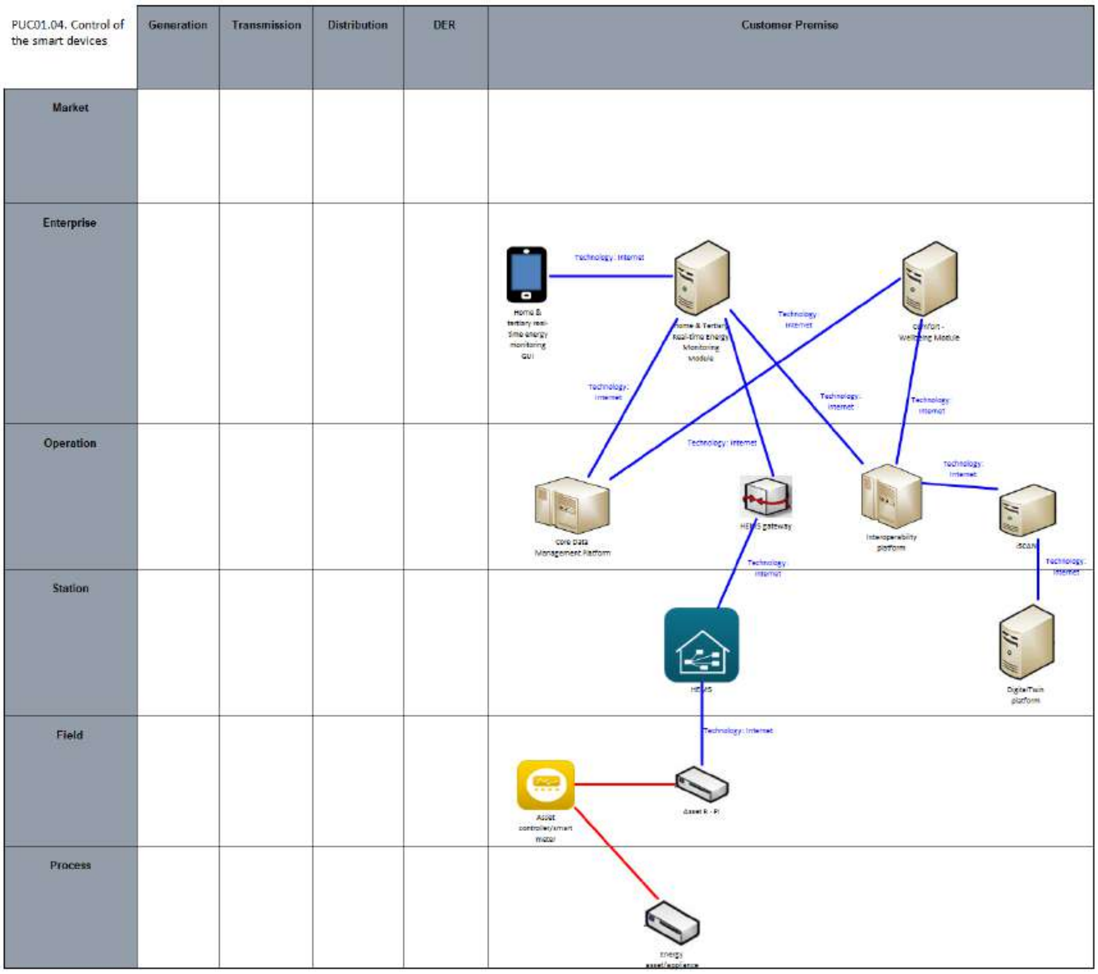

Figure 35:SGAM Component Layer PUC01.04

Twinergy has received funding from the European Union's Horizon 2020 research and innovation programme under grant agreement No. 957736

Table 19: List of Components PUC01.04

Component	Component Type
Energy asset/appliance	Physical asset
Asset controller / smart meter	Physical asset
Raspberry-Pi	Physical asset
HEMS	External Application
HEMS gateway	External Application
Digital Twin Platform	TwinERGY application
iSCAN	External application
Interoperability Platform	TwinERGY application
Core Data Management Platform	TwinERGY application
Home & Tertiary Real-time Energy Monitoring Module	TwinERGY application
Consumer – Wellbeing Module	TwinERGY application
Home & Tertiary real-time energy monitoring GUI	TwinERGY application

Twinergy has received funding from the European Union's Horizon 2020 research and innovation programme under grant agreement No. 957736

5.4.4. SGAM Communication Layer

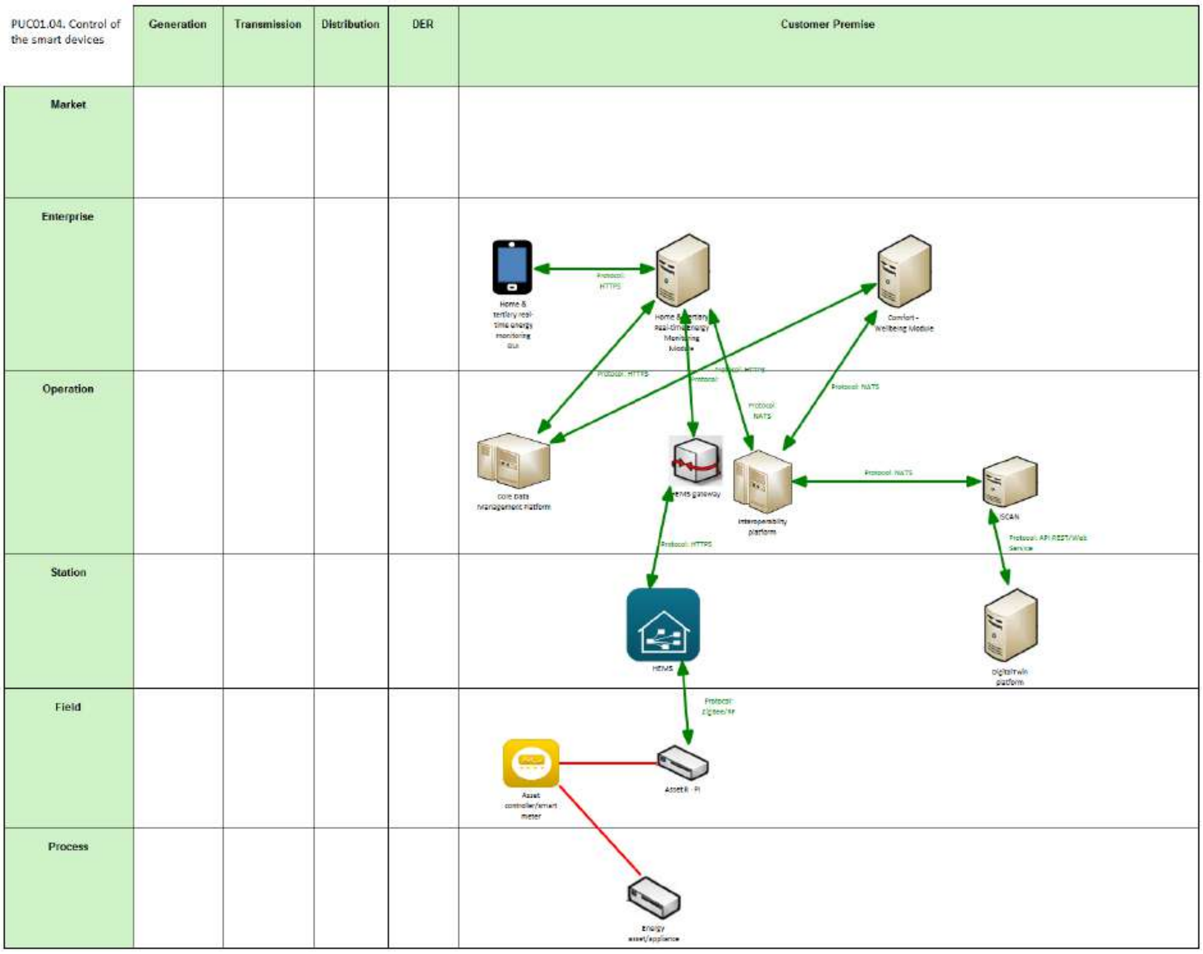

Figure 36: SGAM Communication Layer PUC01.04

Table 20: List of Communication technologies involved in PUC01.04

Communication Technology	Description
HTTPS	HyperText Transfer Protocol Secure. It is an extension of the Hypertext Transfer Protocol (HTTP), used for secure communication over a computer network. In HTTPS, the communication protocol is encrypted using Transport Layer Security (TLS) or, formerly, Secure Sockets Layer (SSL). The protocol is therefore also referred to as HTTP over TLS, or HTTP over SSL.
NATS	Protocol of messaging that enables the exchange of messages among computer applications and services, not depending on the network location.
API REST	Application Programming Interface for REpresentational State Transfer. API is a software intermediary that allows two

	applications to talk to each other, whilst REST is an architectural style for distributed hypermedia systems, working stateless. Both define a set of distributed resources accessible and manipulable through a set of public functions.
ZigBee/RF	Protocol IEEE 802.15.4, designed to communicate data through noisy RF environments. This standard operates on the physical radio specification and operates in unlicensed bands including 2.4 GHz, 900 MHz and 868 MHz.

5.4.5. SGAM Information Layer

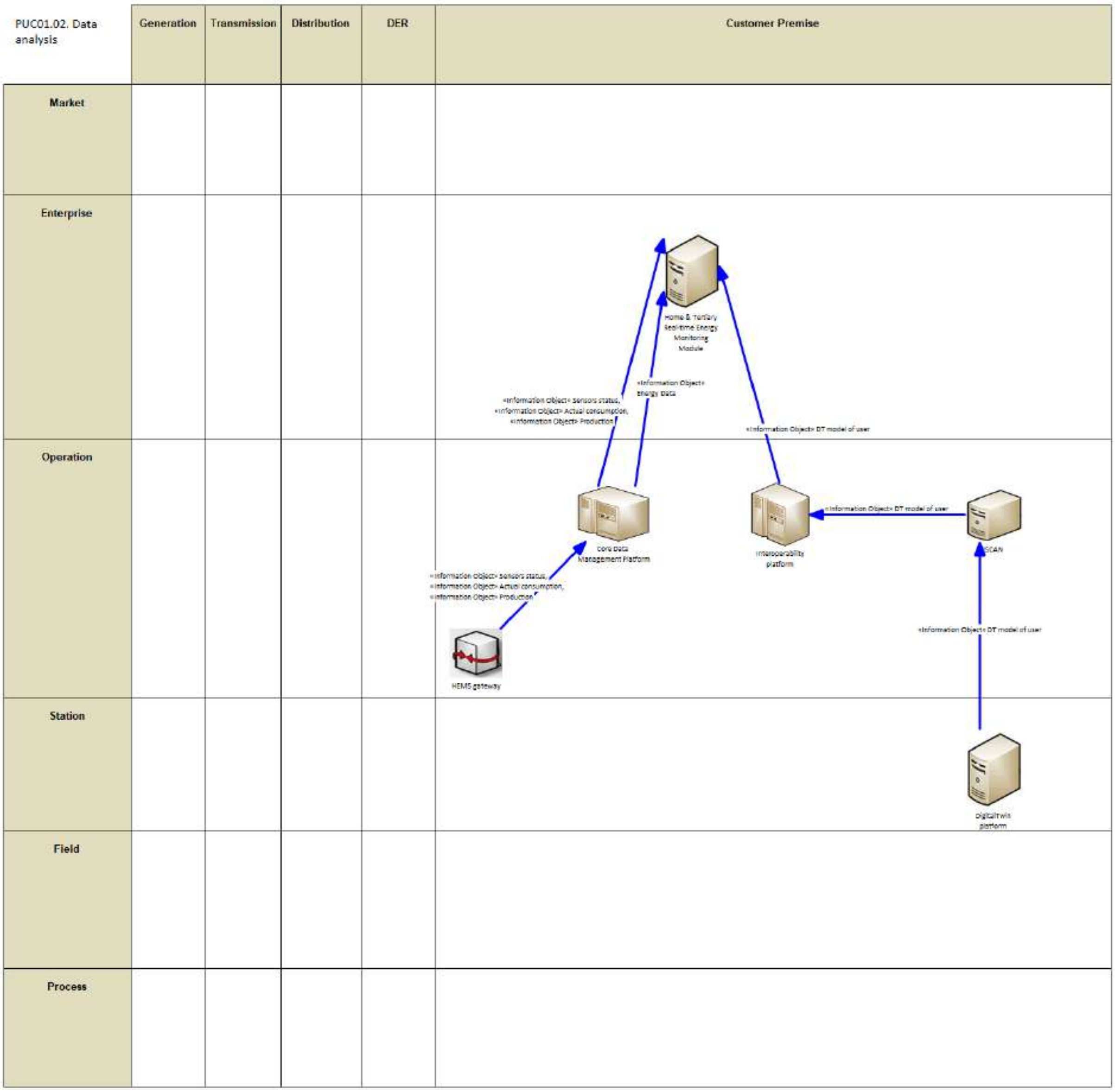

Figure 37: SGAM Information Layer PUC01.04

5.4.6. Canonical Data Model

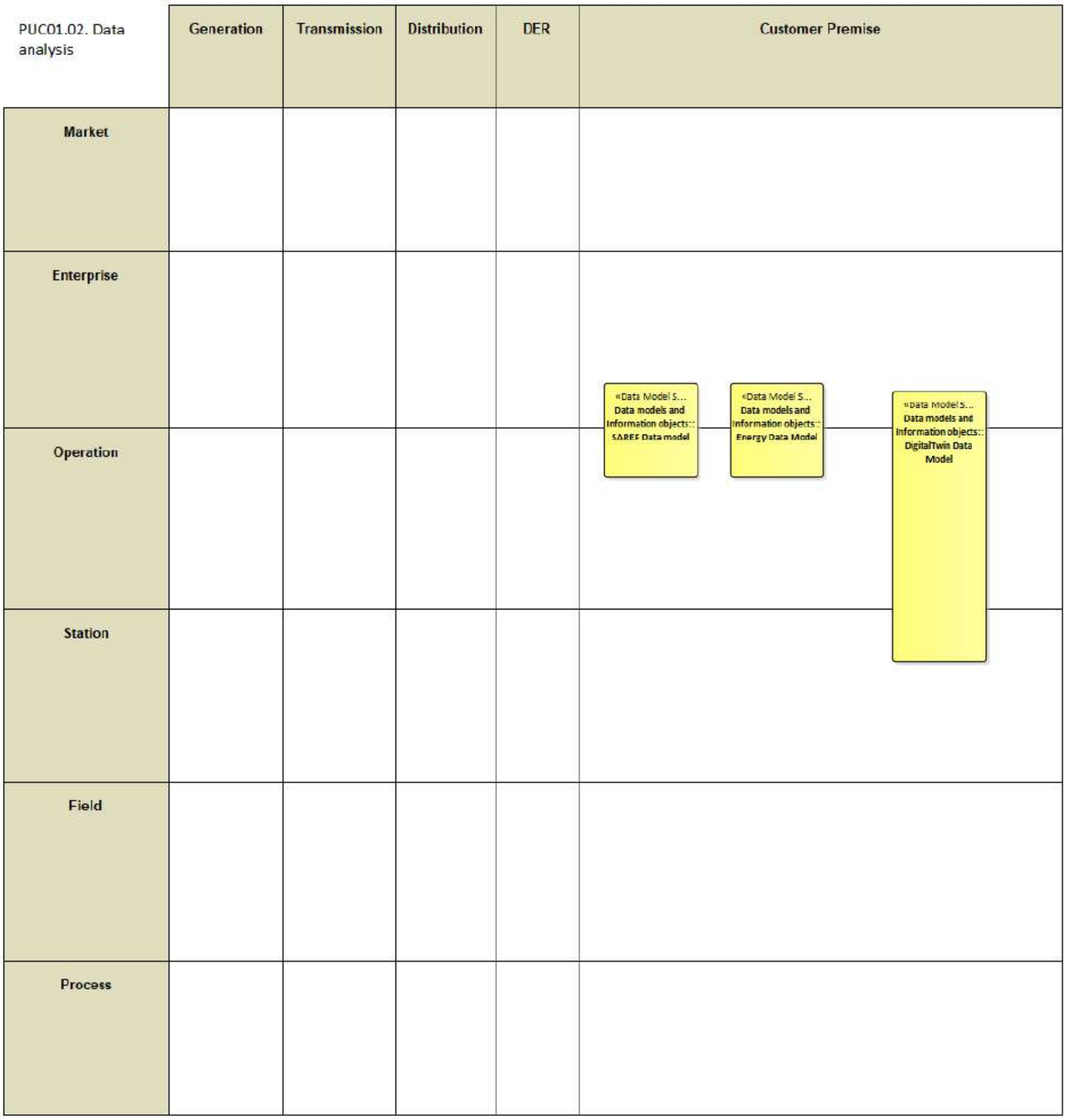

Figure 38: SGAM Canonical Data Model PUC01.04

Table 21: List of Data Models PUC01.04

Data Models
SAREF Data Model
Energy Data Model
Control Analysis Data Model

Comfort Well-Being Data Model
Remote Control Data Model

5.4.7. Standards and Information Object Mapping

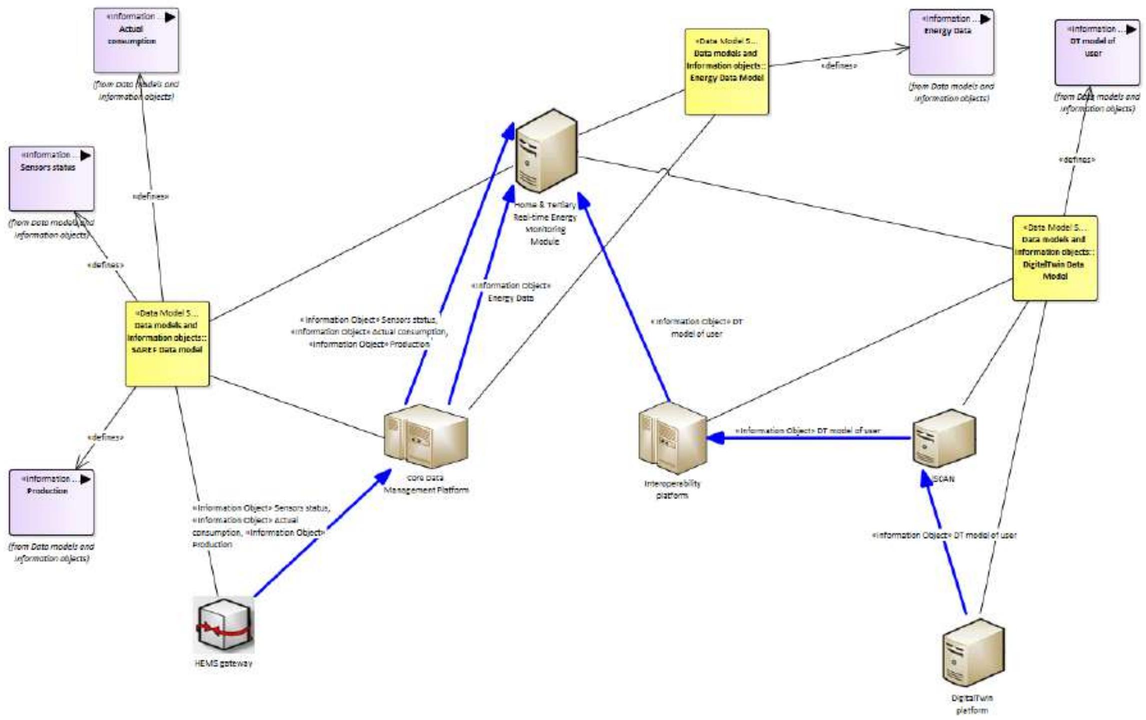

Figure 39: SGAM Standards and Information Object Mapping PUC01.04

Table 22: List of Information Objects PUC01.04

Information Objects	Data Models
Sensor status	SAREF Data model
Control Analysis	Control Analysis Data model
Energy data	Energy Data model
DT model of user	Digital Twin Data model
Comfort Well-Being Evaluation	Comfort Well-Being Data model
Remote Control Data	Remote Control Data Model

5.4.8. Activity Diagram

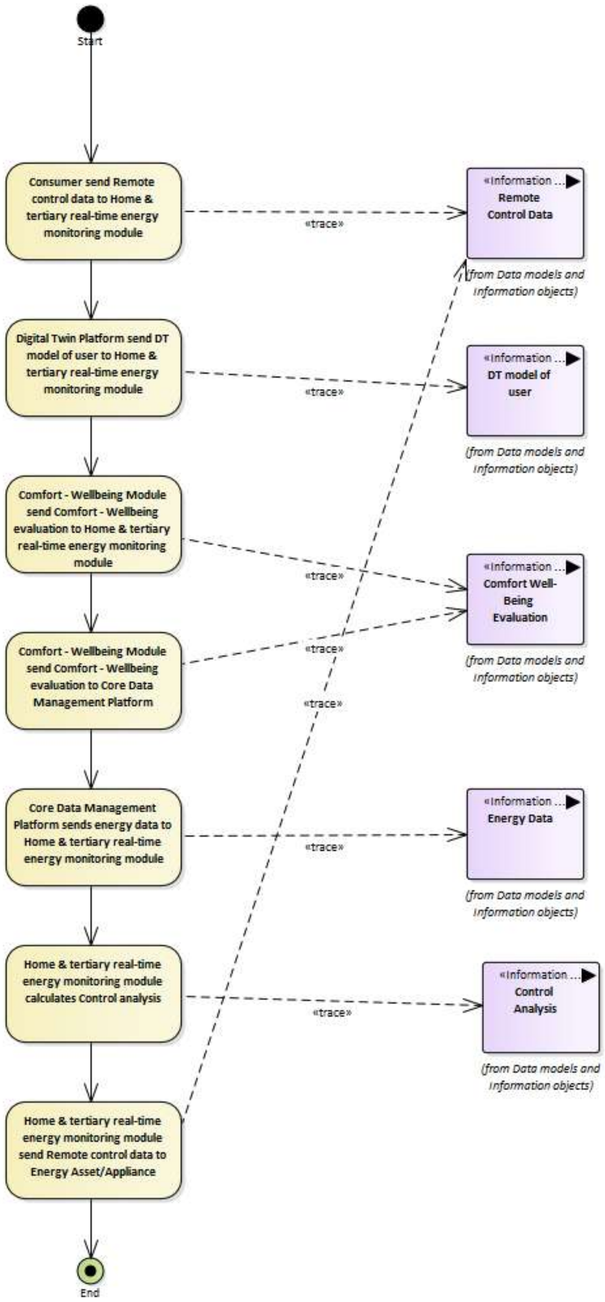

Figure 40: SGAM Activity Diagram PUC01.04

5.4.9. Sequence Diagram

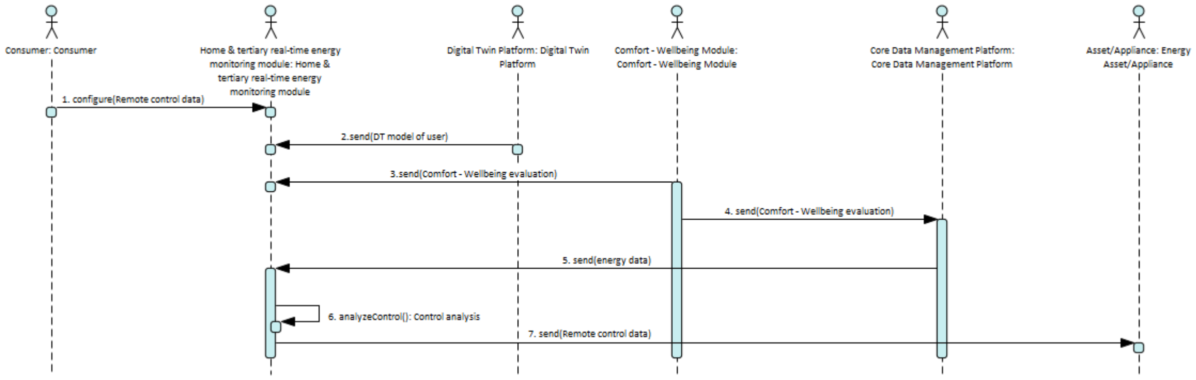

Figure 41: SGAM Sequence Diagram PUC01.04

5.5. SGAM Business Layer

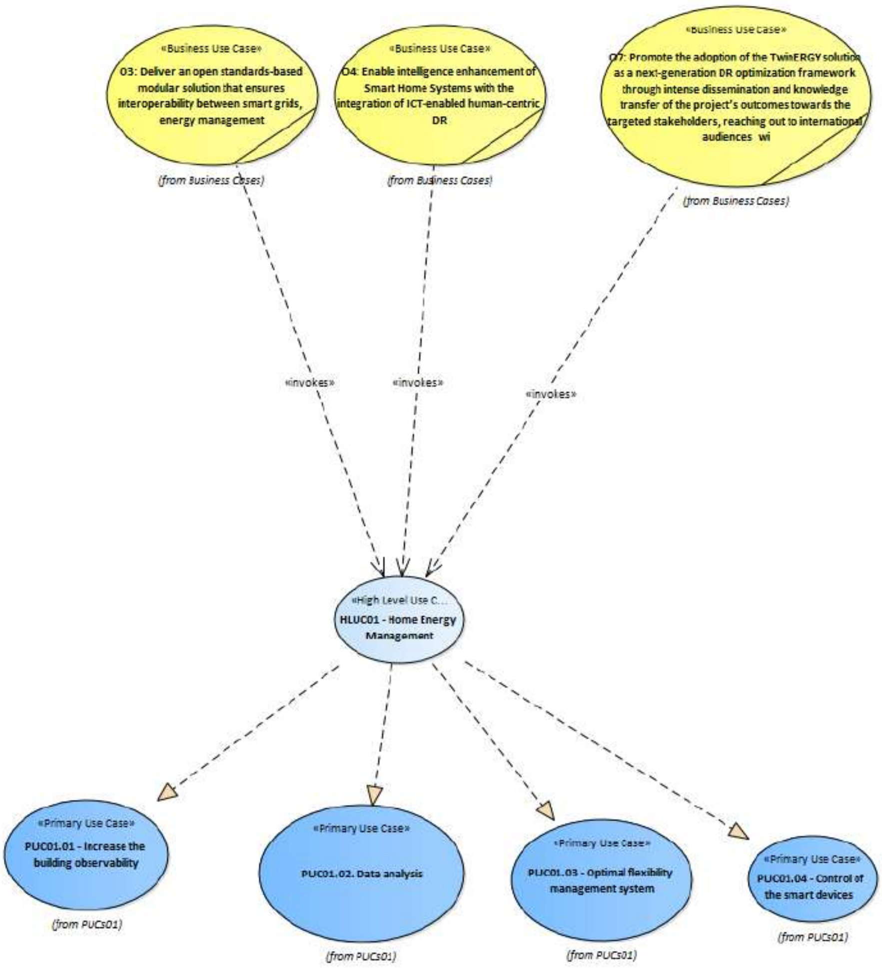

Figure 42: SGAM Business Layer HLUC01

6. HLUC 2: RES generation in domestic and tertiary buildings

6.1. PUC02.01 Dispatch of existing RES in domestic and tertiary buildings to minimise cost/carbon emissions

6.1.1. Use Case Description

This use case will be simulated in both the Neighbourhood and Consumer Demand Flexibility Profiling Modules, which are based on the Digital Twin Platform and connected to the Interoperability Platform through an API. The inputs for this use case include the weather forecast from an external source (requested from the Digital Twin Platform) and installed capacity of RES in the community. Using this, the relevant algorithm will calculate the maximum capacity available to the network to use. This can be used by community/town planners to evaluate future solutions for their community, by DSO planners and operators to plan future expansion and upgrade of the network as required and can also feed into the pricing calculation by community aggregators if required.

6.1.2. SGAM Function Layer

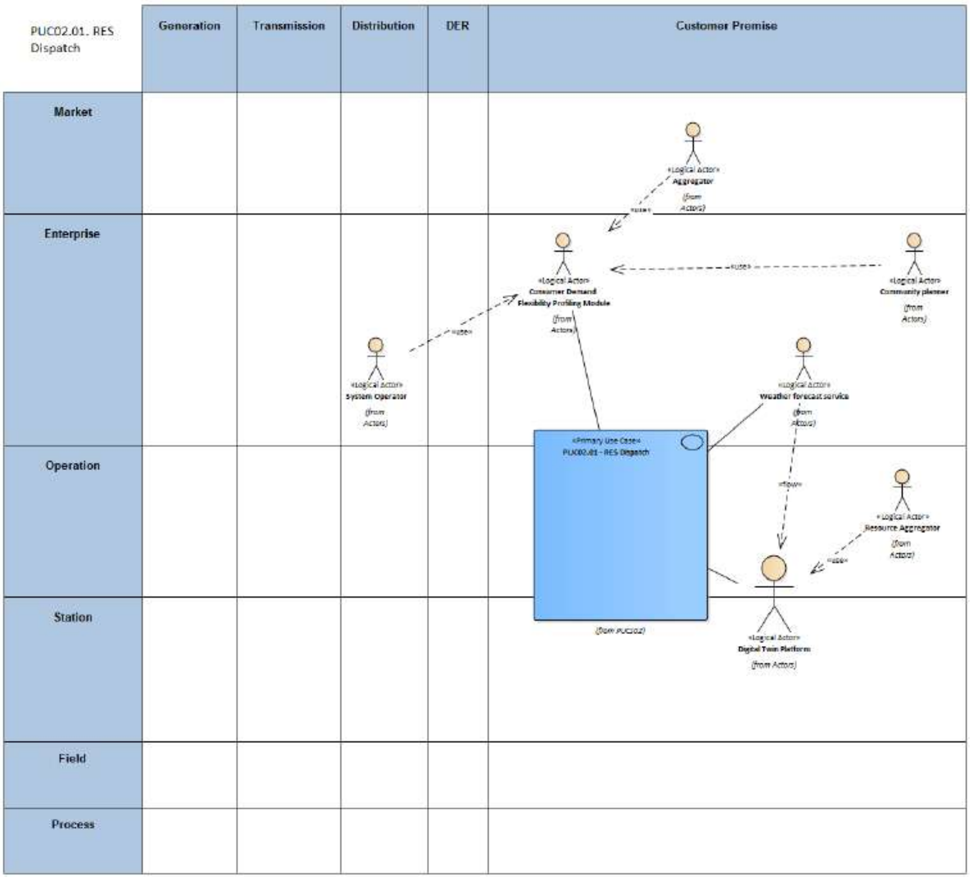

Figure 43: SGAM Function Layer PUC02.01

Table 23: List of Actors Involved PUC02.01

Actor Name	Actor Type
System Operator	Organization
Consumer Demand Flexibility Profiling Module	Application
Aggregator	Logical actor role
Community Planner	Logical actor role
Weather Forecast Service	Application
Resource Aggregator	Logical actor role
Digital Twin Platform	Application

6.1.3. SGAM Component Layer

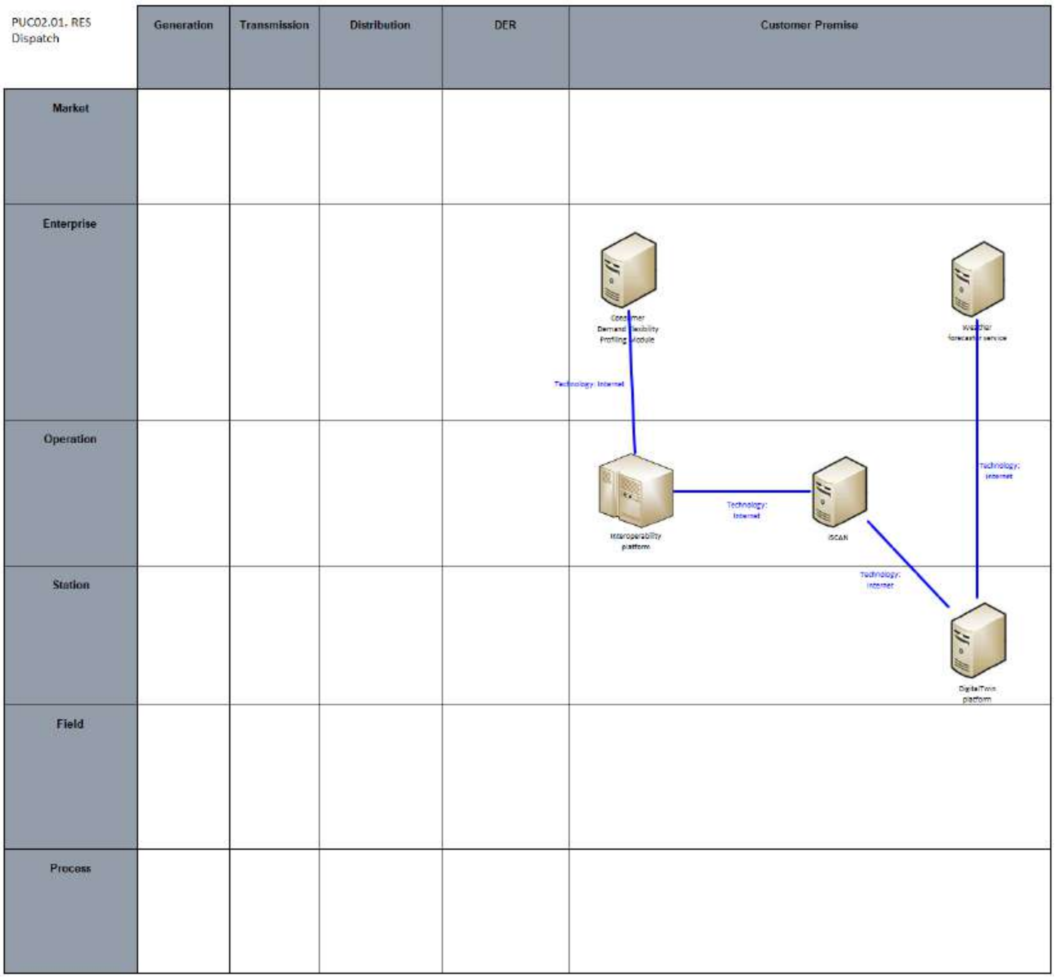

Figure 44:SGAM Component Layer PUC02.01

Table 24: List of Components PUC02.01

Component	Component Type
Consumer Demand Flexibility Profiling Module	TwinERGY application
Interoperability Platform	TwinERGY application
iSCAN	External application
Digital Twin Platform	TwinERGY application
Weather forecast service	External application

6.1.4. SGAM Communication Layer

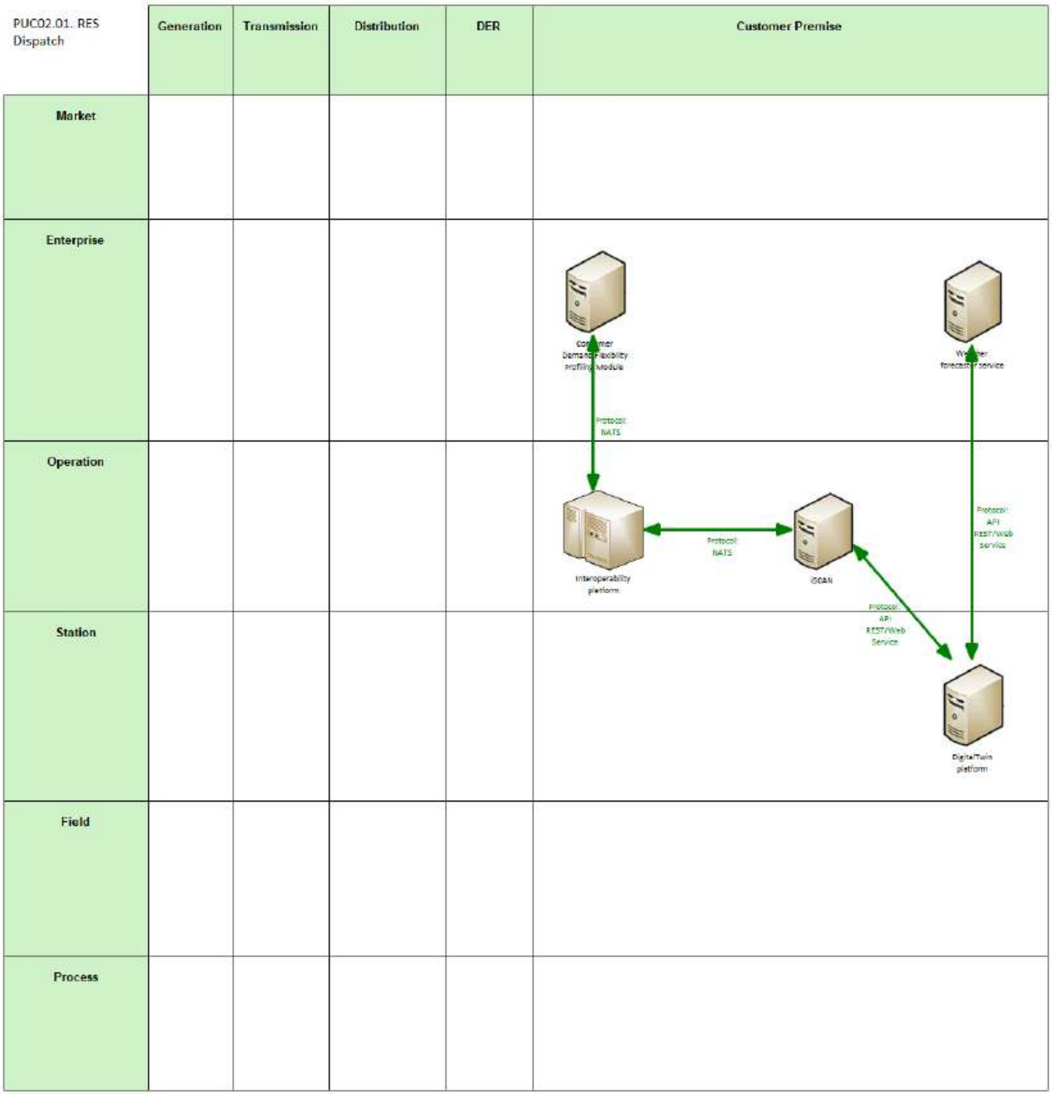

Figure 45: SGAM Communication Layer PUC02.01

Twinergy has received funding from the European Union's Horizon 2020 research and innovation programme under grant agreement No. 957736

Table 25: List of Communication technologies involved in PUC02.01

Communication Technology	Description
NATS	Protocol of messaging that enables the exchange of messages among computer applications and services, not depending on the network location.
API REST	Application Programming Interface for REpresentational State Transfer. API is a software intermediary that allows two applications to talk to each other, whilst REST is an architectural style for distributed hypermedia systems, working stateless. Both define a set of distributed resources accessible and manipulable through a set of public functions.

6.1.5. SGAM Information Layer

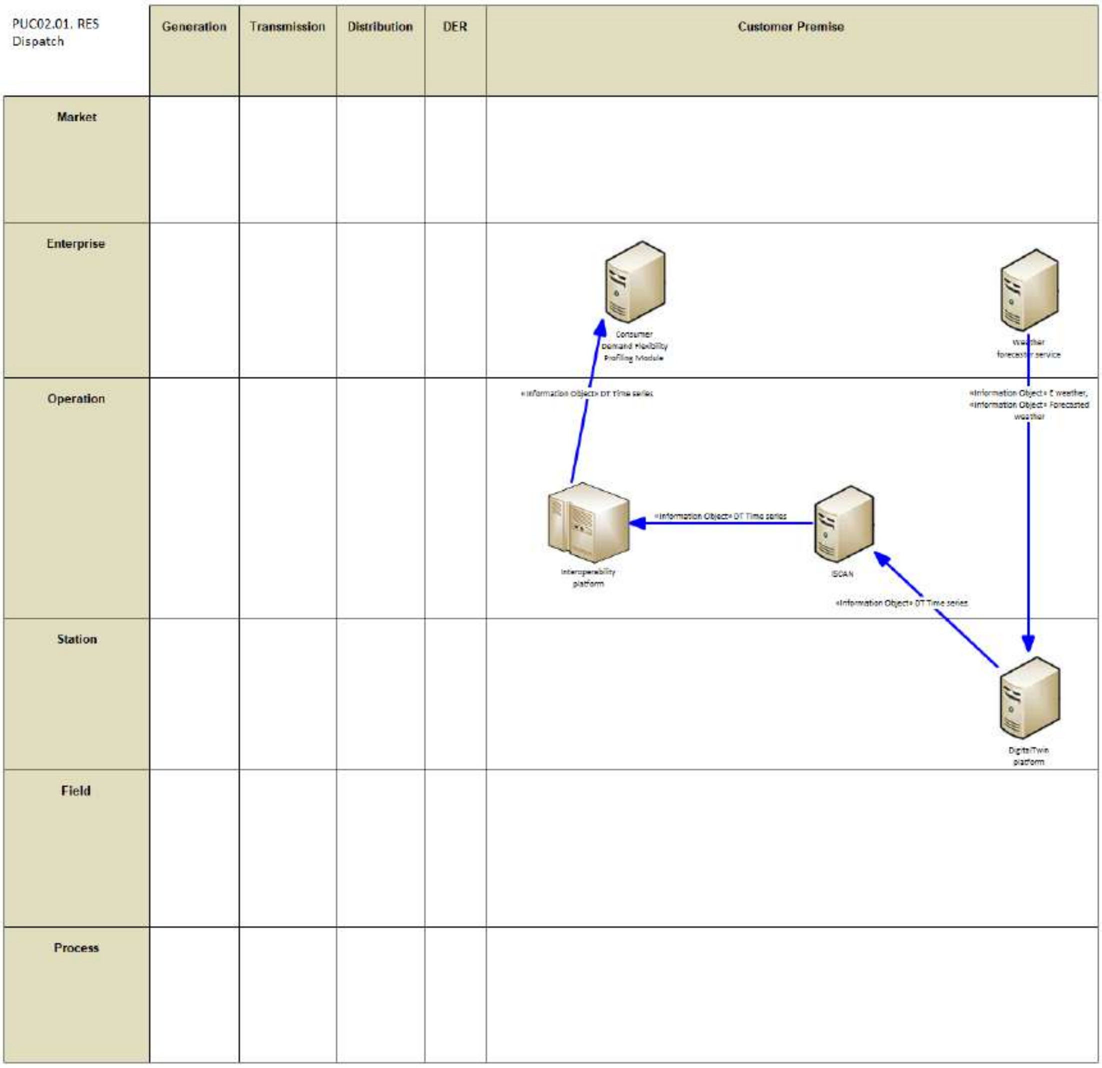

Figure 46: SGAM Information Layer PUC02.01

6.1.6. Canonical Data Model

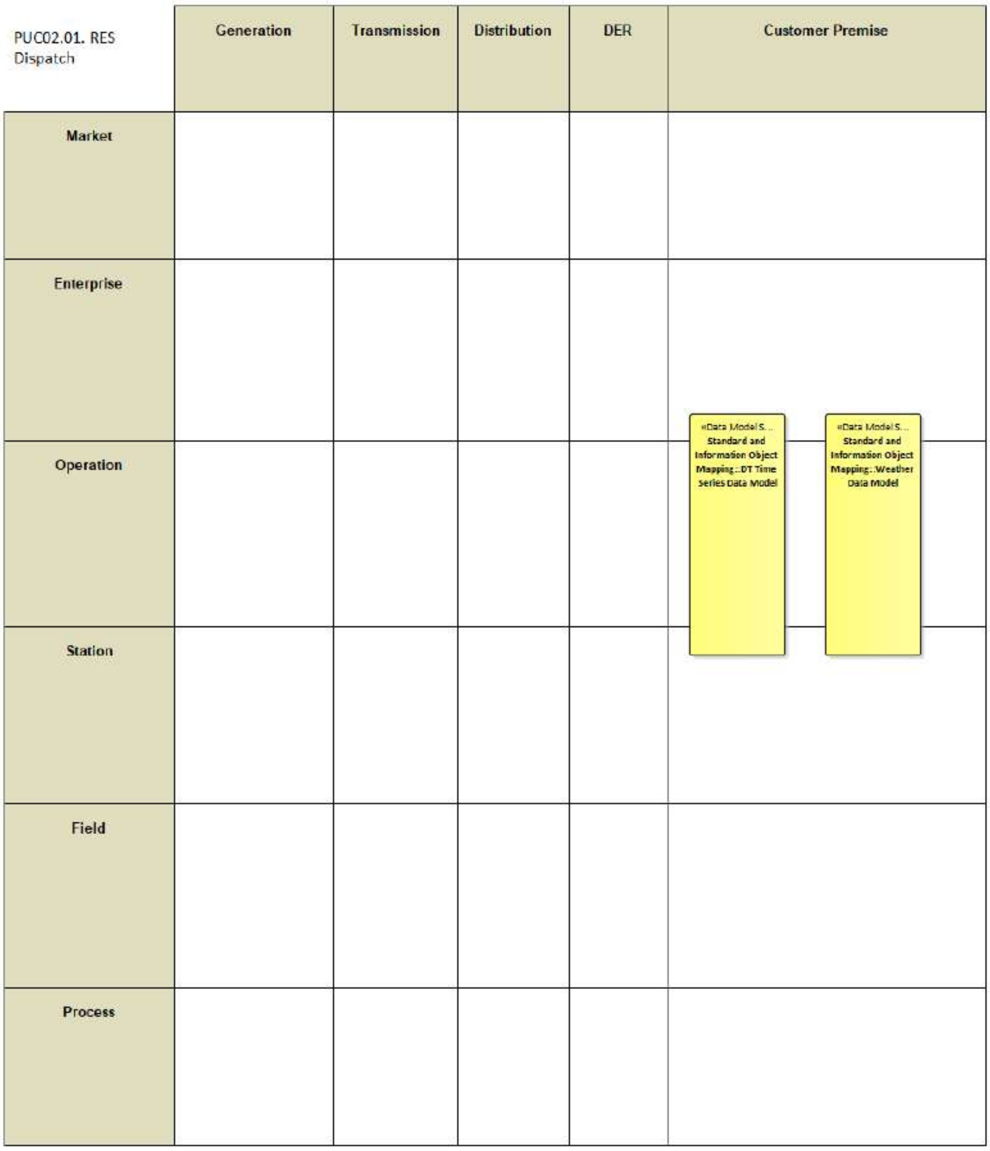

Figure 47: SGAM Canonical Data Model PUC02.01

Table 26: List of Data Models PUC02.01

Data Models
DT Time Series Data Model
Weather Data Model

Twinergy has received funding from the European Union's Horizon 2020 research and innovation programme under grant agreement No. 957736

6.1.7. Standards and Information Object Mapping

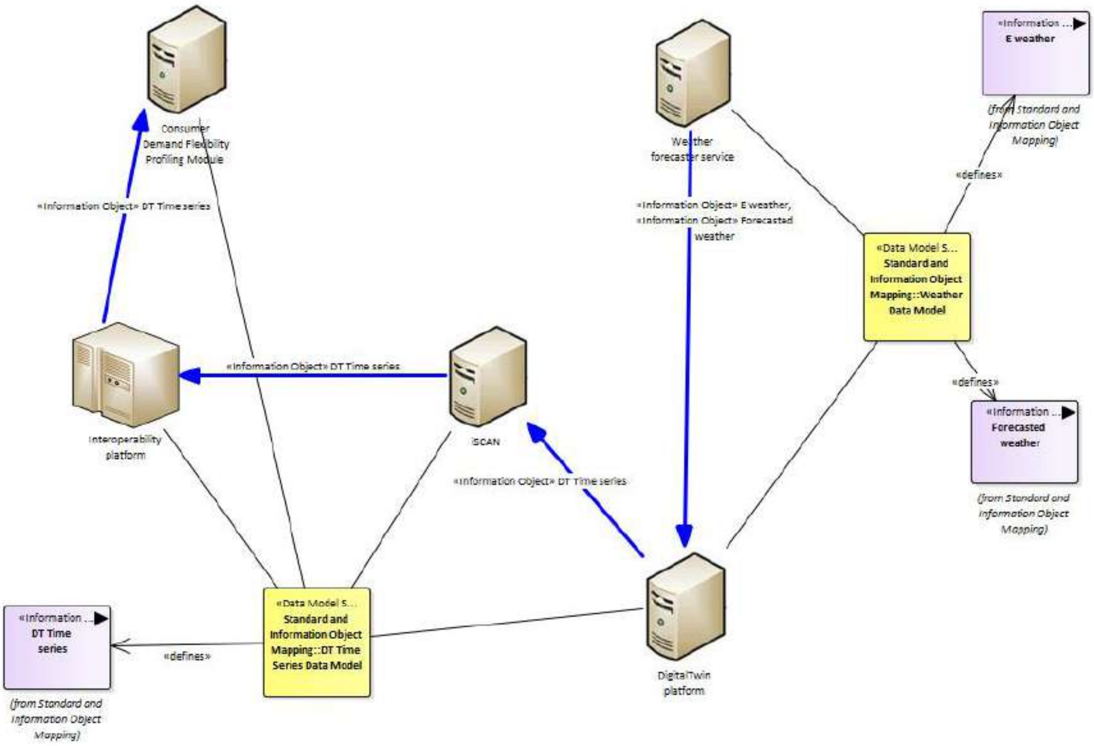

Figure 48: SGAM Standards and Information Object Mapping PUC02.01

Table 27: List of Information Objects PUC02.01

Information Objects	Data Models
E weather	Weather Data Model
Forecasted weather	Weather Data Model
DT Time Series	DT Time Series Data Model

6.1.8. Activity Diagram

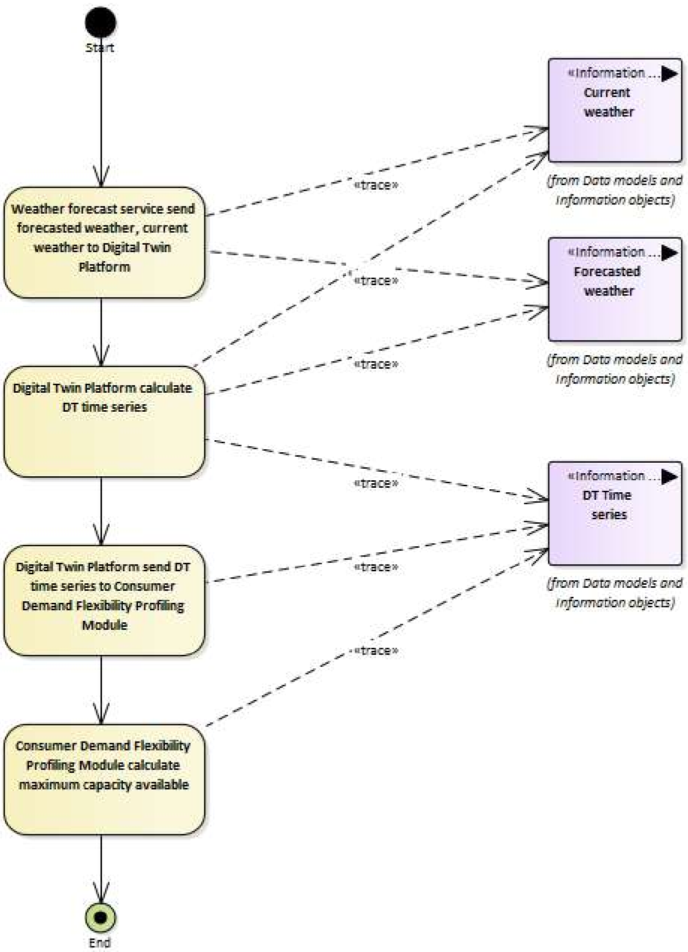

Figure 49: SGAM Activity Diagram PUC02.01

6.1.9. Sequence Diagram

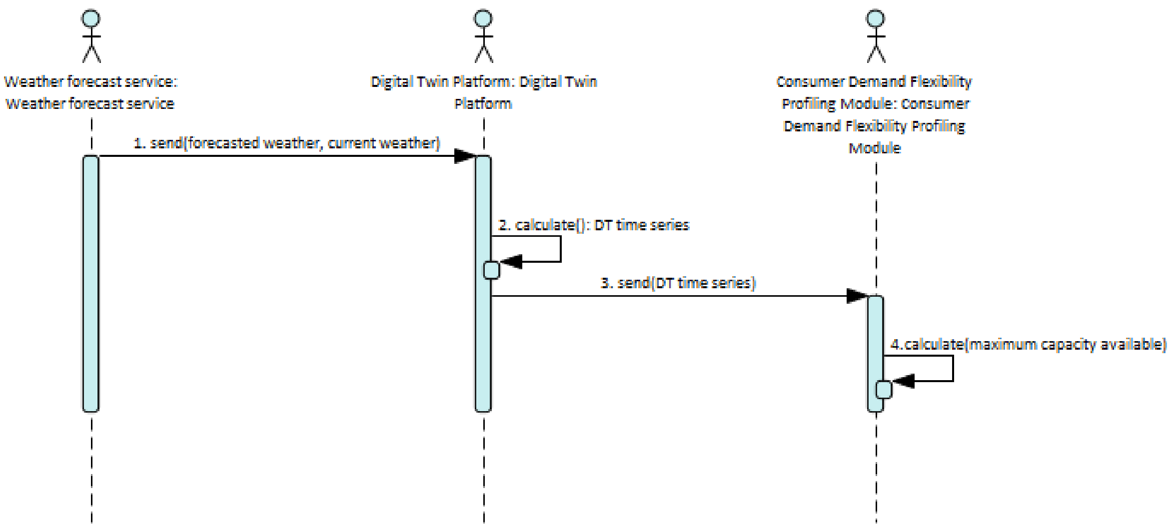

Figure 50: SGAM Sequence Diagram PUC02.01

Twinergy has received funding from the European Union's Horizon 2020 research and innovation programme under grant agreement No. 957736

6.2. PUC02.02 Optimal future energy storage to maximise RES production

6.2.1. Use Case Description

The Digital Twin Platform and associated optimisation algorithm within the tool will calculate the optimal installation of energy storage to maximise renewable generation, which forms the main part of both the Neighbourhood and Consumer Demand Flexibility Profiling modules. The inputs will include installed renewable capacity and other relevant constraints such as capital costs and will output the optimised solution in terms of energy storage. This information can then be used by other modules within the TwinERGY architecture through the Interoperability Platform. This can be used by community/town planners to evaluate future solutions for their community, by DSO planners and operators to plan future expansion and upgrade of the network as required and can also feed into the pricing calculation by community aggregators if required.

6.2.2. SGAM Function Layer

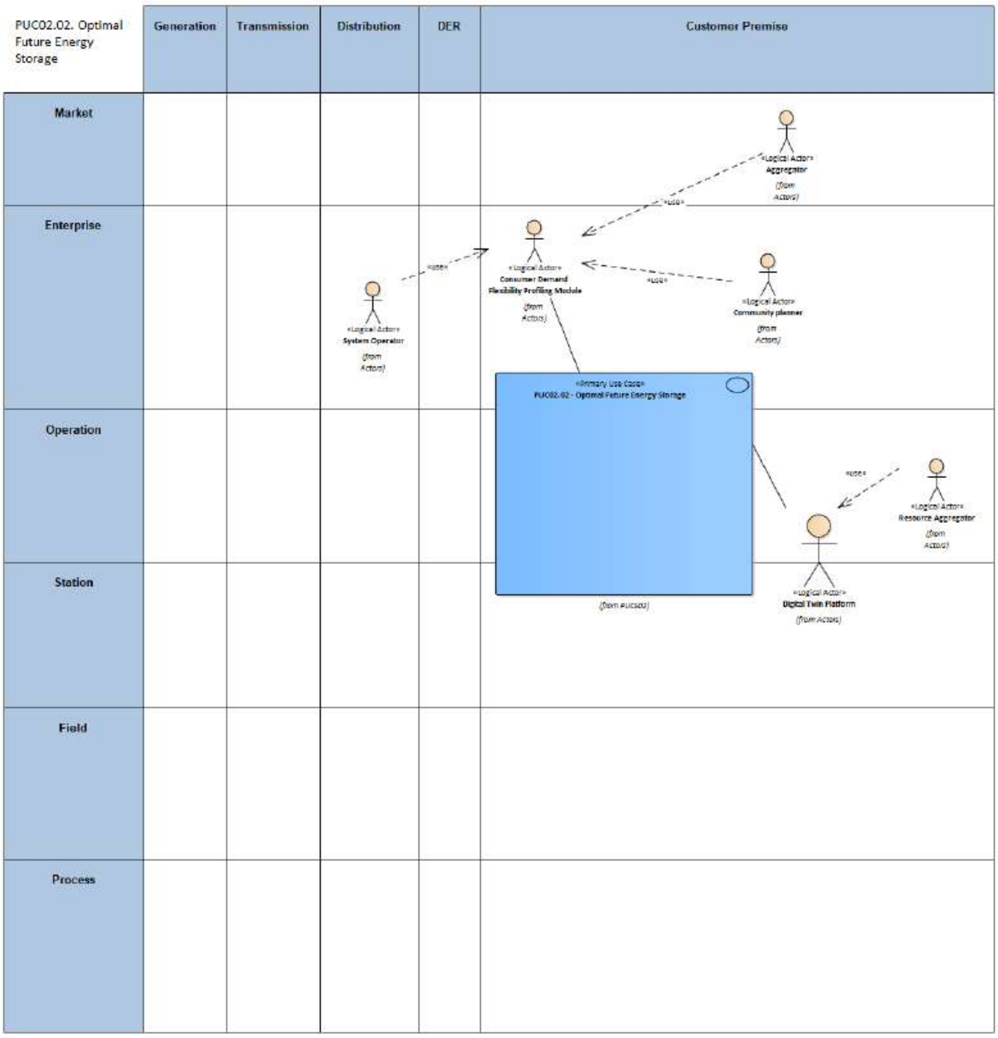

Figure 51: SGAM Function Layer PUC02.02

Twinergy has received funding from the European Union's Horizon 2020 research and innovation programme under grant agreement No. 957736

Table 28: List of Actors Involved PUC02.02

Actor Name	Actor Type
System Operator	Organization
Consumer Demand Flexibility Profiling Module	Application
Aggregator	Logical actor role
Community Planner	Logical actor role
Resource Aggregator	Logical actor role
Digital Twin Platform	Application

6.2.3. SGAM Component Layer

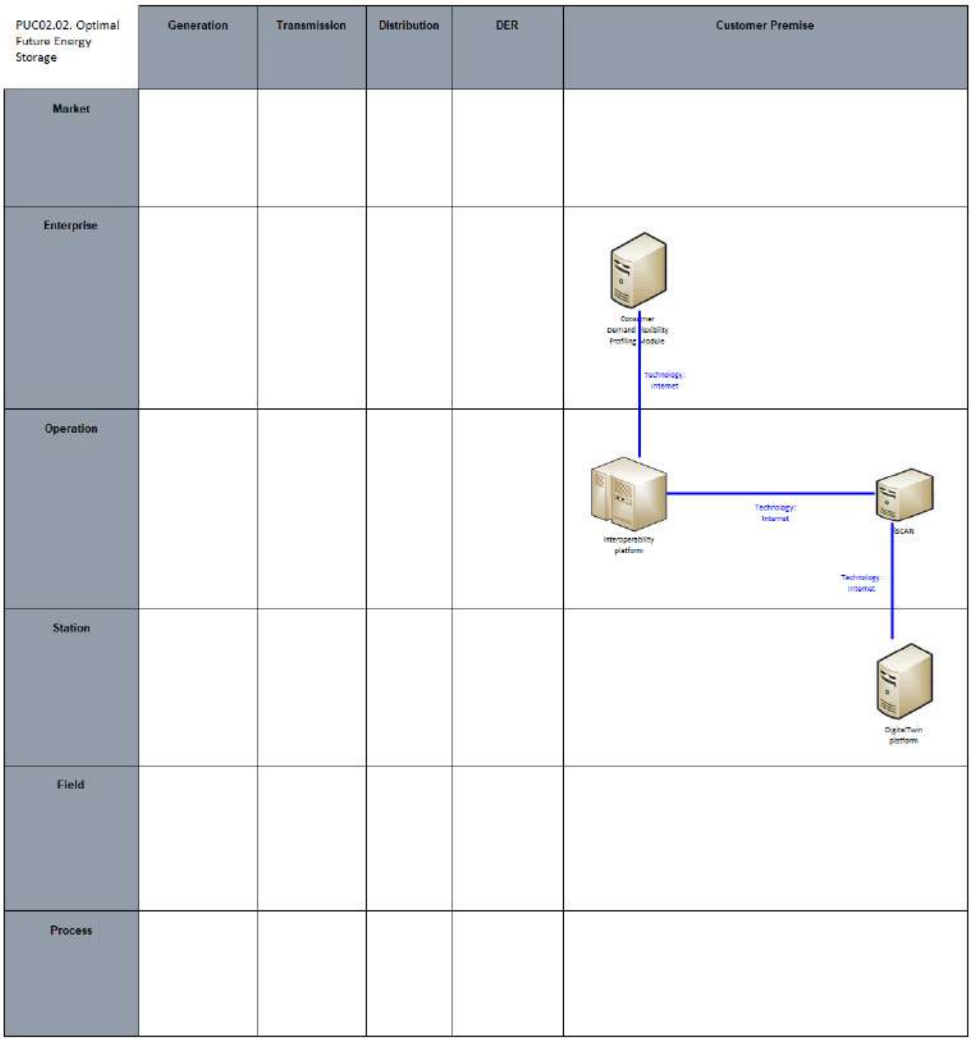

Figure 52: SGAM Component Layer PUC02.02

Table 29: List of Components PUC02.02

Component	Component Type
Consumer Demand flexibility Profiling Module	TwinERGY application
Interoperability Platform	TwinERGY application
iSCAN	External application
Digital Twin Platform	TwinERGY application

6.2.4. SGAM Communication Layer

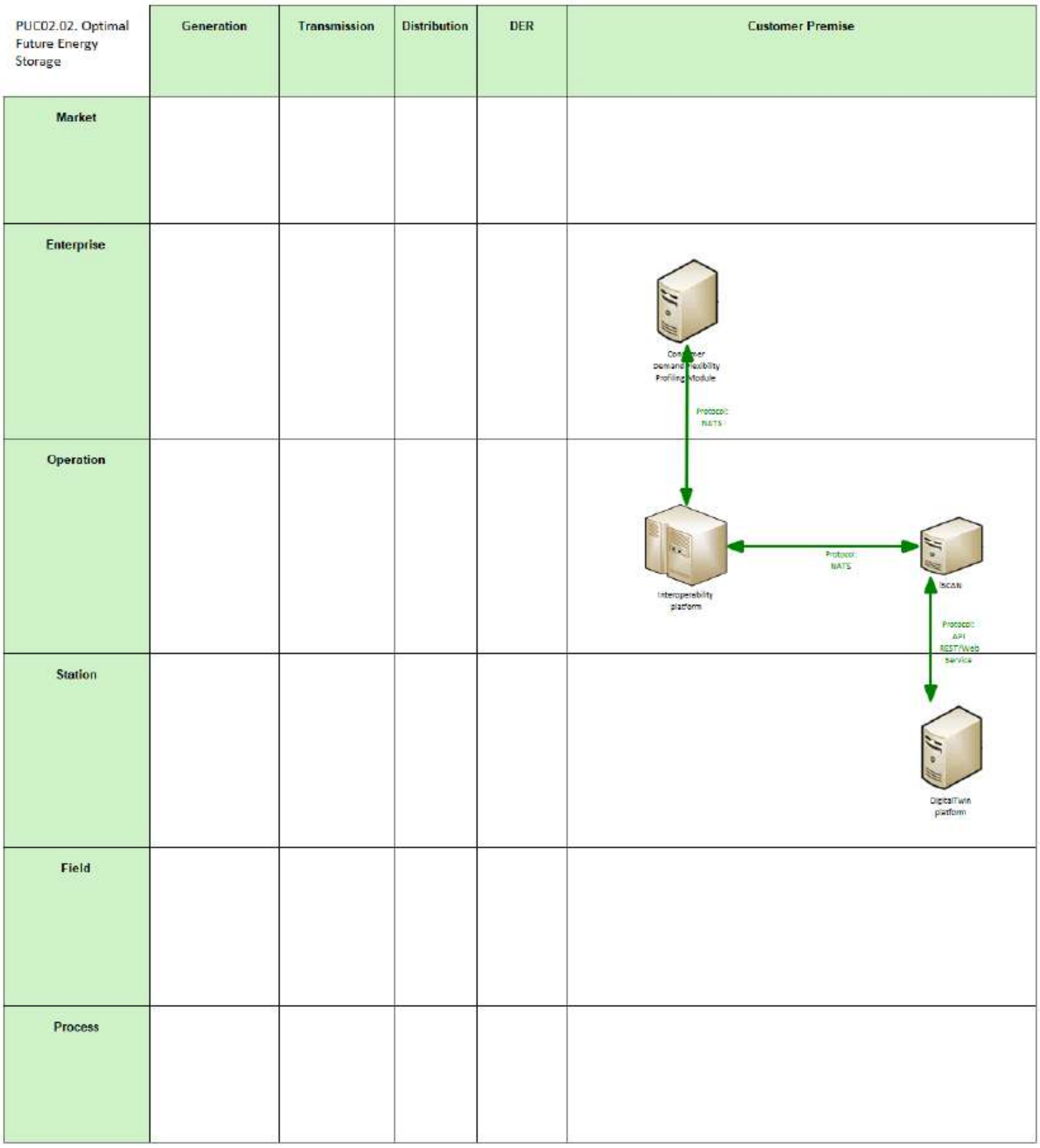

Figure 53: SGAM Communication Layer PUC02.02

Table 30: List of Communication technologies involved in PUC02.02

Communication Technology	Description
NATS	Protocol of messaging that enables the exchange of messages among computer applications and services, not depending on the network location.
API REST	Application Programming Interface for REpresentational State Transfer. API is a software intermediary that allows two applications to talk to each other, whilst REST is an architectural style for distributed hypermedia systems, working stateless. Both define a set of distributed resources accessible and manipulable through a set of public functions.

6.2.5. SGAM Information Layer

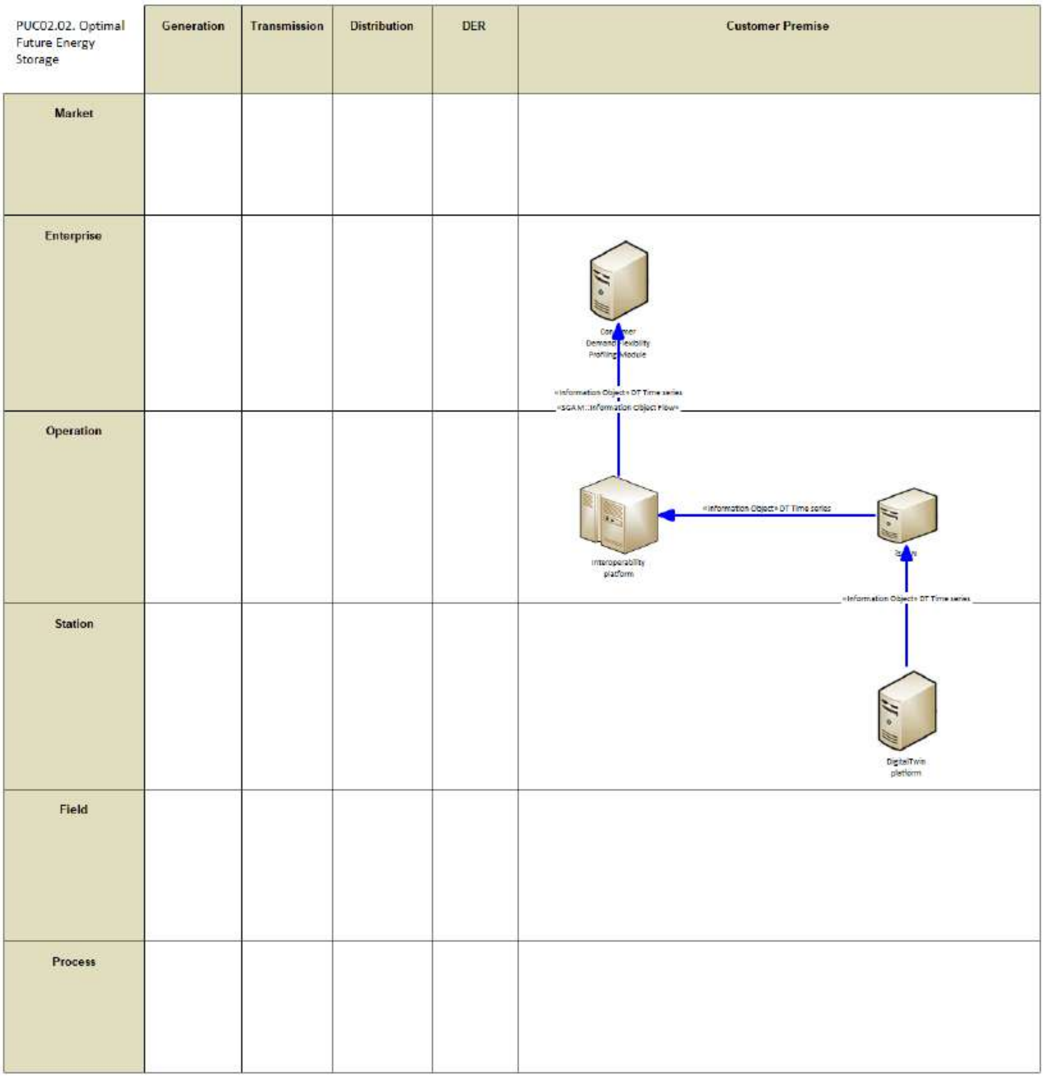

Figure 54: SGAM Information Layer PUC02.02

6.2.6. Canonical Data Model

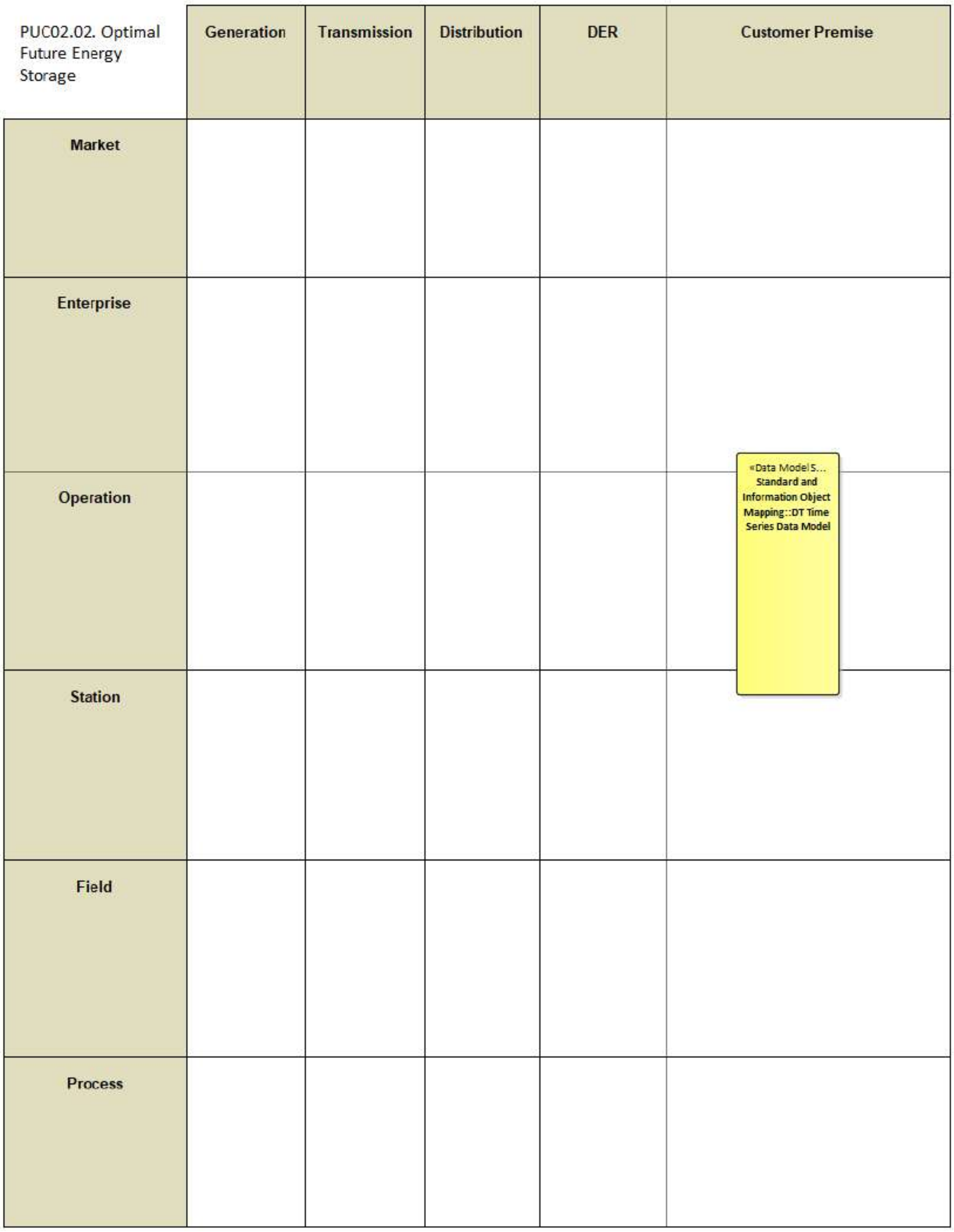

Figure 55: SGAM Canonical Data Model PUC02.02

Table 31: List of Data Models PUC02.02

Data Models
DT Time Series Data Model

6.2.7. Standards and Information Object Mapping

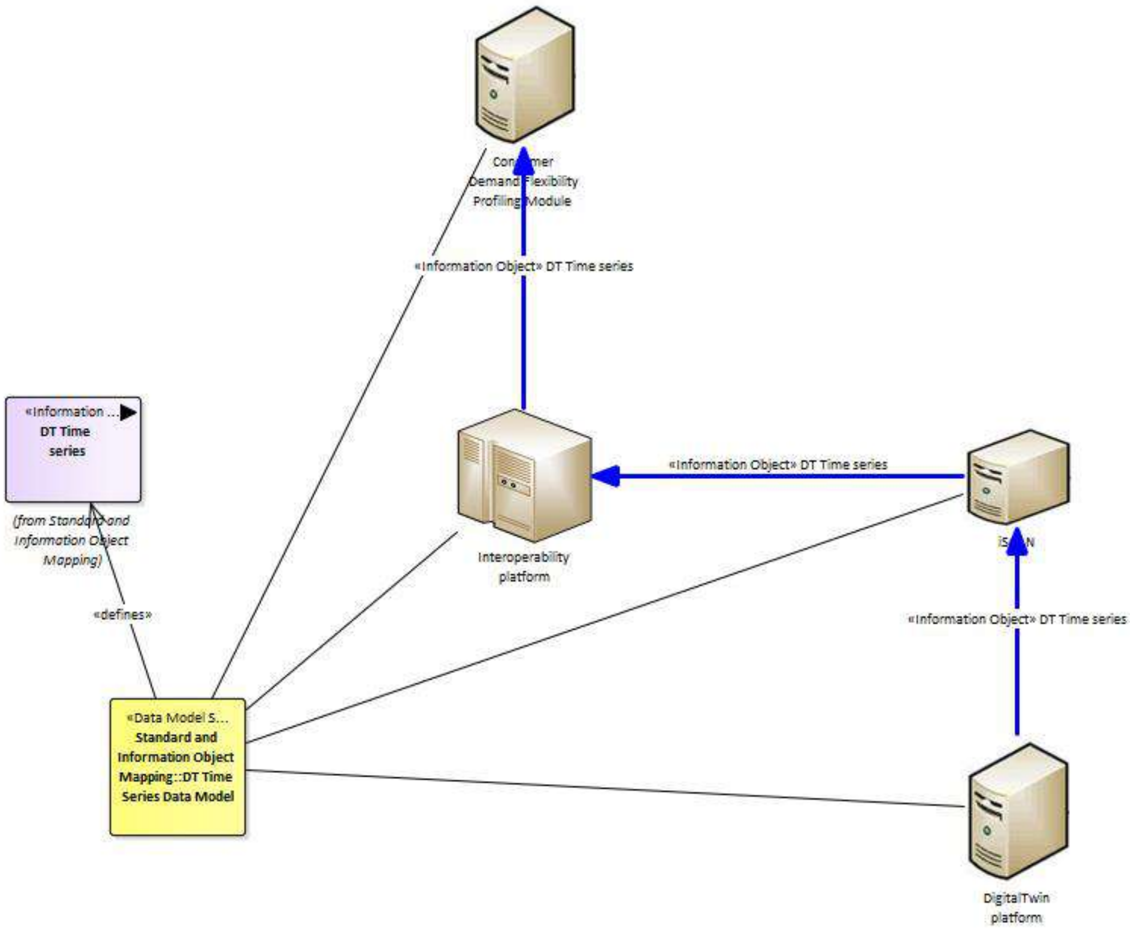

Figure 56: SGAM Standards and Information Object Mapping PUC02.02

Table 32: List of Information Objects PUC02.02

Information Objects	Data Models
DT Time series	DT Time series Data model

6.2.8. Activity Diagram

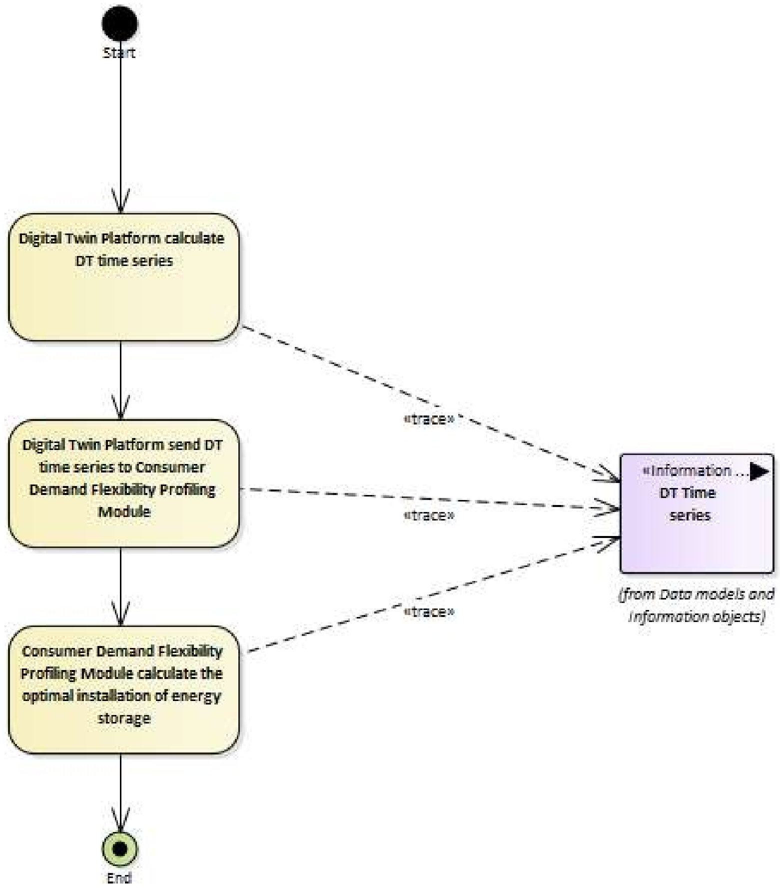

Figure 57: SGAM Activity Diagram PUC02.02

6.2.9. Sequence Diagram

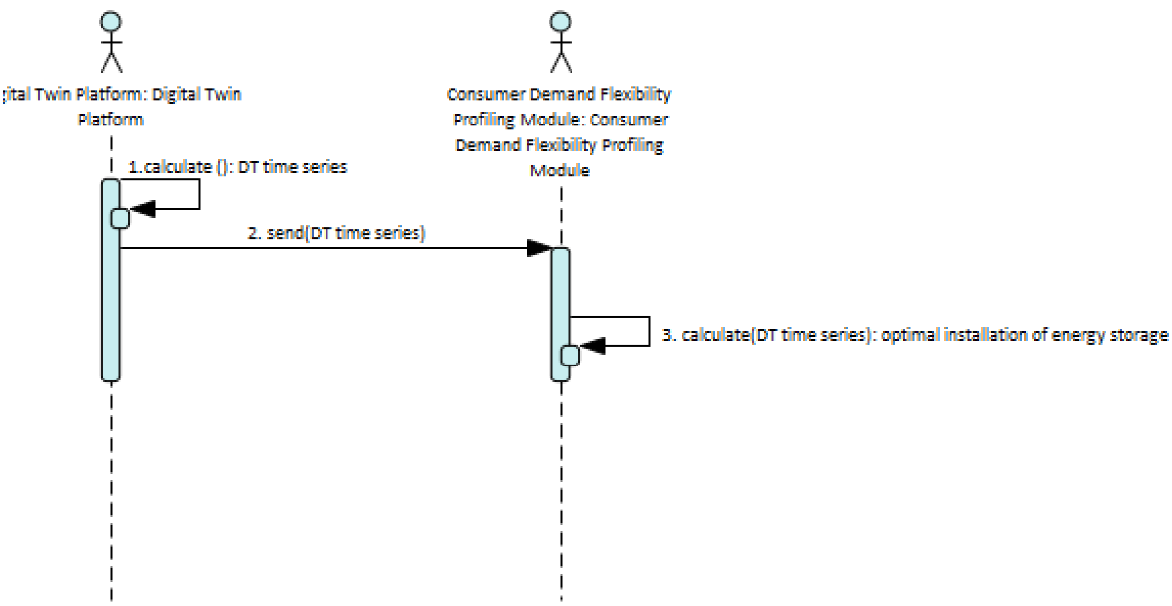

Figure 58: SGAM Sequence Diagram PUC02.02

6.3. PUC02.03 Maximum future RES capacity

6.3.1. Use Case Description

The Digital Twin Platform and associated optimisation algorithm within the Neighbourhood and Consumer Demand Flexibility Profiling modules will calculate the optimal installation of renewable generation. The inputs will include installed renewable capacity and other relevant constraints such as capital costs and will output the optimised solution in terms of RES which in turn will be available to the other TwinERGY modules through the Interoperability Platform. This can be used by community/town planners to evaluate future solutions for their community, by DSO planners and operators to plan future expansion and upgrade of the network as required and can also feed into the pricing calculation by community aggregators if required.

6.3.2. SGAM Function Layer

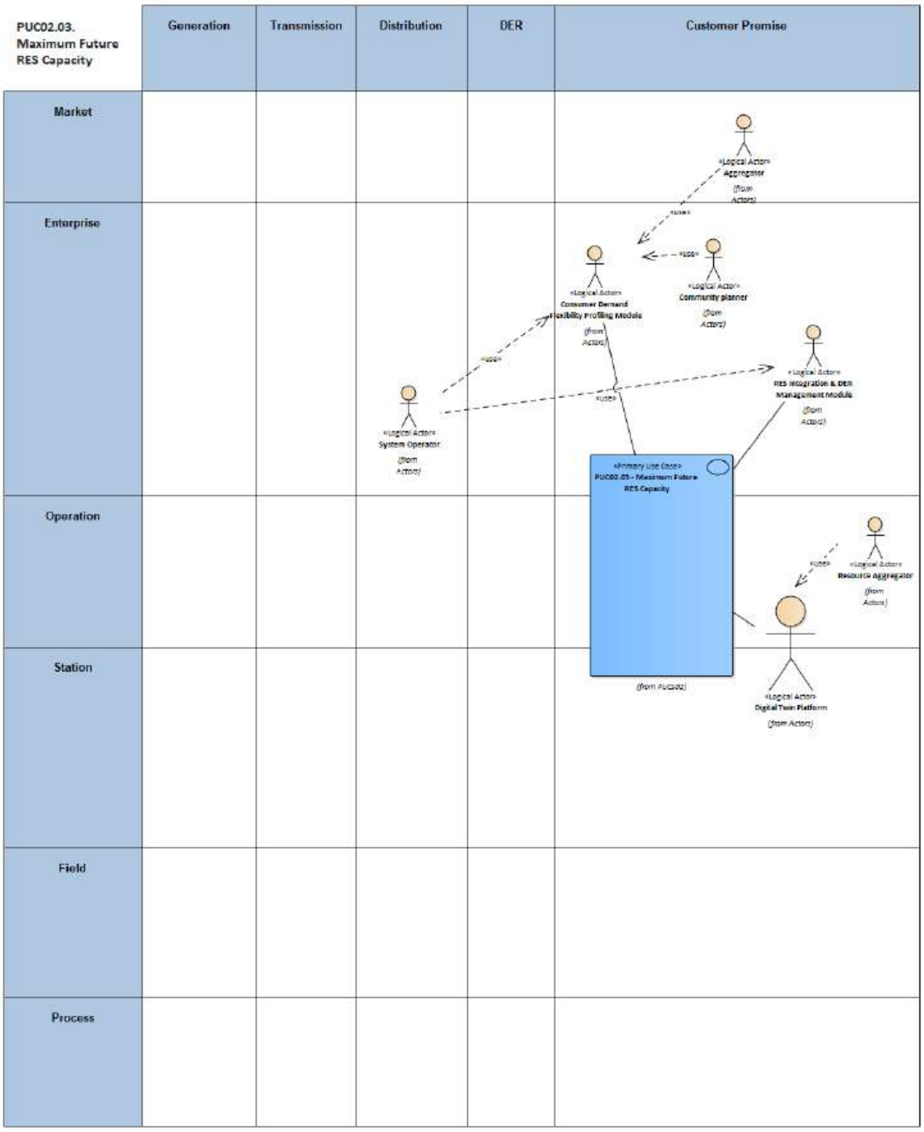

Figure 59: SGAM Function Layer PUC02.03

Twinergy has received funding from the European Union's Horizon 2020 research and innovation programme under grant agreement No. 957736

Table 33: List of Actors Involved PUC02.03

Actor Name	Actor Type
System Operator	Organization
Consumer Demand Flexibility Profiling Module	Application
RES Integration & DER Management Module	Application
Aggregator	Logical actor role
Community Planner	Logical actor role
Resource Aggregator	Logical actor role
Digital Twin Platform	Application

6.3.3. SGAM Component Layer

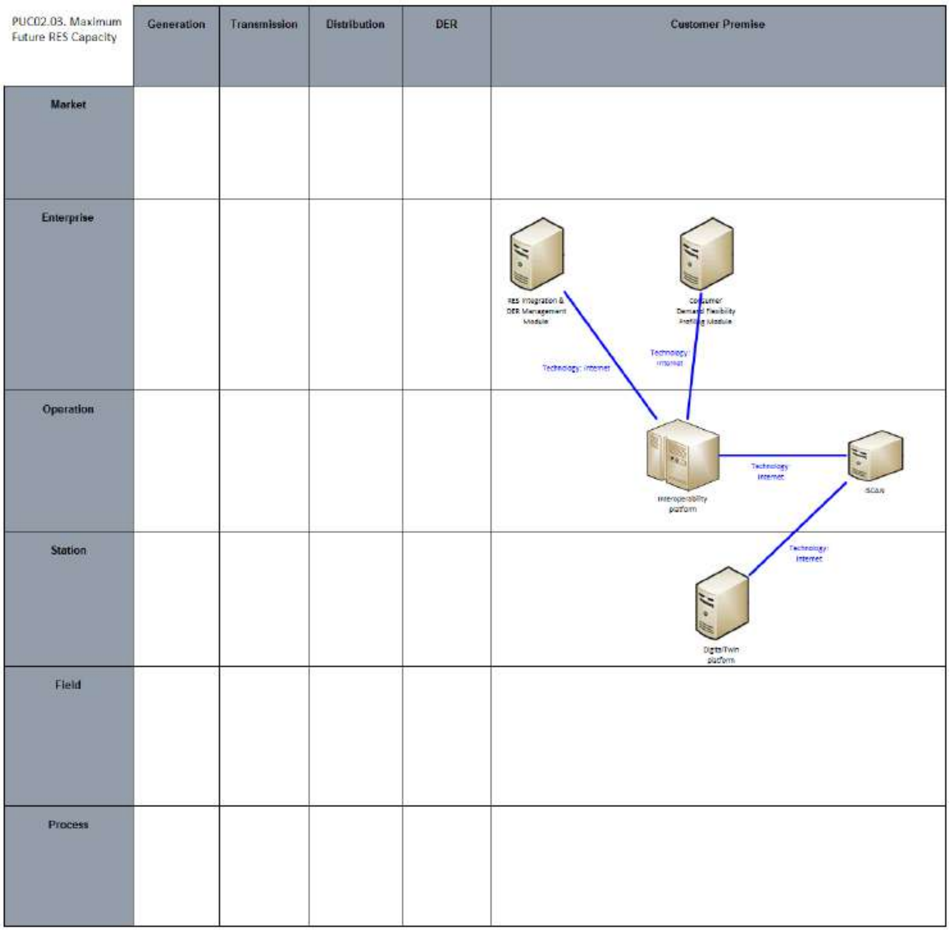

Figure 60: SGAM Component Layer PUC02.03

Table 34: List of Components PUC02.03

Component	Component Type
RES integration & DER Management Module	TwinERGY application
Consumer Demand Flexibility Profiling Module	TwinERGY application
Interoperability Platform	TwinERGY application
iSCAN	External application
Digital Twin Platform	TwinERGY application

6.3.4. SGAM Communication Layer

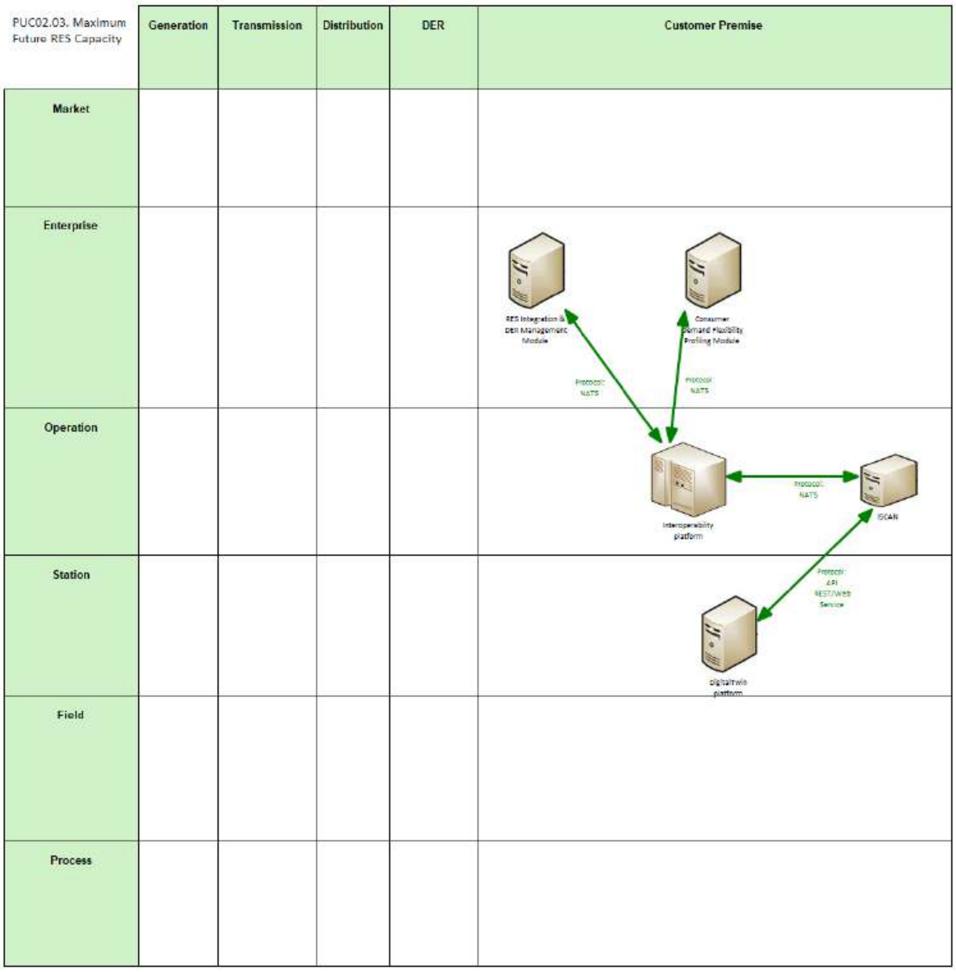

Figure 61: SGAM Communication Layer PUC02.03

Table 35: List of Communication technologies involved in PUC02.03

Communication Technology	Description
NATS	Protocol of messaging that enables the exchange of messages among computer applications and services, not depending on the network location.
API REST	Application Programming Interface for REpresentational State Transfer. API is a software intermediary that allows two applications to talk to each other, whilst REST is an architectural style for distributed hypermedia systems, working stateless. Both define a set of distributed resources accessible and manipulable through a set of public functions.

6.3.5. SGAM Information Layer

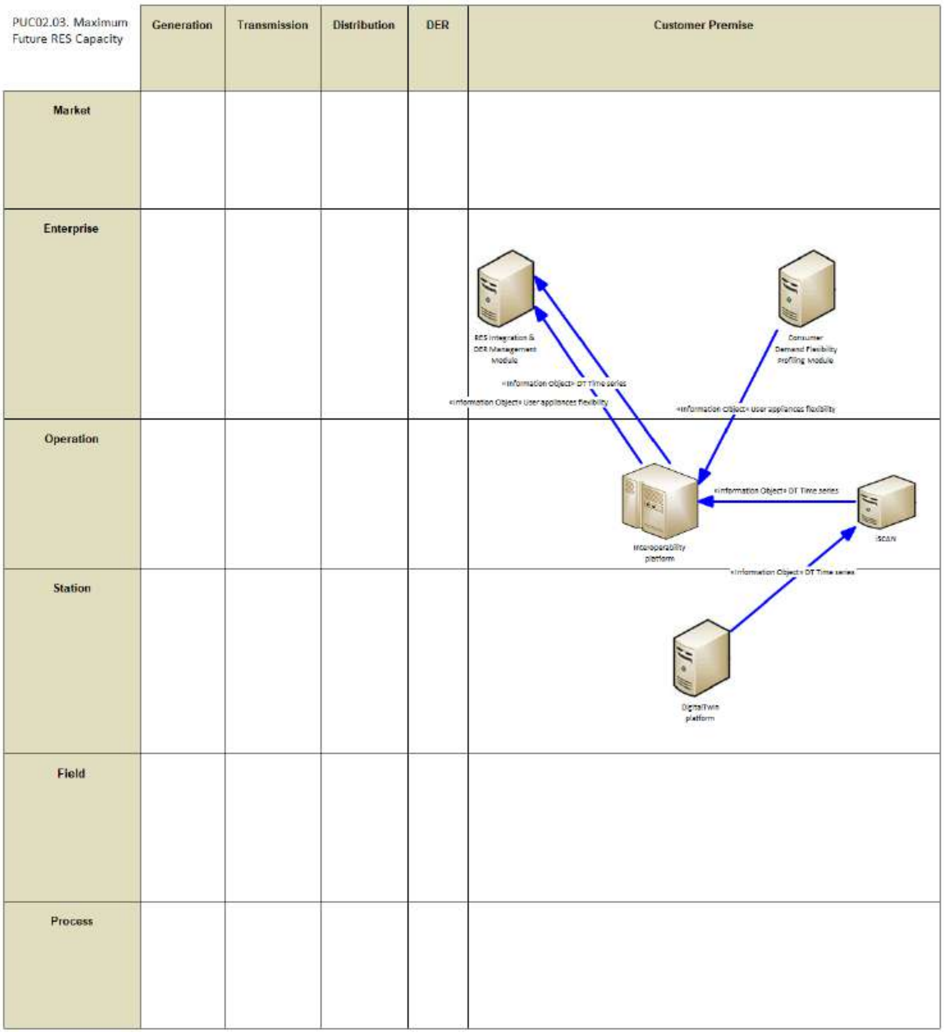

Figure 62: SGAM Information Layer PUC02.03

6.3.6. Canonical Data Model

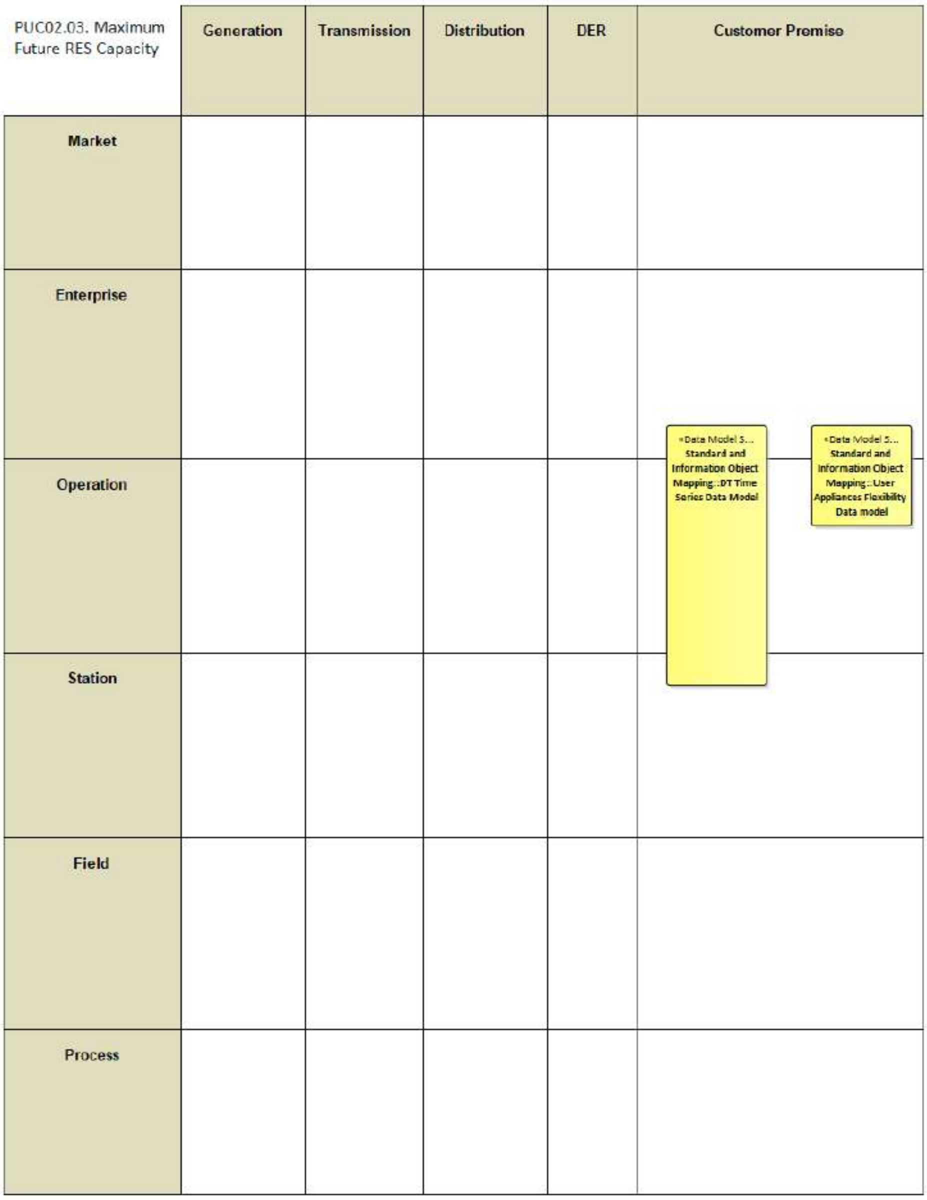

Figure 63: SGAM Canonical Data Model PUC02.03

Table 36: List of Data Models PUC02.03

Data Models
DT Time Series Data Model
User Appliances Flexibility Data Model

6.3.7. Standards and Information Object Mapping

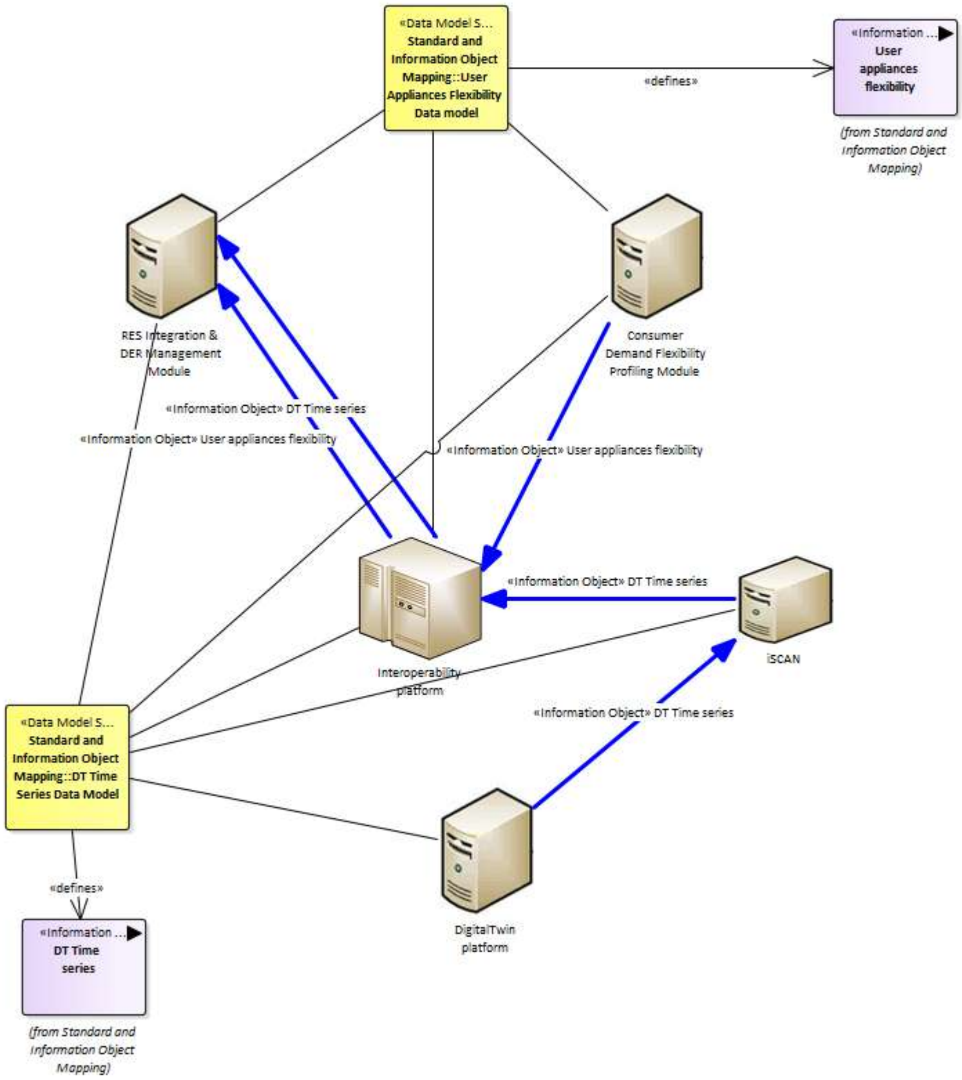

Figure 64: SGAM Standards and Information Object Mapping PUC02.03

Table 37: List of Information Objects PUC02.03

Information Objects	Data Models
User appliances flexibility	User Appliances Flexibility Data model
DT Time Series	DT Time Series Data Model

6.3.8. Activity Diagram

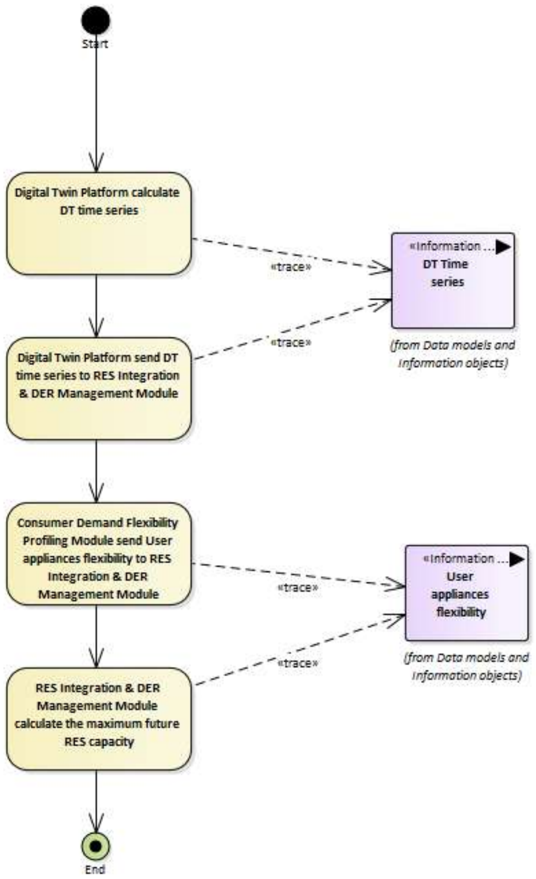

Figure 65: SGAM Activity Diagram PUC02.03

6.3.9. Sequence Diagram

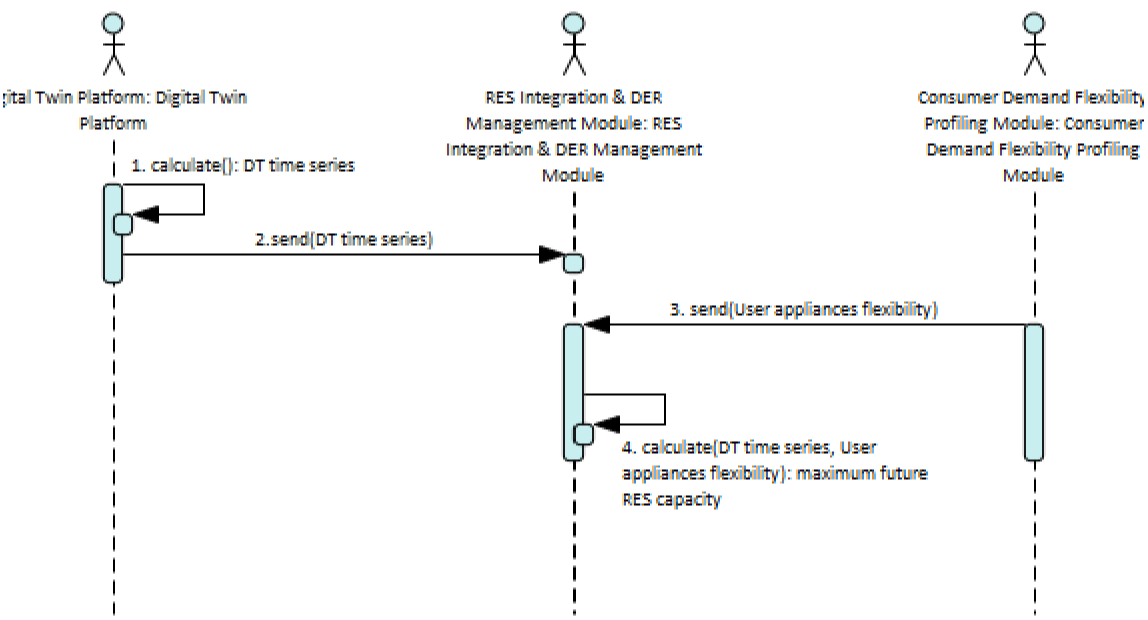

Figure 66: SGAM Sequence Diagram PUC02.03

6.4. PUC02.04 Optimal CHP solution specific to the pilot site in terms of capital costs and network capacity

6.4.1. Use Case Description

The Digital Twin Platform and associated optimisation algorithm within the Neighbourhood and Consumer Demand Flexibility Profiling Modules will calculate the optimal CHP installation. The inputs will include all information about the buildings and networks at present and other relevant constraints such as costs and will output the optimised solution including a CHP installation which in turn will be made available to the other TwinERGY modules through the Interoperability Platform. This can be used by community/town planners to evaluate future solutions for their community, by DSO planners and operators to plan future expansion and upgrade of the network as required and can also feed into the pricing calculation by community aggregators if required.

6.4.2. SGAM Function Layer

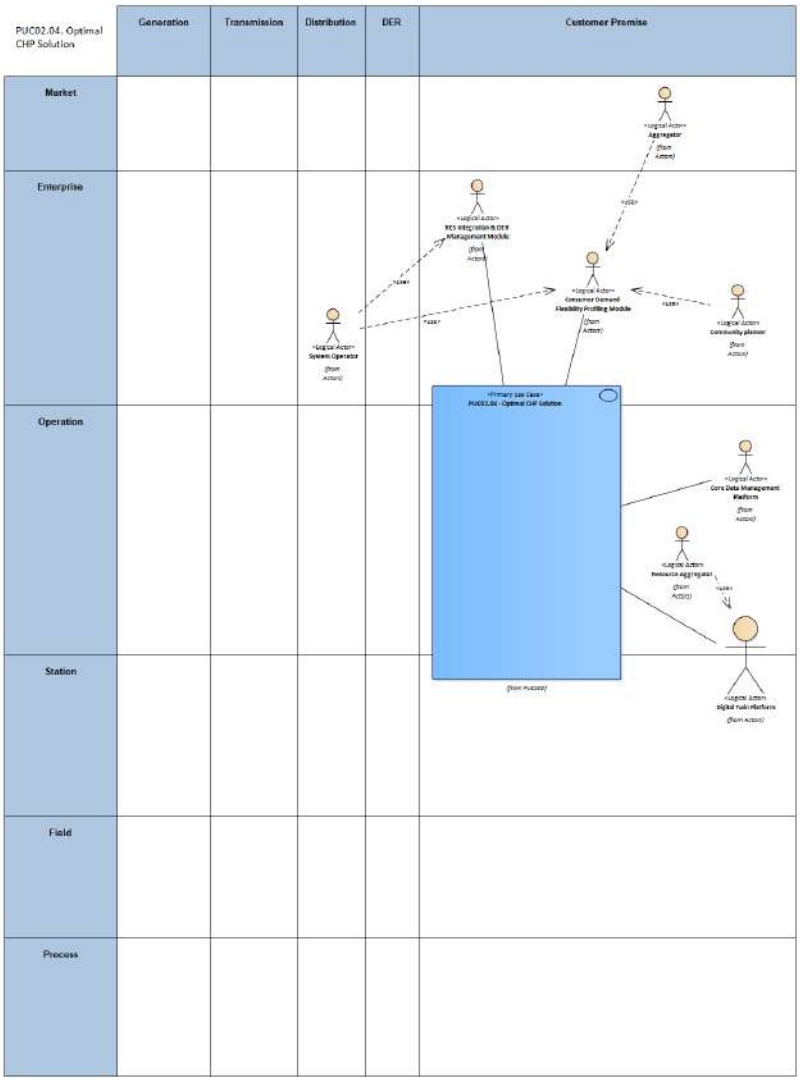

Figure 67: SGAM Function Layer PUC02.04

Table 38: List of Actors Involved PUC02.04

Actor Name	Actor Type
System Operator	Organization
Consumer Demand Flexibility Profiling Module	Application
RES Integration & DER Management Module	Application
Aggregator	Logical actor role
Community Planner	Logical actor role
Resource Aggregator	Logical actor role
Core Data Management Platform	Application
Digital Twin Platform	Application

6.4.3. SGAM Component Layer

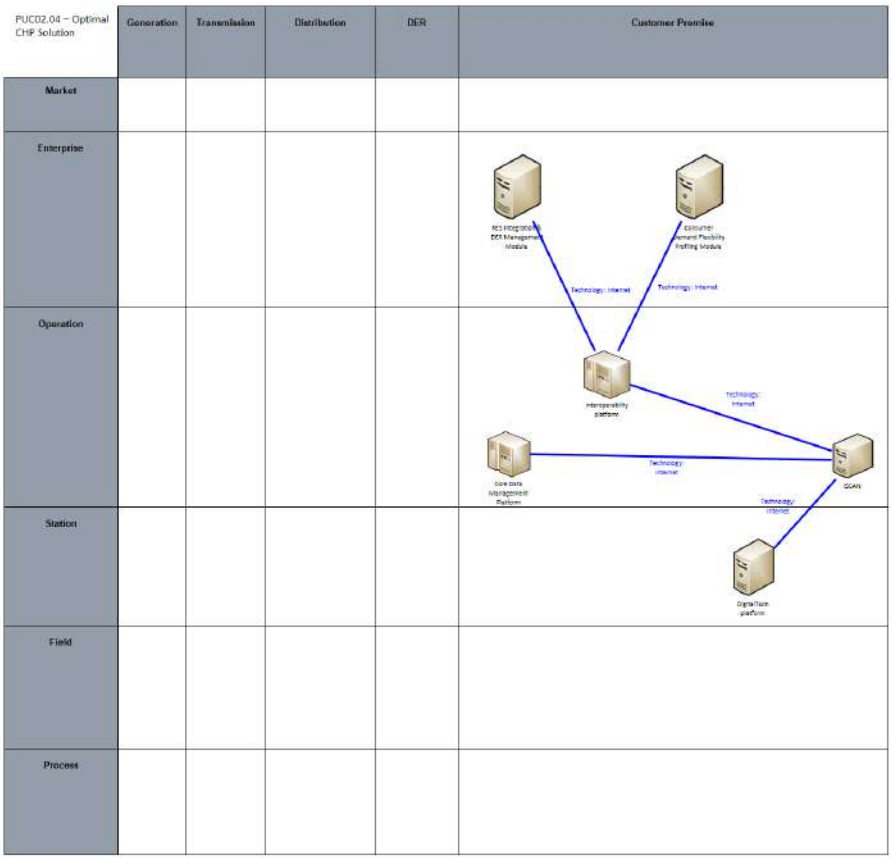

Figure 68: SGAM Component Layer PUC02.04

Table 39: List of Components PUC02.04

Component	Component Type
RES Integration & DER Management Module	TwinERGY application
Consumer Demand Flexibility Profiling Module	TwinERGY application
Interoperability Platform	TwinERGY application
Core Data Management Platform	TwinERGY application
iSCAN	External application
Digital Twin Platform	TwinERGY application

6.4.4. SGAM Communication Layer

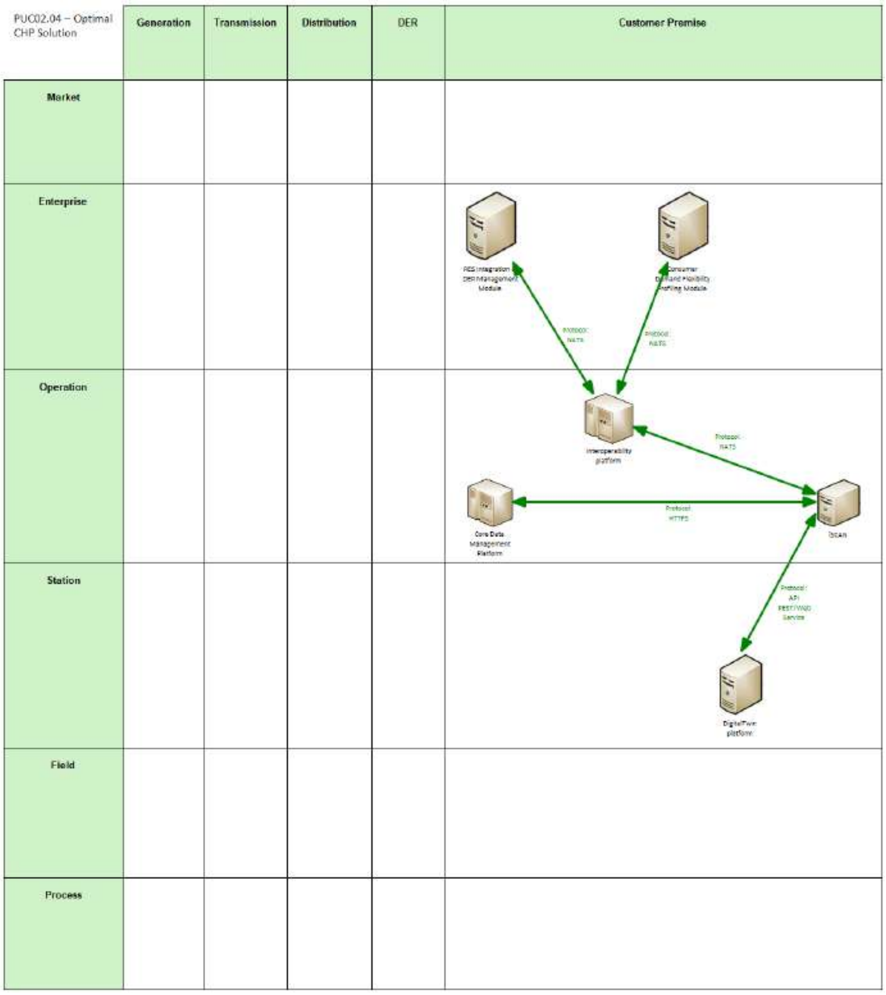

Figure 69: SGAM Communication Layer PUC02.04

Table 40: List of Communication technologies involved in PUC02.04

Communication Technology	Description
NATS	Protocol of messaging that enables the exchange of messages among computer applications and services, not depending on the network location.
HTTPS	HyperText Transfer Protocol Secure. It is an extension of the Hypertext Transfer Protocol (HTTP), used for secure communication over a computer network. In HTTPS, the communication protocol is encrypted using Transport Layer Security (TLS) or, formerly, Secure Sockets Layer (SSL). The protocol is therefore also referred to as HTTP over TLS, or HTTP over SSL.
API REST	Application Programming Interface for REpresentational State Transfer. API is a software intermediary that allows two applications to talk to each other, whilst REST is an architectural style for distributed hypermedia systems, working stateless. Both define a set of distributed resources accessible and manipulable through a set of public functions.

6.4.5. SGAM Information Layer

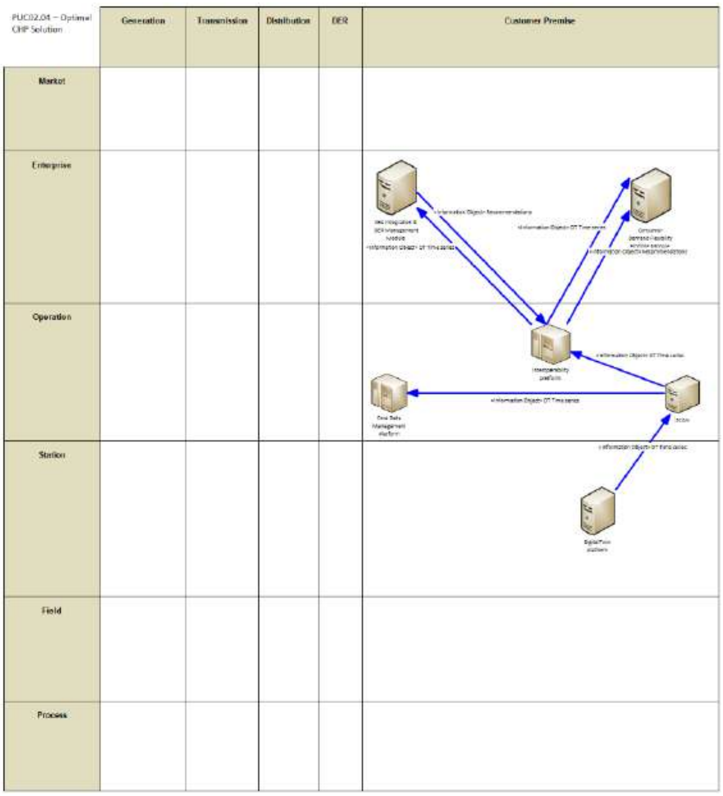

Figure 70: SGAM Information Layer PUC02.04

6.4.6. Canonical Data Model

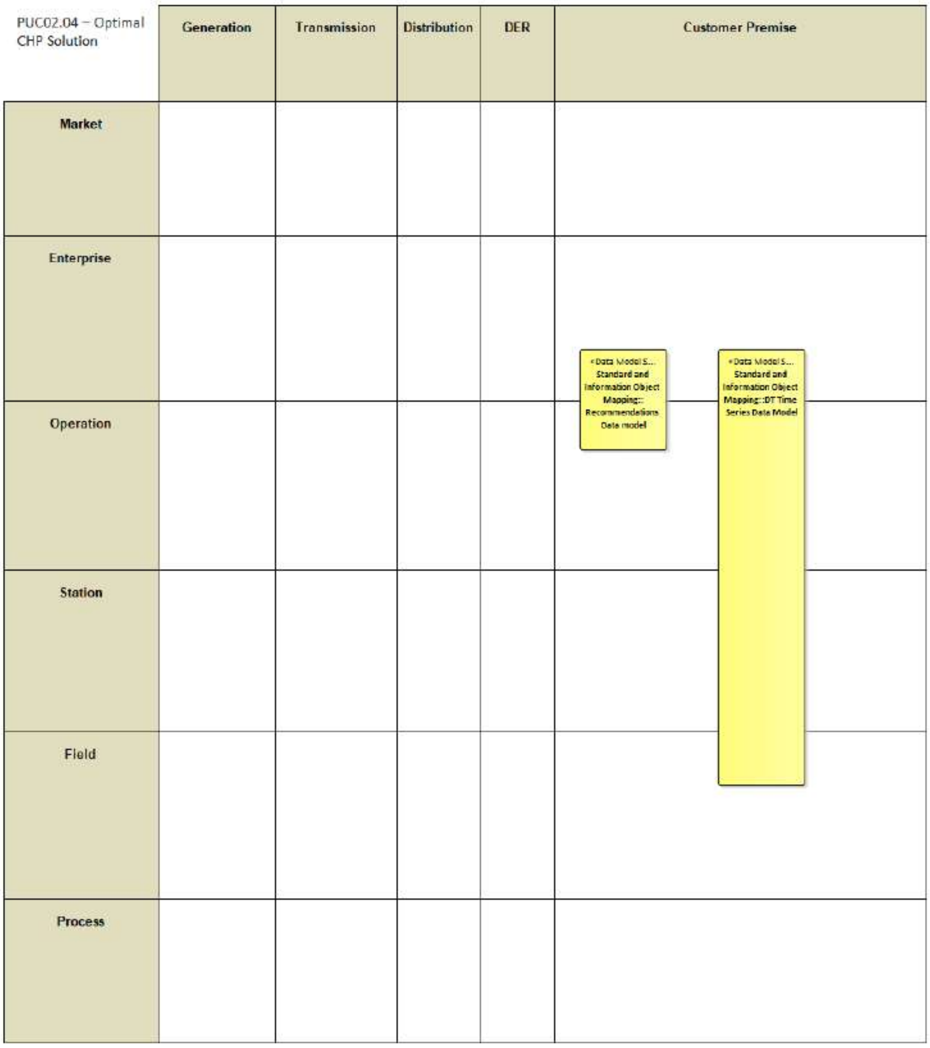

Figure 71: SGAM Canonical Data Model PUC02.04

Table 41: List of Data Models PUC02.04

Data Models
Recommendations Data model
DT Time Series Data Model

6.4.7. Standards and Information Object Mapping

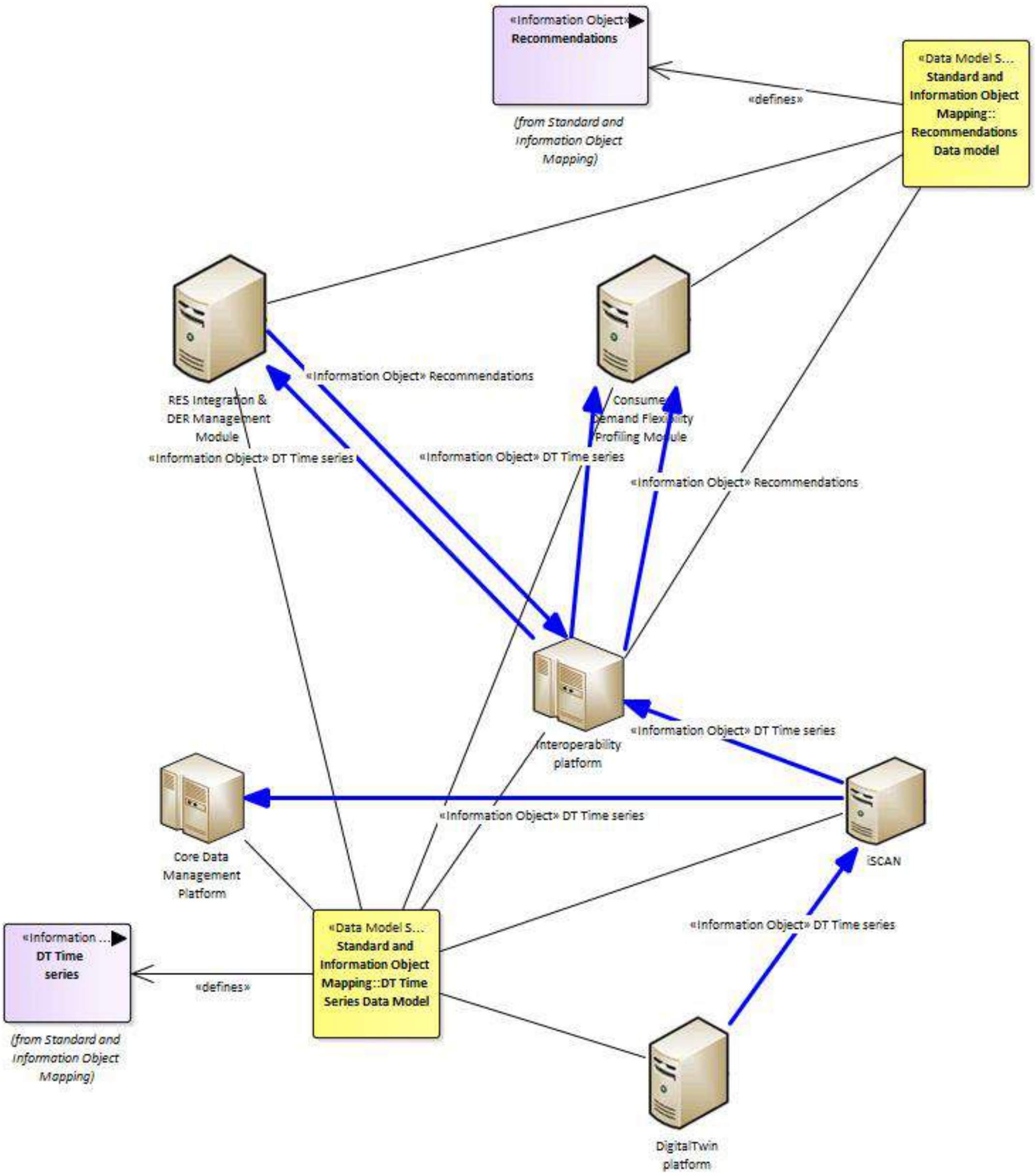

Figure 72: SGAM Standards and Information Object Mapping PUC02.04

Table 42: List of Information Objects PUC02.04

Information Objects	Data Models
DT Time series	DT Time Series Data Model
Recommendations	Recommendations Data Model

6.4.8. Activity Diagram

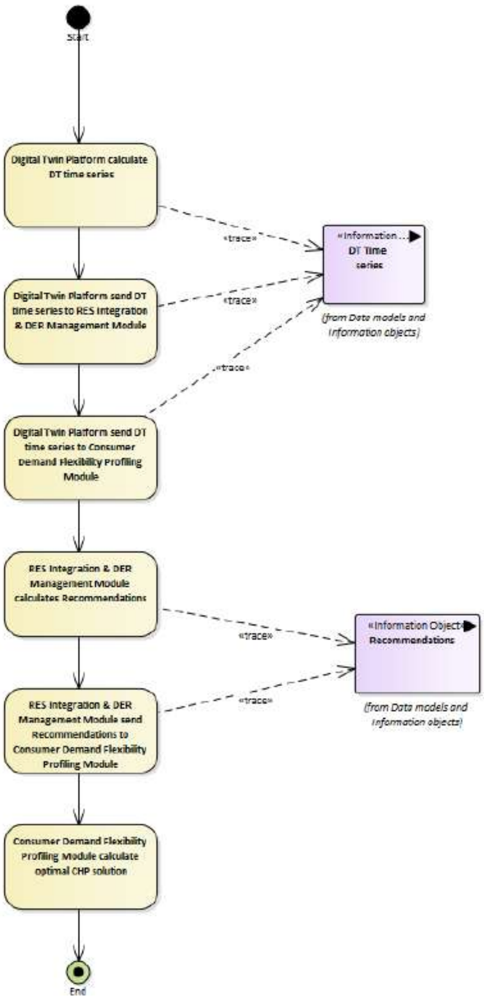

Figure 73: SGAM Activity Diagram PUC02.04

6.4.9. Sequence Diagram

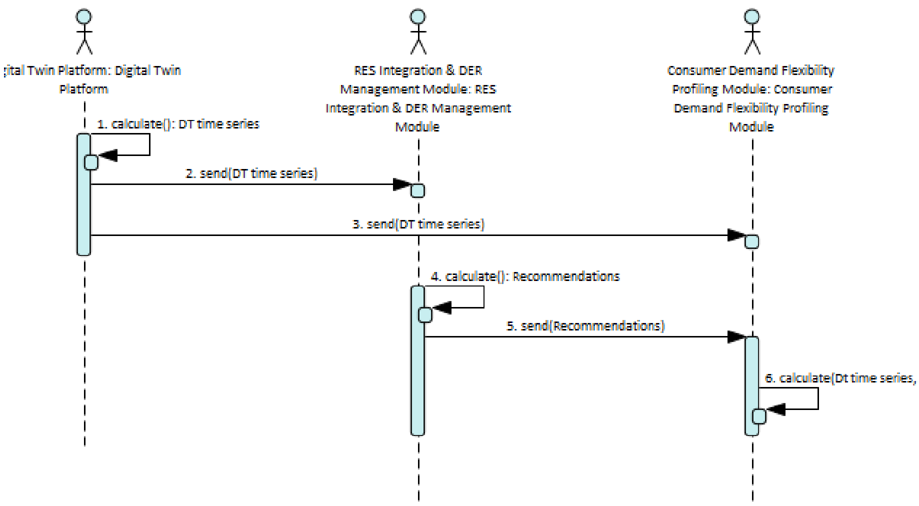

Figure 74: SGAM Sequence Diagram PUC02.04

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6.5. PUC02.05 Optimal scenario of future energy storage and RES to minimise energy costs for the end user/carbon emissions

6.5.1. Use Case Description

The Digital Twin Platform and associated optimisation algorithm within both Consumer and Neighbourhood Demand Flexibility Profiling Modules will calculate the optimal combined installation of renewable generation and battery storage, both at an individual house and community level as required. The inputs will include installed renewable capacity and other relevant constraints such as capital costs, network information and building demand (which are provided by the energy community leaders) and will output the optimised solution in terms of RES and BES which in turn will be made available to the other TwinERGY modules through the Interoperability Platform. This can be used by community/town planners to evaluate future solutions for their community, by DSO planners and operators to plan future expansion and upgrade of the network as required, and can also feed into the pricing calculation by community aggregators if required.

6.5.2. SGAM Function Layer

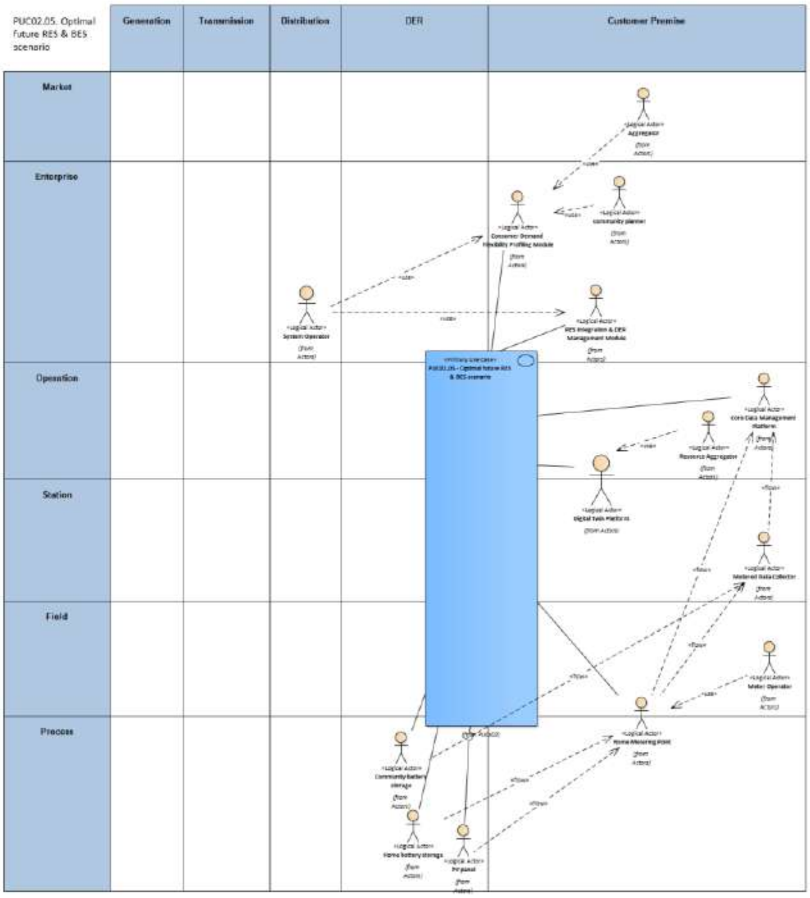

Figure 75: SGAM Function Layer PUC02.05

Table 43: List of Actors Involved PUC02.05

Actor Name	Actor Type
System Operator	Organization
Consumer Demand Flexibility Profiling Module	Application
RES Integration & DER Management Module	Application
Aggregator	Logical actor role
Community Planner	Logical actor role
Resource Aggregator	Logical actor role
Core Data Management Platform	Application
Digital Twin Platform	Application
Metered Data Collector	Device
Meter Operator	Device
Home Metering Point	Device
Community Battery Storage	Device
Home Battery Storage	Device
PV Panel	Device

6.5.3. SGAM Component Layer

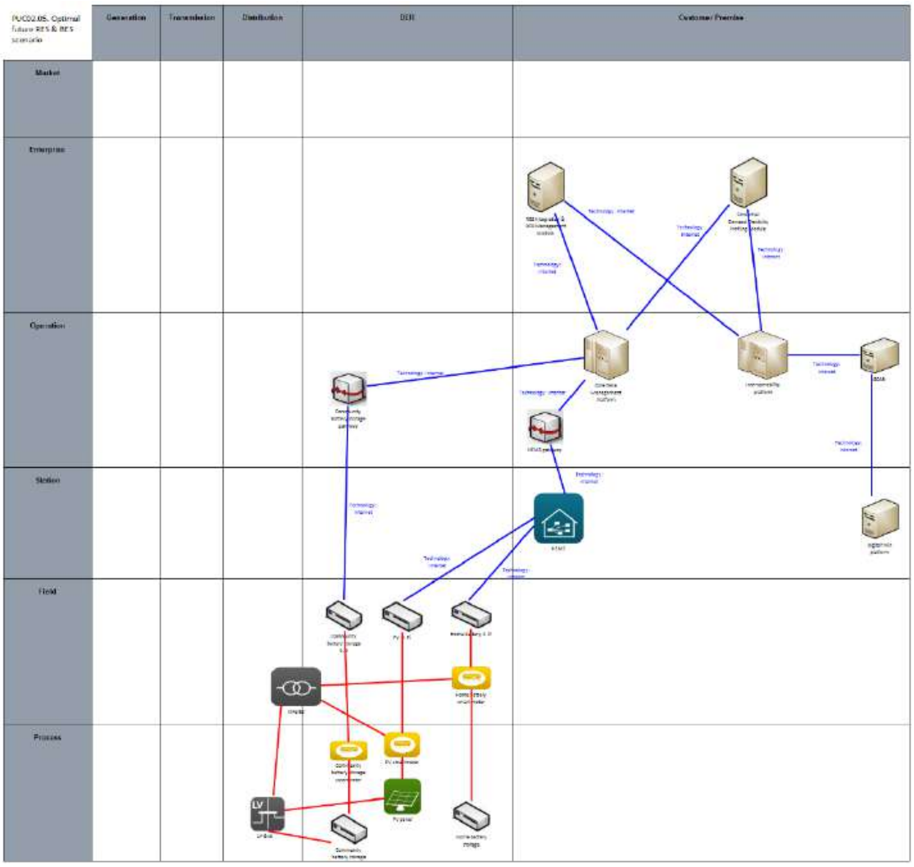

Figure 76: SGAM Component Layer PUC02.05

Table 44: List of Components PUC02.05

Component	Component Type
LV Grid	Physical asset
PV Panel	Physical asset
Home Battery Storage	Physical asset
Inverter	Physical asset
PV Smart Meter	Physical asset
Home Battery Smart Meter	Physical asset
Community battery Smart Meter	Physical asset
Raspberry Pi	Physical asset
Community battery storage	Physical asset

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Community battery storage gateway	External Application
HEMS	External Application
HEMS Gateway	External application
Core Data Management Platform	TwinERGY application
RES integration & DER Management Module	TwinERGY application
Consumer Demand Flexibility Profiling Module	TwinERGY application
Interoperability Platform	TwinERGY application
iSCAN	External application
Digital Twin Platform	TwinERGY application

6.5.4. SGAM Communication Layer

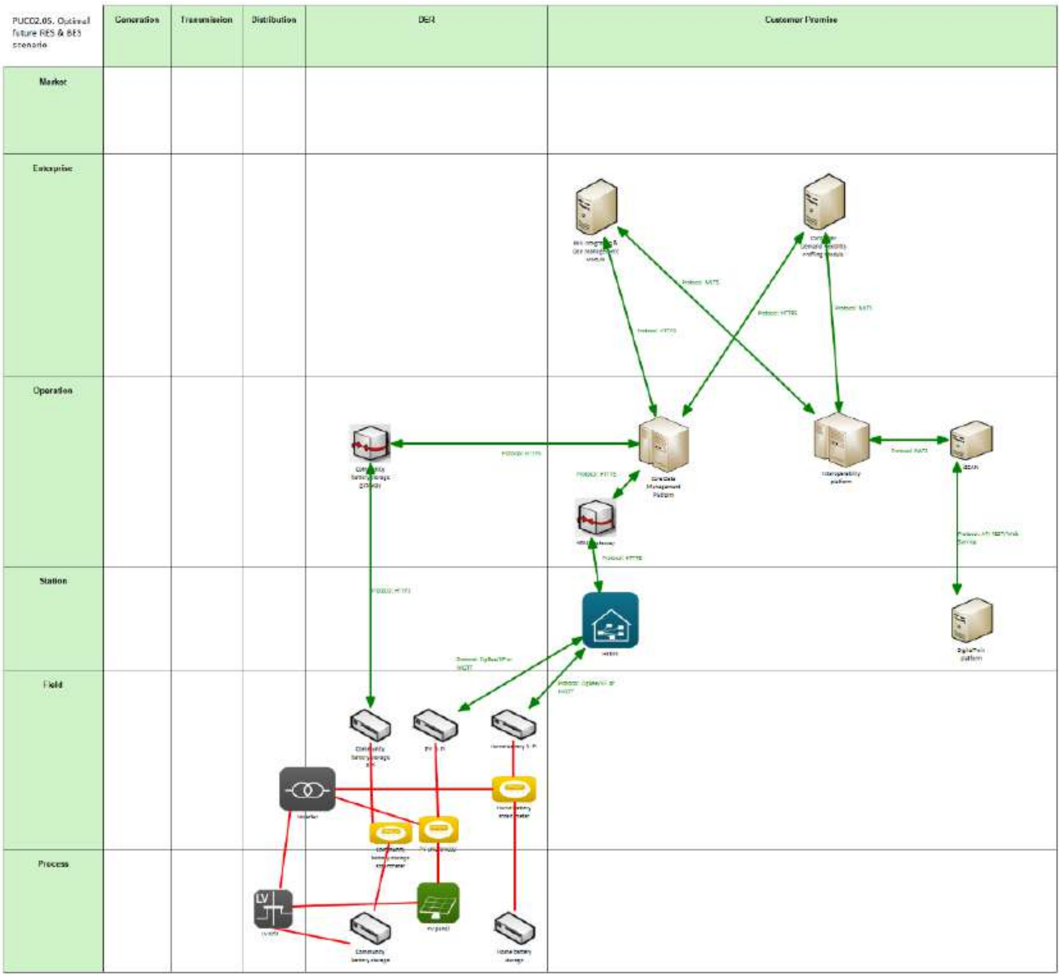

Figure 77: SGAM Communication Layer PUC02.05

Twinergy has received funding from the European Union's Horizon 2020 research and innovation programme under grant agreement No. 957736

Table 45: List of Communication technologies involved in PUC02.05

Communication Technology	Description
API REST	Application Programming Interface for REpresentational State Transfer. API is a software intermediary that allows two applications to talk to each other, whilst REST is an architectural style for distributed hypermedia systems, working stateless. Both define a set of distributed resources accessible and manipulable through a set of public functions.
NATS	Protocol of messaging that enables the exchange of messages among computer applications and services, not depending on the network location.
HTTPS	HyperText Transfer Protocol Secure. It is an extension of the Hypertext Transfer Protocol (HTTP), used for secure communication over a computer network. In HTTPS, the communication protocol is encrypted using Transport Layer Security (TLS) or, formerly, Secure Sockets Layer (SSL). The protocol is therefore also referred to as HTTP over TLS, or HTTP over SSL.
ZigBee/RF	Protocol IEEE 802.15.4, designed to communicate data through noisy RF environments. This standard operates on the physical radio specification and operates in unlicensed bands including 2.4 GHz, 900 MHz and 868 MHz.
MQTT	MQ Telemetry Transport. It is an open OASIS standard and an ISO recommendation (ISO/IEC 20922) over TCP/IP, being a lightweight, publish-subscribe network protocol that transports messages between devices.

6.5.5. SGAM Information Layer

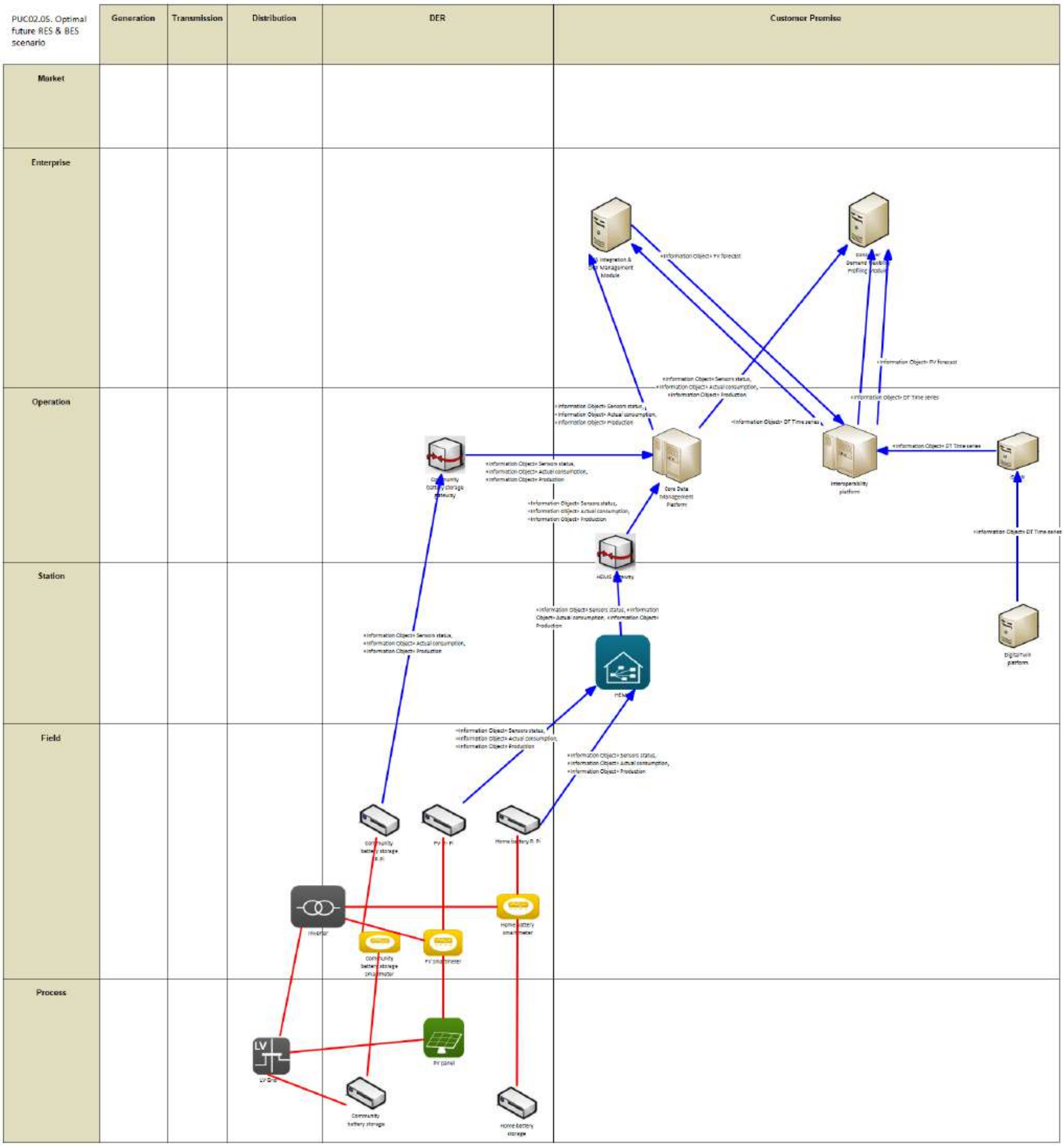

Figure 78: SGAM Information Layer PUC02.05

Twinergy has received funding from the European Union's Horizon 2020 research and innovation programme under grant agreement No. 957736

6.5.6. Canonical Data Model

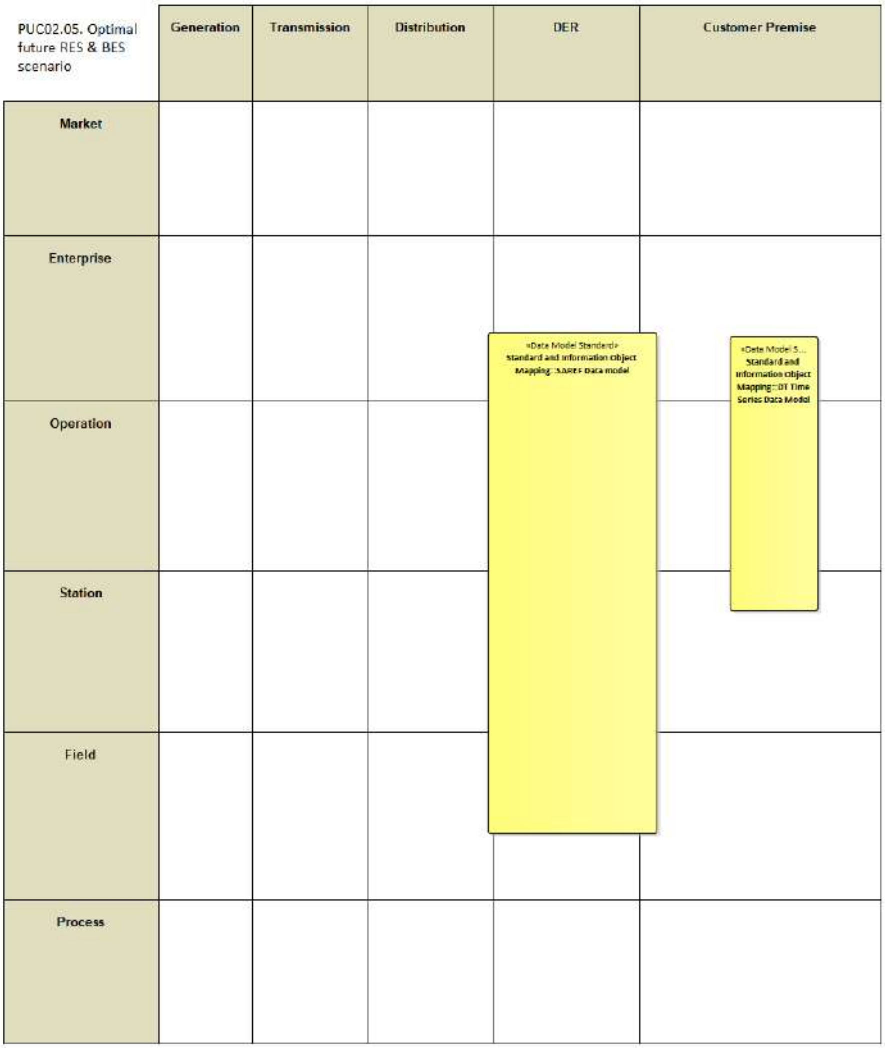

Figure 79: SGAM Canonical Data Model PUC02.05

Table 46: List of Data Models PUC02.05

Data Models
SAREF Data Model
DT Time Serise Data Model

6.5.7. Standards and Information Object Mapping

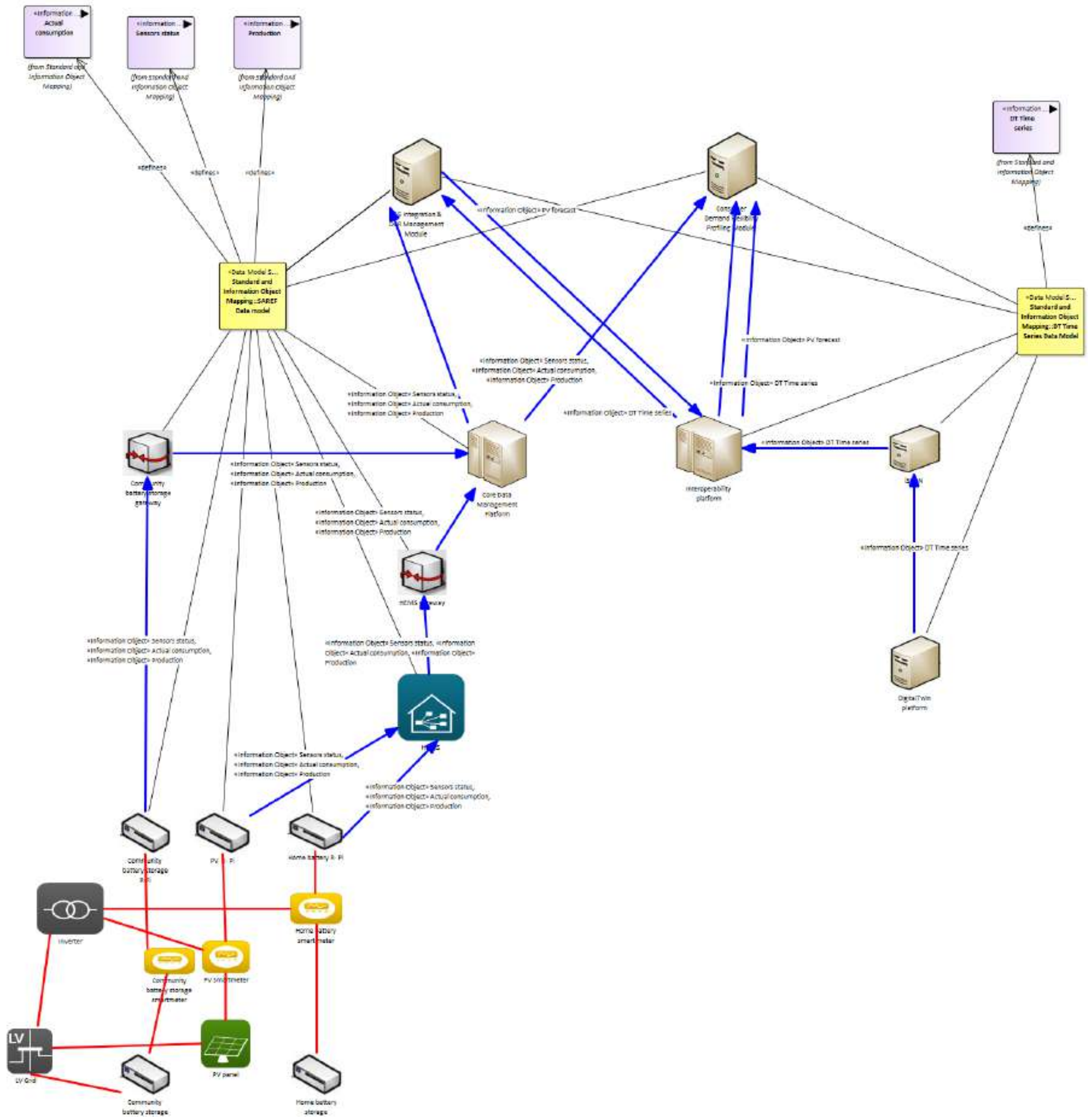

Figure 80: SGAM Standards and Information Object Mapping PUC02.05

Table 47:List of Information Objects PUC02.05

Information Objects	Data Models
Actual consumption	SAREF Data Model
Sensor Status	SAREF Data Model
Production	SAREF Data Model
DT Time series	DT Time Series Data Model

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6.5.8. Activity Diagram

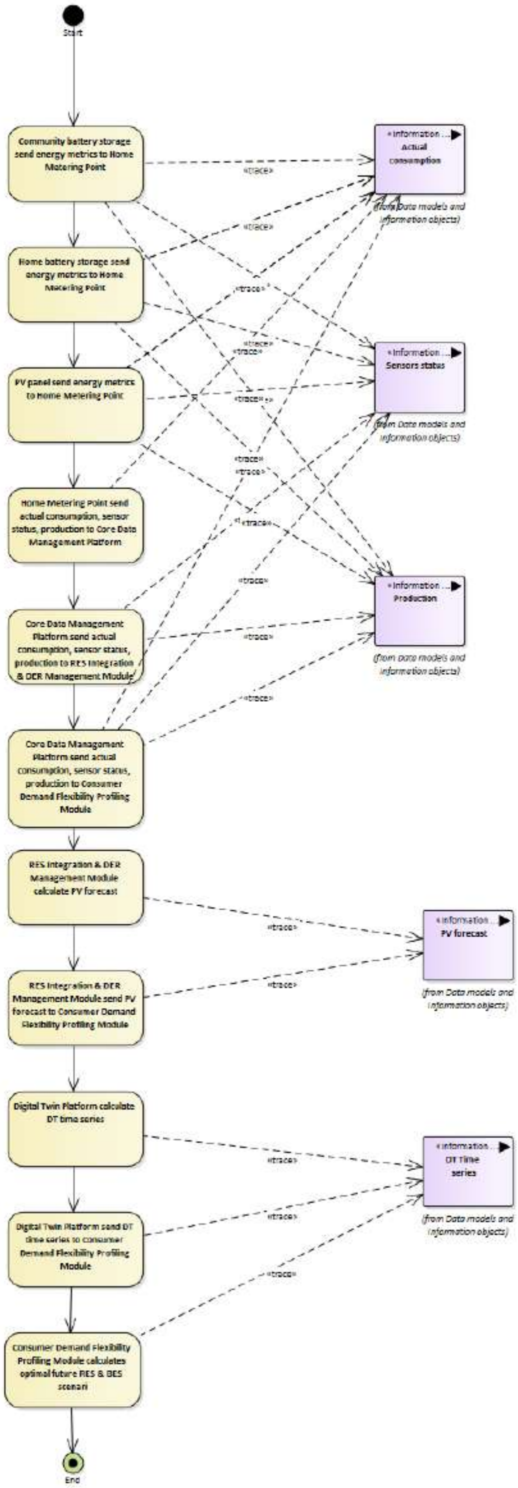

Figure 81: SGAM Activity Diagram PUC02.05

6.5.9. Sequence Diagram

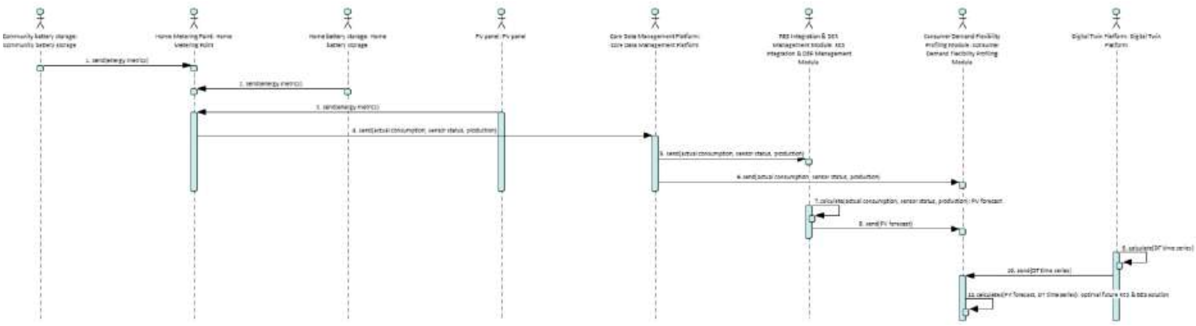

Figure 82: SGAM Sequence Diagram PUC02.05

6.6. PUC02.06 Optimal domestic and tertiary demand response, based on RES, to minimise cost/carbon emissions

6.6.1. Use Case Description

The optimisation algorithm within the Digital Twin Platform (which forms the basis of the Consumer and Neighbourhood Demand Flexibility Profiling Modules) is used to identify flexible loads and determines when the best time is to shift them to, based on renewable generation forecasts and other relevant information, such as building demand. All input data is gathered from the pilot site: metered data is collected through the TwinERGY Storage System, and static information is provided by energy community leaders.

Once calculated, this flexible load capacity is then passed to the TwinERGY Interoperability Platform which can be used by the other TwinERGY modules, including the RES Integration & DER Management Module which can determine the dispatch of said load based on optimal network conditions.

This can be used by community/town planners to evaluate future solutions for their community, by DSO planners and operators to plan future expansion and upgrade of the network as required and can also feed into the pricing calculation by community aggregators if required. Building owners can also use this information to optimise the operation of their buildings in real time.

Twinergy has received funding from the European Union's Horizon 2020 research and innovation programme under grant agreement No. 957736

6.6.2. SGAM Function Layer

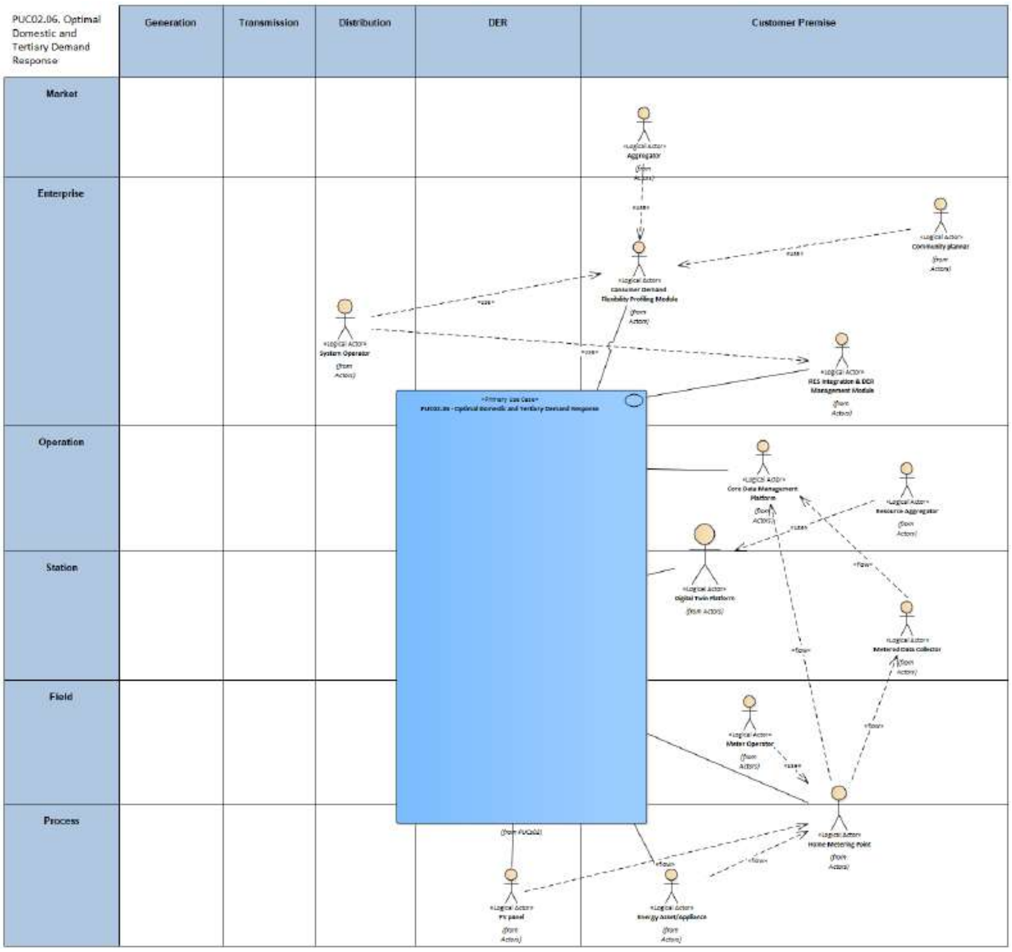

Figure 83: SGAM Function Layer PUC02.06

Table 48: List of Actors Involved PUC02.06

Actor Name	Actor Type
System Operator	Organization
Consumer Demand Flexibility Profiling Module	Application
RES Integration & DER Management Module	Application
Aggregator	Logical actor role
Community Planner	Logical actor role
Resource Aggregator	Logical actor role
Core Data Management Platform	Application

Digital Twin Platform	Application
Metered Data Collector	Device
Meter Operator	Device
Home Metering Point	Device
Energy Asset/Appliance	Device
PV Panel	Device

6.6.3. SGAM Component Layer

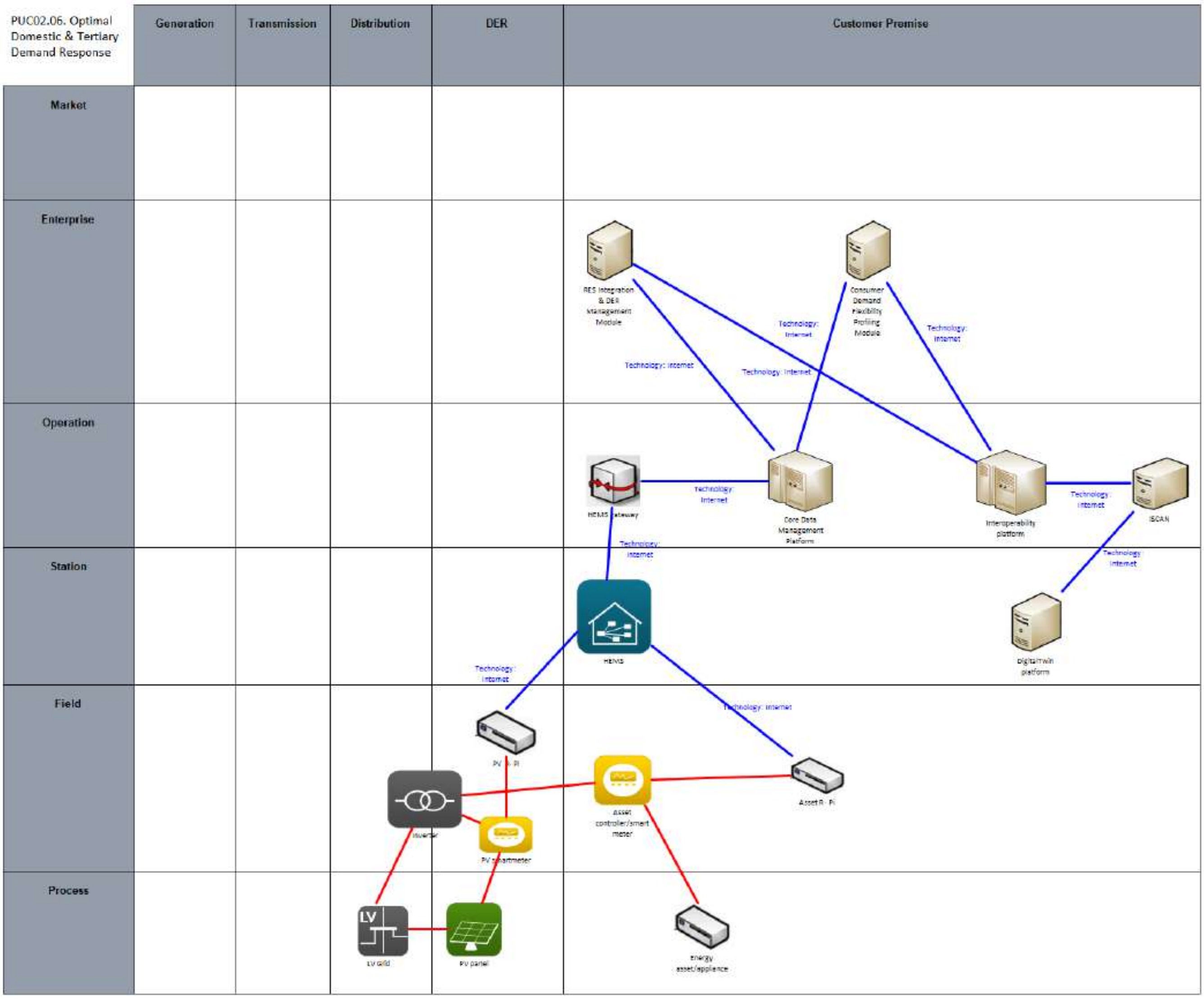

Figure 84: SGAM Component Layer PUC02.06

Table 49: List of Components PUC02.06

Component	Component Type
LV Grid	Physical asset
PV Panel	Physical asset
Inverter	Physical asset
PV Smart Meter	Physical asset
Energy asset/appliance	Physical asset
Asset controller / Smart meter	Physical asset
Raspberry Pi	Physical asset
HEMS	External Application
HEMS Gateway	External application
Core Data Management Platform	TwinERGY application
RES integration & DER Management Module	TwinERGY application
Consumer Demand Flexibility Profiling Module	TwinERGY application
Interoperability Platform	TwinERGY application
iSCAN	External application
Digital Twin Platform	TwinERGY application

6.6.4. SGAM Communication Layer

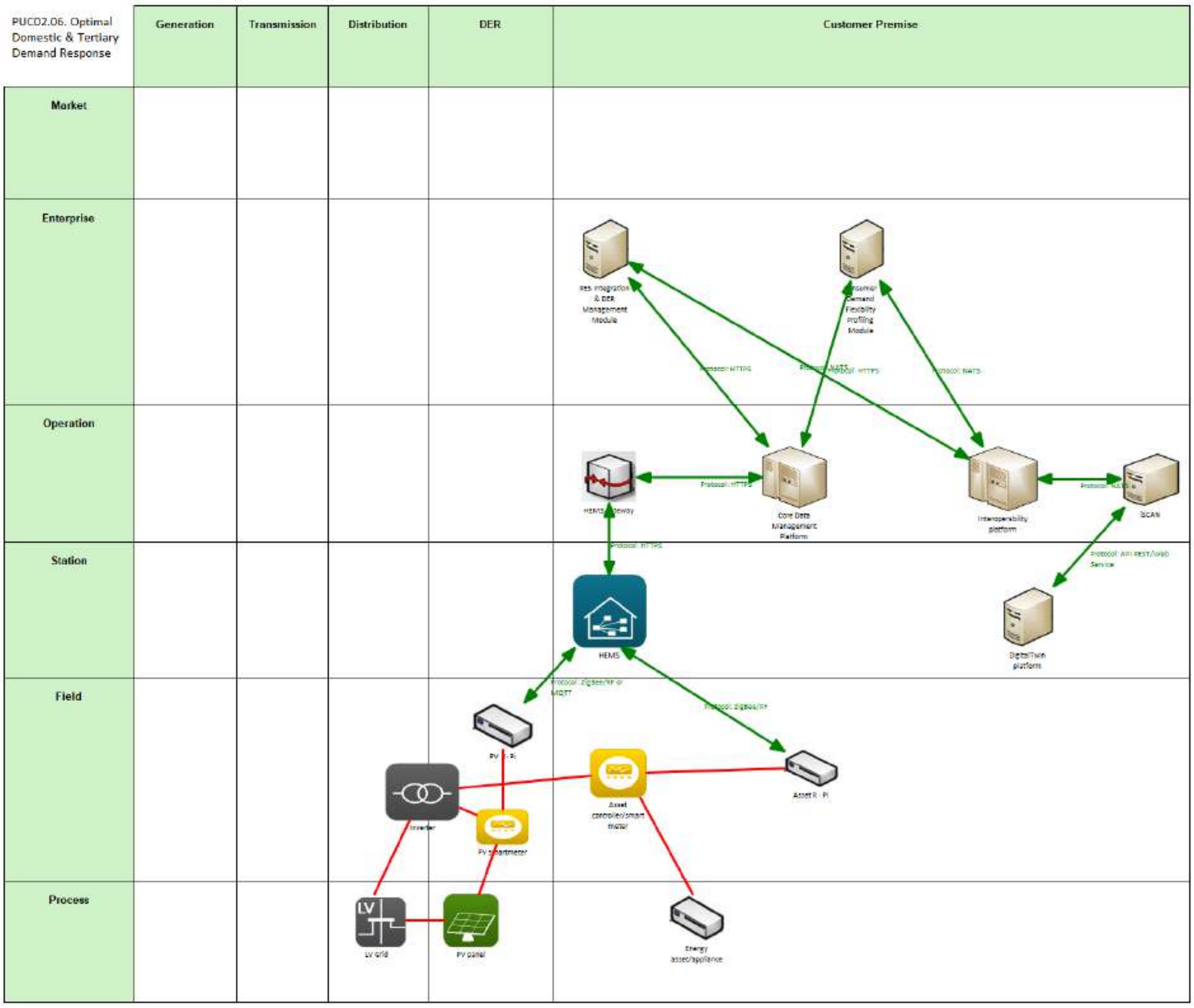

Figure 85: SGAM Communication Layer PUC02.06

Table 50: List of Communication technologies involved in PUC02.06

Communication Technology	Description
API REST	Application Programming Interface for REpresentational State Transfer. API is a software intermediary that allows two applications to talk to each other, whilst REST is an architectural style for distributed hypermedia systems, working stateless. Both define a set of distributed resources accessible and manipulable through a set of public functions.
NATS	Protocol of messaging that enables the exchange of messages among computer applications and services, not depending on the network location.
HTTPS	HyperText Transfer Protocol Secure. It is an extension of the Hypertext Transfer Protocol (HTTP), used for secure

	communication over a computer network. In HTTPS, the communication protocol is encrypted using Transport Layer Security (TLS) or, formerly, Secure Sockets Layer (SSL). The protocol is therefore also referred to as HTTP over TLS, or HTTP over SSL.
ZigBee/RF	Protocol IEEE 802.15.4, designed to communicate data through noisy RF environments. This standard operates on the physical radio specification and operates in unlicensed bands including 2.4 GHz, 900 MHz and 868 MHz.
MQTT	MQ Telemetry Transport. It is an open OASIS standard and an ISO recommendation (ISO/IEC 20922) over TCP/IP, being a lightweight, publish-subscribe network protocol that transports messages between devices.

6.6.5. SGAM Information Layer

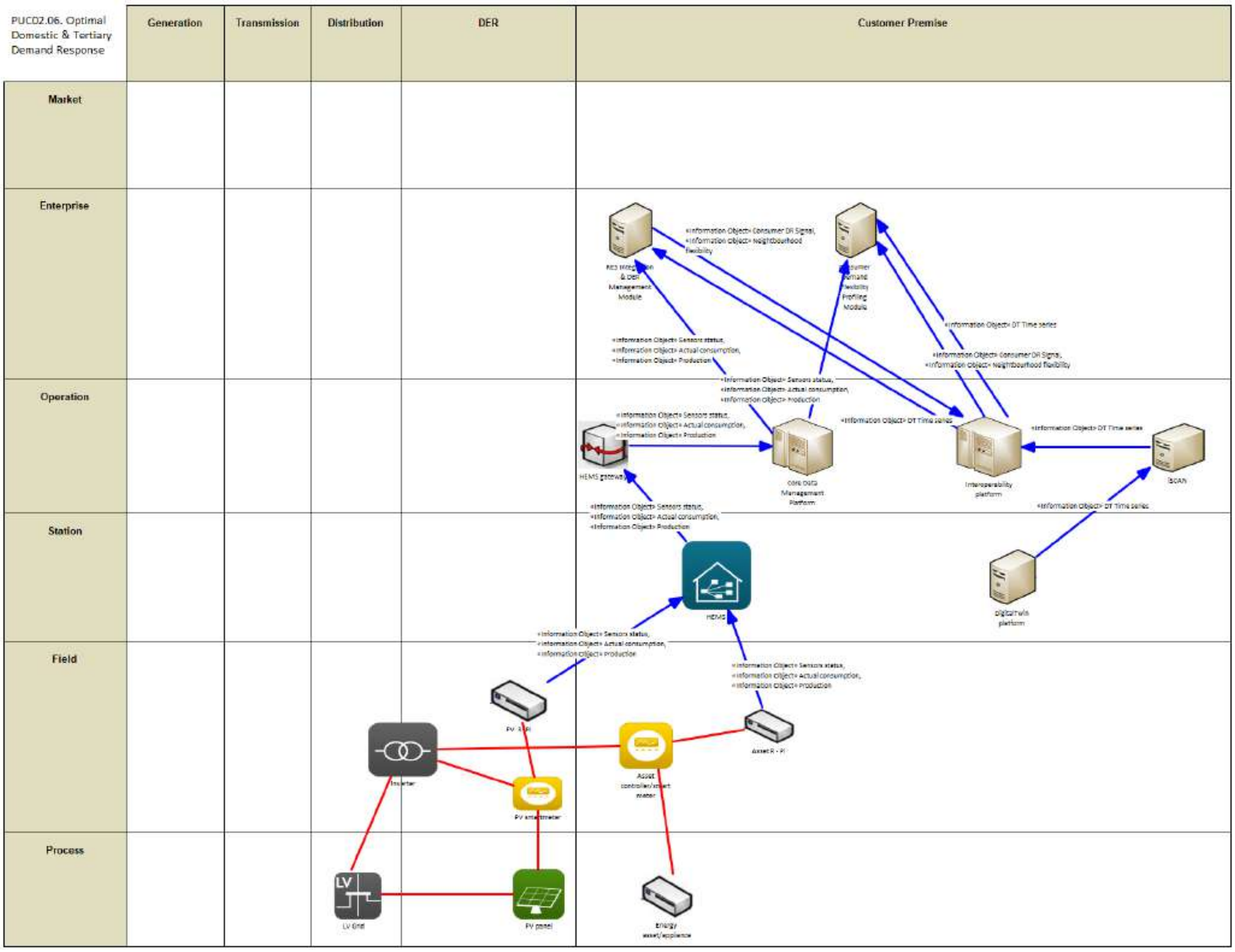

Figure 86: SGAM Information Layer PUC02.06

6.6.6. Canonical Data Model

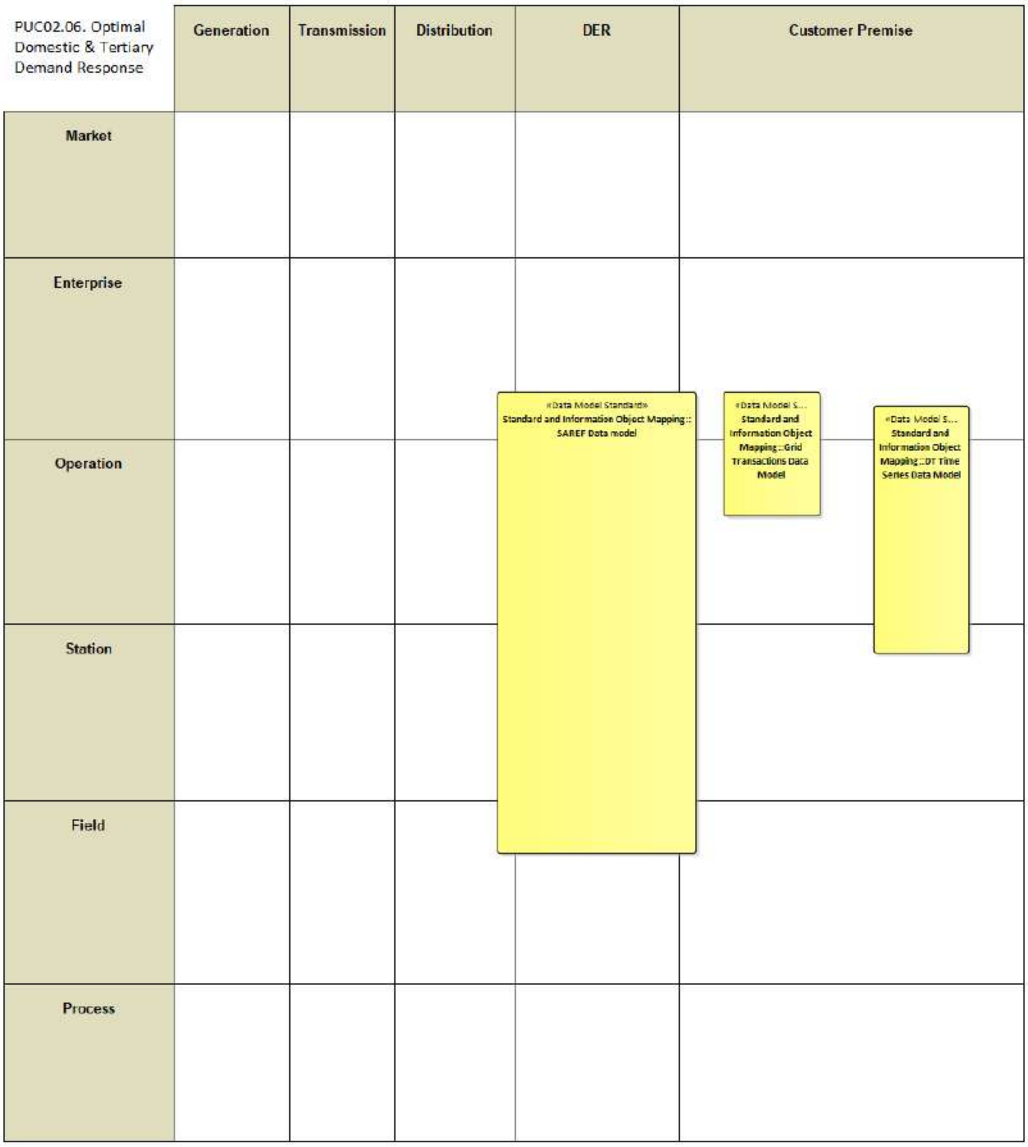

Figure 87: SGAM Canonical Data Model PUC02.06

Table 51: List of Data Models PUC02.06

Data Models
SAREF Data model
Grid Transactions Data Model
DT Time Series Data Model

6.6.7. Standards and Information Object Mapping

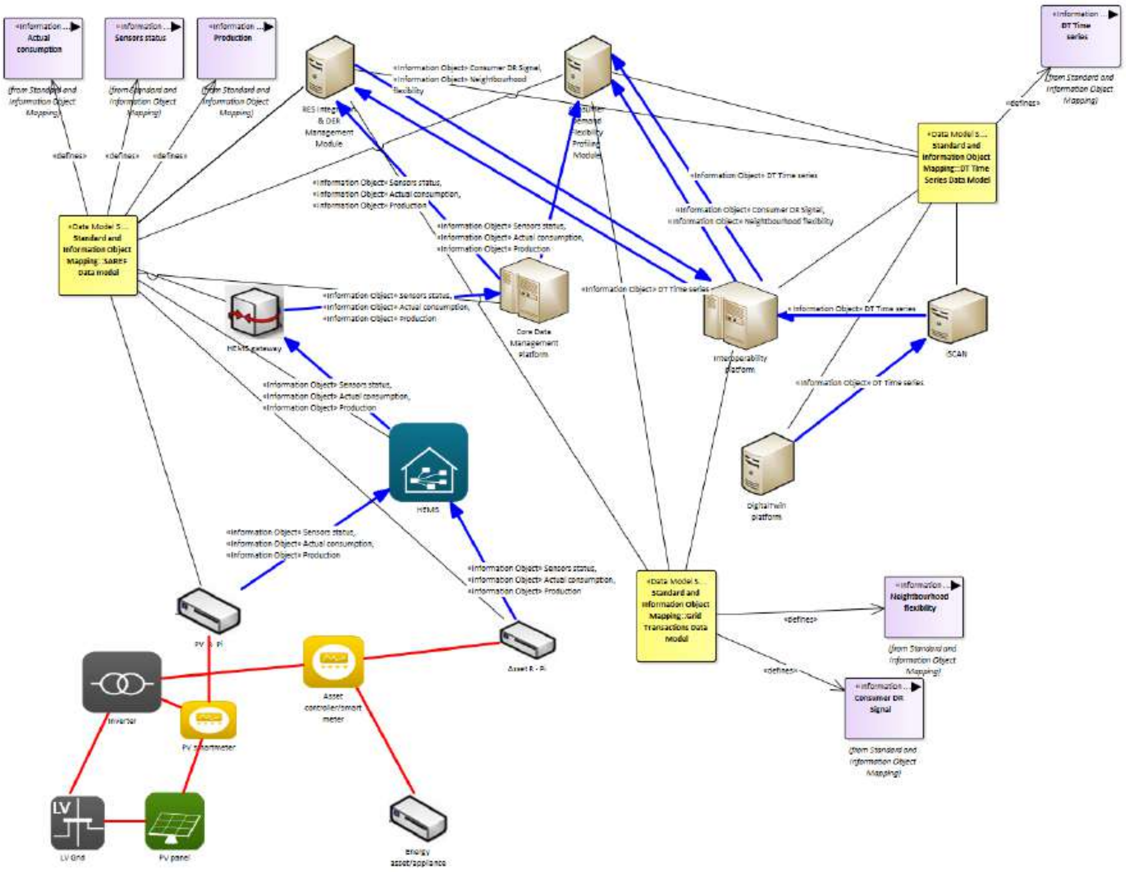

Figure 88: SGAM Standards and Information Object Mapping PUC02.06

Table 52: List of Information Objects PUC02.06

Information Objects	Data Models
Actual consumption	SAREF Data model
Sensor status	SAREF Data model
Production	SAREF Data model
DT Time Series	DT Time Series Data Model
Neighbourhood flexibility	Grid Transaction Data Model
Consumer DR Signal	Grid Transaction Data Model

6.6.8. Activity Diagram

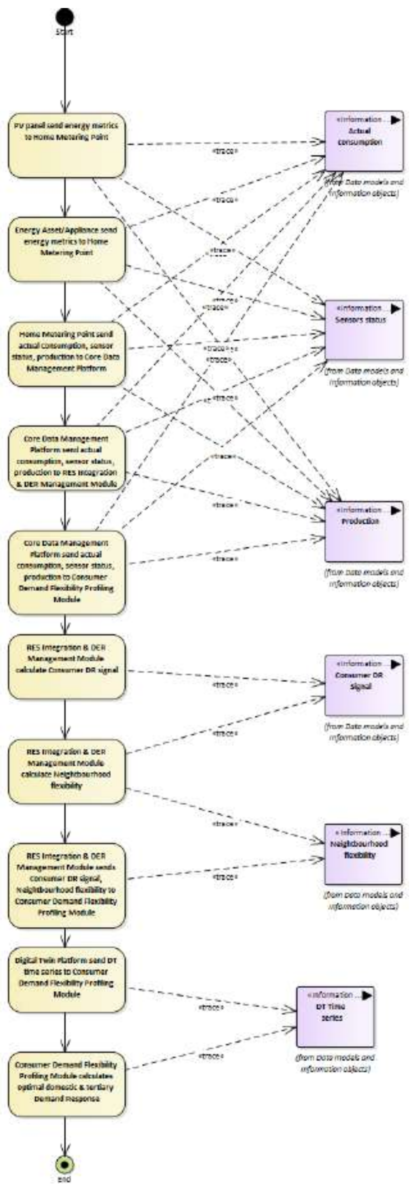

Figure 89: SGAM Activity Diagram PUC02.06

6.6.9. Sequence Diagram

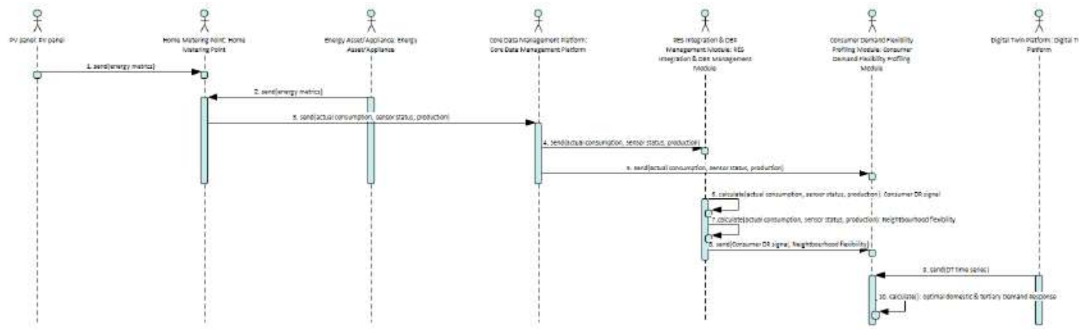

Figure 90: SGAM Sequence Diagram PUC02.06

6.7. SGAM Business Layer

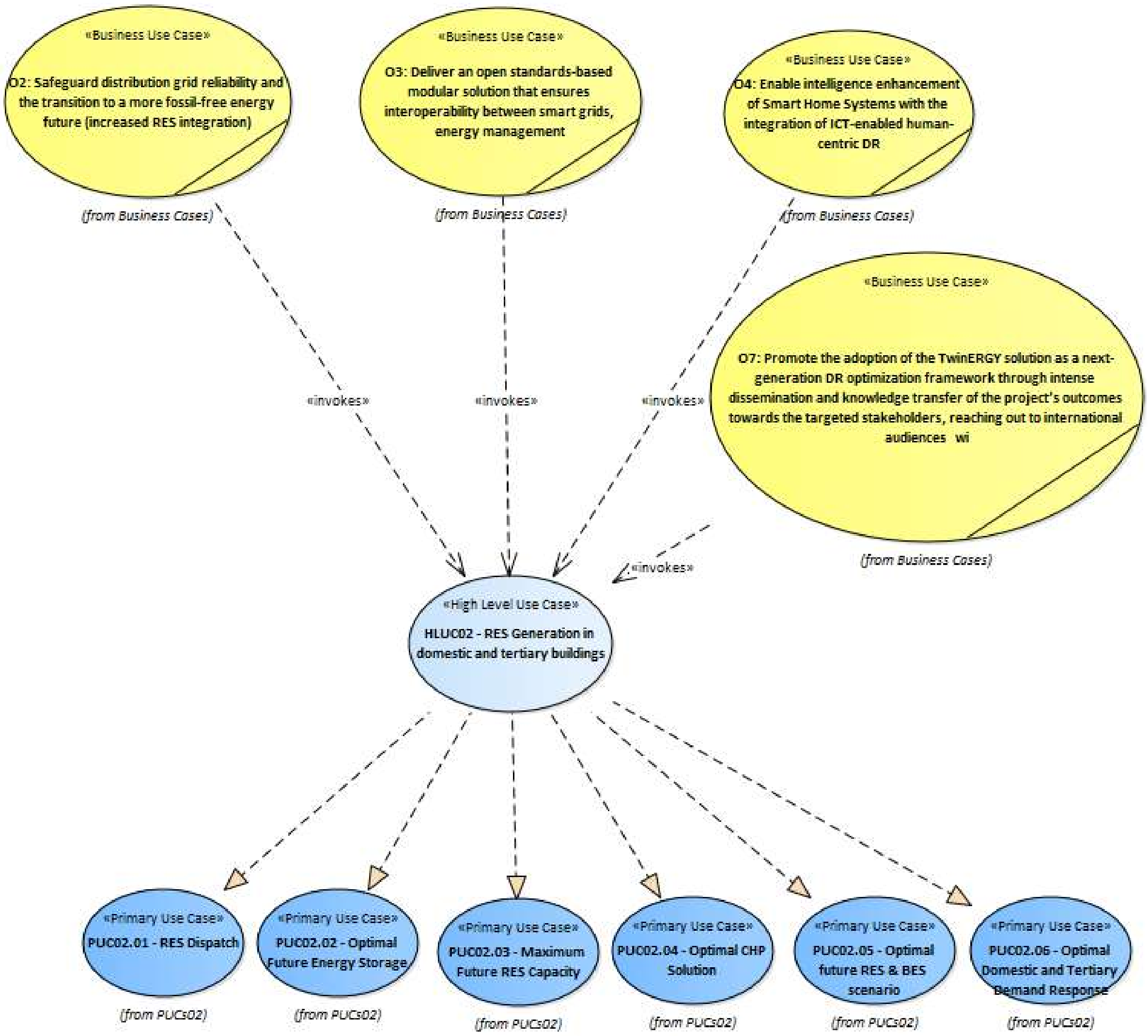

Figure 91: SGAM Business Layer HLUC02

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7. HLUC03. Grid capacity enhancement utilizing e-mobility

7.1. PUC03.01. Booking a charge session

7.1.1. Use Case Description

This Use case starts when a user wants to charge his/her vehicle in a nearby station. The steps to complete this are the following ones:

1. In theTwinEV driver App., the user introduces the vehicle identifier and selects a station with free charging points.
2. The backend loads the request and send a petition of "Lock" to the CPO
3. The CPO locks one charging point and returns the identifier of the charging point
4. The backend returns this identifier
5. The interface shows the confirmation of the operation and the identifier of the charging point
6. In case of error, the interface shows an error message
7. The driver drives the EV to the Charging Point and starts the charging process, so the CPO unlocks the charging point.
8. If the driver does not drive to the charging point, the CPO unlocks the charging point after a defined time period (15 minutes)

7.1.2. SGAM Function Layer

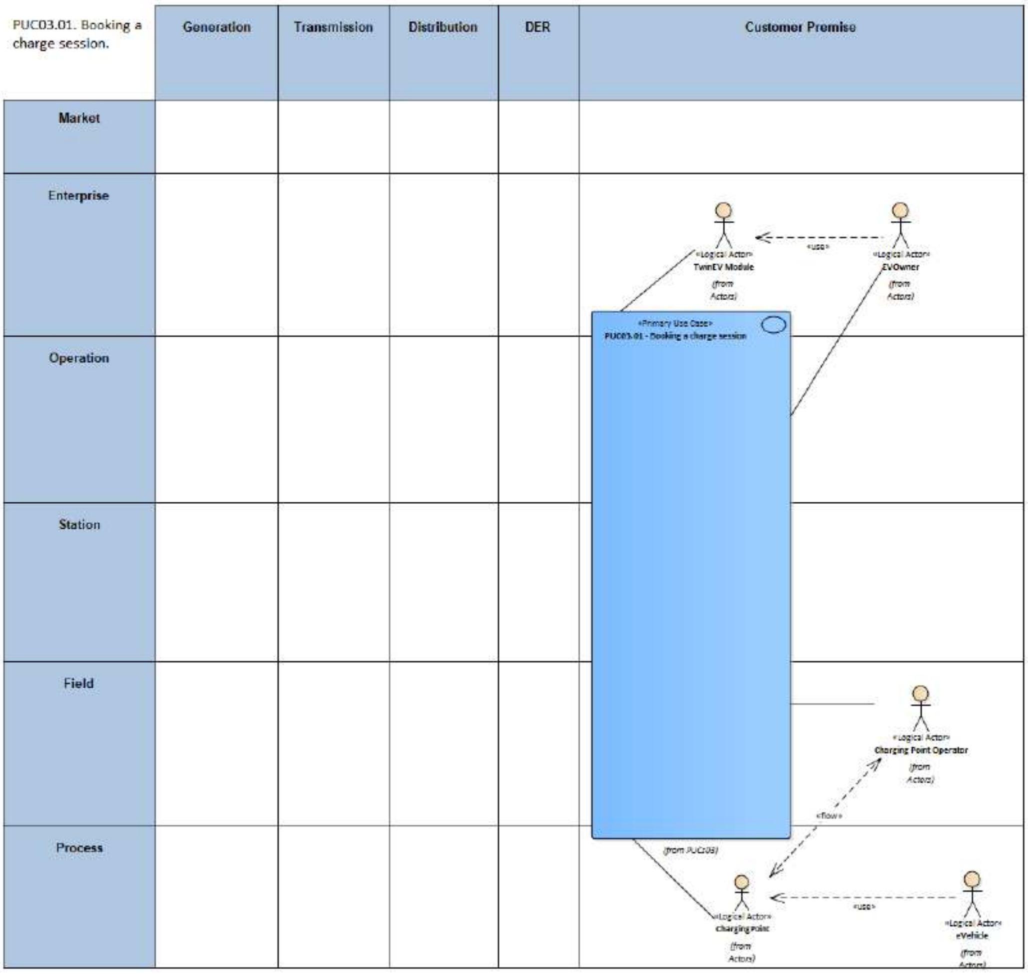

Figure 92: SGAM Function Layer PUC03.01

Table 53: List of Actors Involved PUC03.01

Actor Name	Actor Type
Charging Point	Device
eVehicle	Device
Charging Point Operator	Organization
EV Owner	Logical actor role
TwinEV Module	Application

7.1.3. SGAM Component Layer

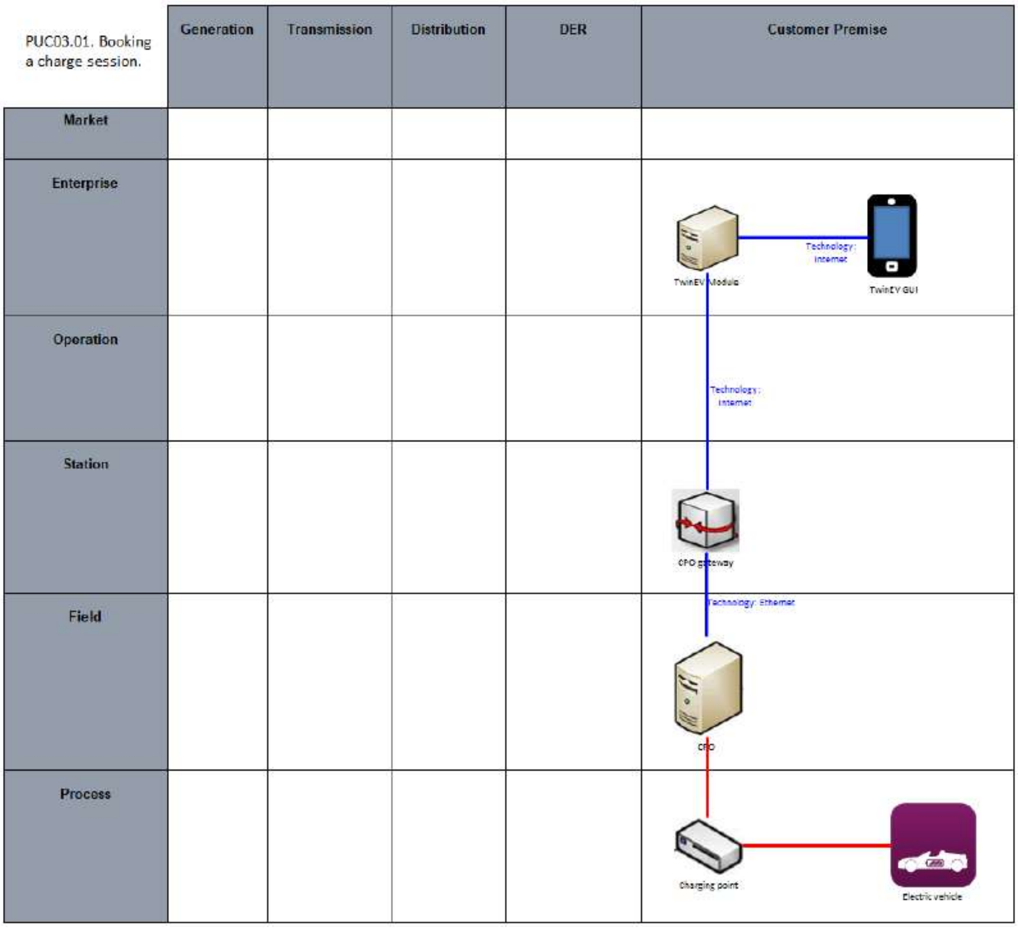

Figure 93: SGAM Component Layer PUC03.01

Table 54: List of Components PUC03.01

Component	Component Type
Electric Vehicle	Physical asset
Charging Point	Physical asset
Charging Point Operator	External application
Charging Point Operator Gateway	External application
TwinEV Module	TwinERGY application
TwinEV GUI	TwinERGY application

7.1.4. SGAM Communication Layer

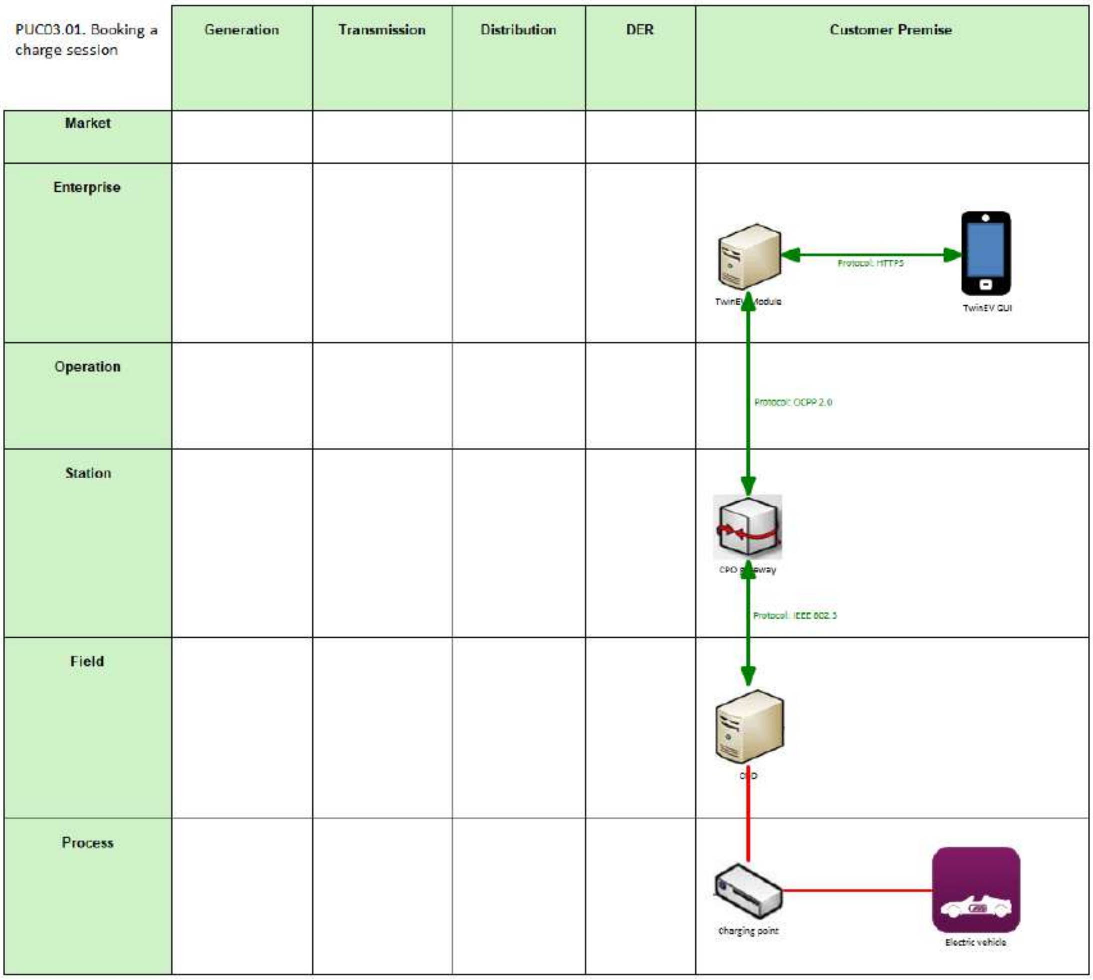

Figure 94:SGAM Communication Layer PUC03.01

Table 55: List of Communication technologies involved in PUC03.01

Communication Technology	Description
IEEE 802.3	
OCPP 2.0	The Open Charge Point Protocol is an application protocol for communication between Electric vehicle, charging stations and a central management system.
HTTPS	HyperText Transfer Protocol Secure. It is an extension of the Hypertext Transfer Protocol (HTTP), used for secure communication over a computer network. In HTTPS, the communication protocol is encrypted using Transport Layer Security (TLS) or, formerly, Secure Sockets Layer (SSL). The protocol is therefore also referred to as HTTP over TLS, or HTTP over SSL.

7.1.5. SGAM Information Layer

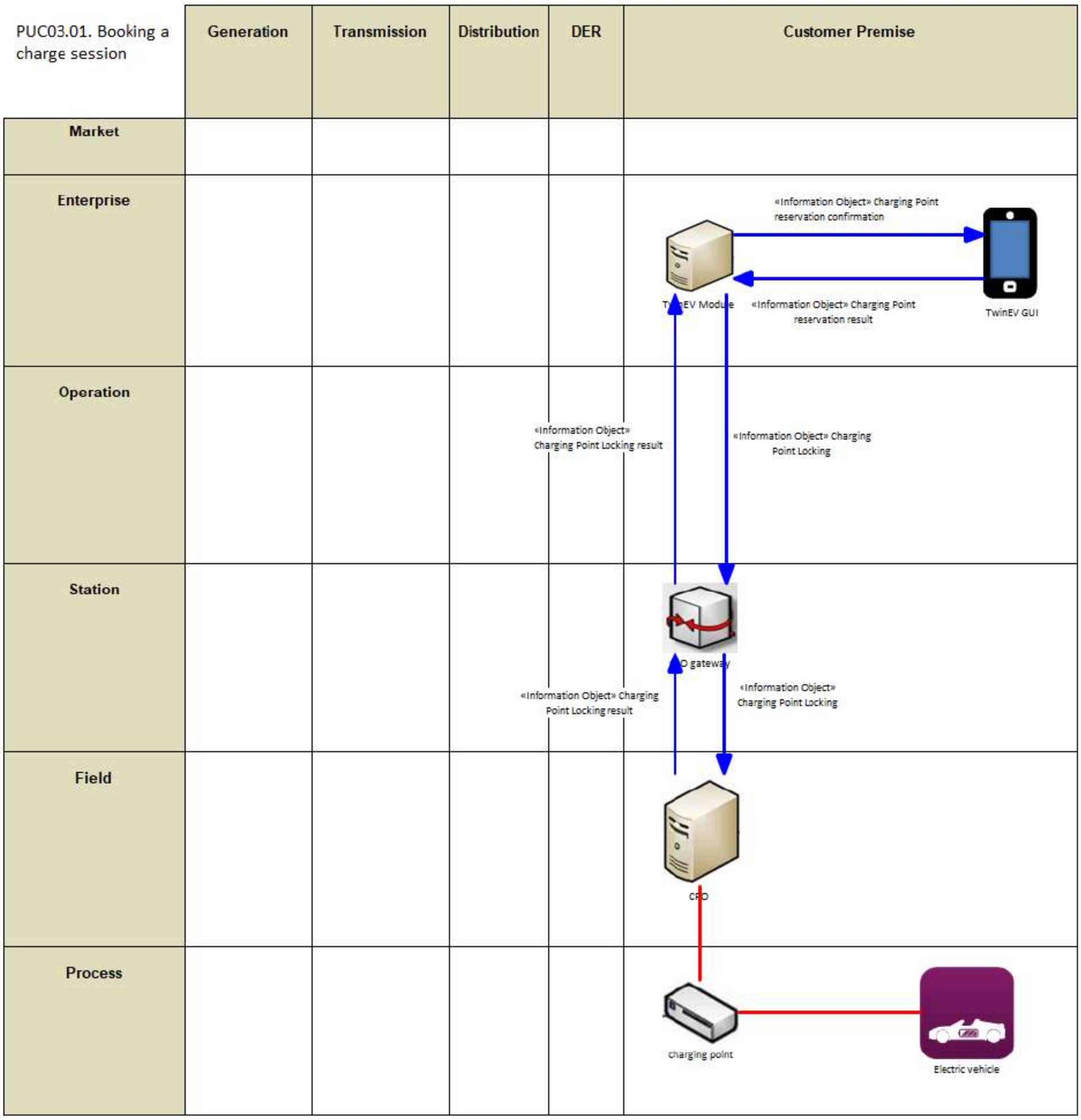

Figure 95: SGAM Information Layer PUC03.01

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7.1.6. Canonical Data Model

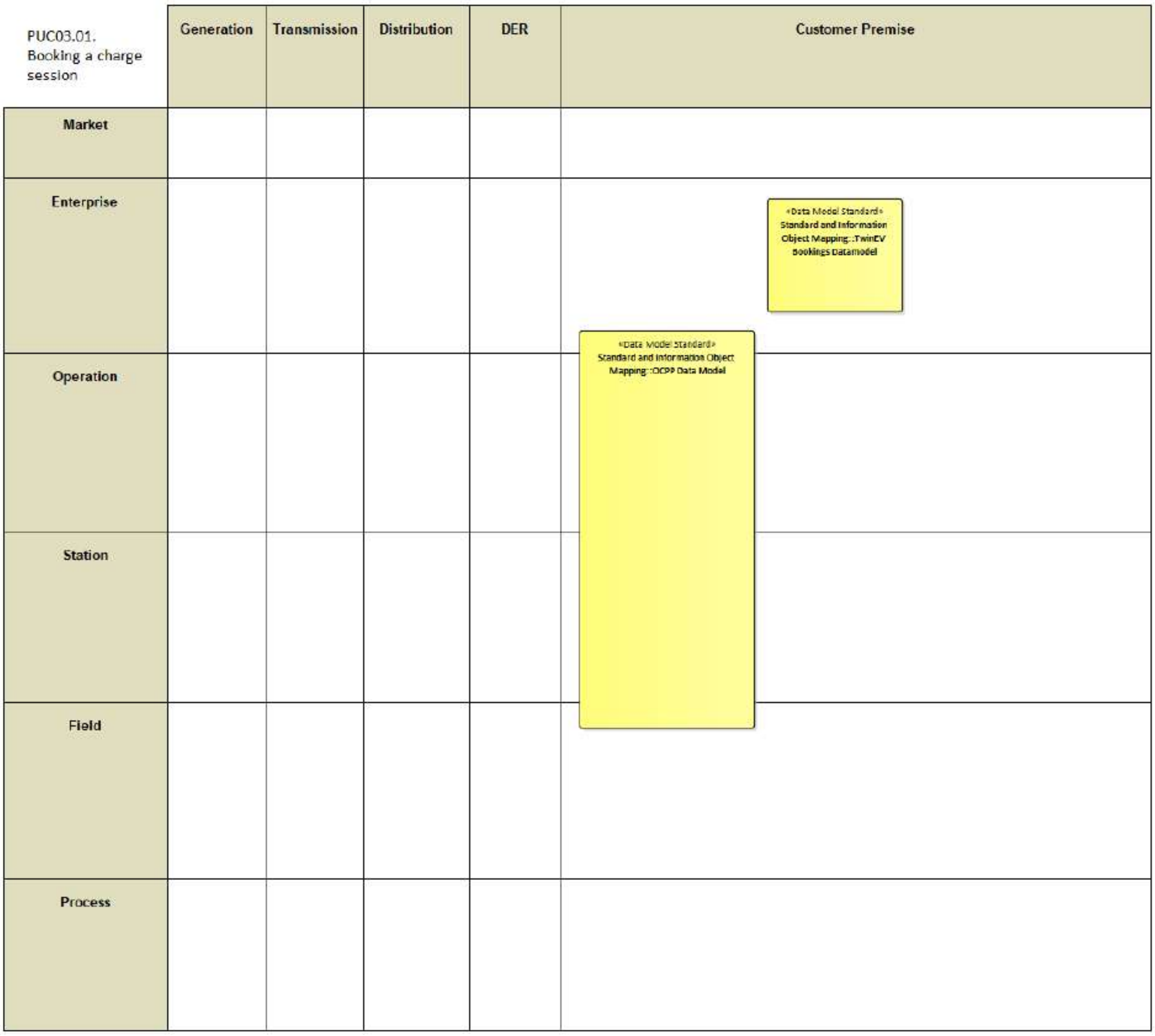

Figure 96: SGAM Canonical Data Model PUC03.01

Table 56:List of Data Models PUC03.01

Data Models
OCPP Data Model
TwinEV Bookings Datamodel

7.1.7. Standards and Information Object Mapping

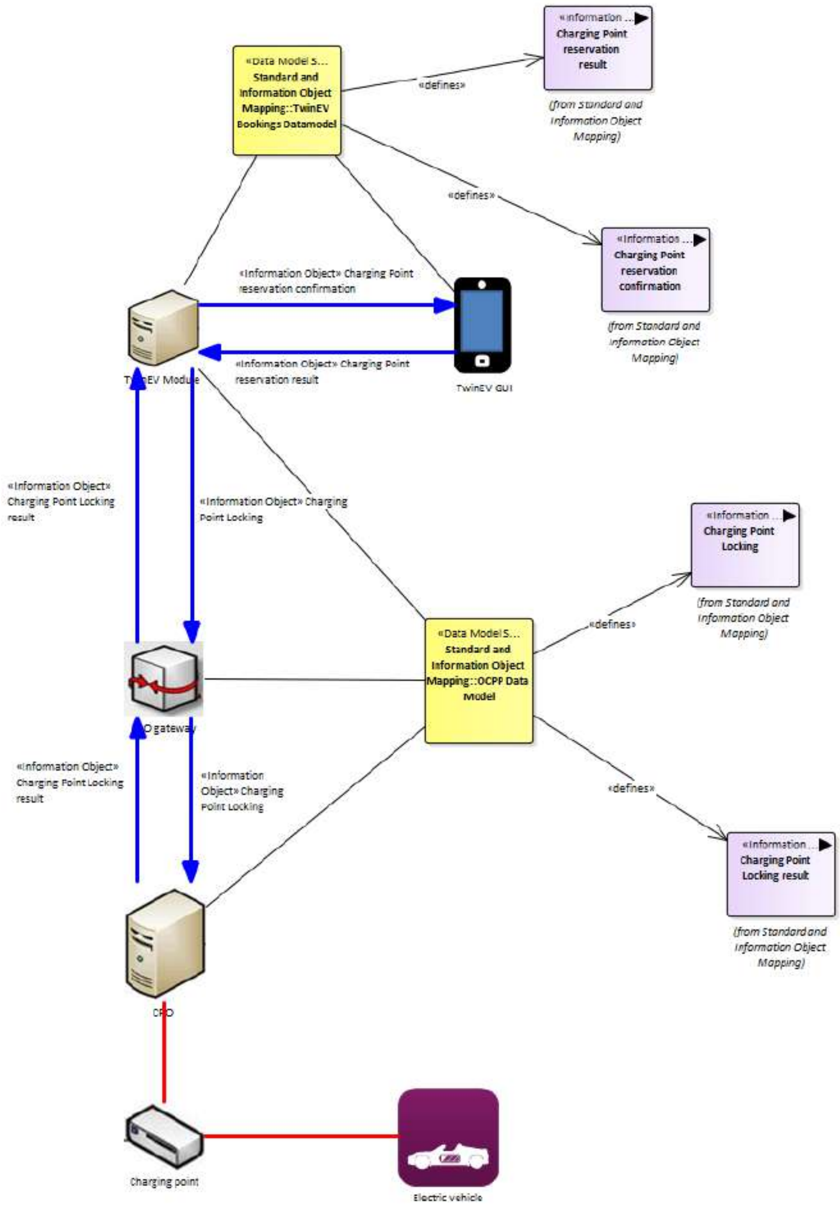

Figure 97: SGAM Standards and Information Object Mapping PUC03.01

Table 57: List of Information Objects PUC03.01

Information Objects	Data Models
Charging Point reservation result	TwinEV Bookings Data model
Charging Point reservation confirmation	TwinEV Bookings Data model
Charging Point Locking	OCPP Data Model
Charging Point Locking result	OCPP Data Model

7.1.8. Activity Diagram

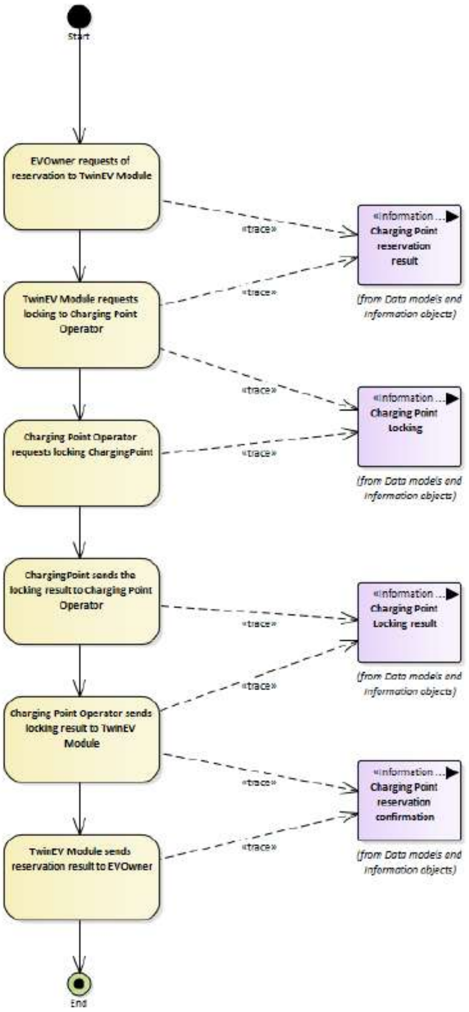

Figure 98: SGAM Activity Diagram PUC03.01

7.1.9. Sequence Diagram

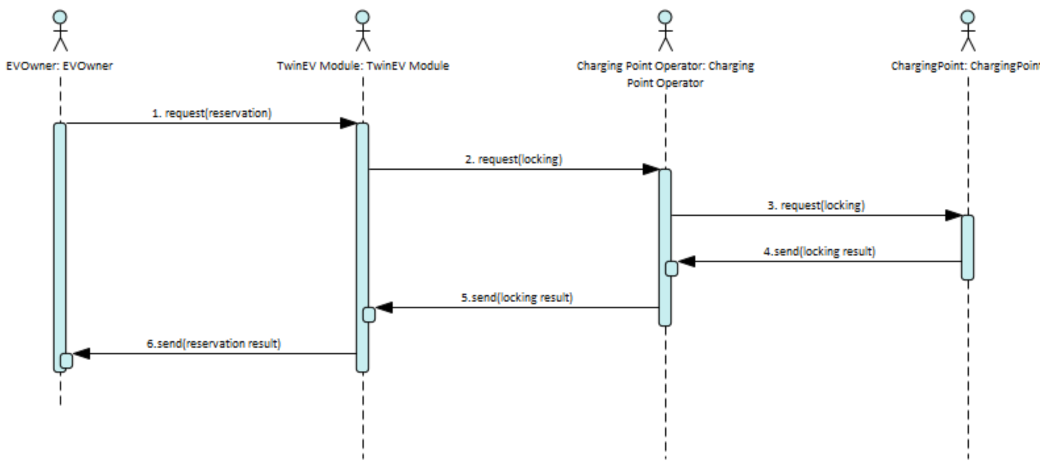

Figure 99: SGAM Sequence Diagram PUC03.01

7.2. PUC03.02. Smart Charging to follow grid requests

7.2.1. Use Case Description

This Use case starts when the process of charging starts. The steps to be followed are:

1. The user starts the charging session, linking his/her device with the charging point (CP), by using the TwinEV drivers app.
2. When the CP indicates, the user connects the eVehicle to the CP.
3. If the CP is private, the user has to introduce the data about the charge: vehicle, current battery level (%), desired battery level (%), desired charge time (minutes).
4. If the CP is public or semi-public, the user selects the reservation and introduces the current battery level (%).
5. The TwinEV module loads auxiliary data about the session:
    - CP information (availability)
    - Battery features (capacity)
    - Grid restrictions.
    - Energy prices (given by Local energy markets).
    - Limitation of power on supply point (maximum and minimum)
    - Forecasts of demand and production (from modules RES integration & DER management, Neighbourhood demand flexibility profiling and Consumer demand flexibility profiling)
    - Nominal power of connectors
    - Target slots
    - Flexibility orders given by DSO from TwinEV Dashboard
6. The system calculates a charge curve for the session, where defined restrictions that have been established by the DSO must be met.
7. The TwinEV module calculates the cost of the operation.
8. The system sends the curve to the CP via the Charging Point Operator (CPO).
9. The charge starts and the application informs to the user about the remaining time and the total cost of the operation.
10. During the charge, depending on the energy value in each slot, the CP can inject energy to the eVehicle or extract energy from the eVehicle if V2G is enabled.
11. The user can interrupt the charging session while it is active.
12. When the current time is the charging time, the charge finishes.
13. If the charging point is public and the user exceeds the limit of time to pick up the vehicle, the total cost of the operation is increased. The interface informs about it to the user.
14. The payment of the cost is done via the Transactive Energy Module.
15. The user ends the session.
16. The user disconnects the eVehicle from the CP.

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7.2.2. SGAM Function Layer

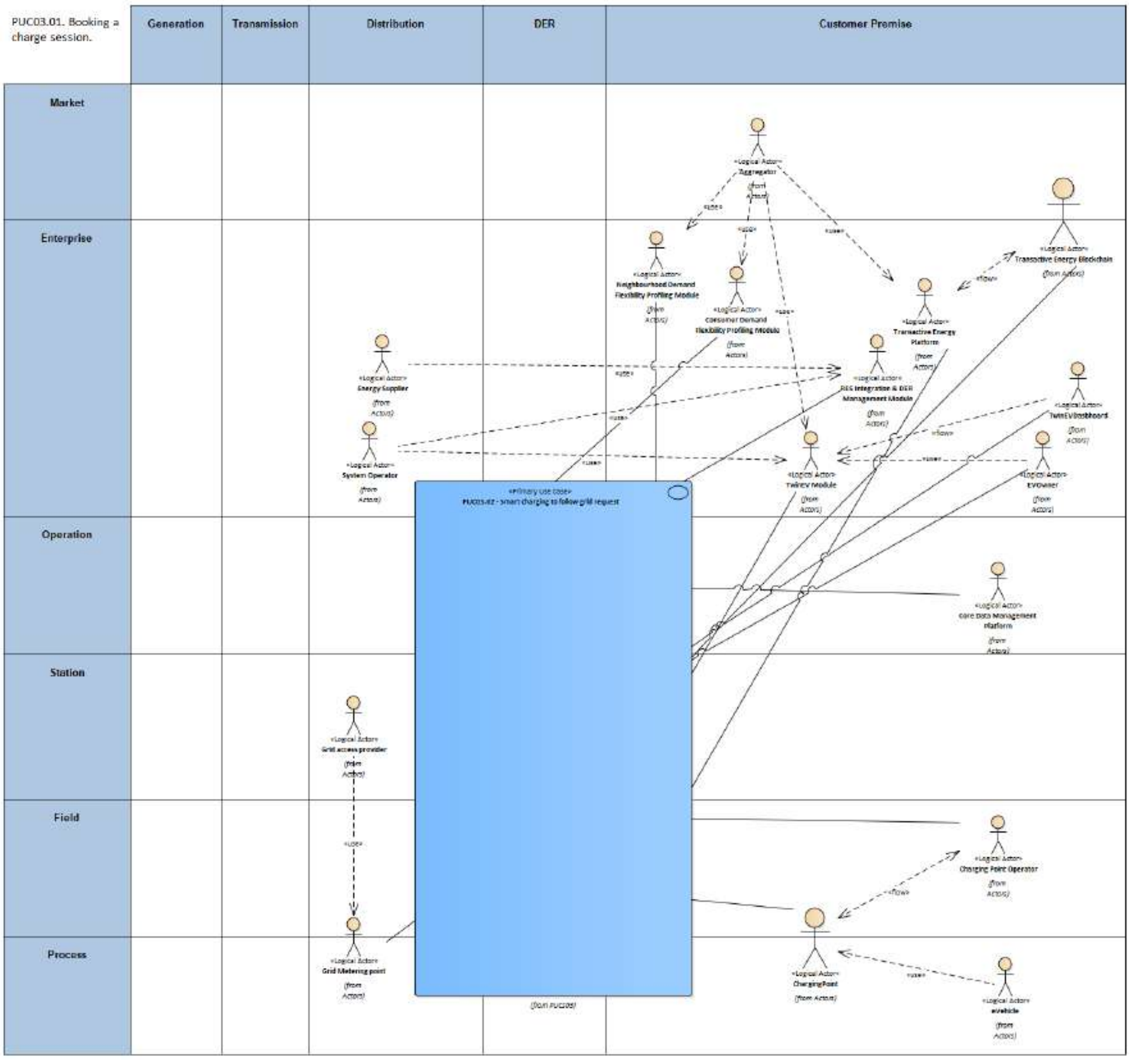

Figure 100: SGAM Function Layer PUC03.02

Table 58: List of Actors Involved PUC03.02

Actor Name	Actor Type
Aggregator	Local actor role
Neighbourhood Demand Flexibility Profiling Module	Application
Consumer Demand Flexibility Profiling Module	Application
Transactive Energy Blockchain	Application
Transactive Energy Platform	Application

Energy Supplier	Organization
System Operator	Organization
Grid Access Provider	Organization
Grid Metering Point	Device
Charging Point	Device
eVehicle	Device
Charging Point Operator	Organization
Core Data Management Platform	Application
EV Owner	Logical actor role
TwinEV Dashboard	Application
TwinEV Module	Application
RES Integration & DER Management Module	Application

7.2.3. SGAM Component Layer

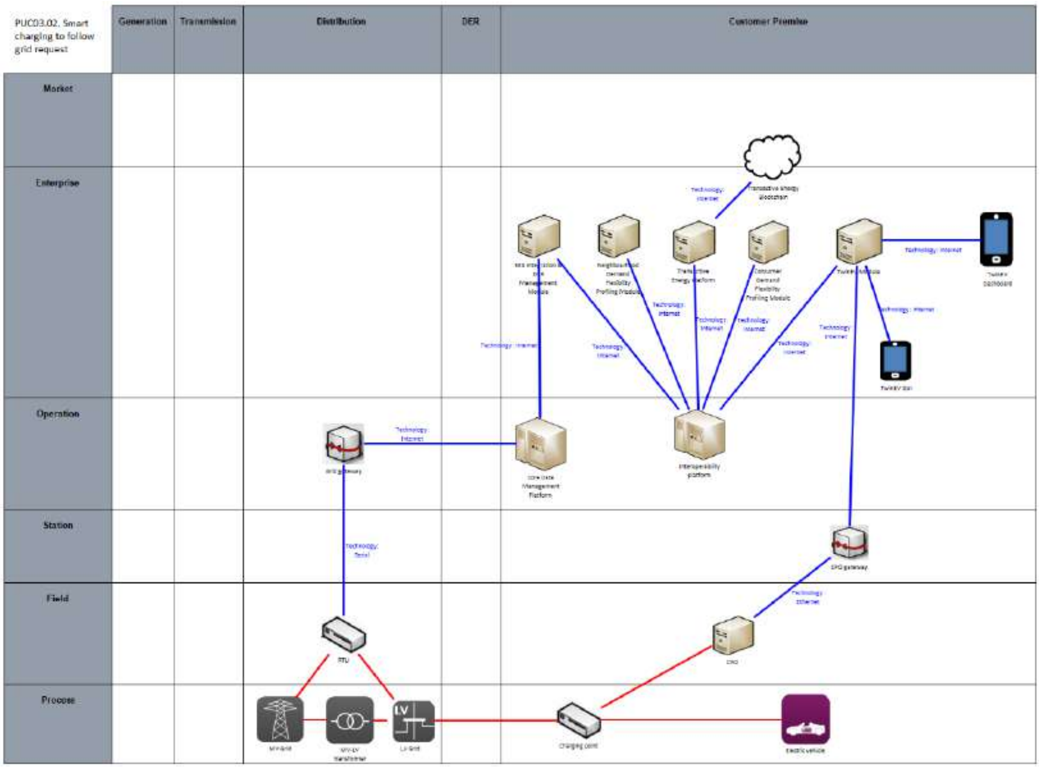

Figure 101:SGAM Component Layer PUC03.02

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Table 59: List of Components PUC03.02

Component	Component Type
MV Grid	Physical asset
MV-LV transformer	Physical asset
LV Grid	Physical asset
RTU	Physical asset
Grid gateway	External application
Charging Point	Physical asset
Electric Vehicle	Physical asset
Charging Point Operator	Organization
Charging Point Operator Gateway	External application
Core Data Management Platform	TwinERGY application
RES Integration & DER Management Module	TwinERGY application
Neighbourhood Demand Flexibility Profiling Module	TwinERGY application
Transactive Energy Platform	TwinERGY application
Consumer Demand Flexibility Profiling Module	TwinERGY application
TwinEV Module	TwinERGY application
Interoperability Platform	TwinERGY application
TwinEV GUI	TwinERGY application
TwinEV Dashboard	TwinERGY application
Transactive Energy Blockchain	TwinERGY application

7.2.4. SGAM Communication Layer

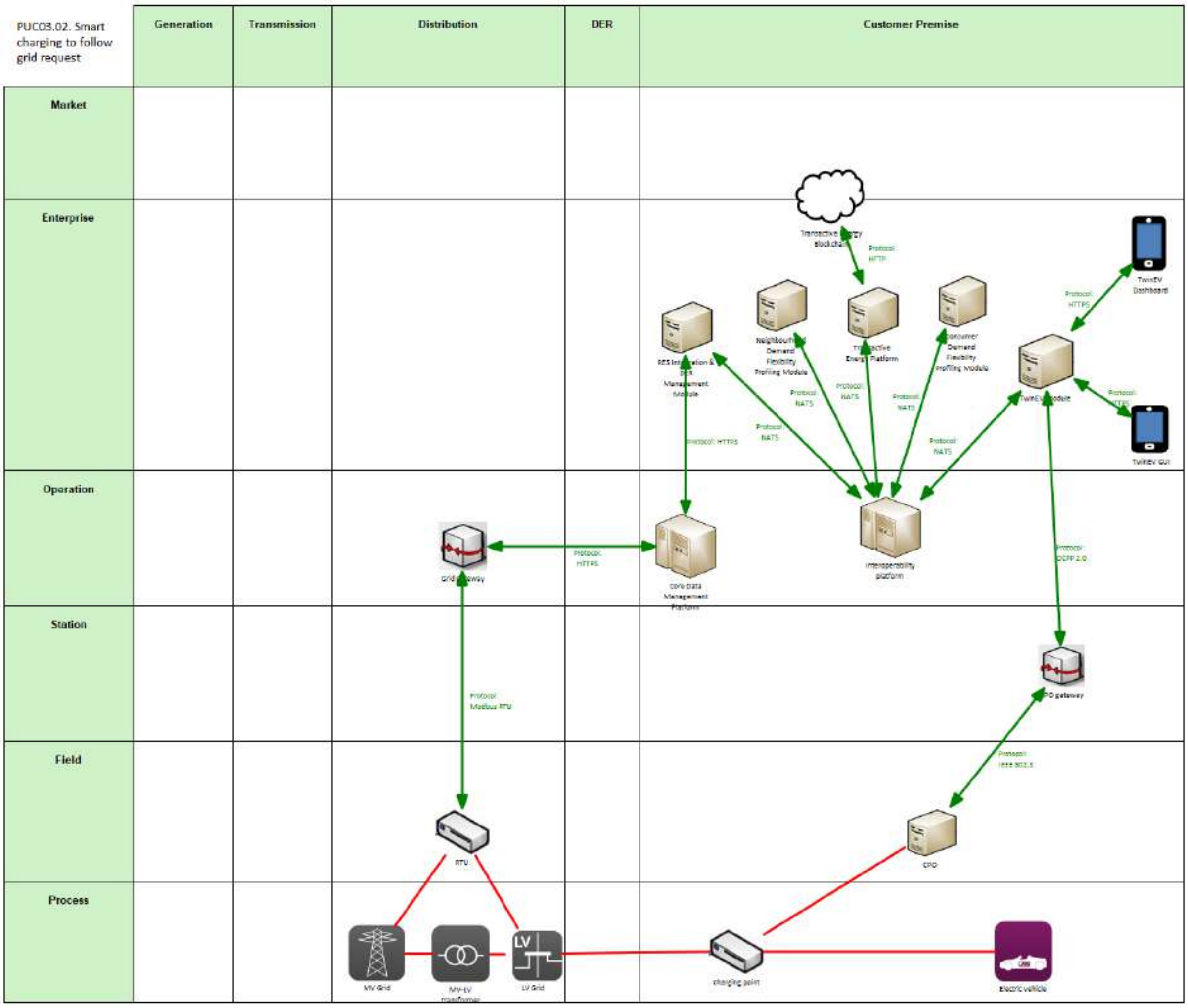

Figure 102: SGAM Communication Layer PUC03.02

Table 60: List of Communication technologies involved in PUC03.02

Communication Technology	Description
Modbus RTU	Data communications protocol for using with programmable logic controllers (PLCs), where devices are connected to the same cable or Ethernet network. It is used on industrial environments
HTTPS	HyperText Transfer Protocol Secure. It is an extension of the Hypertext Transfer Protocol (HTTP), used for secure communication over a computer network. In HTTPS, the communication protocol is encrypted using Transport Layer Security (TLS) or, formerly, Secure Sockets Layer (SSL). The protocol is therefore also referred to as HTTP over TLS, or HTTP over SSL.

HTTP	Stand for Hypertext Transfer Protocol. It is an application layer protocol in the Internet protocol suite model for distributed, collaborative, hypermedia information systems
NATS	Protocol of messaging that enables the exchange of messages among computer applications and services, not depending on the network location.
OCPP 2.0	The Open Charge Point Protocol is an application protocol for communication between Electric vehicle, charging stations and a central management system.
IEE 802.3	Protocol that defines the physical layer and data link layer's media access control (MAC) of wired Ethernet. This is generally a local area network (LAN) technology with some wide area network (WAN) applications

7.2.5. SGAM Information Layer

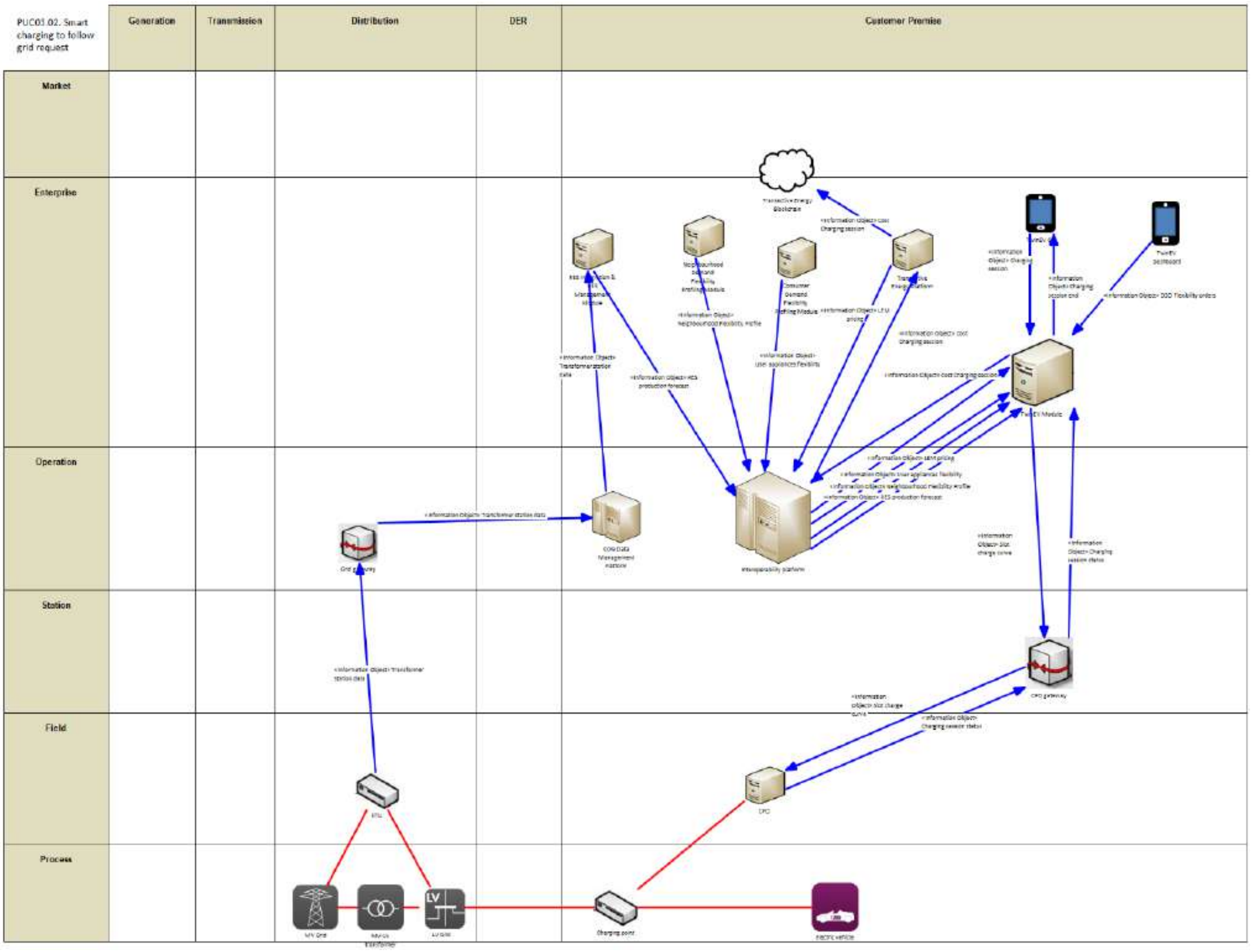

Figure 103: SGAM Information Layer PUC03.02

7.2.6. Canonical Data Model

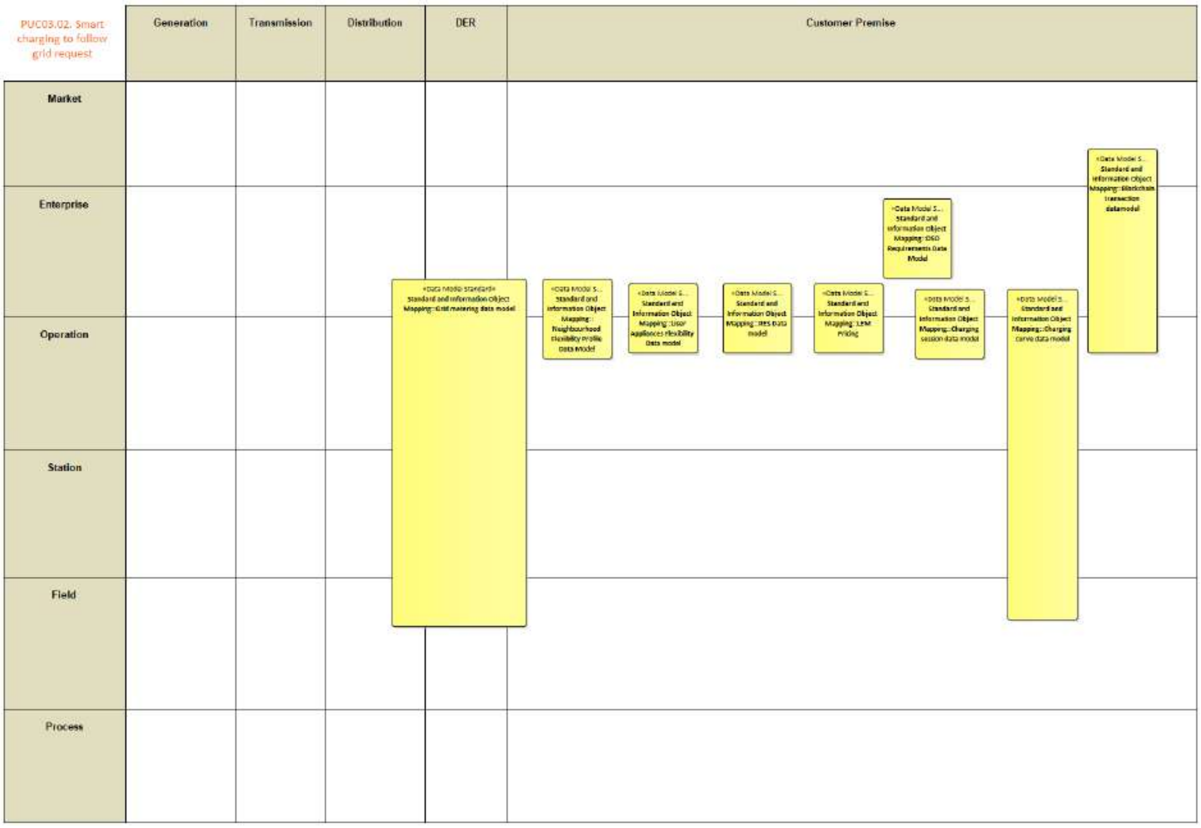

Figure 104: SGAM Canonical Data Model PUC03.02

Table 61: List of Data Models PUC03.02

Data Models
Grid metering Data Model
Neighbourhood Flexibility Profile Data Model
User Appliances Flexibility Data Model
RES Data model
LEM Pricing
DSO Requirements Data Model
Charging session Data Model
Charging curve Data Model
Blockchain transaction Data Model

7.2.7. Standards and Information Object Mapping

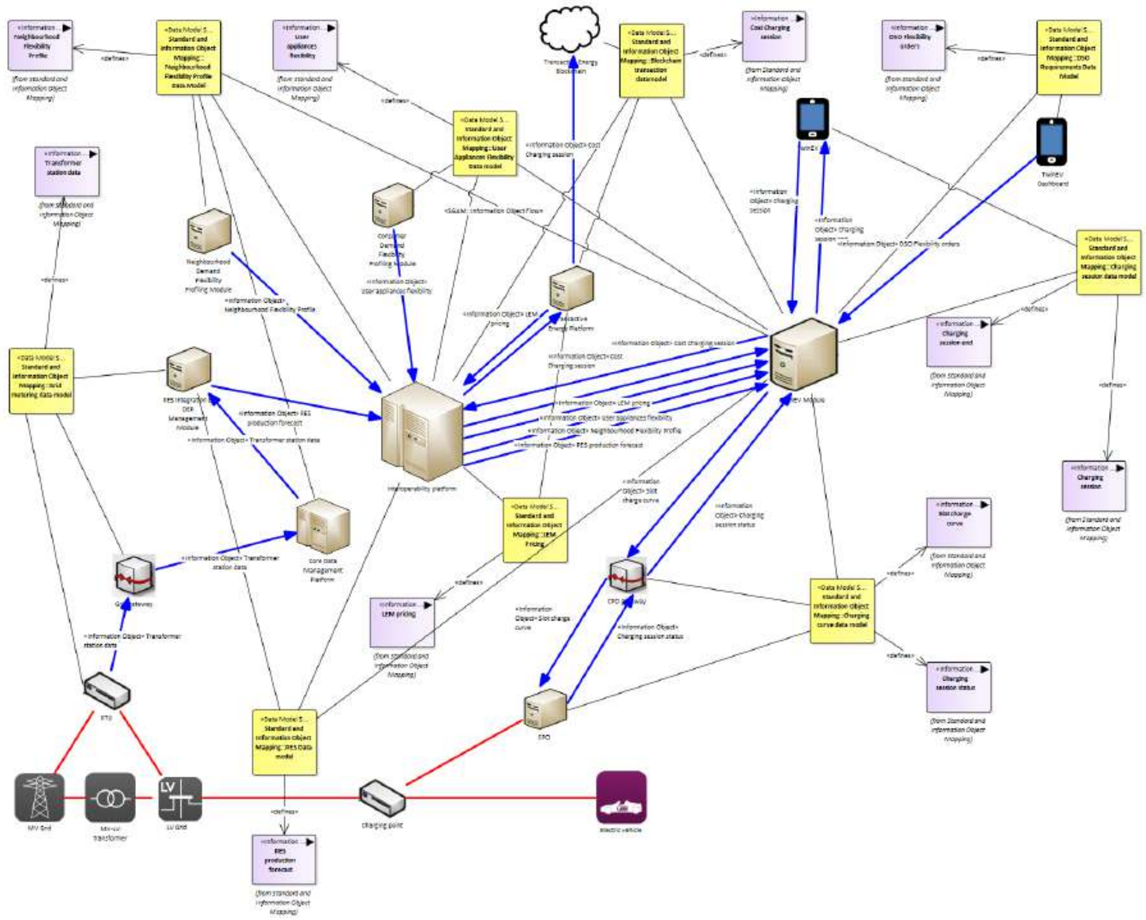

Figure 105: SGAM Standards and Information Object Mapping PUC03.02

Table 62: List of Information Objects PUC03.02

Information Objects	Data Models
Neighbourhood Flexibility Profile	Neighbourhood Flexibility Profile Data Model
Transformer station data	Grid metering data model
RES production forecast	RES Data model
User appliances flexibility	User Appliances Flexibility Data model
LEM pricing	LEM Pricing Data model
Cost Charging session	Blockchain transaction data model
DSO Flexibility orders	DSO Requirements Data Model
Charging session end	Charging session data model

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Charging session	Charging session data model
Slot charge curve	Charging curve data model
Charging session status	Charging curve data model

7.2.8. Activity Diagram

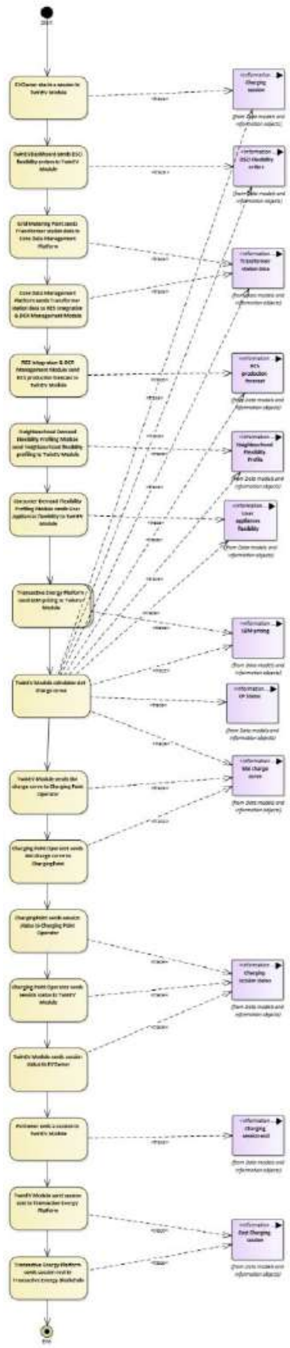

Figure 106: SGAM Activity Diagram PUC03.02

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7.2.9. Sequence Diagram

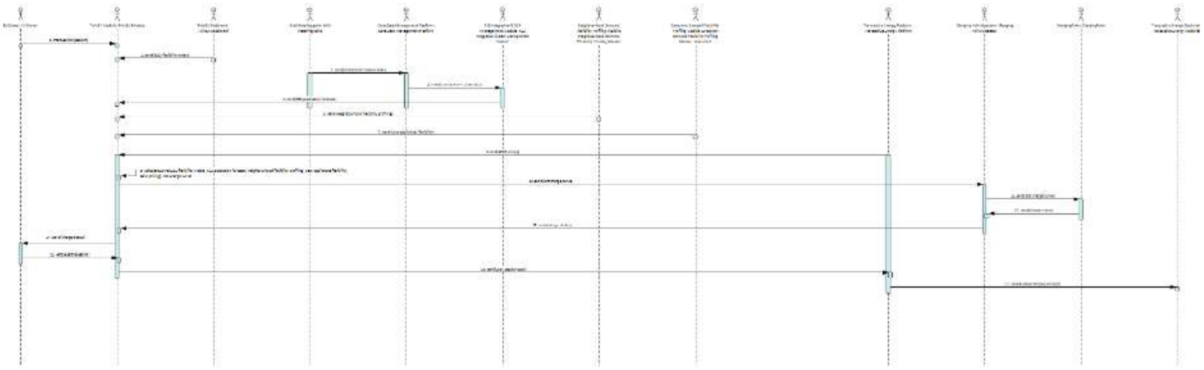

Figure 107: SGAM Sequence Diagram PUC03.02

7.3. PUC03.03. Smart Charging to maximize RES integration

7.3.1. Use Case Description

This Use case starts when the process of charging starts. The steps to be followed are:

1. The user starts the charging session, linking his/her device with the CP, via the TwinEV drivers app.
2. When the CP indicates, the user connects the eVehicle to the charging point (CP).
3. If the CP is private, the user must introduce the data about the charge: vehicle, current battery level (%), desired battery level (%), desired charge time (minutes).
4. If the CP is public or semi-public, the user selects the reservation and introduces the current battery level (%).
5. The TwinEV module loads auxiliary data about the session and the grid status:
    - CP information,
    - Vehicle battery features (capacity, SoC- State of Charge)
    - Grid restrictions.
    - Energy stored by batteries (community and home) and energy generated by PV panels
    - Energy prices (given by Local energy markets).
    - Energy MIX from the external service of ENTSO-E [11] given by its Transparency platform). This information is returned via the Digital Twin Platform.
    - Limitation of power on supply point (maximum and minimum)
    - Forecasts of demand and production (from modules RES Integration & DER Management, Neighbourhood Demand Flexibility Profiling and Consumer Demand Flexibility Profiling)
    - Nominal power of connectors
    - Target slots
    - Flexibility orders given by DSO from TwinEV Dashboard

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6. The system calculates a charge curve for the session in which the most amount of energy charged corresponds to slots of time where the energy mix composed mainly by RES, always meeting the restrictions stablished by the DSO.
7. The TwinEV module calculates cost of the operation.
8. The TwinEV module sends the curve to the CP via the CPO.
9. The charge starts and the application informs the user about the remaining time and the total cost of the operation.
10. During the charge, depending on the energy value in each slot, the CP can inject energy to the EV or extract energy from the EV if V2G is enabled
11. The user can interrupt the charging session while it is active.
12. When the current time is the charging time, the charge finishes.
13. If the charging point is public and the user exceeds the limit of time to pick up the vehicle, the total cost of the operation is increased. The interface informs the user regarding the updated charge rate.
14. The payment of the cost is handled via the Transactive Energy Module.
15. The user ends the session.
16. The user disconnects the eVehicle from the CP.

7.3.2. SGAM Function Layer

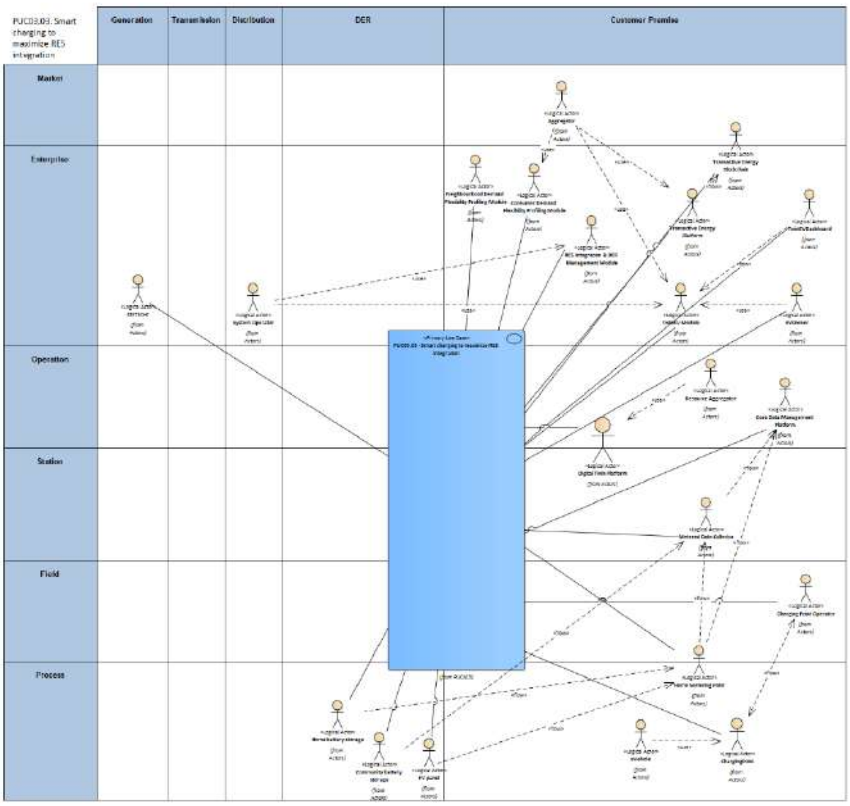

Figure 108: SGAM Function Layer PUC03.03

Table 63: List of Actors Involved PUC03.03

Actor Name	Actor Type
Aggregator	Local actor role
Neighbourhood Demand Flexibility Profiling Module	Application
Consumer Demand Flexibility Profiling Module	Application
Transactive Energy Blockchain	Application
Transactive Energy Platform	Application
ENTSO-E	Organization
System Operator	Organization
Meter Data Collector	Device
Home Metering Point	Device
Community Battery Storage	Device
Home Battery Storage	Device
PV Panel	Device
Charging Point	Device
eVehicle	Device
Charging Point Operator	Organization
Core Data Management Platform	Application
EV Owner	Logical actor role
TwinEV Dashboard	Application
TwinEV Module	Application
RES Integration & DER Management Module	Application
Digital Twin Platform	Application

Twinergy has received funding from the European Union's Horizon 2020 research and innovation programme under grant agreement No. 957736

7.3.3. SGAM Component Layer

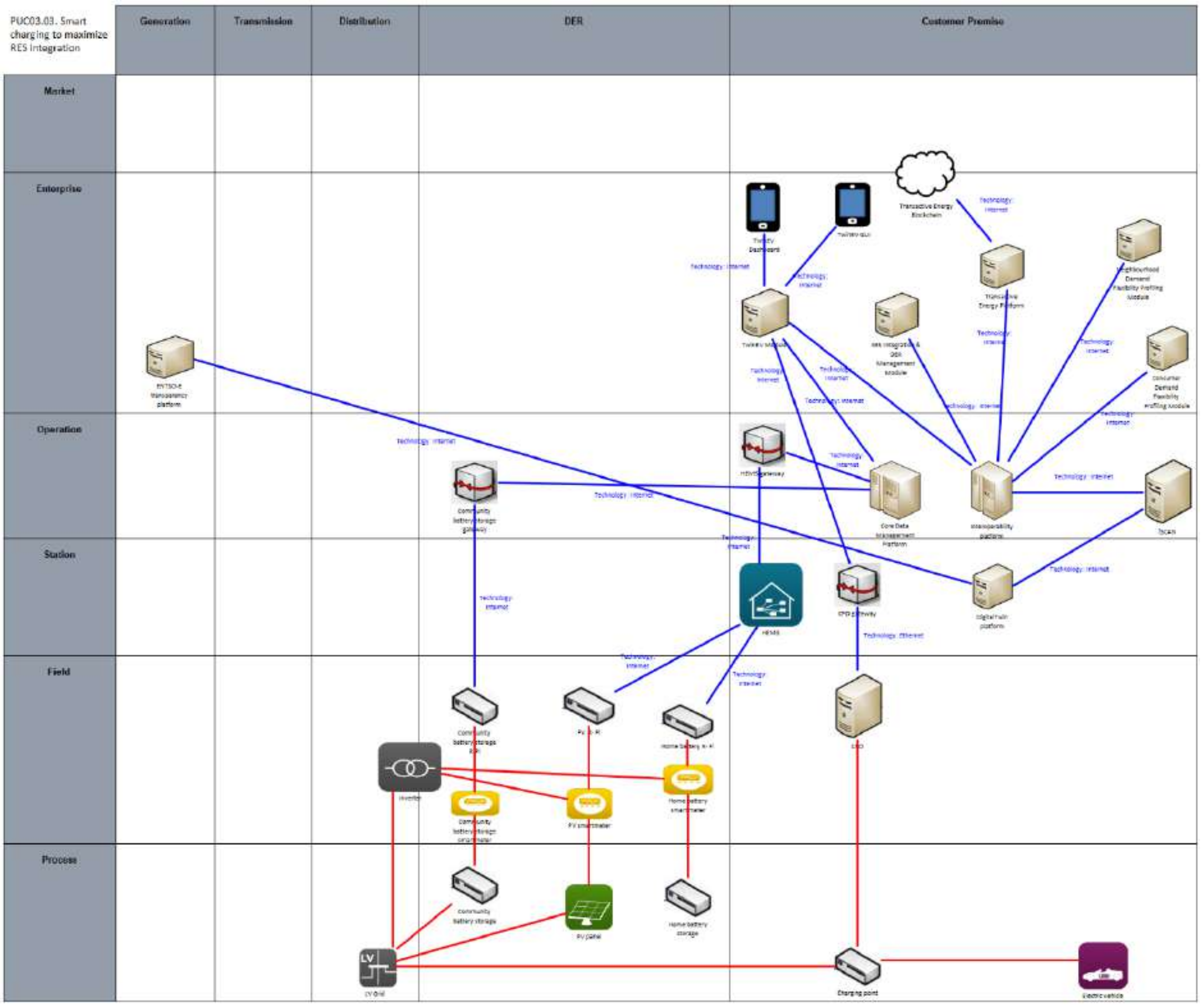

Figure 109: SGAM Component Layer PUC03.03

Table 64: List of Components PUC03.03

Component	Component Type
LV Grid	Physical asset
Community battery storage	Physical asset
Community battery storage smart meter	Physical asset
Community battery storage gateway	External application
PV Panel	Physical asset
PV smart meter	Physical asset
Inverter	Physical asset

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Home battery storage	Physical asset
Home storage smart meter	Physical asset
Raspberry Pi	Physical asset
ENTSO-E transparency platform	External Application
HEMS	External Application
Electric Vehicle	Physical asset
Charging Point Operator	Organization
Charging Point	Physical asset
Charging Point Operator Gateway	External application
Core Data Management Platform	TwinERGY application
RES Integration & DER Management Module	TwinERGY application
Neighbourhood Demand Flexibility Profiling Module	TwinERGY application
Transactive Energy Platform	TwinERGY application
Consumer Demand Flexibility Profiling Module	TwinERGY application
TwinEV Module	TwinERGY application
Interoperability Platform	TwinERGY application
TwinEV GUI	TwinERGY application
TwinEV Dashboard	TwinERGY application
Transactive Energy Blockchain	TwinERGY application
Digital Twin Platform	TwinERGY application
iSCAN	External application

7.3.4. SGAM Communication Layer

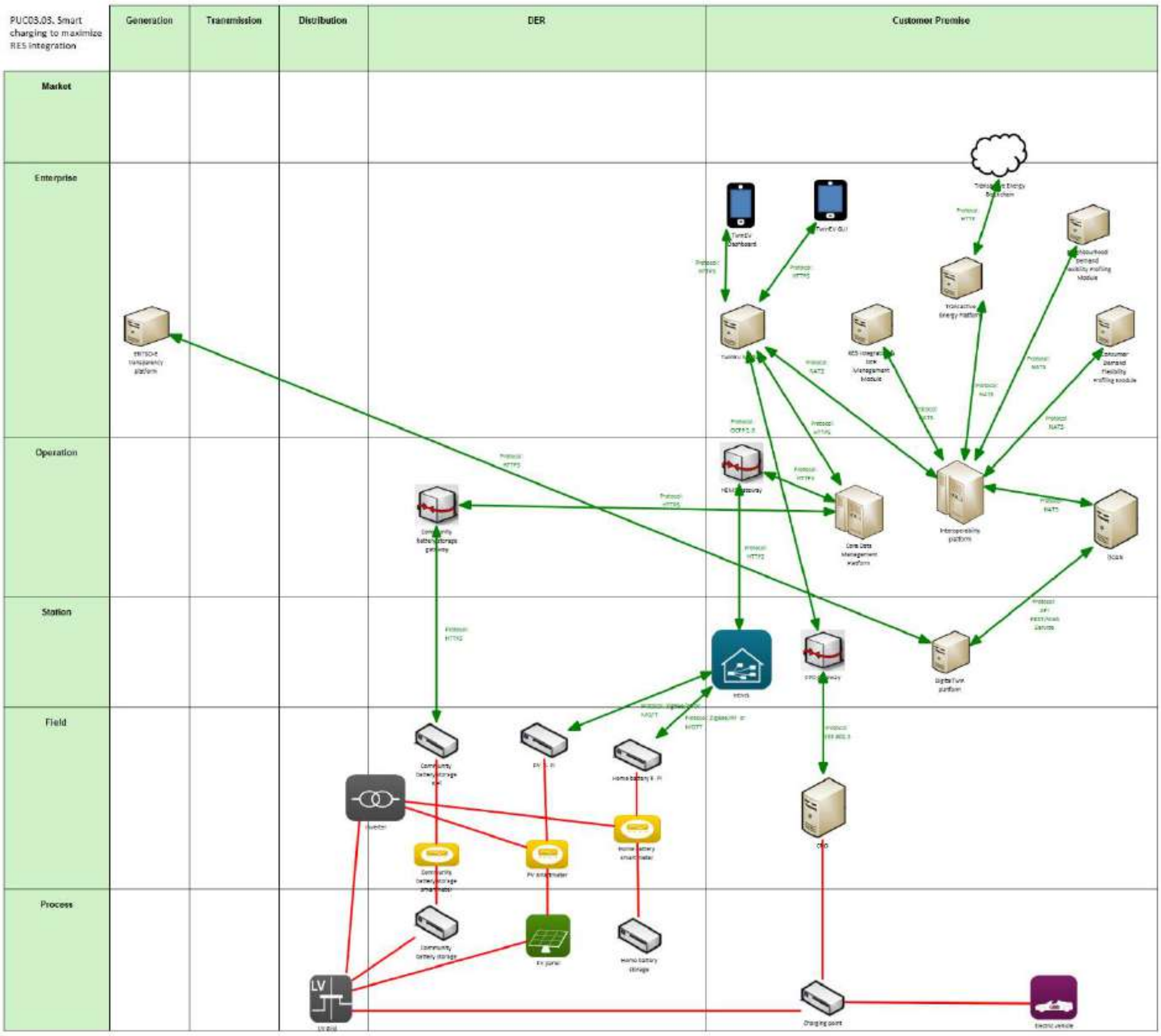

Figure 110: SGAM Communication Layer PUC03.03

Table 65: List of Communication technologies involved in PUC03.03

Communication Technology	Description
API REST	Application Programming Interface for REpresentational State Transfer. API is a software intermediary that allows two applications to talk to each other, whilst REST is an architectural style for distributed hypermedia systems, working stateless. Both define a set of distributed resources accessible and manipulable through a set of public functions.
HTTPS	HyperText Transfer Protocol Secure. It is an extension of the Hypertext Transfer Protocol (HTTP), used for secure communication over a computer network. In HTTPS, the communication protocol is encrypted using Transport Layer

	Security (TLS) or, formerly, Secure Sockets Layer (SSL). The protocol is therefore also referred to as HTTP over TLS, or HTTP over SSL.
HTTP	Stand for Hypertext Transfer Protocol. It is an application layer protocol in the Internet protocol suite model for distributed, collaborative, hypermedia information systems
NATS	Protocol of messaging that enables the exchange of messages among computer applications and services, not depending on the network location.
OCPP 2.0	The Open Charge Point Protocol is an application protocol for communication between Electric vehicle, charging stations and a central management system.
IEE 802.3	Protocol that defines the physical layer and data link layer's media access control (MAC) of wired Ethernet. This is generally a local area network (LAN) technology with some wide area network (WAN) applications
ZigBee/RF	Protocol IEEE 802.15.4, designed to communicate data through noisy RF environments. This standard operates on the physical radio specification and operates in unlicensed bands including 2.4 GHz, 900 MHz and 868 MHz.
MQTT	MQ Telemetry Transport. It is an open OASIS standard and an ISO recommendation (ISO/IEC 20922) over TCP/IP, being a lightweight, publish-subscribe network protocol that transports messages between devices.

7.3.5. SGAM Information Layer

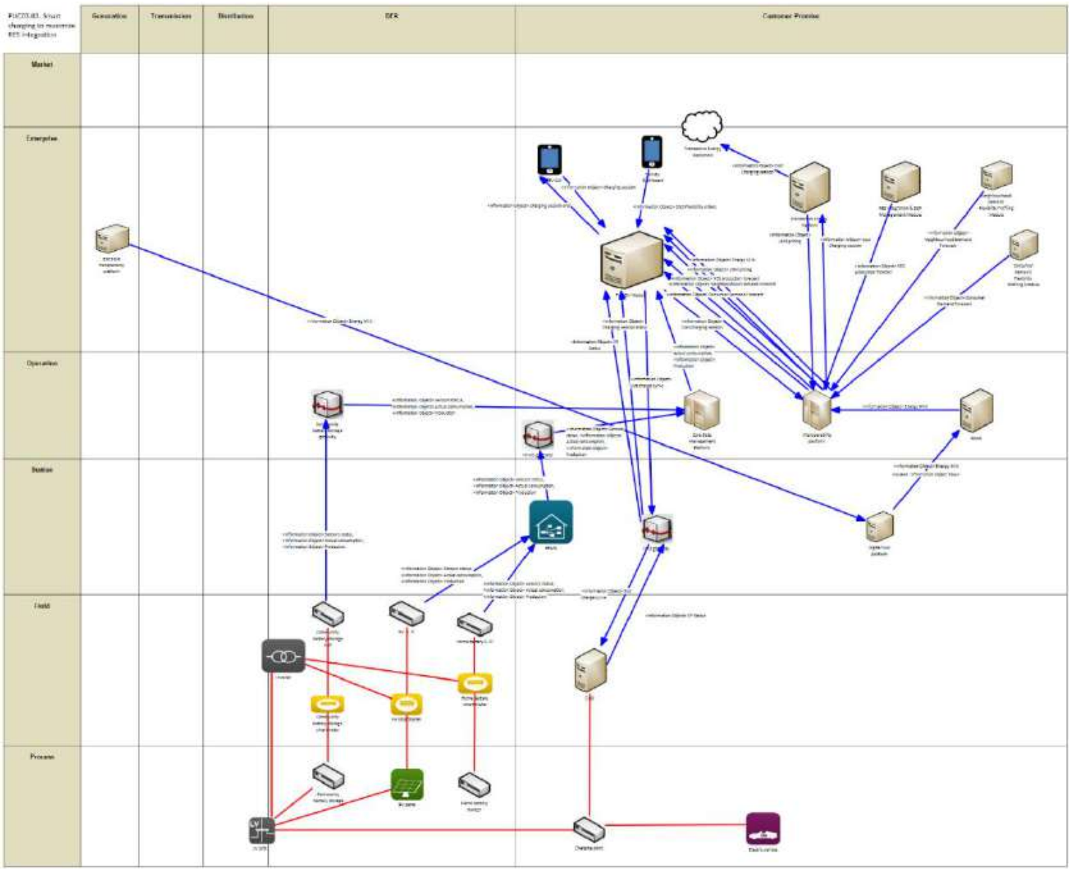

Figure 111: SGAM Information Layer PUC03.03

7.3.6. Canonical Data Model

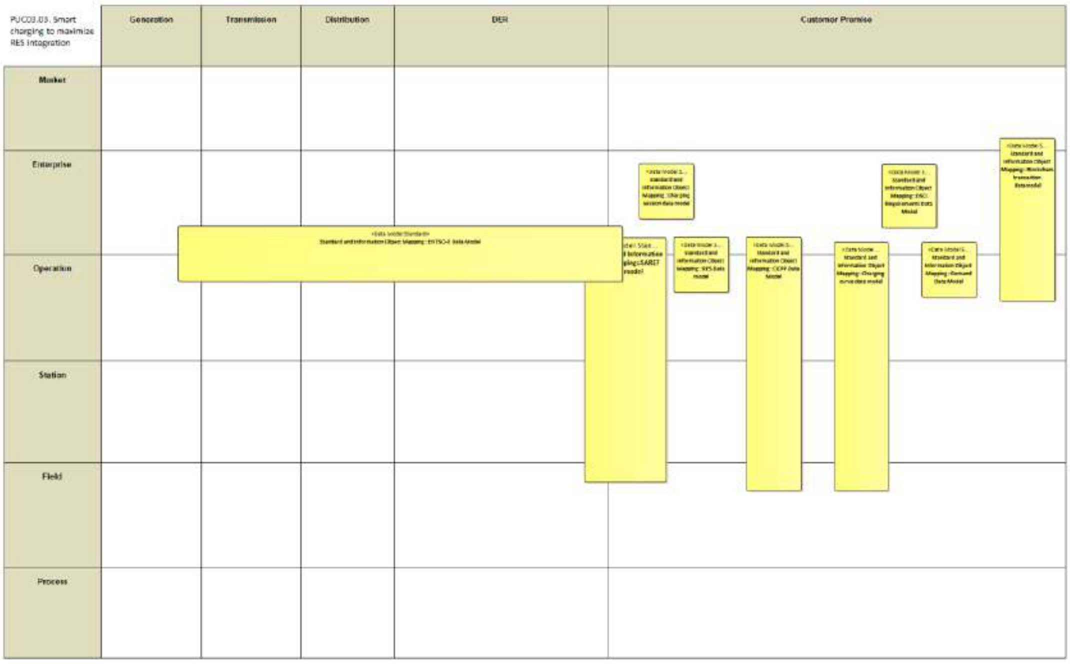

Figure 112: SGAM Canonical Data Model PUC03.03

Table 66: List of Data Models PUC03.03

Data Models
ENTSO-E Data Model
SAREF Data Model
Charging Session Data Model
RES Data Model
OCPP Data Model
Charging Curve Data Model
DSO Requirements Data Model
Demand Data Model
Blockchain Transaction Data Model

7.3.7. Standards and Information Object Mapping

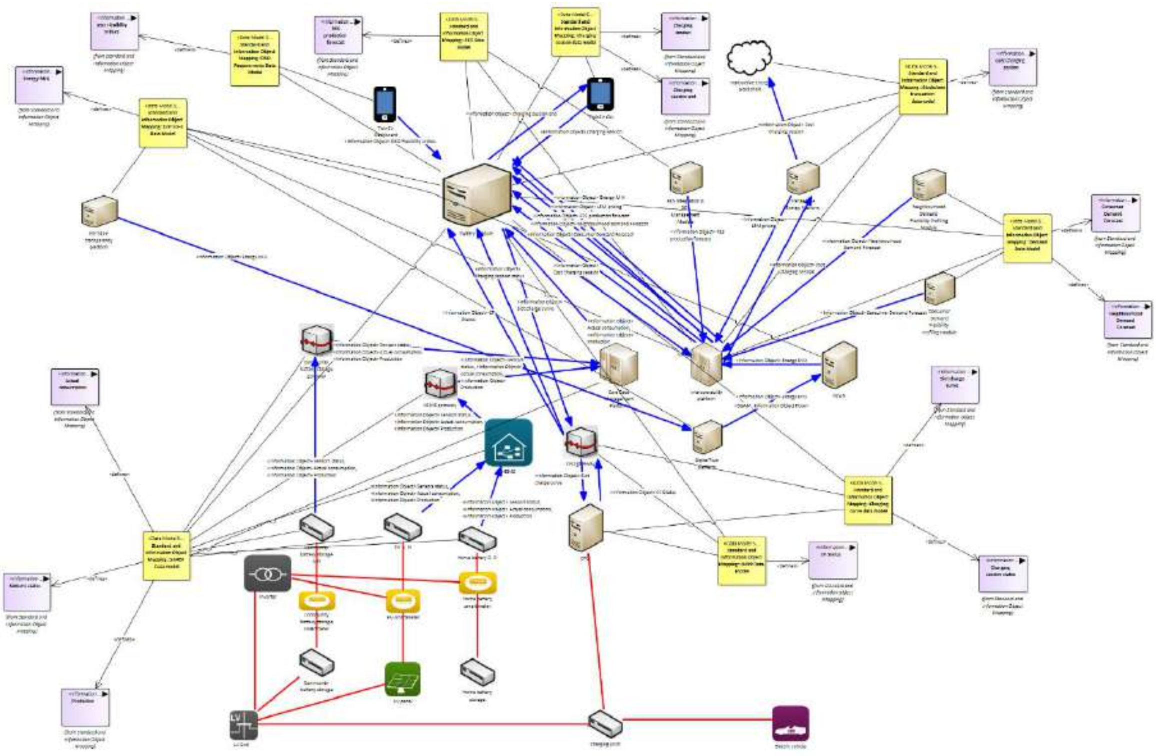

Figure 113: SGAM Standards and Information Object Mapping PUC03.03

Twinergy has received funding from the European Union's Horizon 2020 research and innovation programme under grant agreement No. 957736

Table 67: List of Information Objects PUC03.03

Information Objects	Data Models
Energy MIX	ENTSO-E Data Model
DSO Flexibility orders	DSO Requirements Data Model
RES production forecast	RES Data model
Charging session	Charging session data model
Charging session end	Charging session data model
Cost Charging session	Blockchain transaction data model
Consumer Demand Forecast	Demand Data Model
Neighbourhood Demand Forecast	Demand Data Model
Actual consumption	SAREF Data model
Sensor status	SAREF Data model
Production	SAREF Data model
Slot charge curve	Charging curve data model
Charging session status	Charging curve data model
CP Status	OCPP Data Model

7.3.8. Activity Diagram

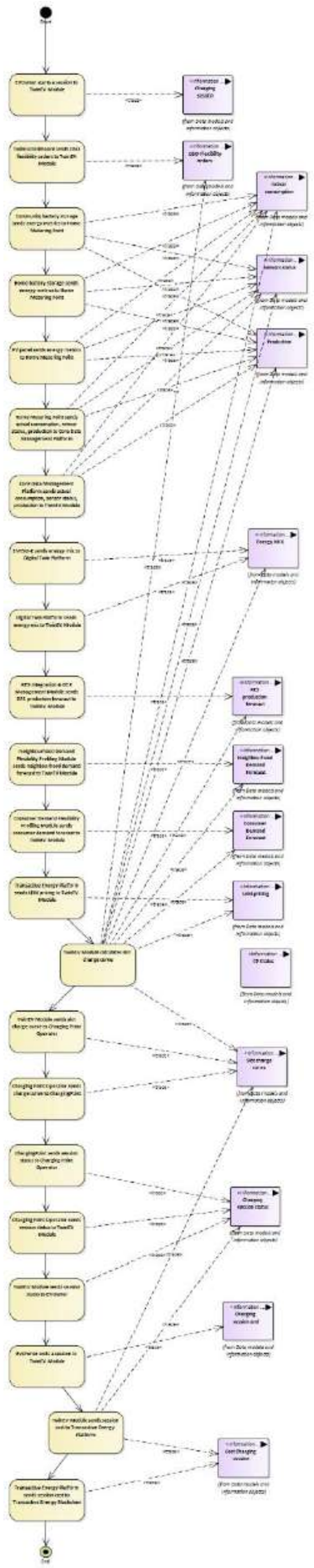

Figure 114: SGAM Activity Diagram PUC03.03

Twinergy has received funding from the European Union's Horizon 2020 research and innovation programme under grant agreement No. 957736

7.3.9. Sequence Diagram

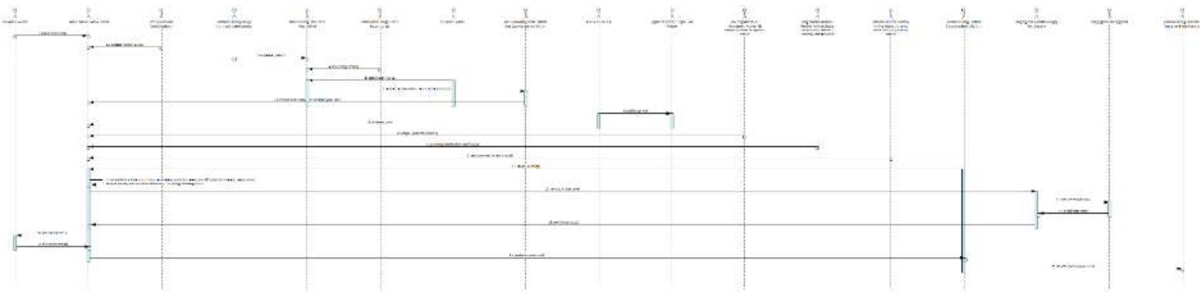

Figure 115: SGAM Sequence Diagram PUC03.03

7.4. PUC03.04. Smart Charging to minimize charge costs

7.4.1. Use Case Description

This Use case starts when the process of charging starts. The steps to be followed are:

1. The user starts the charging session, linking his/her device with the CP, via the TwinEV drivers app.
2. When the CP indicates, the user connects the eVehicle to the charging point (CP).
3. If the CP is private, the user has to introduce the data about the charge: vehicle, current battery level (%), desired battery level (%), desired charge time (minutes).
4. If the CP is public or semi-public, the user selects the reservation and introduces the current battery level (%).
5. The TwinEV module loads auxiliary data about the session:
    - CP information,
    - Battery features (capacity)
    - Grid restrictions.
    - Energy prices (given by Transactive Energy Module).
    - Limitation of power supply point (maximum and minimum)
    - Forecasts of demand and production (from modules RES integration & DER management, Neighbourhood demand flexibility profiling and Consumer demand flexibility profiling)
    - Nominal power of connectors
    - Target Slots
    - Flexibility orders given by DSO from TwinEV Dashboard
6. The TwinEV module calculates a charge curve for the session, in which the most amount of energy charged corresponds to slots of time where the energy price is the lowest, always meeting the restrictions stablished by the DSO.
7. The TwinEV module calculates cost of the operation.
8. The TwinEV module sends the curve to the CP via the CPO.
9. The charge starts and the application informs to the user about the remaining time and the total cost of the operation.
10. During the charge, depending on the energy value in each slot, the CP can inject energy to the EV or extract energy from the EV if V2G is enabled

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11. The user can interrupt the charging session while it is active.
12. When the current time is the charging time, the charge finishes.
13. If the charging point is public and the user exceeds the limit of time to pick up the vehicle, the total cost of the operation is increased. The interface informs about it to the user.
14. The payment of the cost is done via the Transactive Energy Module.
15. The user ends the session.
16. The user disconnects the eVehicle from the CP.

7.4.2. SGAM Function Layer

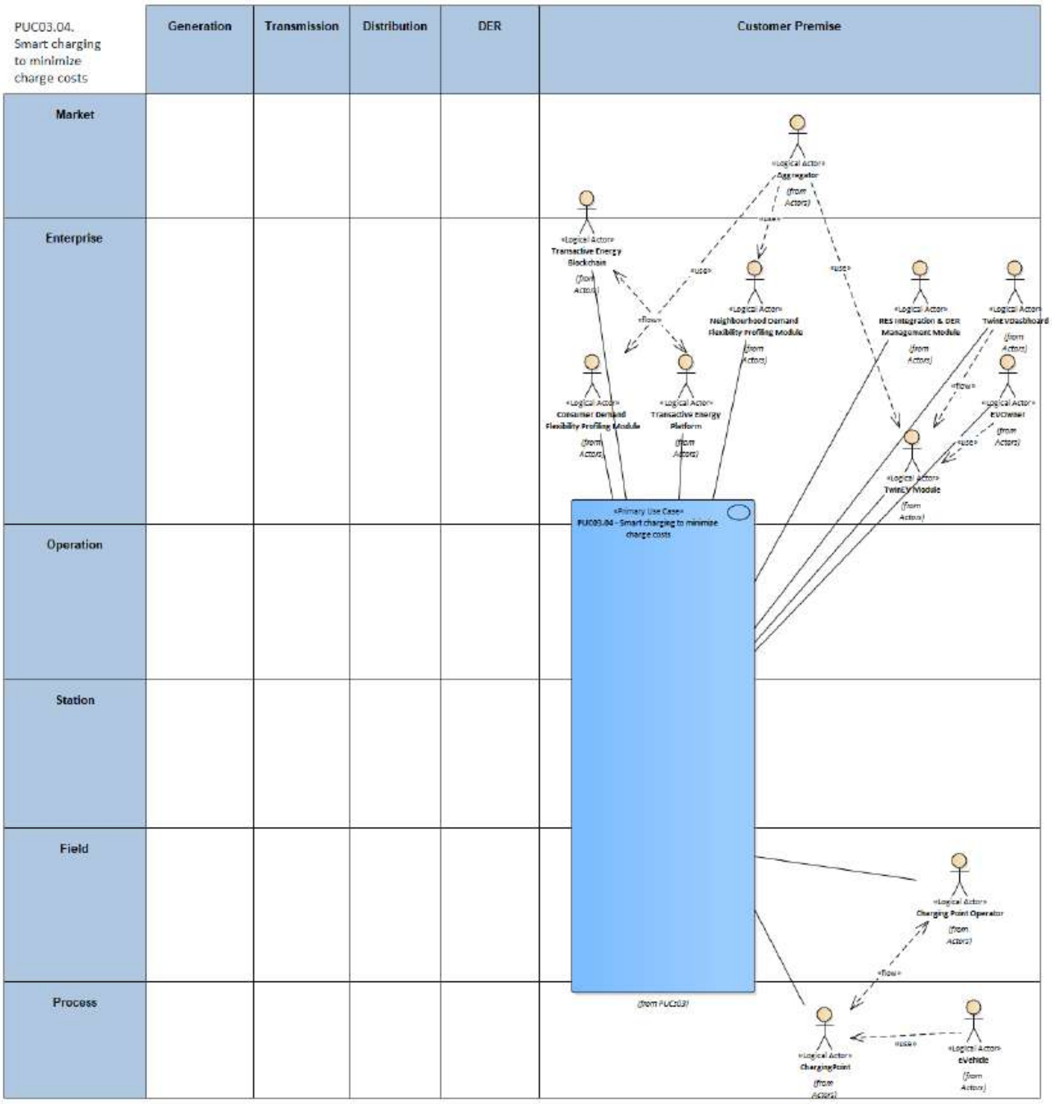

Figure 116: SGAM Function Layer PUC03.04

Twinergy has received funding from the European Union's Horizon 2020 research and innovation programme under grant agreement No. 957736

Table 68: List of Actors Involved PUC03.04

Actor Name	Actor Type
Aggregator	Local actor role
Neighbourhood Demand Flexibility Profiling Module	Application
Consumer Demand Flexibility Profiling Module	Application
Transactive Energy Blockchain	Application
Transactive Energy Platform	Application
Charging Point	Device
eVehicle	Device
Charging Point Operator	Organization
EV Owner	Logical actor role
TwinEV Dashboard	Application
TwinEV Module	Application
RES Integration & DER Management Module	Application

7.4.3. SGAM Component Layer

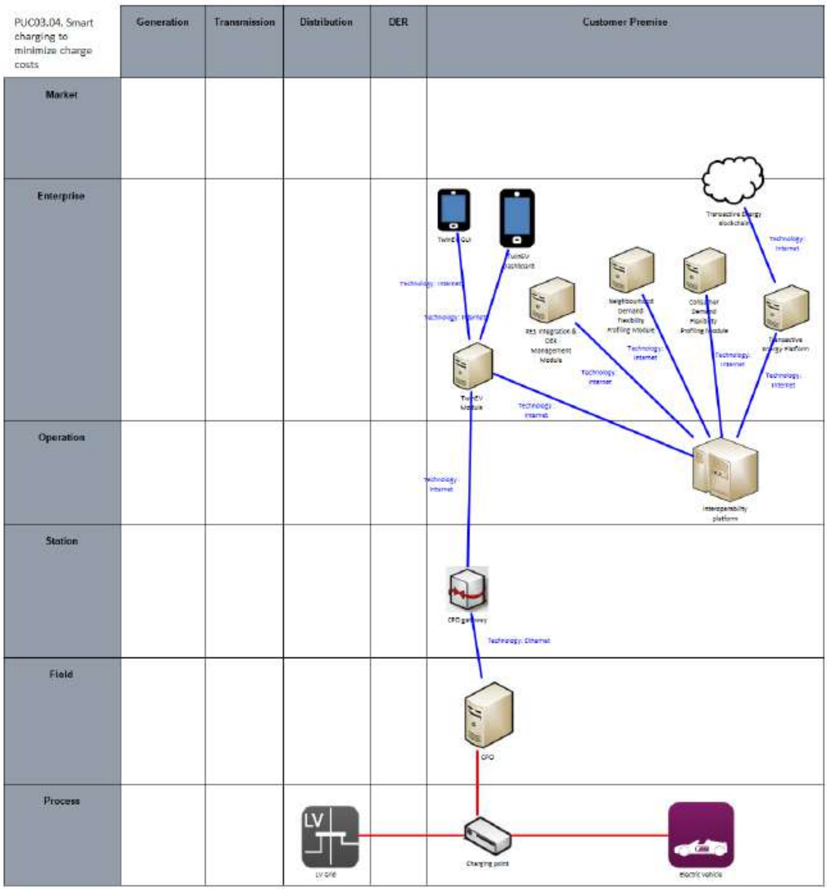

Figure 117: SGAM Component Layer PUC03.04

Table 69: List of Components PUC03.04

Component	Component Type
LV Grid	Physical asset
Charging Point	Physical asset
Electric Vehicle	Physical asset
Charging Point Operator	Organization
Charging Point Operator Gateway	External application
TwinEV Module	TwinERGY application
TwinEV GUI	TwinERGY application
TwinEV Dashboard	TwinERGY application

Interoperability Platform	TwinERGY application
RES Integration & DER Management Module	TwinERGY application
Neighbourhood Demand Flexibility Profiling Module	TwinERGY application
Consumer Demand Flexibility Profiling Module	TwinERGY application
Transactive Energy Platform	TwinERGY application
Transactive Energy Blockchain	TwinERGY application

7.4.4. SGAM Communication Layer

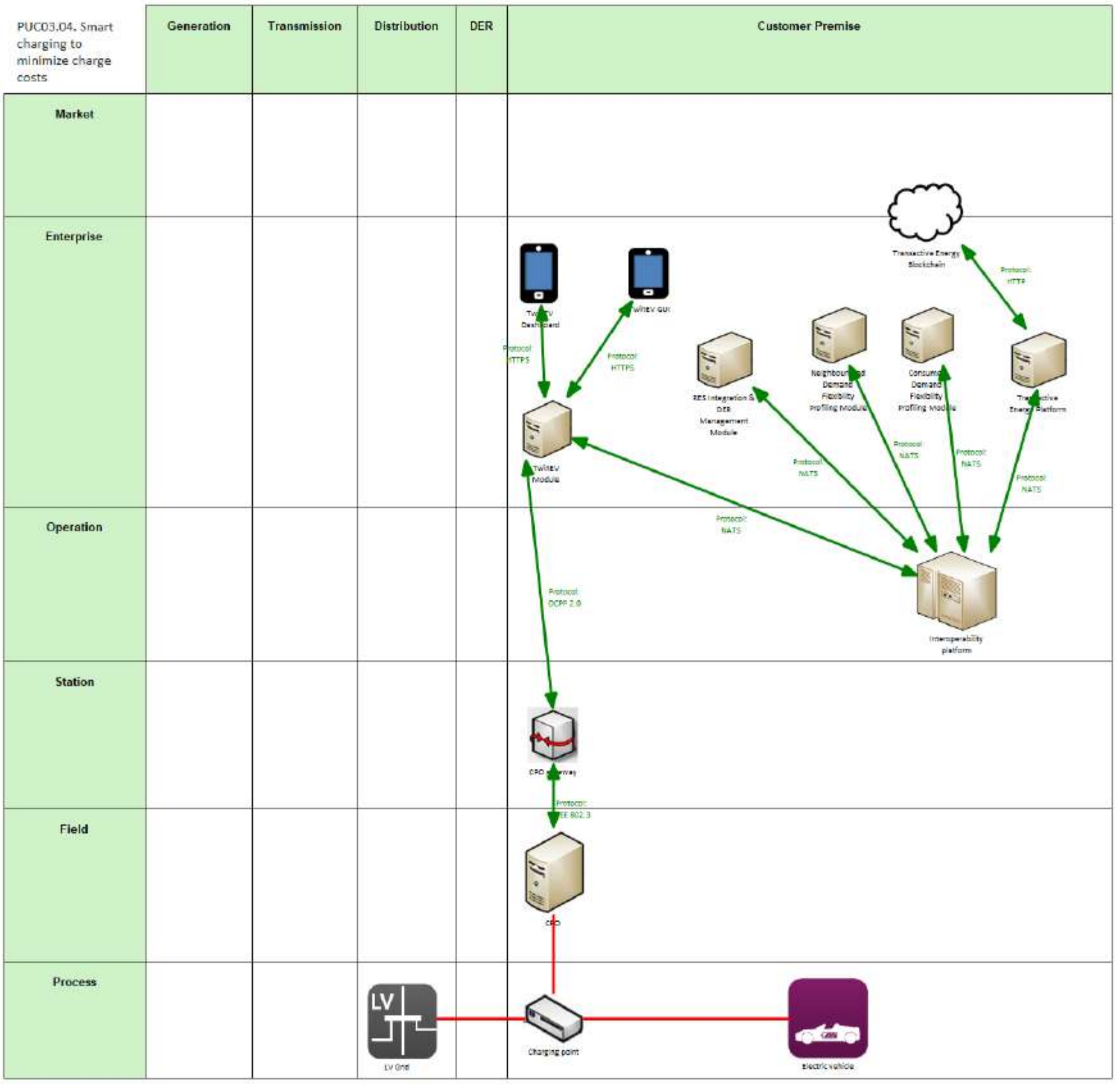

Figure 118: SGAM Communication Layer PUC03.04

Table 70: List of Communication technologies involved in PUC03.04

Communication Technology	Description
HTTP	Stand for Hypertext Transfer Protocol. It is an application layer protocol in the Internet protocol suite model for distributed, collaborative, hypermedia information systems
HTTPS	HyperText Transfer Protocol Secure. It is an extension of the Hypertext Transfer Protocol (HTTP), used for secure communication over a computer network. In HTTPS, the communication protocol is encrypted using Transport Layer Security (TLS) or, formerly, Secure Sockets Layer (SSL). The protocol is therefore also referred to as HTTP over TLS, or HTTP over SSL.
NATS	Protocol of messaging that enables the exchange of messages among computer applications and services, not depending on the network location.
OCPP 2.0	The Open Charge Point Protocol is an application protocol for communication between Electric vehicle, charging stations and a central management system.
IEE 802.3	Protocol that defines the physical layer and data link layer's media access control (MAC) of wired Ethernet. This is generally a local area network (LAN) technology with some wide area network (WAN) applications

7.4.5. SGAM Information Layer

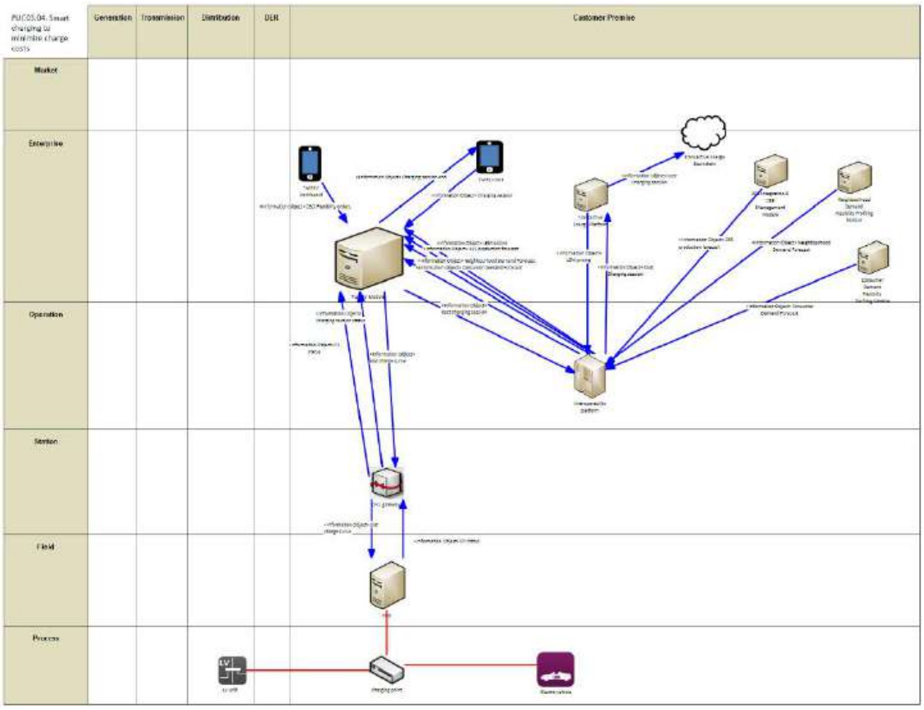

Figure 119: SGAM Information Layer PUC03.04

7.4.6. Canonical Data Model

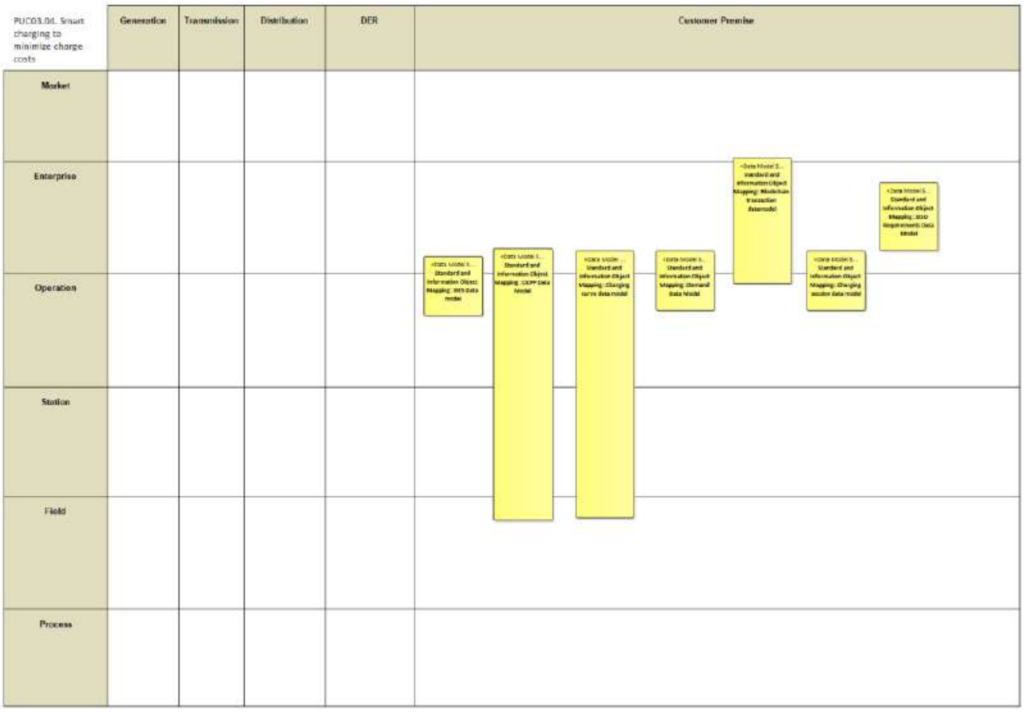

Figure 120: SGAM Canonical Data Model PUC03.04

Table 71: List of Data Models PUC03.04

Data Models
RES Data model
OCPP Data Model
Charging curve data model
Demand Data Model
Blockchain transaction Data Model
Charging Session Data Model
DSO Requirements Data Model

7.4.7. Standards and Information Object Mapping

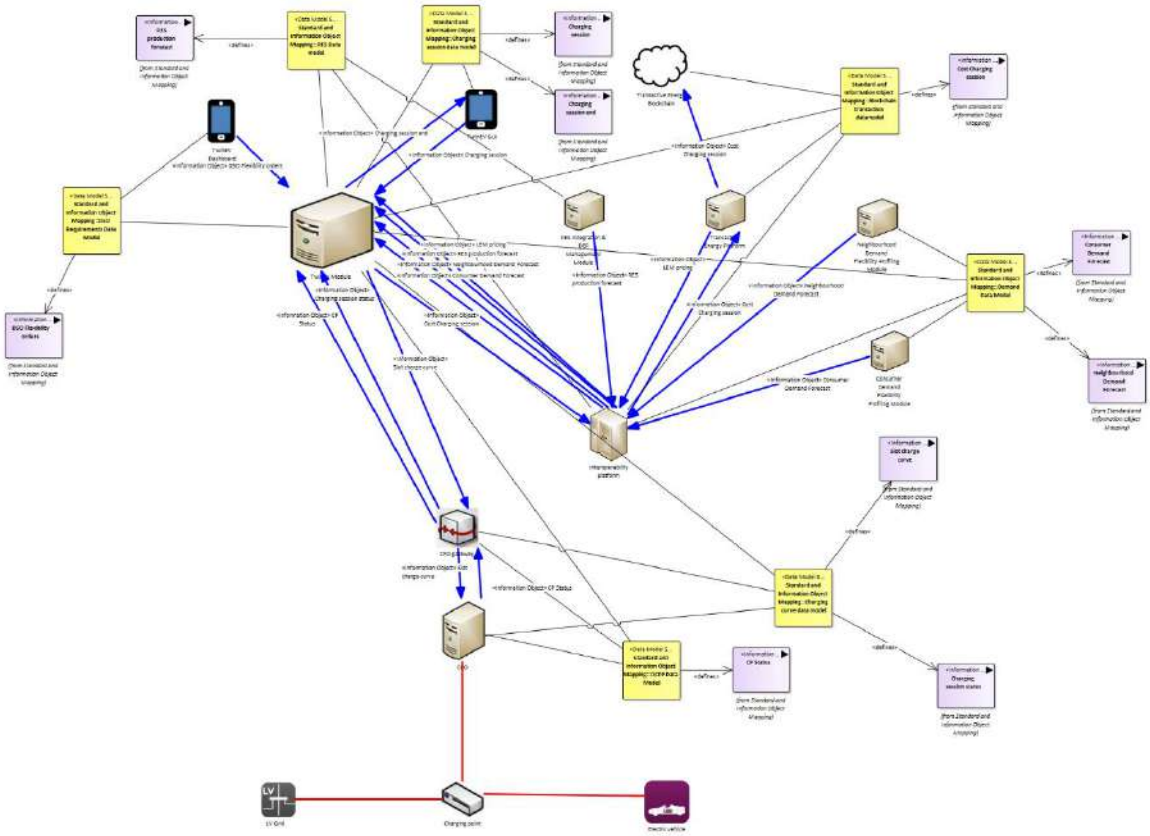

Figure 121: SGAM Standards and Information Object Mapping PUC03.04

Twinergy has received funding from the European Union's Horizon 2020 research and innovation programme under grant agreement No. 957736

Table 72: List of Information Objects PUC03.04

Information Objects	Data Models
RES production forecast	RES Data model
Charging session	Charging session data model
Charging session end	Charging session data model
DSO Flexibility orders	DSO Requirements Data Model
Cost Charging session	Blockchain transaction datamodel
Consumer Demand Forecast	Demand Data Model
Neighbourhood Demand Forecast	Demand Data Model
Slot charge curve	Charging curve data model
Charging session status	Charging curve data model
CP Status	OCPP Data Model

7.4.8. Activity Diagram

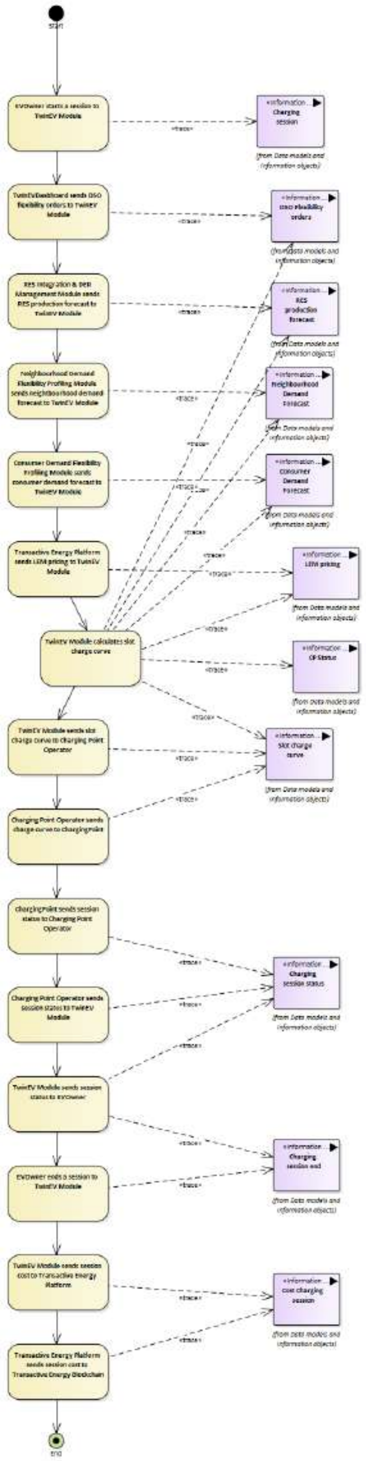

Figure 122:SGAM Activity Diagram PUC03.04

Twinergy has received funding from the European Union's Horizon 2020 research and innovation programme under grant agreement No. 957736

7.4.9. Sequence Diagram

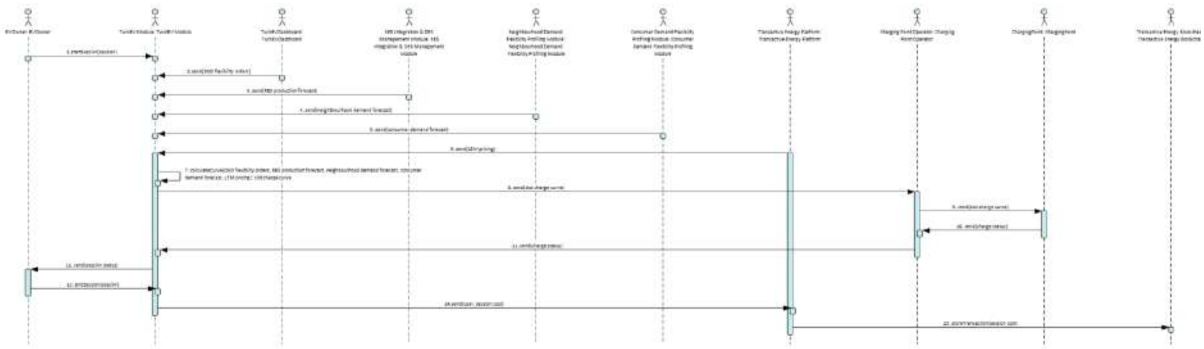

Figure 123: SGAM Sequence Diagram PUC03.04

7.5. PUC03.05. Smart Charging to minimize time of charge

7.5.1. Use Case Description

This Use case starts when the process of charging starts. The steps to be followed are:

1. The user starts the charging session, linking his/her device with the CP, via the TwinEV drivers app.
2. When the CP indicates, the user connects the eVehicle to the charging point (CP).
3. If the CP is private, the user has to introduce the data about the charge: vehicle, current battery level (%), desired battery level (%), desired charge time (minutes).
4. If the CP is public or semi-public, the user selects the reservation and introduces the current battery level (%).
5. The TwinEV module loads auxiliary data about the session:
    - CP information,
    - Battery features (capacity)
    - Grid restrictions.
    - Energy prices (given by Transactive Energy Module).
    - Limitation of power supply point (maximum and minimum)
    - Forecasts of demand and production (from modules RES integration & DER management, Neighbourhood demand flexibility profiling and Consumer demand flexibility profiling)
    - Nominal Power of connectors
    - Target Slots
    - Flexibility orders given by DSO from TwinEV Dashboard
6. The TwinEV module calculates a charge curve for the session, in which all slots of time will contain the maximal value allowed by the restrictions stablished by the DSO.
7. The TwinEV module calculates cost of the operation.
8. The TwinEV module sends the curve to the CP via the Charging Point Operator (CPO).
9. The charge starts and the application informs to the user about the remaining time and the total cost of the operation.

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10. During the charge, depending on the energy value in each slot, the CP can inject energy to the EV or extract energy from the EV if V2G is enabled.
11. The user can interrupt the charging session while it is active.
12. When the current time is the charging time, the charge finishes.
13. If the charging point is public and the user exceeds the limit of time to pick up the vehicle, the total cost of the operation is increased. The interface informs about it to the user.
14. The payment of the cost is done via the Transactive Energy Module.
15. The user ends the session.
16. The user disconnects the eVehicle from the CP.

7.5.2. SGAM Function Layer

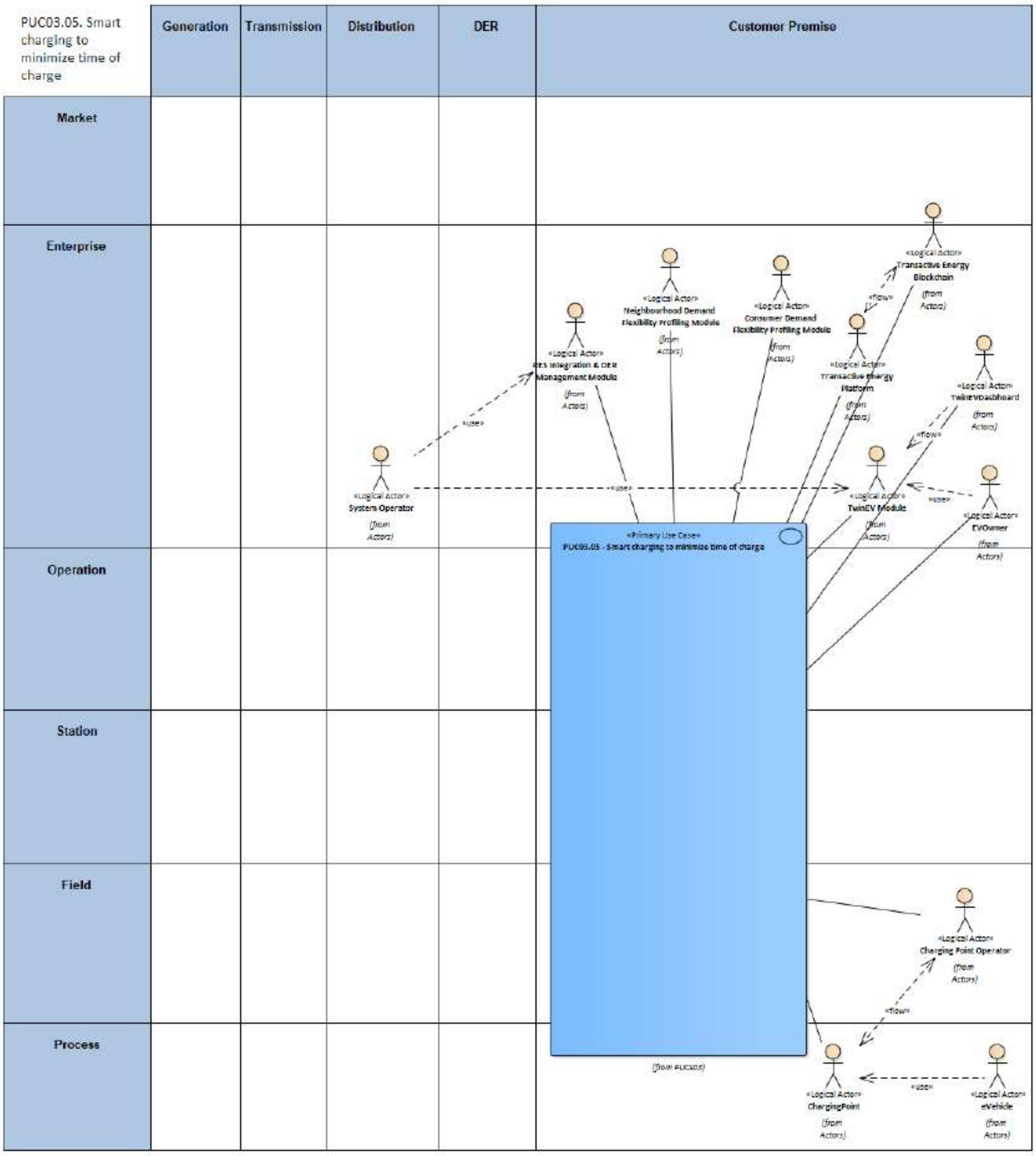

Figure 124: SGAM Function Layer PUC03.05

Twinergy has received funding from the European Union's Horizon 2020 research and innovation programme under grant agreement No. 957736

Table 73: List of Actors Involved PUC03.05

Actor Name	Actor Type
Aggregator	Local actor role
Neighbourhood Demand Flexibility Profiling Module	Application
Consumer Demand Flexibility Profiling Module	Application
System Operator	Organization
Transactive Energy Blockchain	Application
Transactive Energy Platform	Application
Charging Point	Device
eVehicle	Device
Charging Point Operator	Organization
EV Owner	Logical actor role
TwinEV Dashboard	Application
TwinEV Module	Application
RES Integration & DER Management Module	Application

7.5.3. SGAM Component Layer

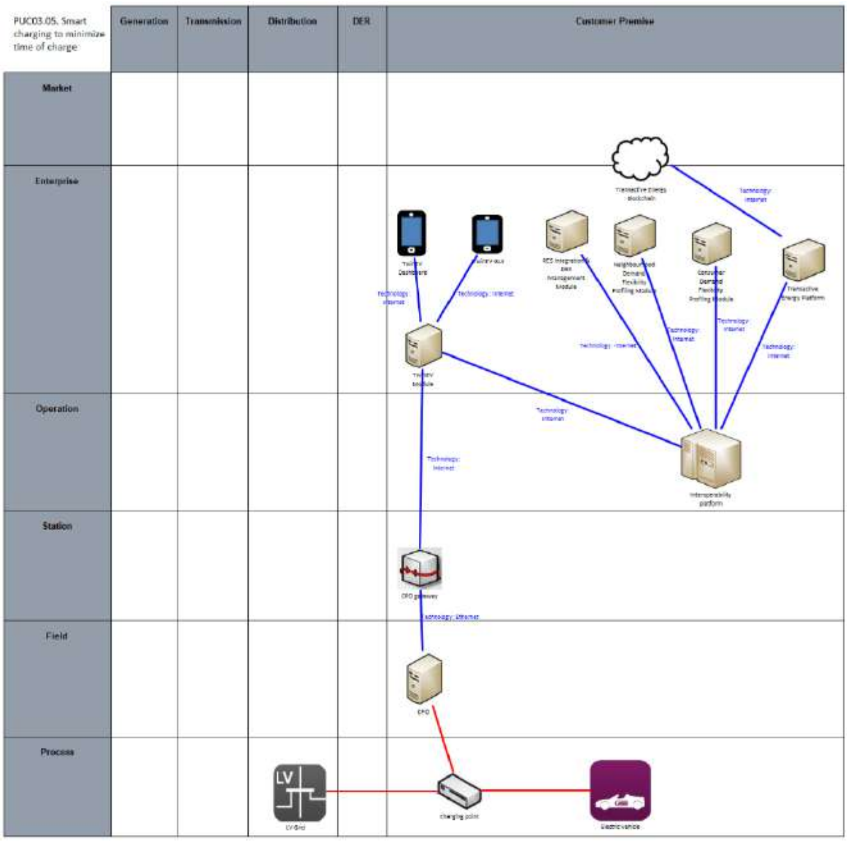

Figure 125: SGAM Component Layer PUC03.05

Table 74: List of Components PUC03.05

Component	Component Type
LV Grid	Physical asset
Charging Point	Physical asset
Electric Vehicle	Physical asset
Charging Point Operator	Organization
Charging Point Operator Gateway	External application
TwinEV Module	TwinERGY application
TwinEV GUI	TwinERGY application
TwinEV Dashboard	TwinERGY application
Interoperability Platform	TwinERGY application

RES Integration & DER Management Module	TwinERGY application
Neighbourhood Demand Flexibility Profiling Module	TwinERGY application
Consumer Demand Flexibility Profiling Module	TwinERGY application
Transactive Energy Platform	TwinERGY application
Transactive Energy Blockchain	TwinERGY application

7.5.4. SGAM Communication Layer

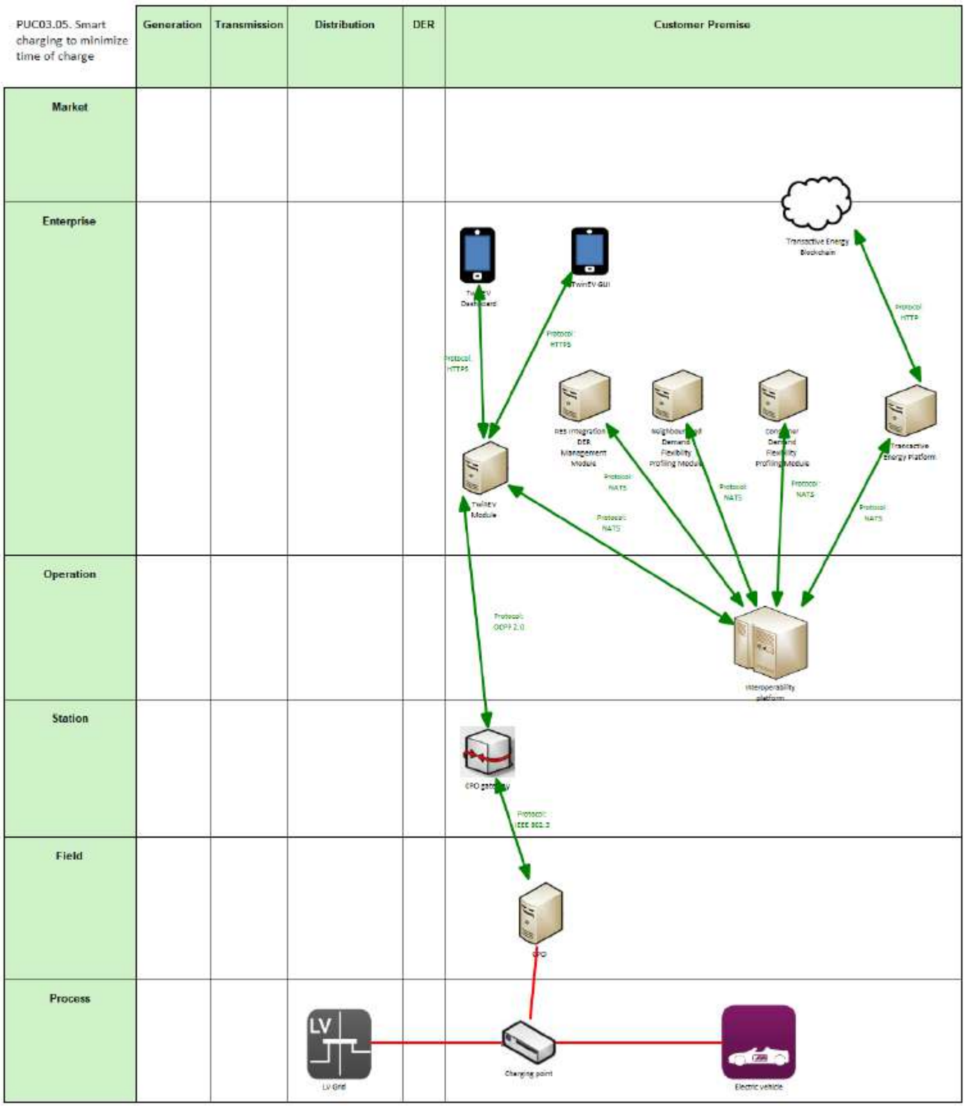

Figure 126: SGAM Communication Layer PUC03.05

Table 75: List of Communication technologies involved in PUC03.05

Communication Technology	Description
HTTP	Stand for Hypertext Transfer Protocol. It is an application layer protocol in the Internet protocol suite model for distributed, collaborative, hypermedia information systems
HTTPS	HyperText Transfer Protocol Secure. It is an extension of the Hypertext Transfer Protocol (HTTP), used for secure communication over a computer network. In HTTPS, the communication protocol is encrypted using Transport Layer Security (TLS) or, formerly, Secure Sockets Layer (SSL). The protocol is therefore also referred to as HTTP over TLS, or HTTP over SSL.
NATS	Protocol of messaging that enables the exchange of messages among computer applications and services, not depending on the network location.
OCPP 2.0	The Open Charge Point Protocol is an application protocol for communication between Electric vehicle, charging stations and a central management system.
IEE 802.3	Protocol that defines the physical layer and data link layer's media access control (MAC) of wired Ethernet. This is generally a local area network (LAN) technology with some wide area network (WAN) applications

7.5.5. SGAM Information Layer

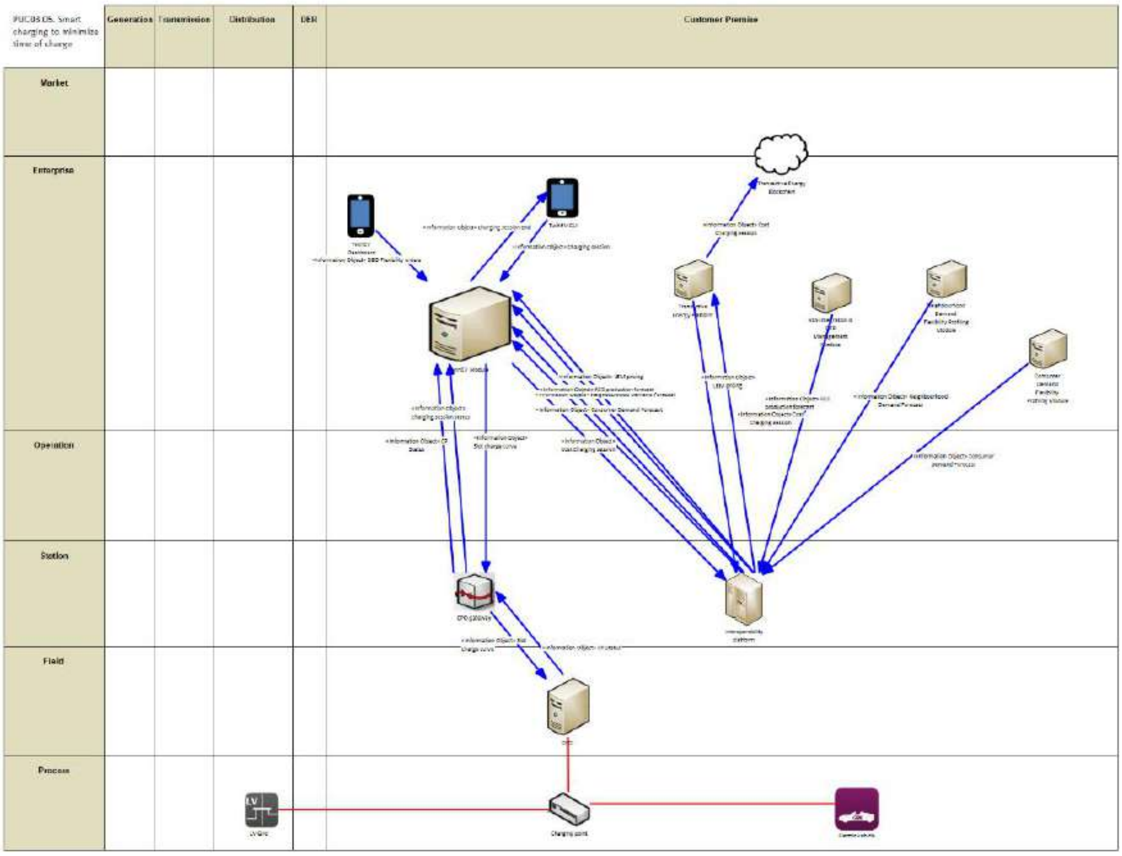

Figure 127: SGAM Information Layer PUC03.05

7.5.6. Canonical Data Model

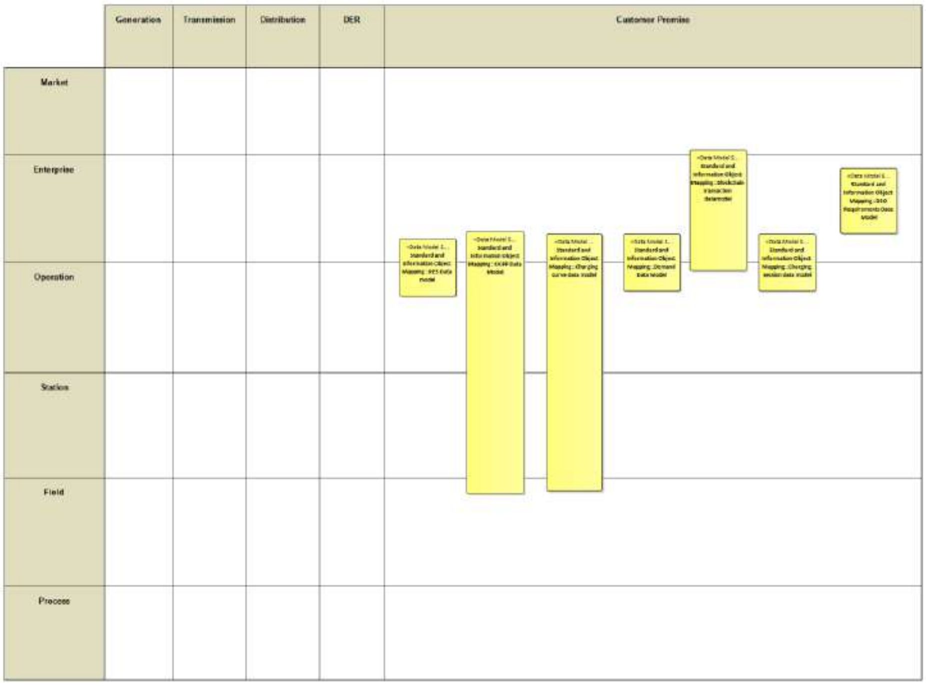

Figure 128: SGAM Canonical Data Model PUC03.05

Table 76: List of Data Models PUC03.05

Data Models
RES Data Model
OCPP Data Model
Charging Curve Data Model
Demand Data Model
Blockchain Transaction Data Model
Charging Session Data Model
DSO Requirements Data Model

7.5.7. Standards and Information Object Mapping

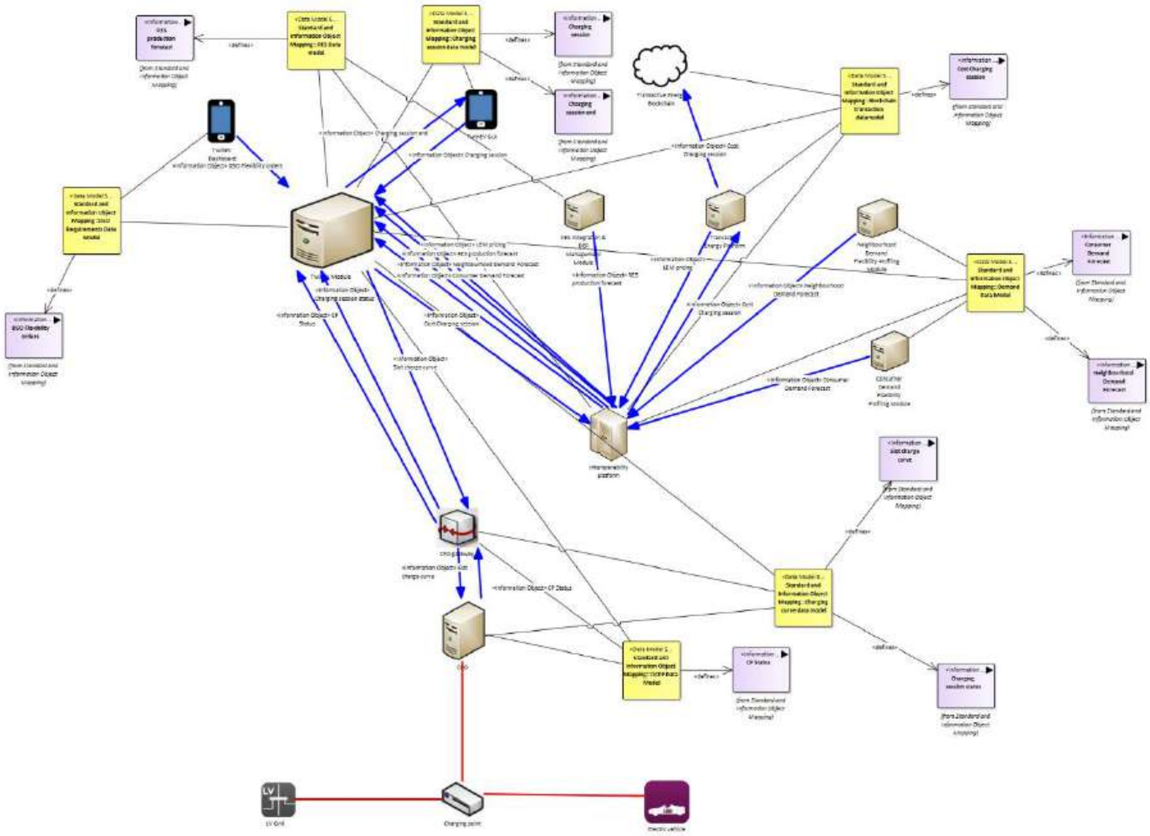

Figure 129: SGAM Standards and Information Object Mapping PUC03.05

Table 77: List of Information Objects PUC03.05

Information Objects	Data Models

Twinergy has received funding from the European Union's Horizon 2020 research and innovation programme under grant agreement No. 957736

RES production forecast	RES Data model
Charging session	Charging session data model
Charging session end	Charging session data model
Cost Charging session	Blockchain transaction data model
Consumer Demand Forecast	Demand Data Model
Neighbourhood Demand Forecast	Demand Data Model
Slot charge curve	Charging curve data model
Charging session status	Charging curve data model
CP Status	OCPP Data Model

7.5.8. Activity Diagram

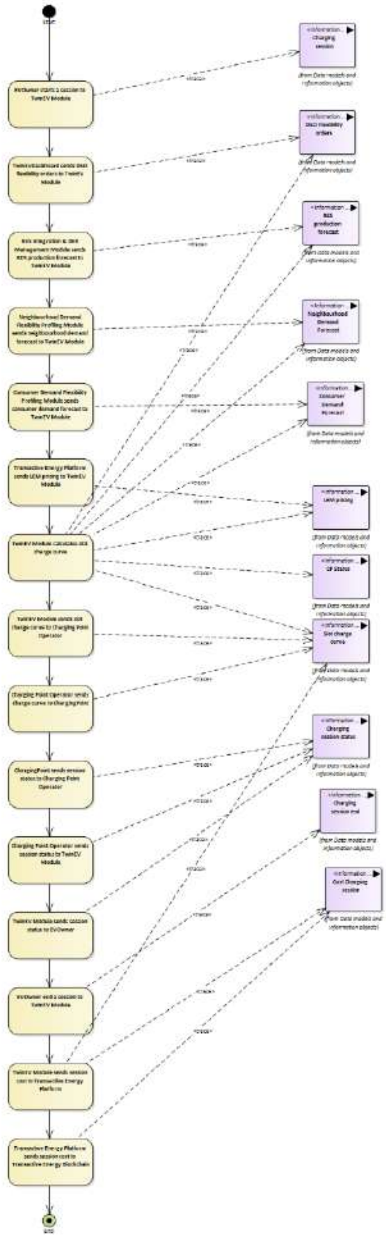

Figure 130: SGAM Activity Diagram PUC03.05

7.5.9. Sequence Diagram

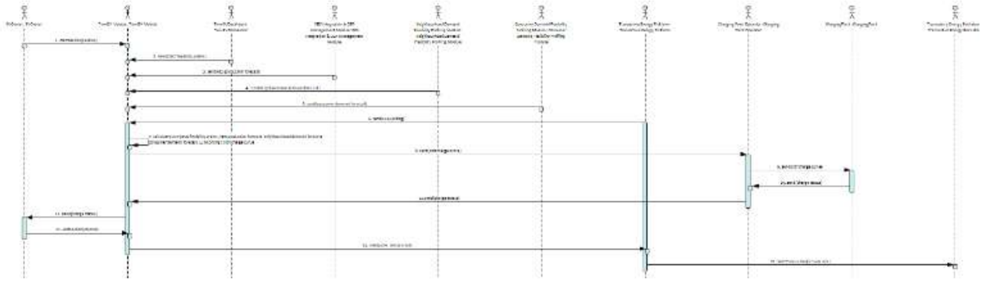

Figure 131: SGAM Sequence Diagram PUC03.05

7.6. PUC03.06. Grid Management

7.6.1. Use Case Description

This Use Case starts when one or several of the following situations occur:

- the DSO predicts or detects a congestion in the grid,
- the DSO predicts or detects a problem of voltage management,
- the DSO needs to reduce the energy supplied in the district,
- the DSO predicts or detects a high demand in dwellings in the district.

The process in this use case is the following:

1. The DSO introduces the desired restrictions for an interval of time in the TwinEV dashboard interface:
    - Maximal and minimal power to be supplied by the charging points,
    - Use of the V2G features so that the vehicle can act as a storage asset
2. The TwinEV module stores the new restrictions to be used in the calculation of the charge curves for new charging sessions.
3. The TwinEV module notifies the orders to the Charging Points Operators.
4. The Charging Points Operators modify the current charge curves for eVehicles which are in an active charging session.
5. When the interval of time finishes, the restrictions are disabled and the restrictions returns to the previous status.

7.6.2. SGAM Function Layer

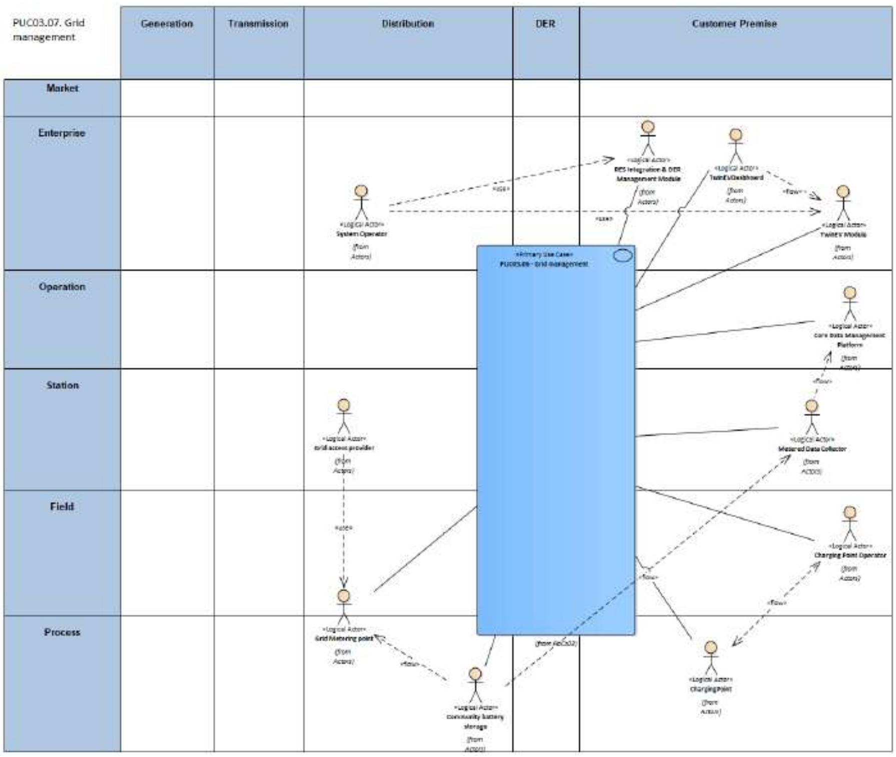

Figure 132: SGAM Function Layer PUC03.06

Table 78: List of Actors Involved PUC03.06

Actor Name	Actor Type
System Operator	Organization
RES Integration & DER Management Module	Application
TwinEV Dashboard	Application
TwinEV Module	Application
Core Data Management Platform	Application
Metered Data Collector	Device
Charging Point Operator	Organization
Charging Point	Device
Community battery storage	Device
Grid Metering Point	Device
Grid access provider	Organization

7.6.3. SGAM Component Layer

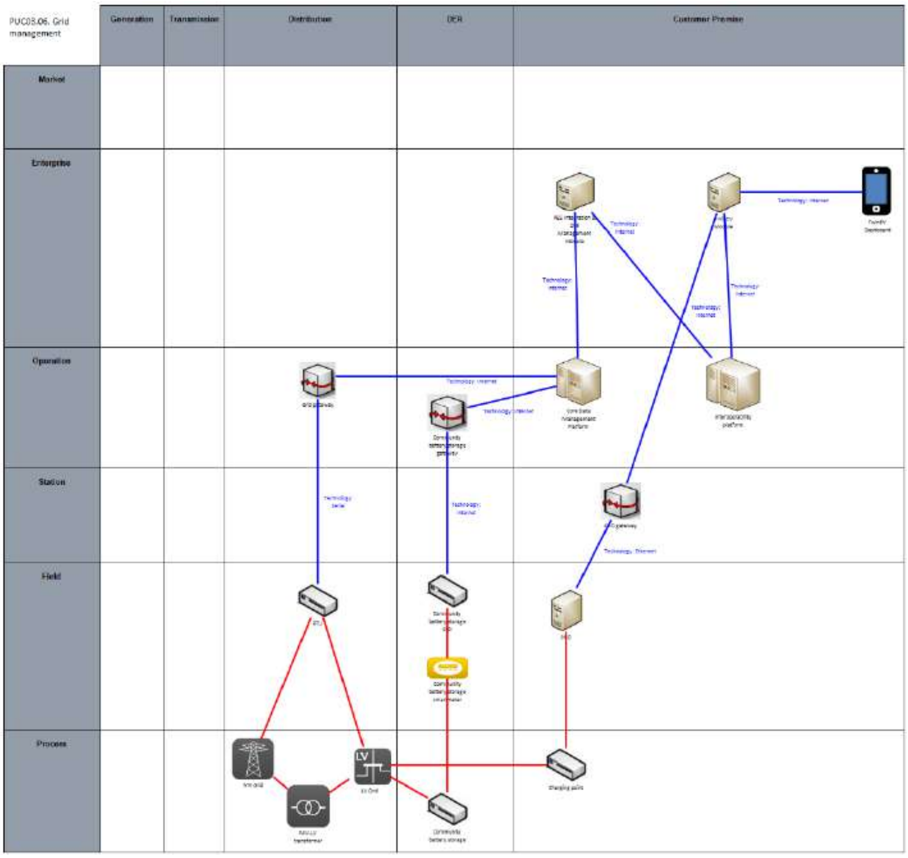

Figure 133: SGAM Component Layer PUC03.06

Table 79: List of Components PUC03.06

Component	Component Type
MV Grid	Physical Asset
MV-LV Transformer	Physical Asset
LV Grid	Physical Asset
RTU	Physical Asset
Grid Gateway	External Application
Community battery storage	Physical Asset
Community battery storage Smart Meter	Physical Asset
Community battery storage gateway	External application
Core Data Management Platform	TwinERGY application

RES Integration & DER Management Module	TwinERGY application
Interoperability Platform	TwinERGY application
TwinEV Module	TwinERGY application
TwinEV Dashboard	TwinERGY application
Charging Point	Physical Asset
Charging Point Operator	Organization
Charging Point Operator Gateway	External application

7.6.4. SGAM Communication Layer

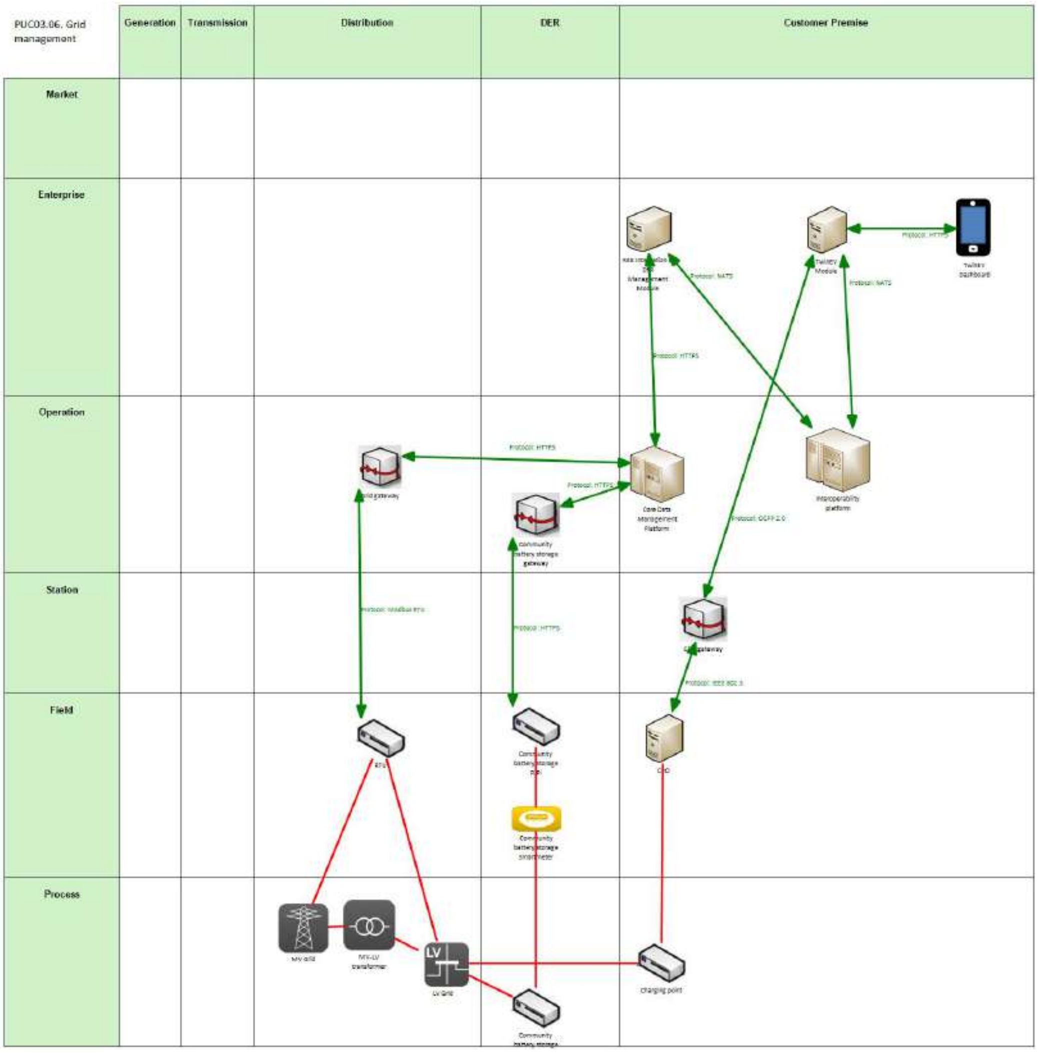

Figure 134: SGAM Communication Layer PUC03.06

Table 80: List of Communication technologies involved in PUC03.06

Communication Technology	Description
Modbus RTU	Data communications protocol for using with programmable logic controllers (PLCs), where devices are connected to the same cable or Ethernet network. It is used on industrial environments
HTTPS	HyperText Transfer Protocol Secure. It is an extension of the Hypertext Transfer Protocol (HTTP), used for secure communication over a computer network. In HTTPS, the communication protocol is encrypted using Transport Layer Security (TLS) or, formerly, Secure Sockets Layer (SSL). The protocol is therefore also referred to as HTTP over TLS, or HTTP over SSL.
NATS	Protocol of messaging that enables the exchange of messages among computer applications and services, not depending on the network location.
OCPP 2.0	The Open Charge Point Protocol is an application protocol for communication between Electric vehicle, charging stations and a central management system.
IEE 802.3	Protocol that defines the physical layer and data link layer's media access control (MAC) of wired Ethernet. This is generally a local area network (LAN) technology with some wide area network (WAN) applications

7.6.5. SGAM Information Layer

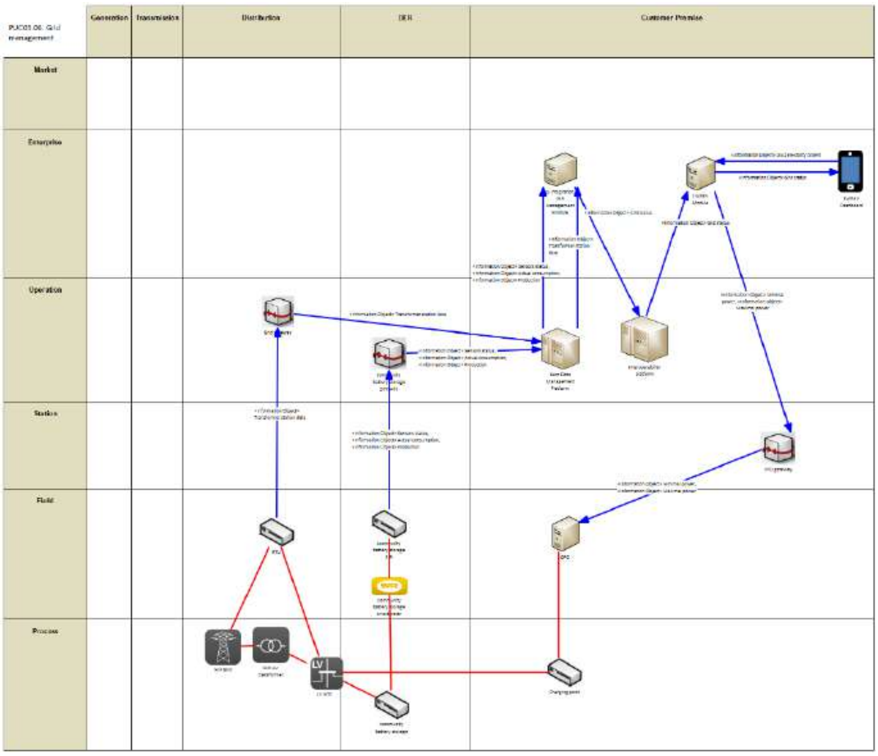

Figure 135: SGAM Information Layer PUC03.06

7.6.6. Canonical Data Model

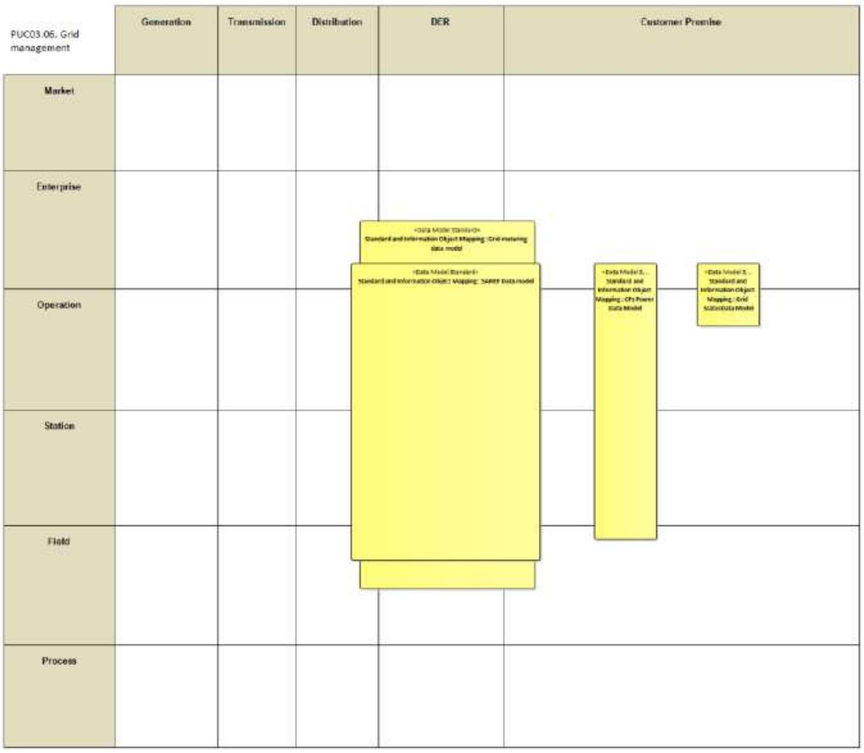

Figure 136: SGAM Canonical Data Model PUC03.06

Table 81: List of Data Models PUC03.06

Data Models
Grid Metering Data Model
SAREF Data Model
CPs Power Data Model
Grid StatusData Model

7.6.7. Standards and Information Object Mapping

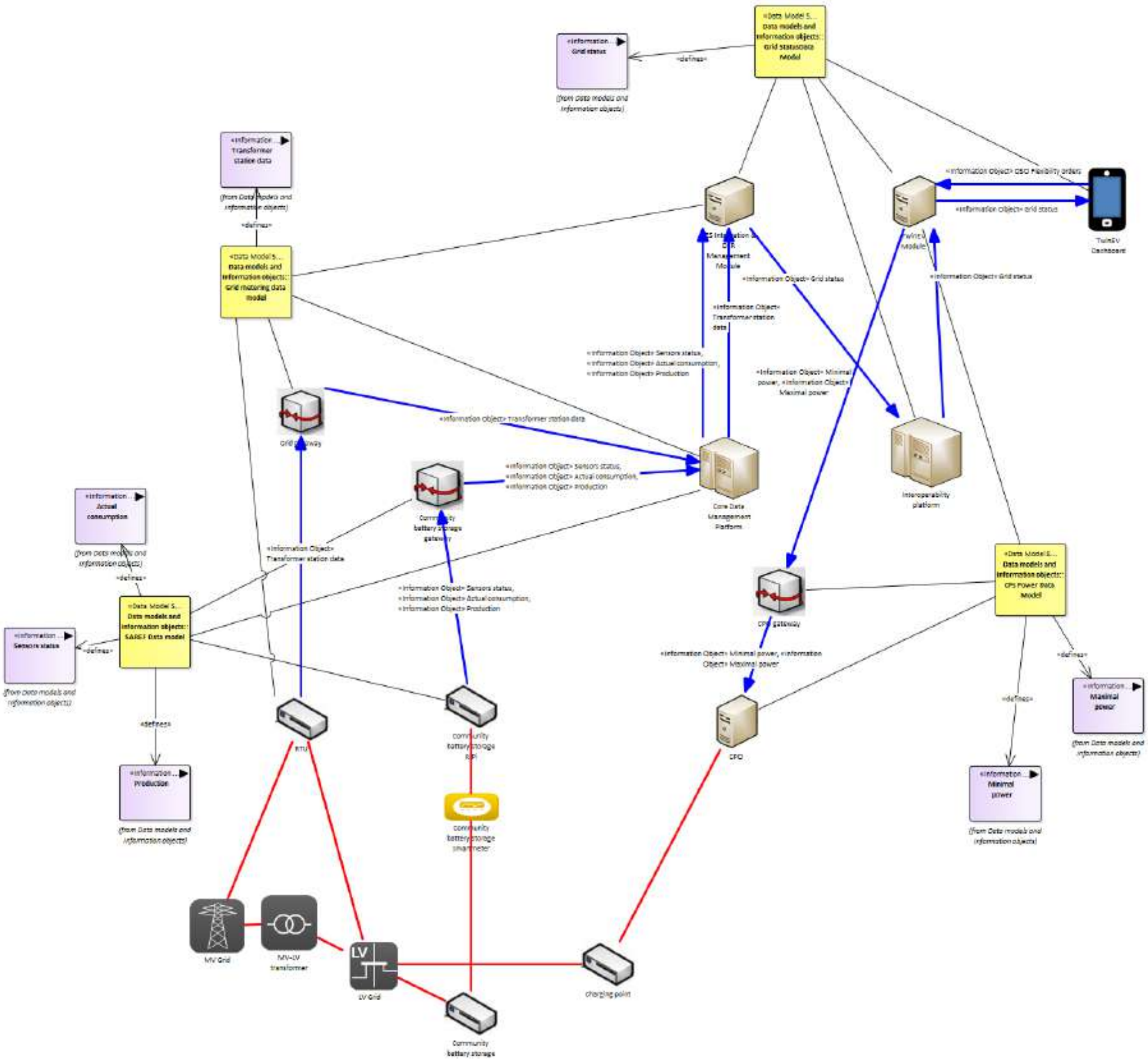

Figure 137: SGAM Standards and Information Object Mapping PUC03.06

Twinergy has received funding from the European Union's Horizon 2020 research and innovation programme under grant agreement No. 957736

Table 82: List of Information Objects PUC03.06

Information Objects	Data Models
Actual consumption	SAREF Data model
Sensor status	SAREF Data model
Production	SAREF Data model
Transformer station data	Grid metering data model
Grid status	Grid Status Data Model
Minimal power	CPs Power Data Model
Maximal power	CPs Power Data Model

Twinergy has received funding from the European Union's Horizon 2020 research and innovation programme under grant agreement No. 957736

7.6.8. Activity Diagram

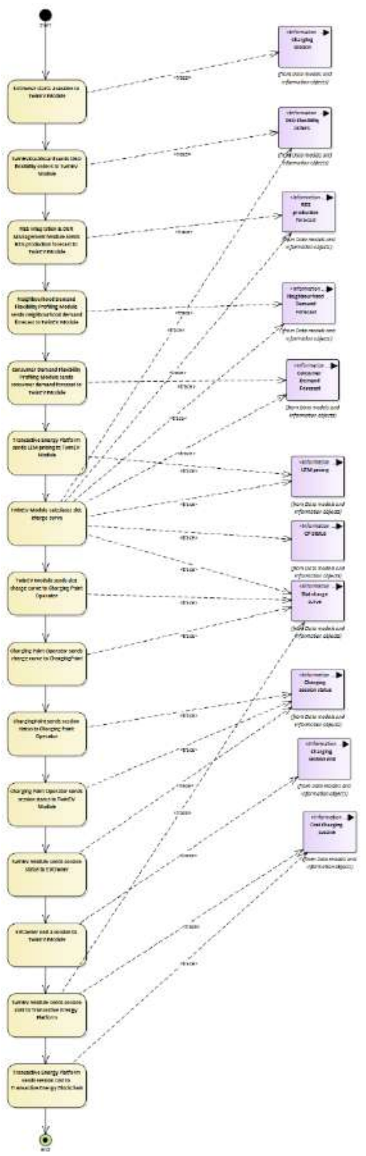

Figure 138: SGAM Activity Diagram PUC03.06

7.6.9. Sequence Diagram

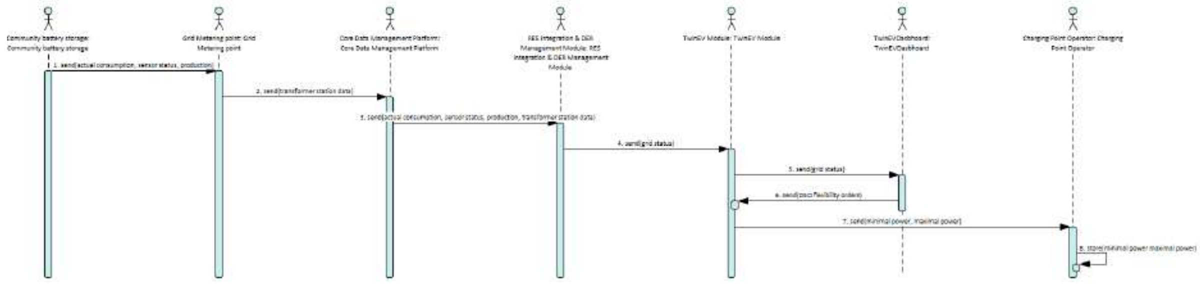

Figure 139: SGAM Sequence Diagram PUC03.06

7.7. SGAM Business Layer

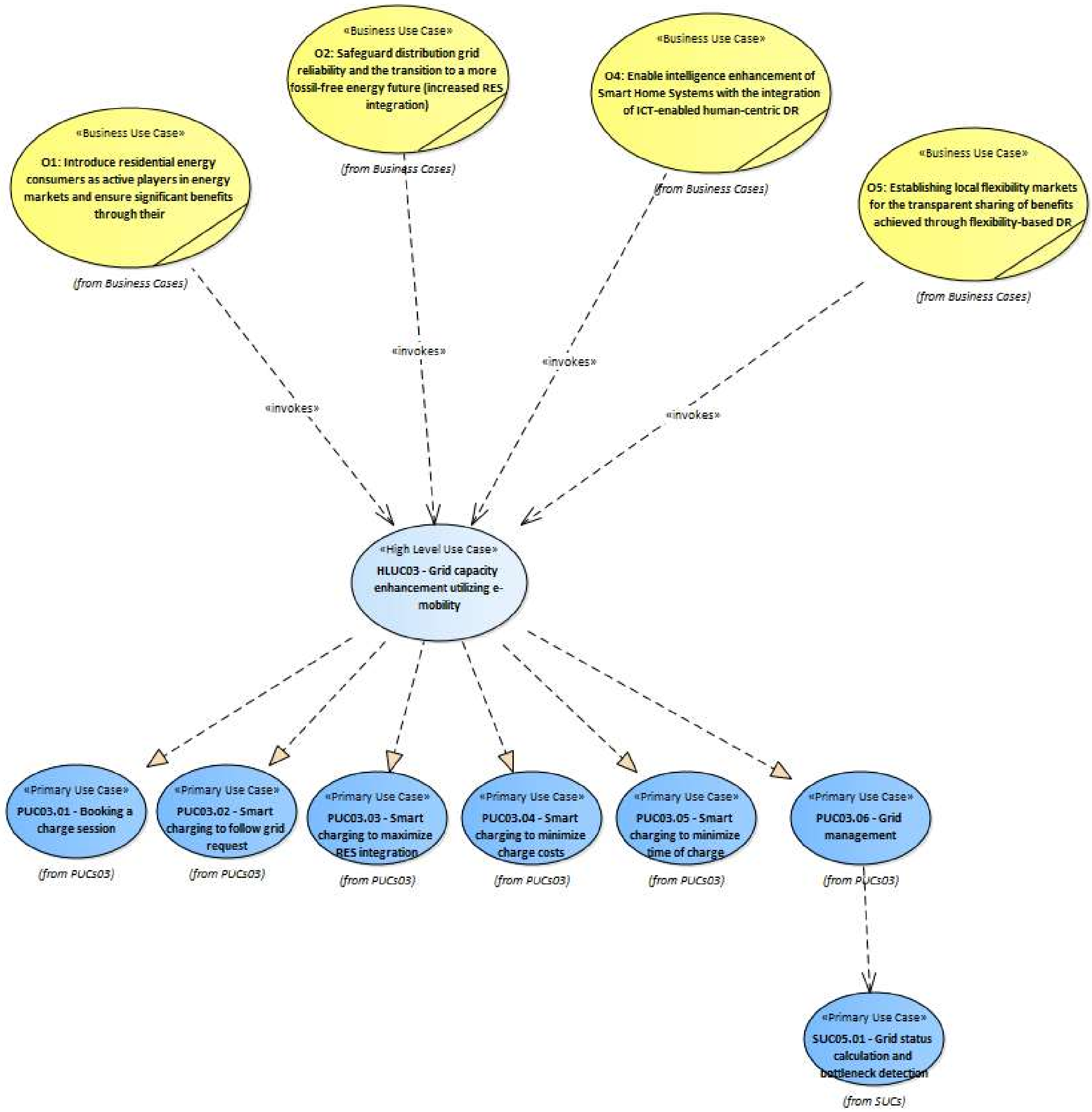

Figure 140: SGAM Business Layer HLUC03

8.HLUC04. Prosumers empowerment in local energy trading markets

8.1.PUC04.01. Recording transactions of energy

8.1.1. Use Case Description

The Transactive Energy Module (TEM) receives messages from measuring devices that a RES charges a public battery or that a battery has started discharging to the dwelling in which it is installed, or to another connected prosumer. The transactions, which take place in the Local Energy Market, are done in the same price level following the determination of the price in the Local Energy Market (LEM). For the determination of the price, the bids both from supply and demand side are taken into consideration. The process can be depicted as follows (A full breakdown of this process and the various scenarios are described in the HLUC04 document):

1. The TEM receives requests about energy transactions from TwinERGY devices (physical assets in the dwellings and Digital Twin Platform).

2. The input data includes prosumer, device, units and destination

3. TEM processes and settles the transaction

4. TEM records transaction on the blockchain with reference to the LEM price transaction which is recorded in the LEM price blockchain. Using the reference "hash", the original price on which the transaction was executed can be verified.

8.1.2. SGAM Function Layer

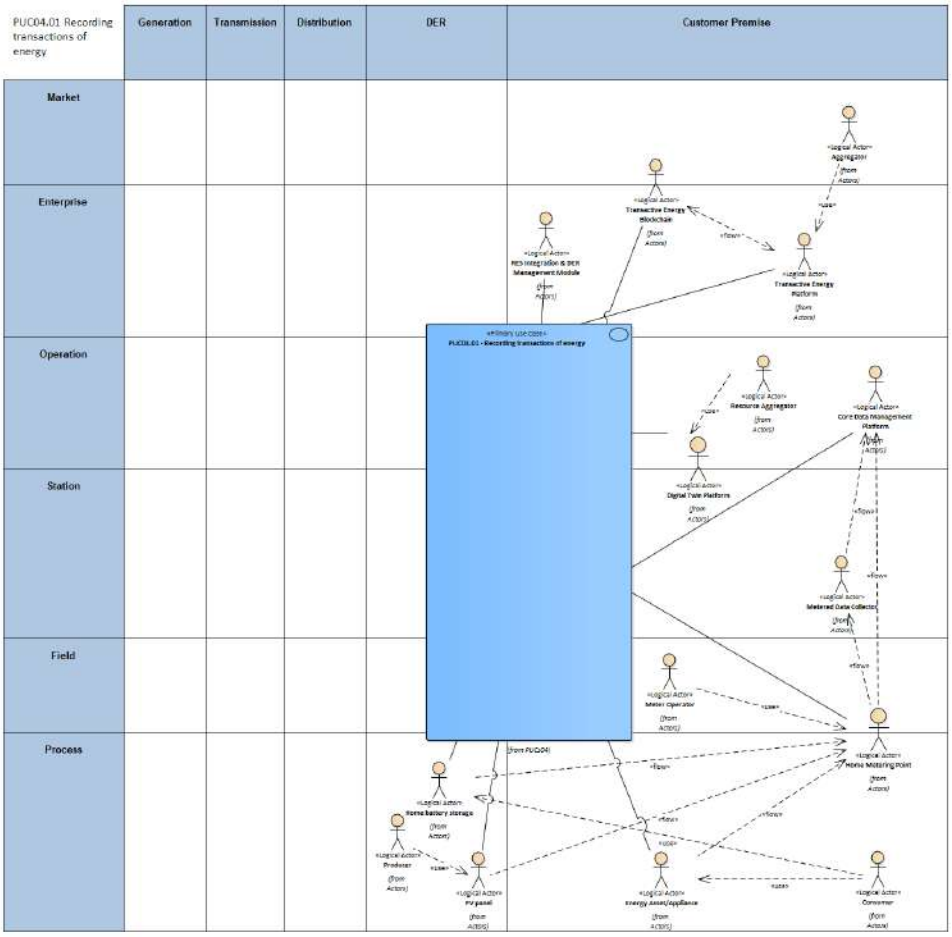

Figure 141: SGAM Function Layer PUC04.01

Table 83: List of Actors Involved PUC04.01

Actor Name	Actor Type
Aggregator	Logical actor role
RES Integration & DER Management Module	Application
Transactive Energy Blockchain	Application
Transactive Energy Platform	Application
Resource Aggregator	Logical actor role
Core Data Management Platform	Application
Digital Twin Platform	Application
Metered Data Collector	Device

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Meter Operator	Device
Home battery storage	Device
Home Metering Point	Device
Energy Asset/Appliance	Device
PV Panel	Device
Consumer	Logical actor role
Producer	Logical actor role

8.1.3. SGAM Component Layer

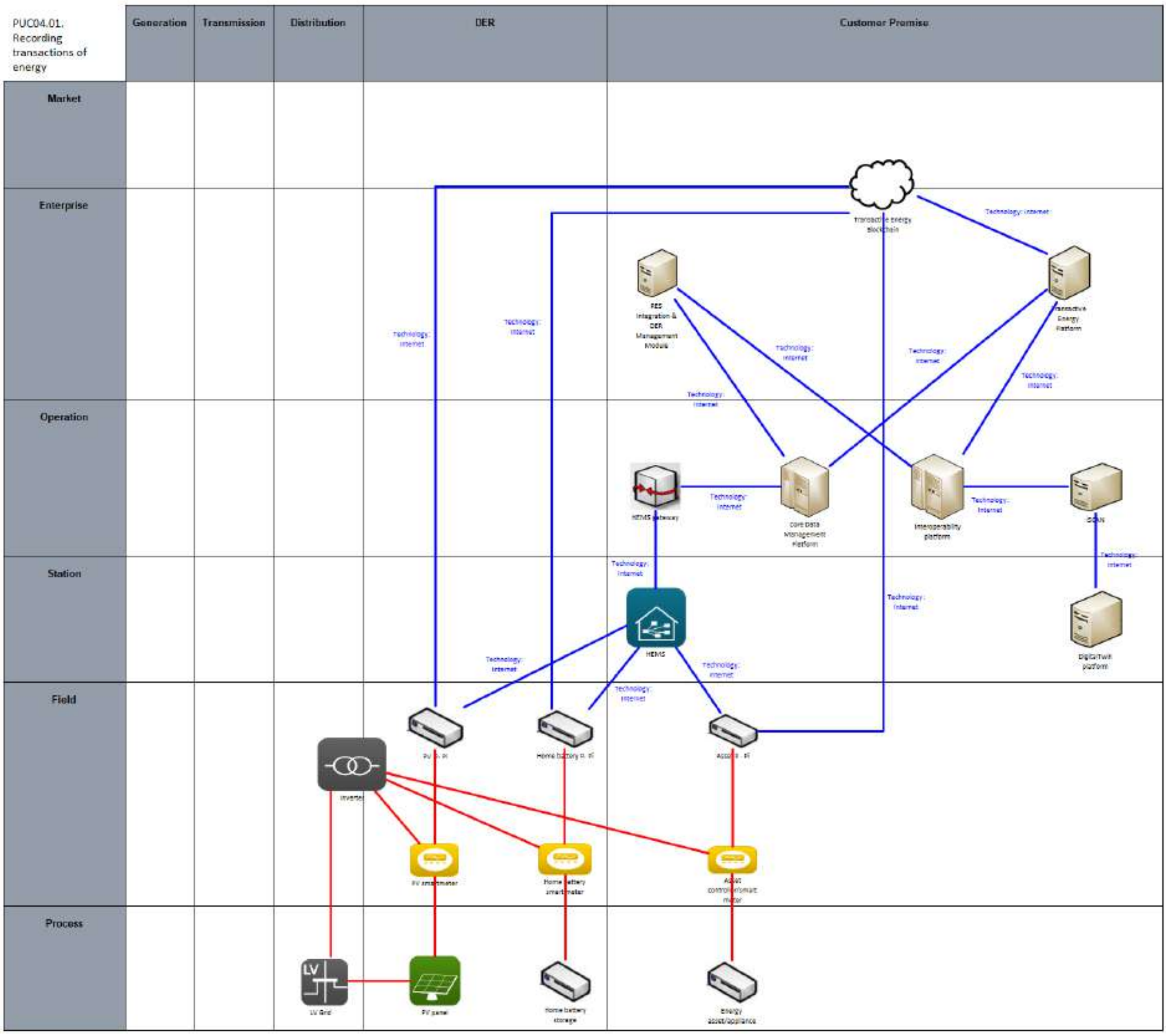

Figure 142:SGAM Component Layer PUC04.01

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Table 84: List of Components PUC04.01

Component	Component Type
LV Grid	Physical asset
Inverter	Physical asset
PV panel	Physical asset
Home Battery Storage	Physical asset
Energy asset/appliance	Physical asset
PV smartmeter	Physical asset
Home battery smartmeter	Physical asset
Asset controler/smart meter	Physical asset
Raspberry-Pi	Physical asset
HEMS	External application
HEMS gateway	External application
Core Data Management Platform	TwinERGY application
Interoperability Platform	TwinERGY application
iSCAN	External application
Digital Twin Platform	TwinERGY application
Transactive Energy Platform	TwinERGY application
RES integration & DER Management Module	TwinERGY application
Transactive Energy Blockchain	TwinERGY application

8.1.4. SGAM Communication Layer

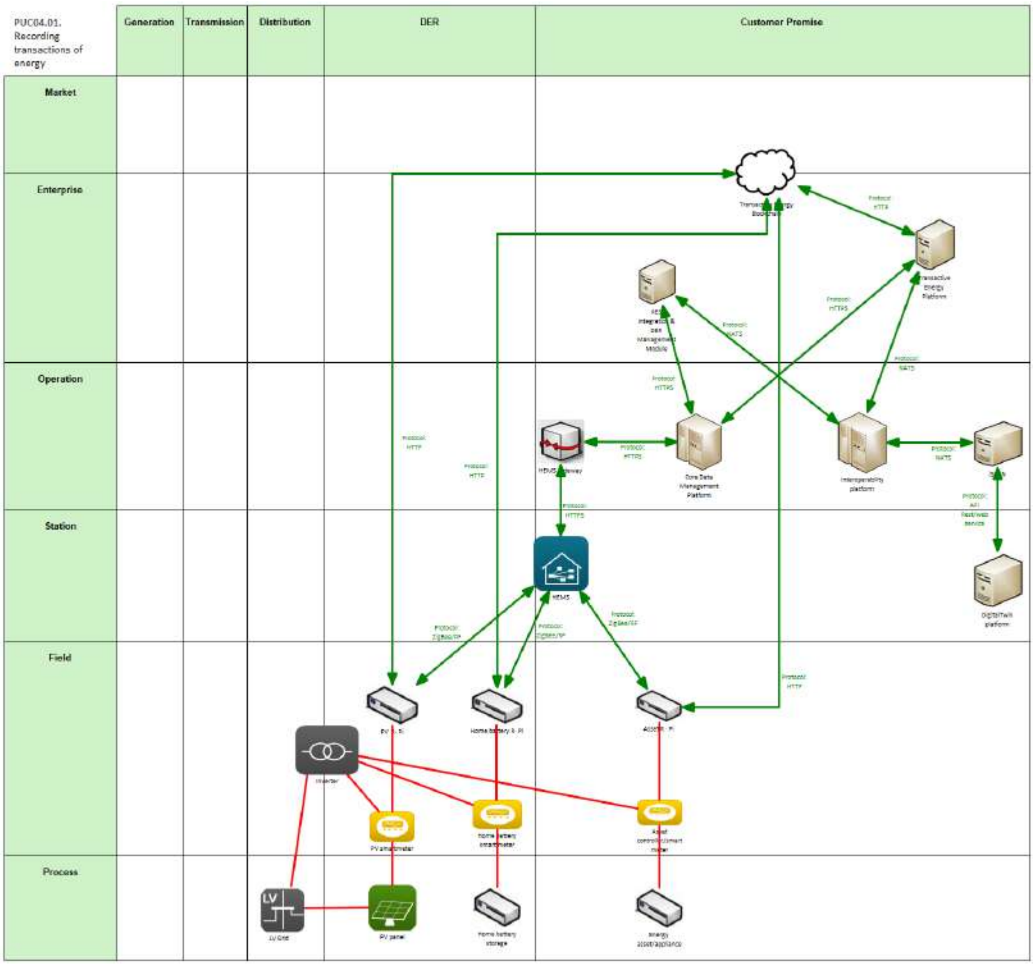

Figure 143: SGAM Communication Layer PUC04.01

Table 85: List of Communication technologies involved in PUC04.01

Communication Technology	Description
HTTP	Stand for Hypertext Transfer Protocol. It is an application layer protocol in the Internet protocol suite model for distributed, collaborative, hypermedia information systems
HTTPS	HyperText Transfer Protocol Secure. It is an extension of the Hypertext Transfer Protocol (HTTP), used for secure communication over a computer network. In HTTPS, the communication protocol is encrypted using Transport Layer Security (TLS) or, formerly, Secure Sockets Layer (SSL). The protocol is therefore also referred to as HTTP over TLS, or HTTP over SSL.

NATS	Protocol of messaging that enables the exchange of messages among computer applications and services, not depending on the network location.
ZigBee/RF	Protocol IEEE 802.15.4, designed to communicate data through noisy RF environments. This standard operates on the physical radio specification and operates in unlicensed bands including 2.4 GHz, 900 MHz and 868 MHz.
API REST	Application Programming Interface for REpresentational State Transfer. API is a software intermediary that allows two applications to talk to each other, whilst REST is an architectural style for distributed hypermedia systems, working stateless. Both define a set of distributed resources accessible and manipulable through a set of public functions.

8.1.5. SGAM Information Layer

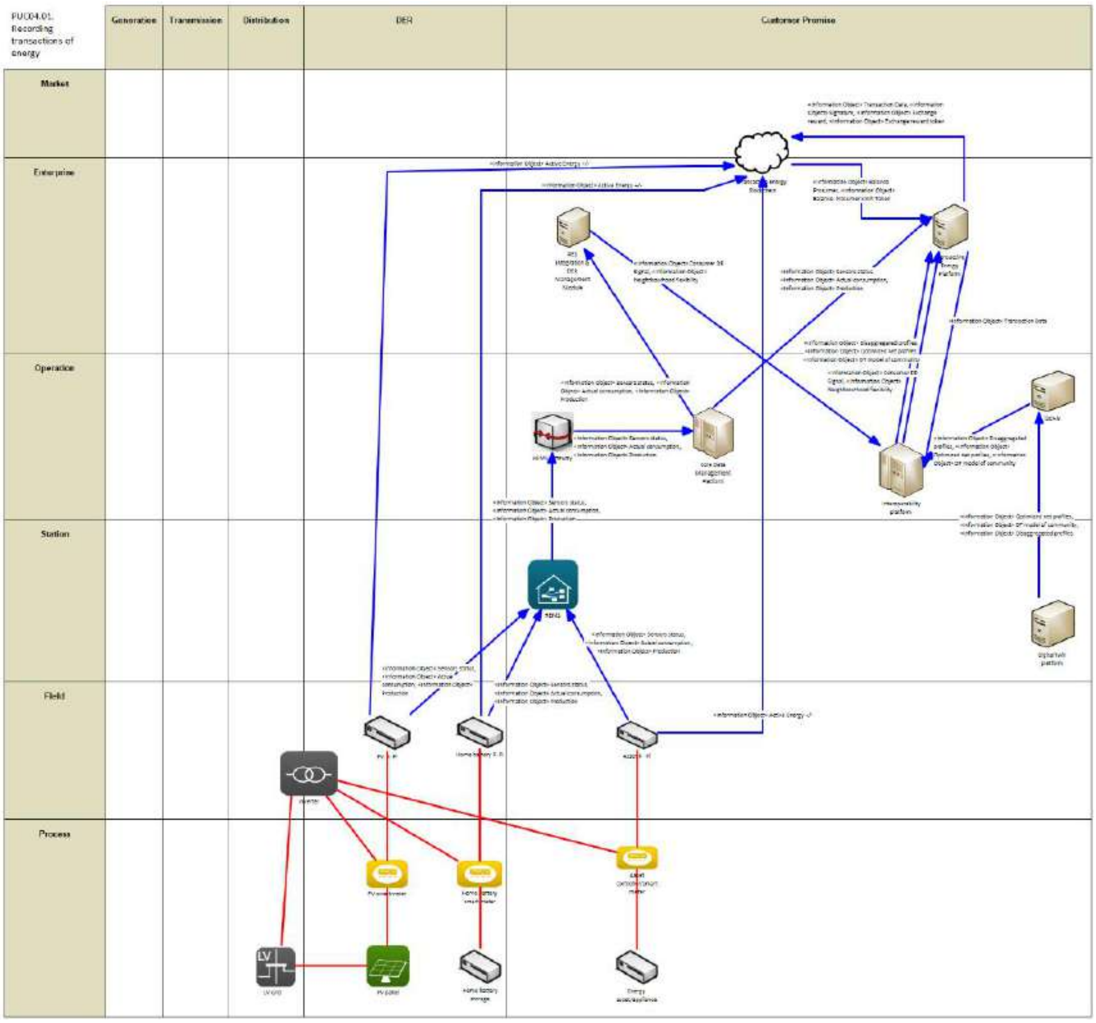

Figure 144: SGAM Information Layer PUC04.01

8.1.6. Canonical Data Model

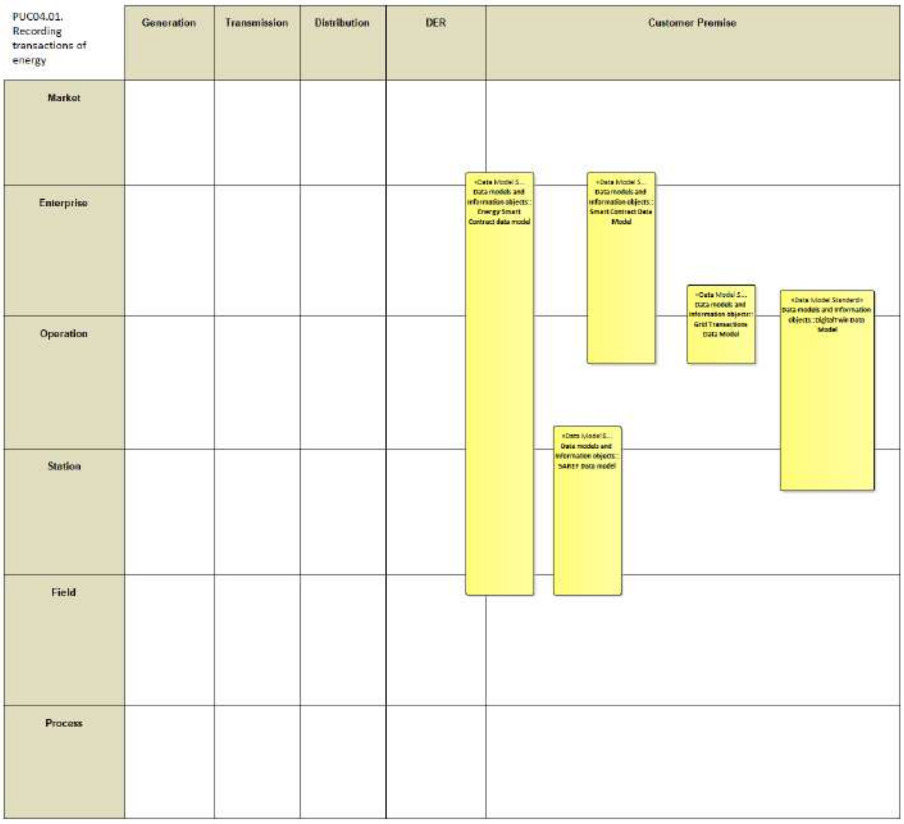

Figure 145: SGAM Canonical Data Model PUC04.01

Table 86: List of Data Models PUC04.01

Data Models
Energy Smart Contract Data Model
SAREF Data Model
Smart Contract Data Model
Grid Transactions Data Model
DigitalTwin Data Model

8.1.7. Standards and Information Object Mapping

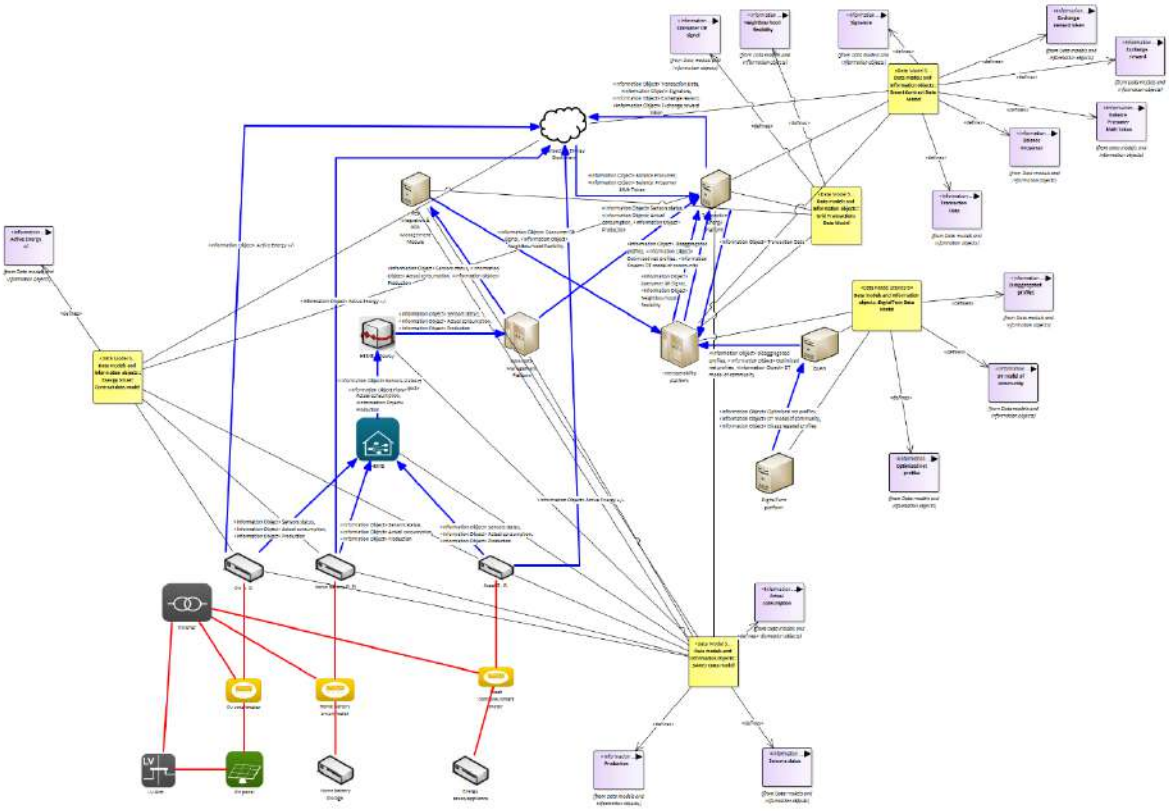

Figure 146: SGAM Standards and Information Object Mapping PUC04.01

Table 87: List of Information Objects PUC04.01

Information Objects	Data Models
Active Energy +/-	Energy Smart Contract data model
Actual consumption	SAREF Data model
Sensor status	SAREF Data model
Production	SAREF Data model
Disaggregated profiles	DigitalTwin Data Model
DT model of community	DigitalTwin Data Model
Optimized net profiles	DigitalTwin Data Model
Consumer DR Signal	Grid Transactions Data Model
Neighbourhood flexibility	Grid Transactions Data Model
Signature	Smart Contract Data Model

Transaction Data	Smart Contract Data Model
Balance Prosumer	Smart Contract Data Model
Balance Prosumer kWh Token	Smart Contract Data Model
Exchange reward	Smart Contract Data Model
Exchange reward token	Smart Contract Data Model

8.1.8. Activity Diagram

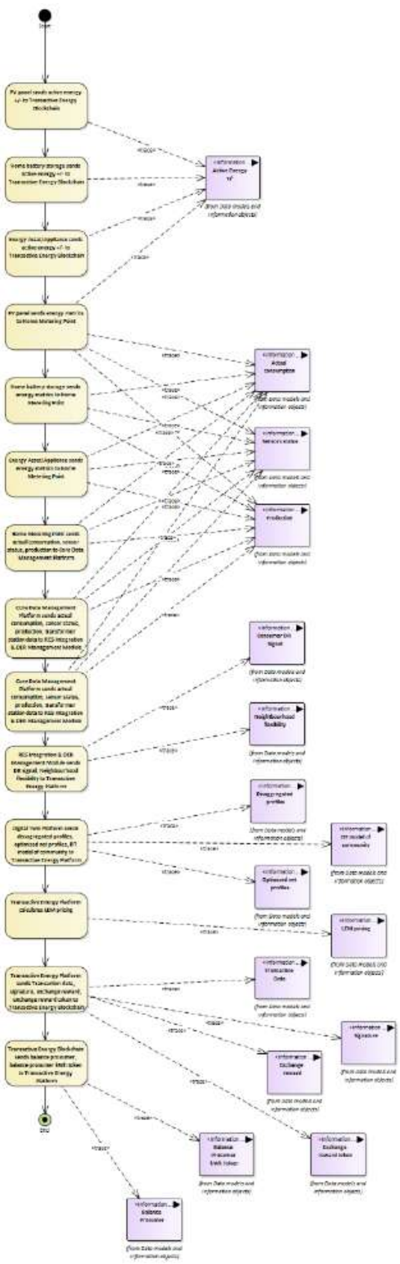

Figure 147: SGAM Activity Diagram PUC04.01

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8.1.9. Sequence Diagram

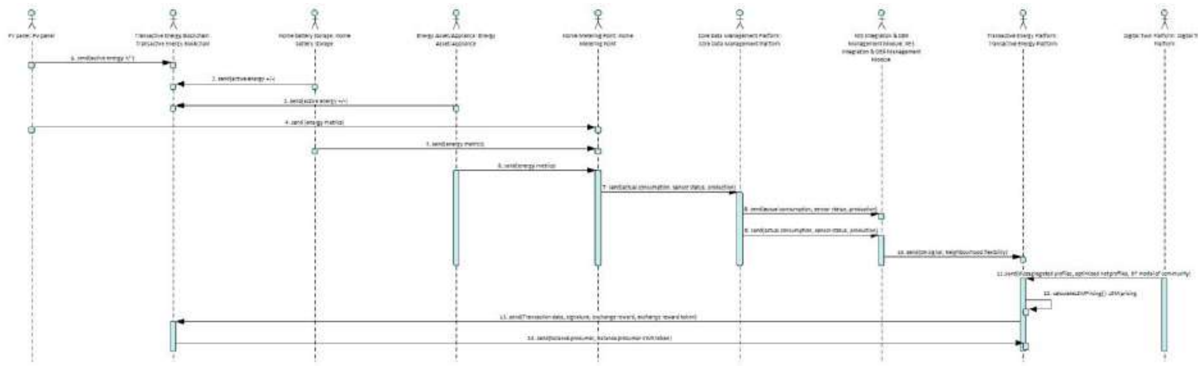

Figure 148: SGAM Sequence Diagram PUC04.01

8.2. PUC04.02. Calculation and broadcasting of LEM pricing compared to DNO/DSO pricing.

8.2.1. Use Case Description

The process can be depicted as follows:

1. The TEM receives updates about energy transactions from TwinERGY devices (physical assets in the dwellings and Digital Twin platform)

2. The input data includes prosumer, device, units and destination

3. TEM receives input data from DSO/DNO. Different energy tariff schemas are applicable in the pilot sites. In most of the cases, static Time of Use (ToU) tariffs are used, in which two different price levels are applied to the customer. This typically refers to consumption over several hours where the price for each hour is determined in advance and remains constant. A simple example of static ToU pricing is day-night pricing, in order for the on-off peak consumption to be reflected. In the case of real time pricing, prices are determined close to real time consumption of electricity and are based on wholesale electricity prices. Such tariffs are mostly composed of the wholesale price of electricity plus a supplier margin. In the case of real time pricing, the inputs will be imported from ENTSOE Transparency Platform API.

4. TEM calculates LEM pricing. The internal LEM pricing requires as a first step the set of bids both from suppliers and consumers' side. It is important to mention here that the producers of the Local energy market can also submit bid as consumers in case their production levels are not adequate. The bids have to follow the same hour resolution as the price signals received in (step 3) from external DSO market. An auction mechanism is then acting in order to determine LEM's energy price. All the transactions inside the LEM will be executed on this energy price for that specific time interval.

5. TEM broadcasts LEM/DSO/DNO pricing on set interval

6. TEM records pricing on the blockchain

8.2.2. SGAM Function Layer

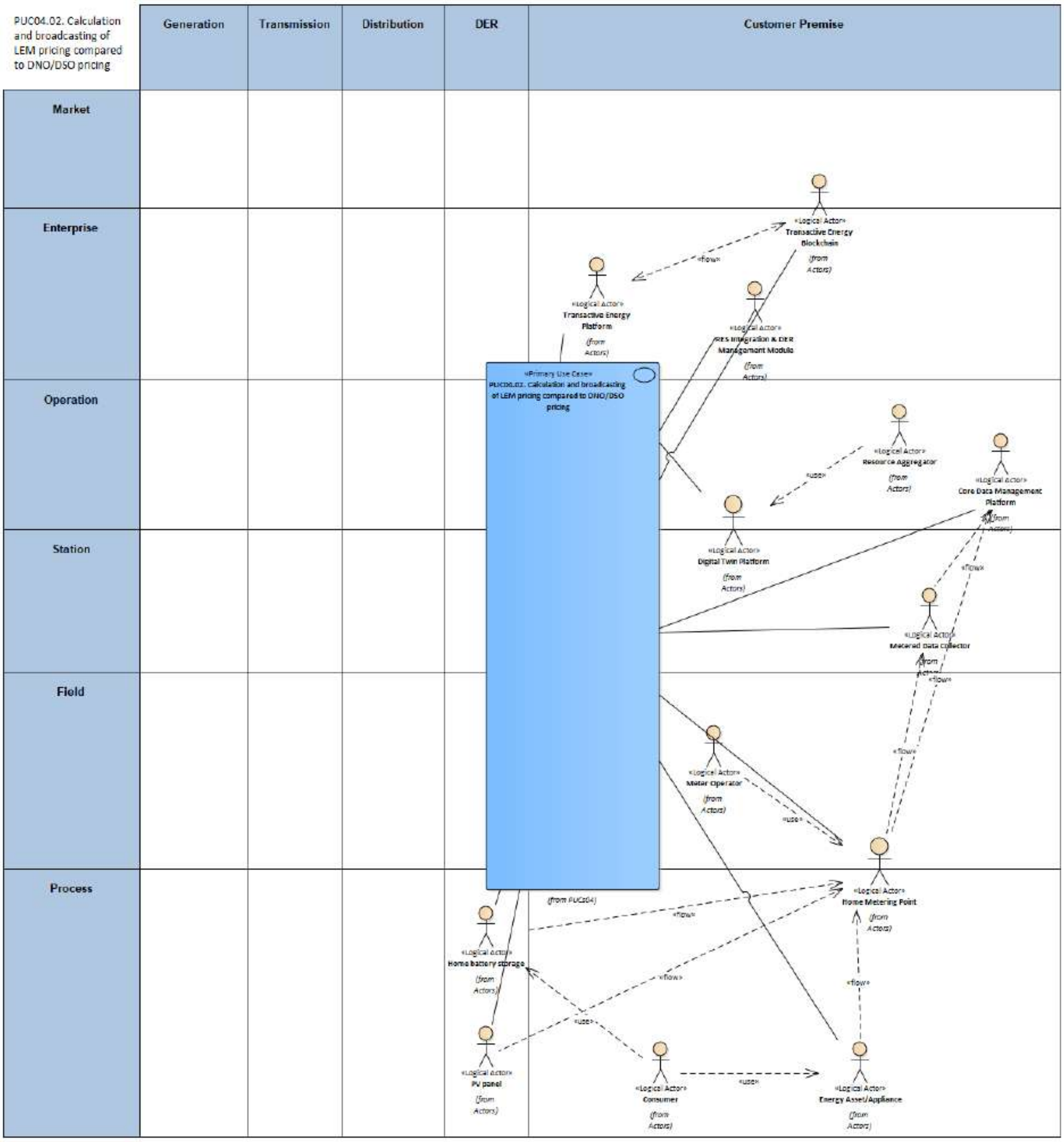

Figure 149: SGAM Function Layer PUC04.02

Table 88: List of Actors Involved PUC04.02

Actor Name	Actor Type
RES Integration & DER Management Module	Application
Transactive Energy Blockchain	Application
Transactive Energy Platform	Application
Resource Aggregator	Logical actor role
Core Data Management Platform	Application
Digital Twin Platform	Application
Metered Data Collector	Device
Meter Operator	Device
Home battery storage	Device
Home Metering Point	Device
Energy Asset/Appliance	Device
PV Panel	Device
Consumer	Logical actor role

8.2.3. SGAM Component Layer

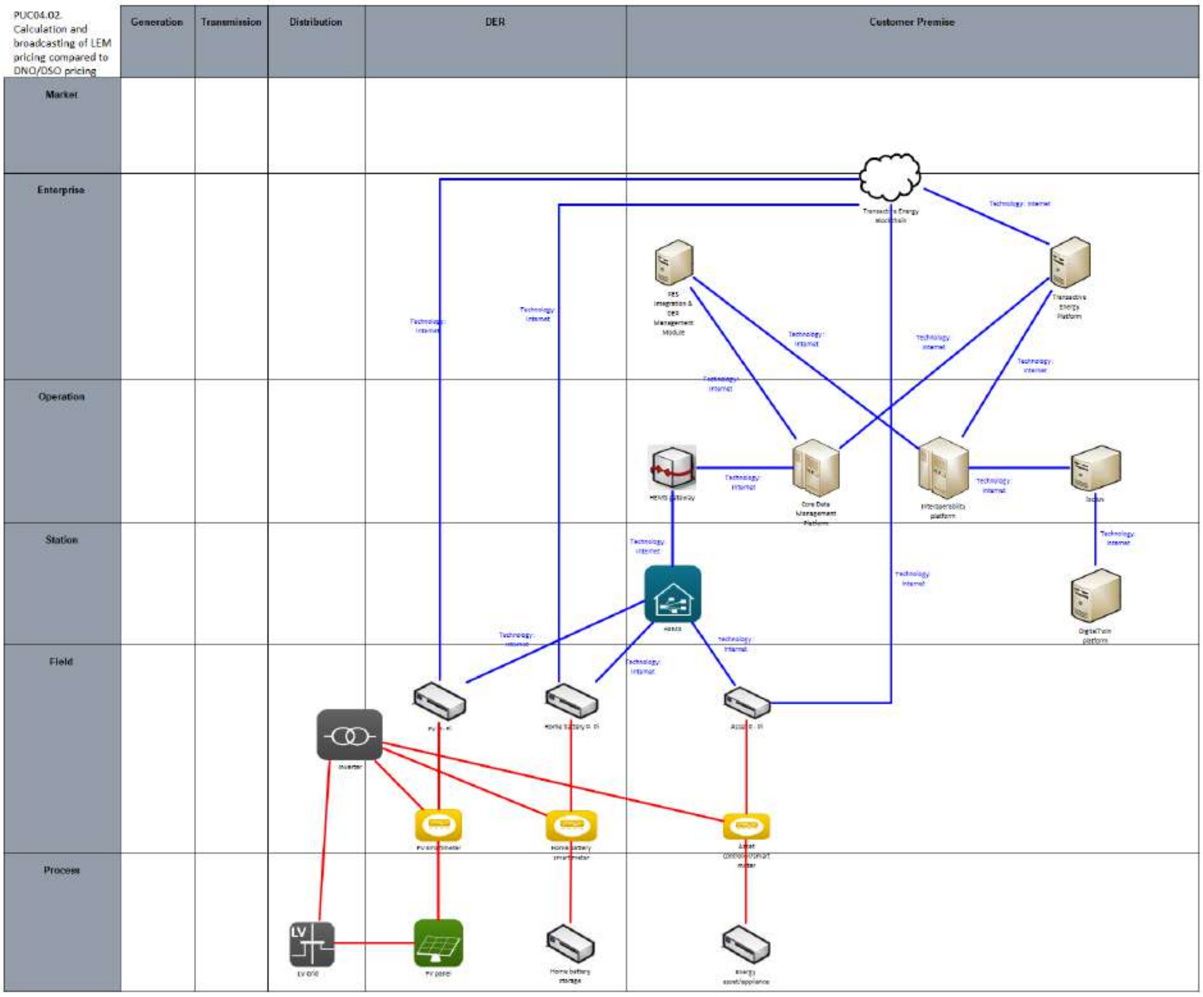

Figure 150: SGAM Component Layer PUC04.02

Table 89: List of Components PUC04.02

Component	Component Type
LV Grid	Physical asset
Inverter	Physical asset
PV panel	Physical asset
Home Battery Storage	Physical asset
Energy asset/appliance	Physical asset
PV smart meter	Physical asset
Home battery smart meter	Physical asset

Asset controller/smart meter	Physical asset
Raspberry-Pi	Physical asset
HEMS	External application
HEMS gateway	External application
Core Data Management Platform	TwinERGY application
Interoperability Platform	TwinERGY application
iSCAN	External application
Digital Twin Platform	TwinERGY application
Transactive Energy Platform	TwinERGY application
RES integration & DER Management Module	TwinERGY application
Transactive Energy Blockchain	TwinERGY application

8.2.4. SGAM Communication Layer

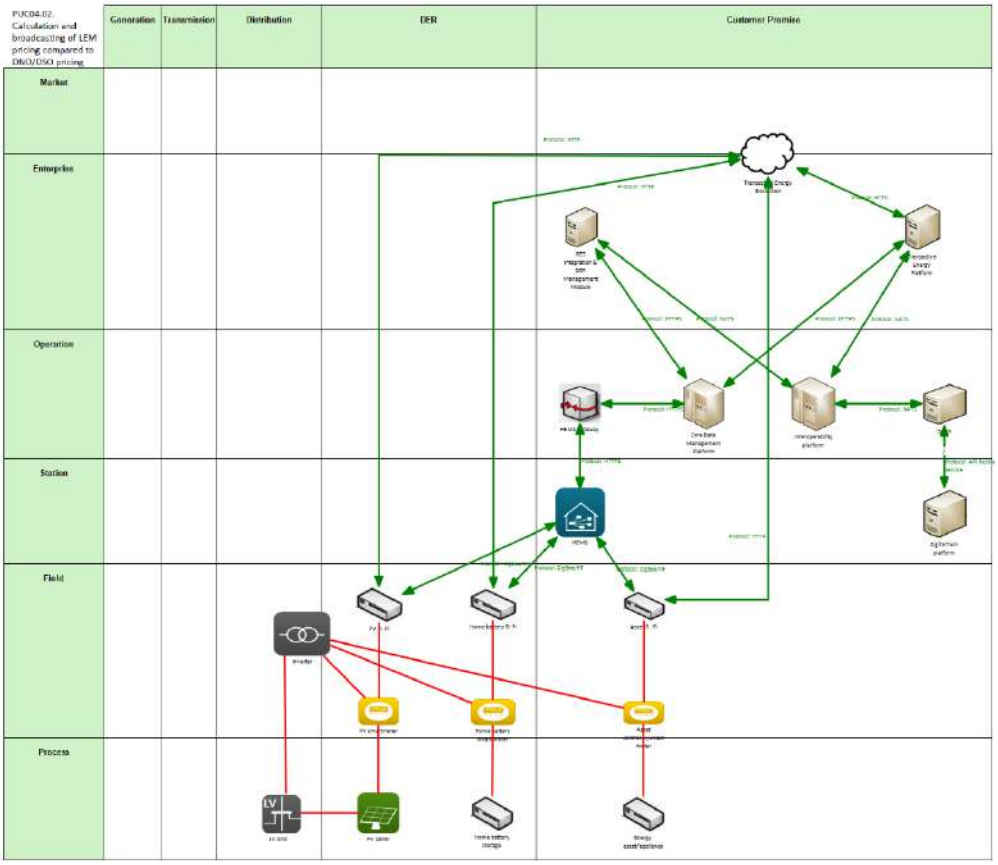

Figure 151: SGAM Communication Layer PUC04.02

Table 90: List of Communication technologies involved in PUC04.02

Communication Technology	Description
HTTP	Stand for Hypertext Transfer Protocol. It is an application layer protocol in the Internet protocol suite model for distributed, collaborative, hypermedia information systems
HTTPS	HyperText Transfer Protocol Secure. It is an extension of the Hypertext Transfer Protocol (HTTP), used for secure communication over a computer network. In HTTPS, the communication protocol is encrypted using Transport Layer Security (TLS) or, formerly, Secure Sockets Layer (SSL). The protocol is therefore also referred to as HTTP over TLS, or HTTP over SSL.
NATS	Protocol of messaging that enables the exchange of messages among computer applications and services, not depending on the network location.

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ZigBee/RF	Protocol IEEE 802.15.4, designed to communicate data through noisy RF environments. This standard operates on the physical radio specification and operates in unlicensed bands including 2.4 GHz, 900 MHz and 868 MHz.
API REST	Application Programming Interface for REpresentational State Transfer. API is a software intermediary that allows two applications to talk to each other, whilst REST is an architectural style for distributed hypermedia systems, working stateless. Both define a set of distributed resources accessible and manipulable through a set of public functions.

8.2.5. SGAM Information Layer

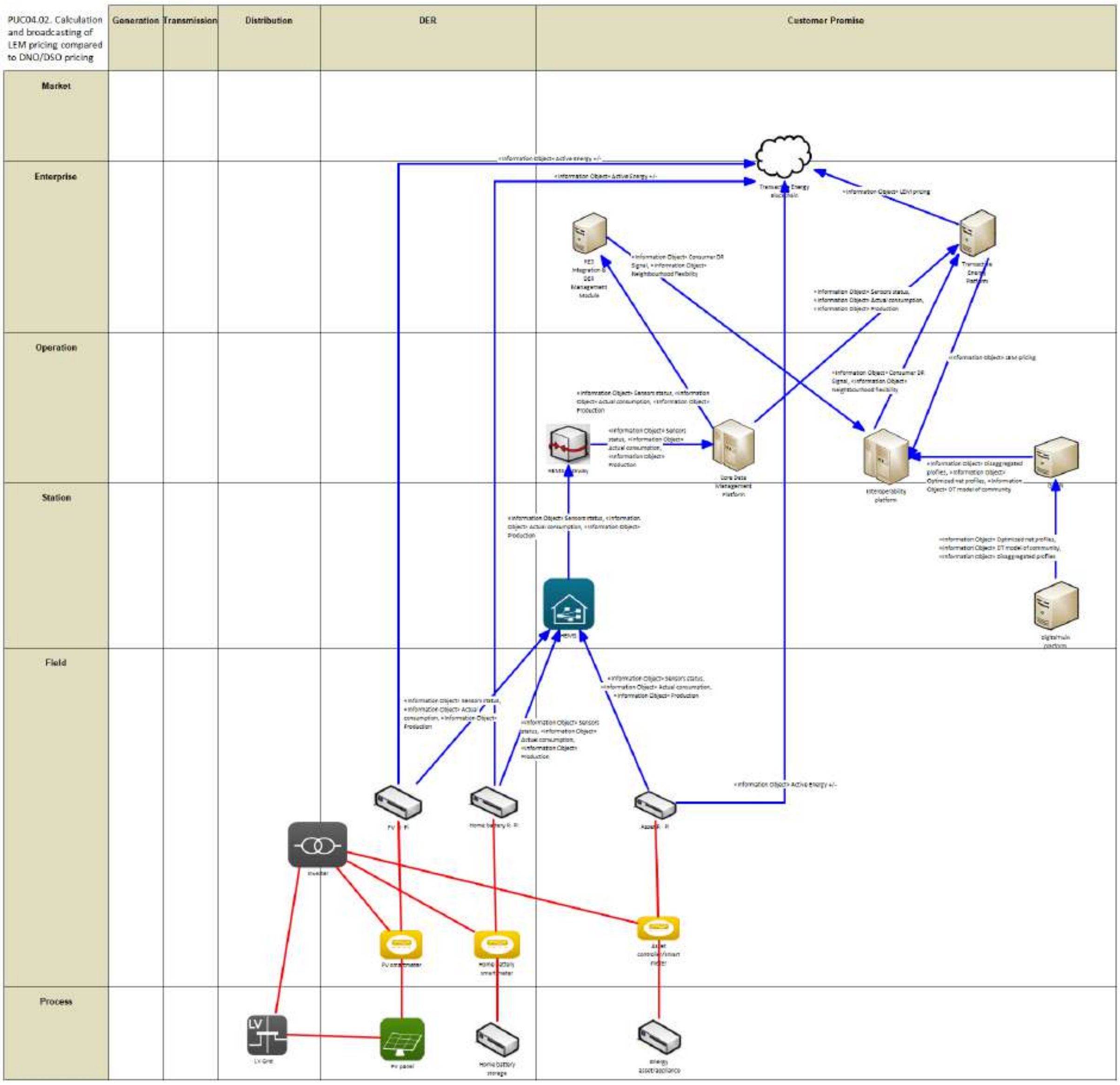

Figure 152:SGAM Information Layer PUC04.02

Twinergy has received funding from the European Union's Horizon 2020 research and innovation programme under grant agreement No. 957736

8.2.6. Canonical Data Model

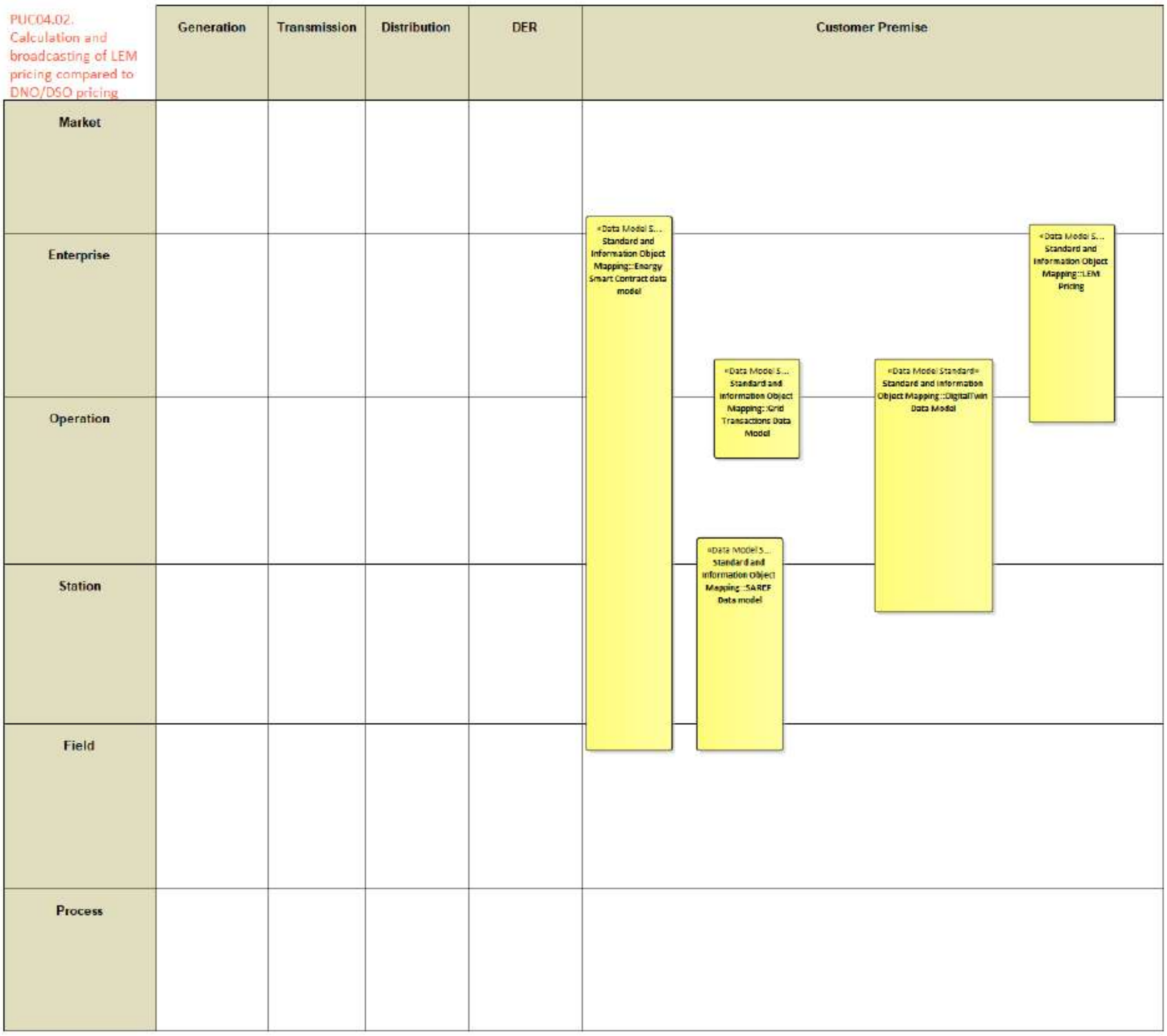

Figure 153: SGAM Canonical Data Model PUC04.02

Table 91: List of Data Models PUC04.02

Data Models
Energy Smart Contract Data Model
SAREF Data Model
Grid Transactions Data Model
Digital Twin Data Model
LEM Pricing

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8.2.7. Standards and Information Object Mapping

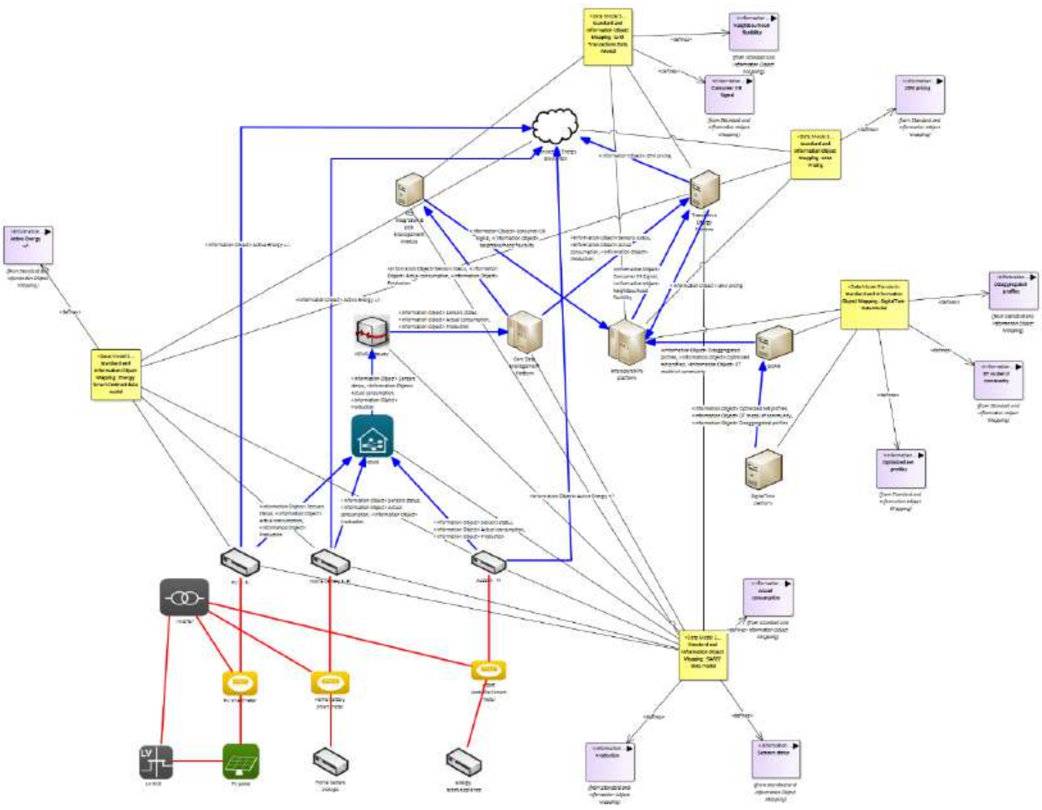

Figure 154: SGAM Standards and Information Object Mapping PUC04.02

Table 92: List of Information Objects PUC04.02

Information Objects	Data Models
Active Energy +/-	Energy Smart Contract data model
Neighbourhood flexibility	Grid Transactions Data Model
Consumer DR Signal	Grid Transactions Data Model
LEM Pricing	LEM Pricing Data model
Disaggregated profiles	DigitalTwin Data Model
DT model of community	DigitalTwin Data Model
Optimized net profiles	DigitalTwin Data Model
Actual consumption	SAREF Data model
Sensor status	SAREF Data model
Production	SAREF Data model

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8.2.8. Activity Diagram

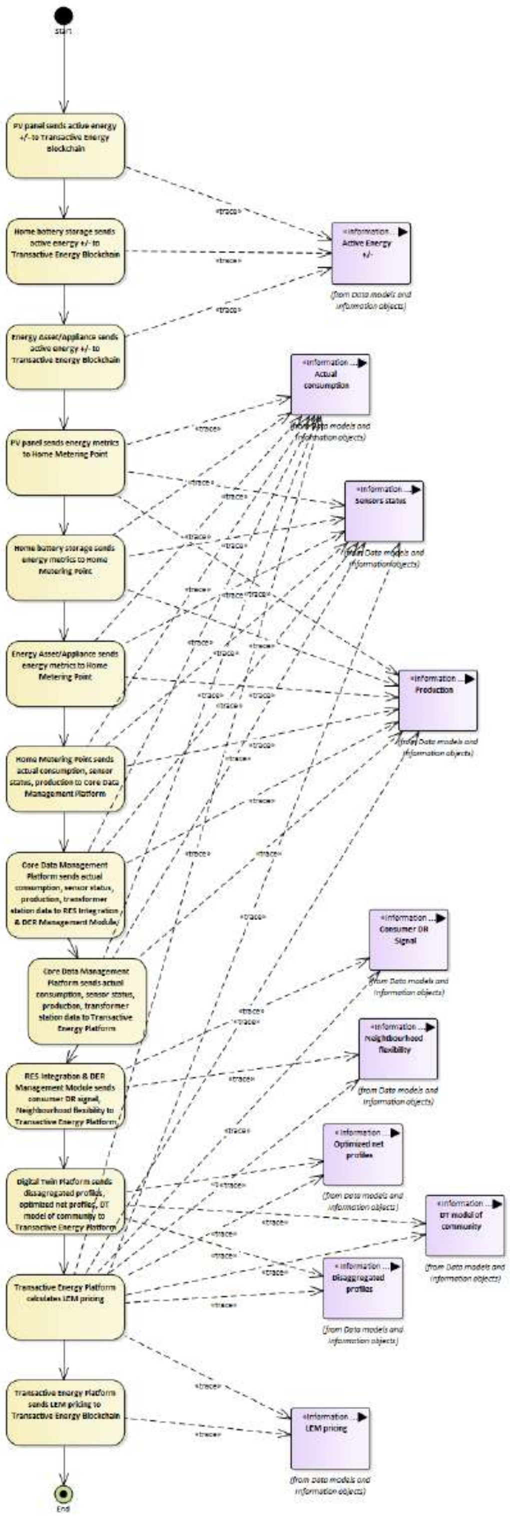

Figure 155: SGAM Activity Diagram PUC04.02

8.2.9. Sequence Diagram

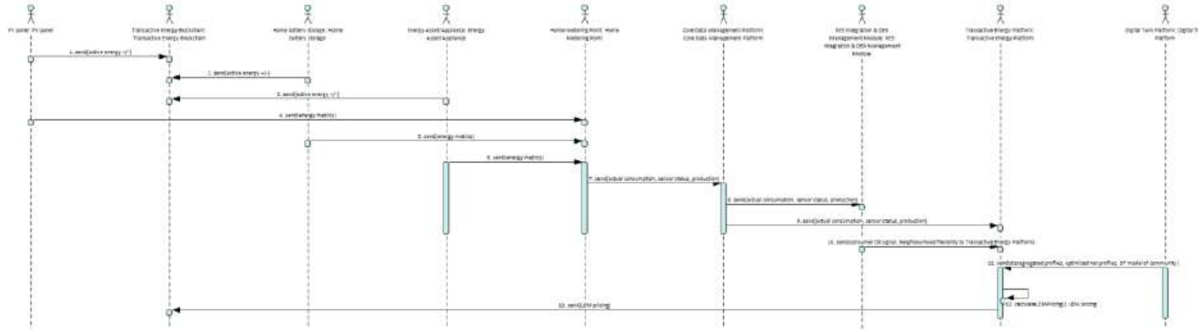

Figure 156: SGAM Sequence Diagram PUC04.02

8.3. SGAM Business Layer

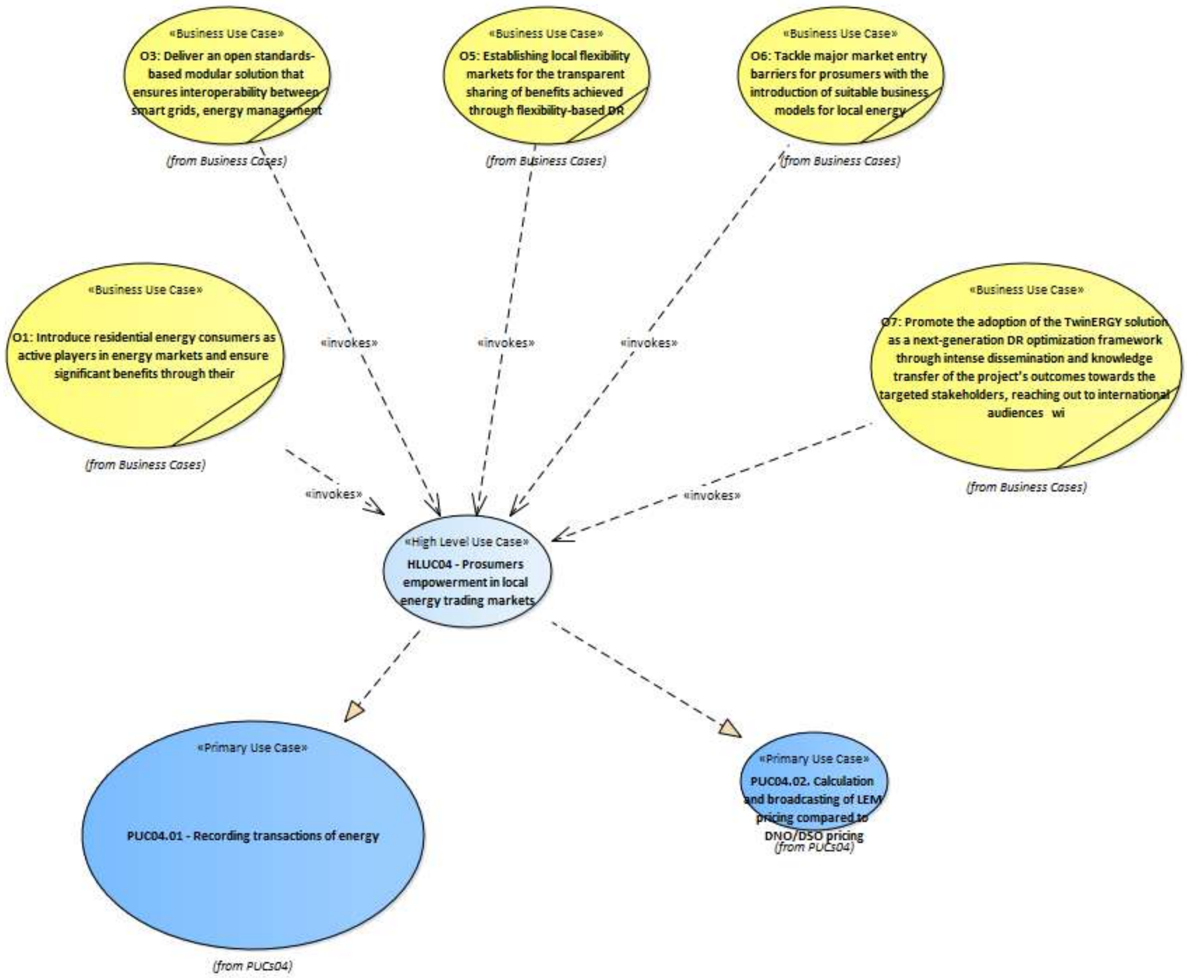

Figure 157: SGAM Business Layer HLUC04

9. HLUC05. Enhance grid flexibility through DER Management

9.1. PUC05.01. Prediction of energy consumption and RES production

9.1.1. Use Case Description

This use case starts at 00:00 during any day. The process below is regularly repeated at specified time intervals throughout the day. This can be every 3 hours or more frequent.

1. Information about the upcoming local weather conditions is retrieved from an external weather forecast provider by the Digital Twin Platform, with a special focus on wind speeds and hours of sunshine.

2. All available RES in the local area for which the forecasted weather conditions apply, are checked and their level of energy production is predicted.
   a) This includes considering individual RES equipment and their estimated energy production based on their specifications. This requires all RES specs to be readily available.
   b) Additionally, the data can be supplemented with historical data of weather and production levels to accommodate for deviations from the specifications, such as in the case of wear.

3. The data is based on previous analysis of consumer behaviour in the local area (sourced by modules Consumer Demand Flexibility Profiling and Neighbourhood Demand Flexibility Profiling). Besides, it is supplemented by historical measured data (from the database placed in the TwinERGY Storage System) and the consumption levels of individual households or quarters are predicted based on the current time of day data (given by Home & Tertiary Real-time Energy Monitoring Module), weekday and weather conditions (with a focus on temperature and sunshine).

4. All gathered forecasts are used by the DSO via the TwinERGY Interoperability Platform, to optimally reroute energy flows within the grid by adapting the grid switching behaviour in a simulated environment to maximize RES consumption and grid stability.
   a) This includes decision making processes to decide where to charge or discharge battery storages.

b) Negative effects such as feedback loops shall be detected this way before they actually appear.

5. The previously tested changes to the power grid are deployed in real life and effects are monitored in real time.
    - Any unwanted effects such as unexpected feedback loops that were not identified beforehand shall be mitigated by corresponding additional changes to the grid switches.

6. The process is repeated at a later point in time.

Note that the whole process is done approximately every 3 hours, because the forecasts do not need a real-time frequency (less that one minute). However, the control of the battery storage or VPP needs real-time control, so points 4 and 5 are executed with real-time frequency.

9.1.2. SGAM Function Layer

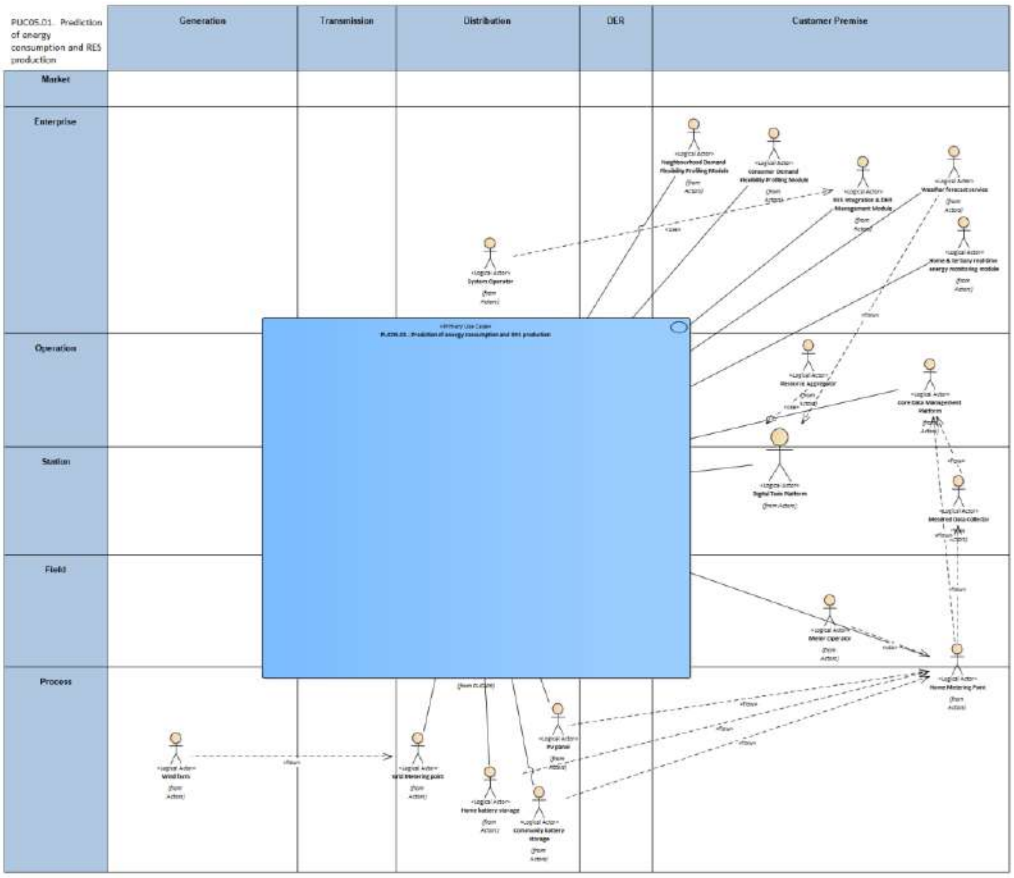

Figure 158: SGAM Function Layer PUC05.01

Twinergy has received funding from the European Union's Horizon 2020 research and innovation programme under grant agreement No. 957736

Table 93: List of Actors Involved PUC05.01

Actor Name	Actor Type
System Operator	Organization
Neighbourhood Demand Flexibility Profiling Module	Application
Consumer Demand Flexibility Profiling Module	Application
RES integration & DER Management Module	Application
Weather Forecast service	Application
Home & Tertiary real-time energy monitoring module	Application
Resource aggregator	Logical actor role
Core Data Management Platform	Application
Digital Twin Platform	Application
Metered Data Collector	Device
Meter Operator	Device
Home Metering Point	Device
Wind Farm	Device
Grid Metering Point	Device
Home Battery Storage	Device
Community Battery storage	Device
PV panel	Device

9.1.3. SGAM Component Layer

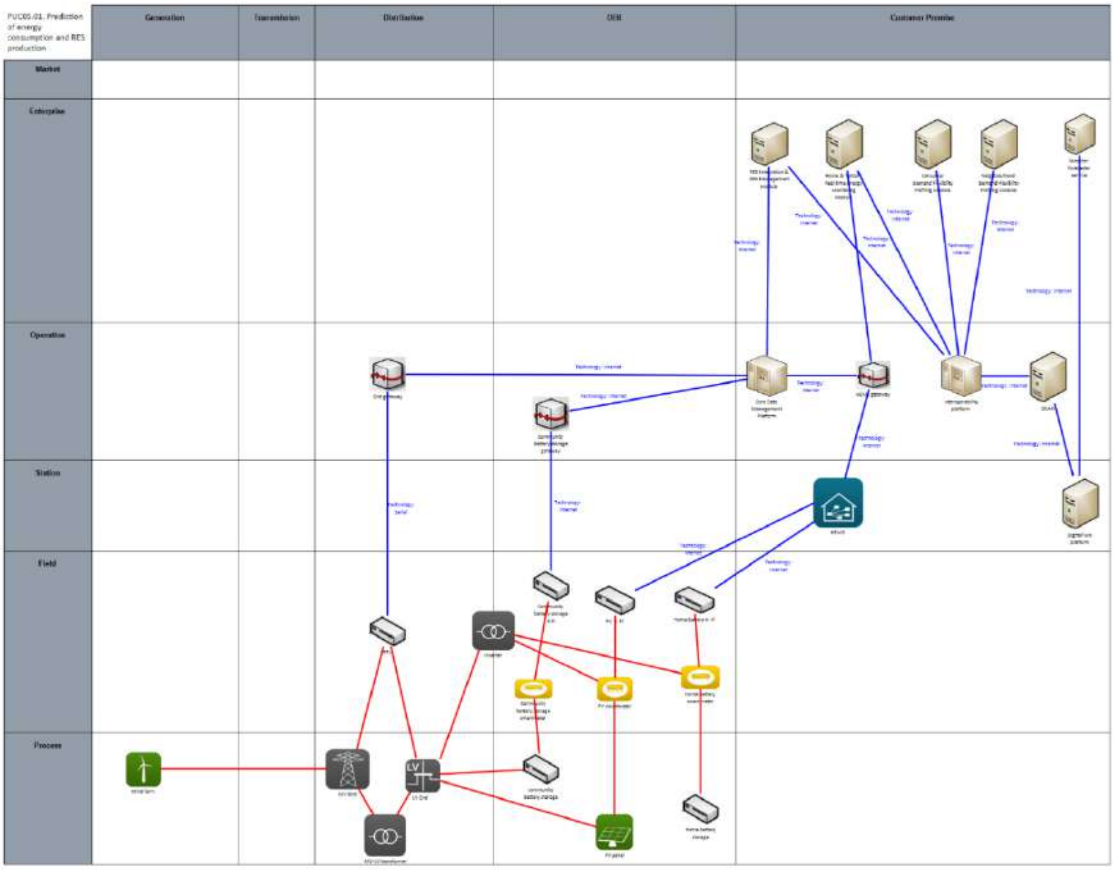

Figure 159: SGAM Component Layer PUC05.01

Table 94: List of Components PUC05.01

Component	Component Type
Wind Farm	Physical asset
MV Grid	Physical asset
MV-LV Transformer	Physical asset
LV Grid	Physical asset
RTU	Physical asset
Grid Gateway	External application
Inverter	Physical asset
Community Battery Storage	Physical asset
PV Panel	Physical asset

Home Battery Storage	Physical asset
Community Battery Storage Smart meter	Physical asset
PV Panel Smart meter	Physical asset
Home Battery Storage Smart meter	Physical asset
Raspberry-Pi	Physical asset
Community Battery Storage Gateway	External application
Core Data Management Platform	TwinERGY application
HEMS	External application
HEMS gateway	External application
RES Integration & DER Management Module	TwinERGY application
Home & Tertiary Energy Monitoring Module	TwinERGY application
Consumer Demand Flexibility Profiling Module	TwinERGY application
Neighbourhood Demand Flexibility Profiling Module	TwinERGY application
Interoperability Platform	TwinERGY application
iSCAN	External application
Digital Twin Platform	TwinERGY application
Weather Forecast service	External application

9.1.4. SGAM Communication Layer

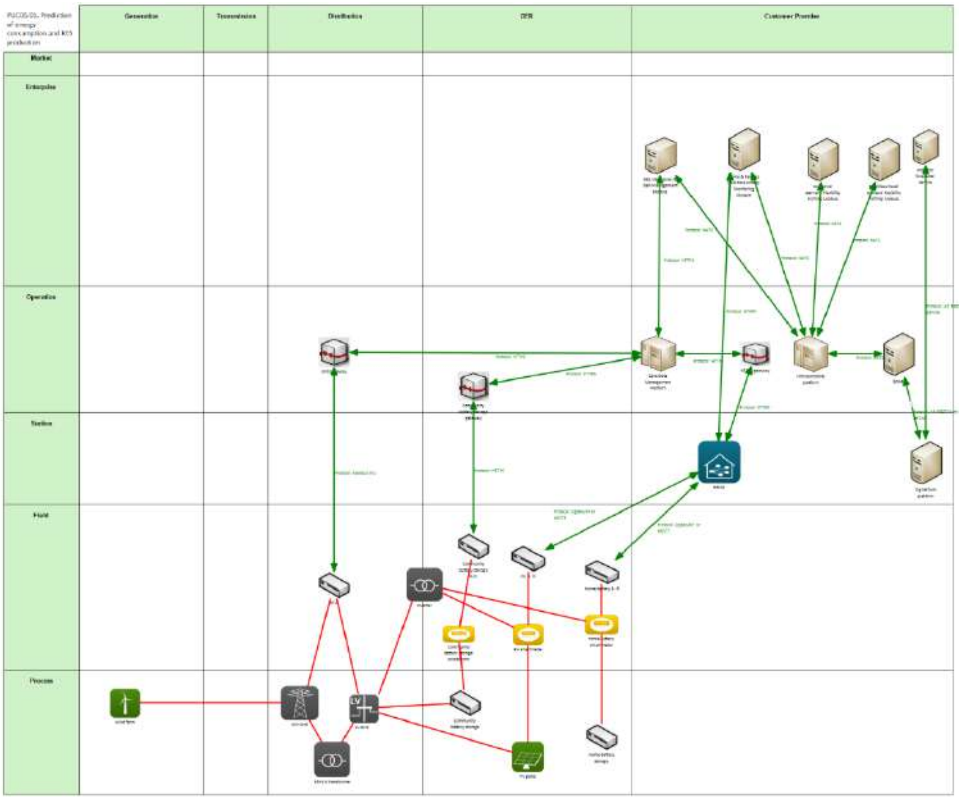

Figure 160: SGAM Communication Layer PUC05.01

Table 95: List of Communication technologies involved in PUC05.01

Communication Technology	Description
Modbus RTU	Data communications protocol for using with programmable logic controllers (PLCs), where devices are connected to the same cable or Ethernet network. It is used on industrial environments
HTTPS	HyperText Transfer Protocol Secure. It is an extension of the Hypertext Transfer Protocol (HTTP), used for secure communication over a computer network. In HTTPS, the communication protocol is encrypted using Transport Layer Security (TLS) or, formerly, Secure Sockets Layer (SSL). The protocol is therefore also referred to as HTTP over TLS, or HTTP over SSL.
NATS	Protocol of messaging that enables the exchange of messages among computer applications and services, not depending on the network location.
ZigBee/RF	Protocol IEEE 802.15.4, designed to communicate data through noisy RF environments. This standard operates on the physical

	radio specification and operates in unlicensed bands including 2.4 GHz, 900 MHz and 868 MHz.
MQTT	MQ Telemetry Transport. It is an open OASIS standard and an ISO recommendation (ISO/IEC 20922) over TCP/IP, being a lightweight, publish-subscribe network protocol that transports messages between devices.
API REST	Application Programming Interface for REpresentational State Transfer. API is a software intermediary that allows two applications to talk to each other, whilst REST is an architectural style for distributed hypermedia systems, working stateless. Both define a set of distributed resources accessible and manipulable through a set of public functions.

9.1.5. SGAM Information Layer

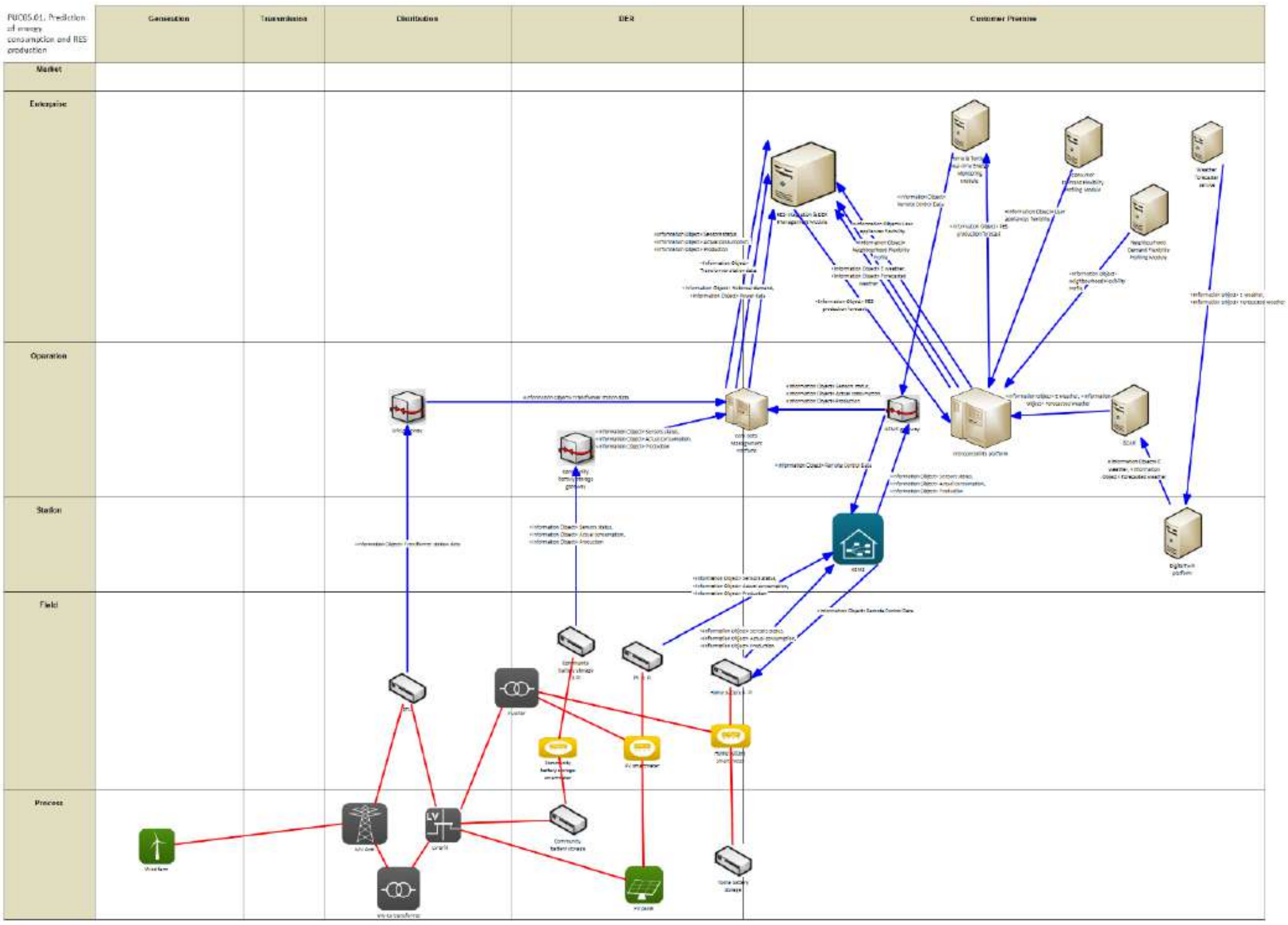

Figure 161: SGAM Information Layer PUC05.01

9.1.6. Canonical Data Model

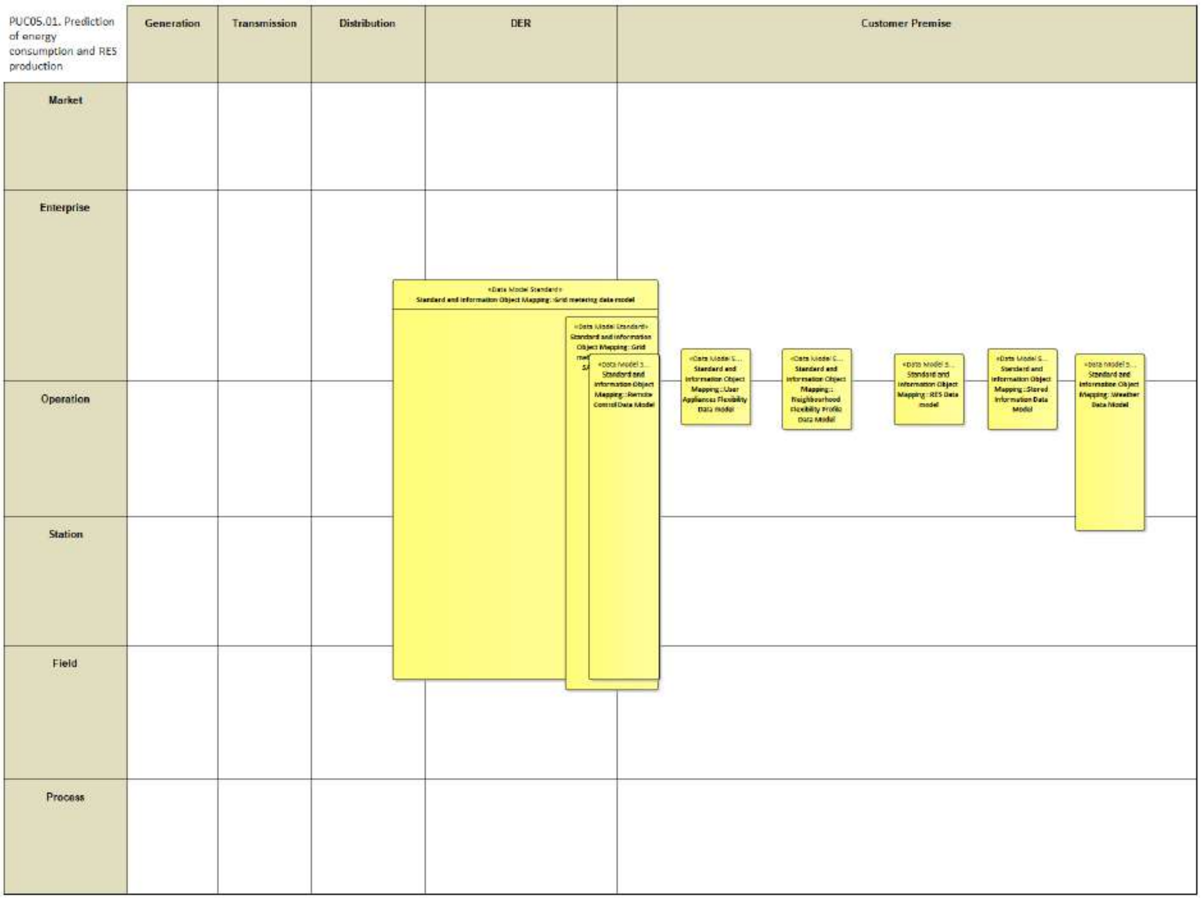

Figure 162: SGAM Canonical Data Model PUC05.01

Table 96: List of Data Models PUC05.01

Data Models
Grid Metering Data Model
SAREF Data Model
Remote Control Data Model
User Appliances Flexibility Data model
Neighbourhood Flexibility Profile Data Model
RES Data Model
Standard Information Data Model
Weather Data Model

9.1.7. Standards and Information Object Mapping

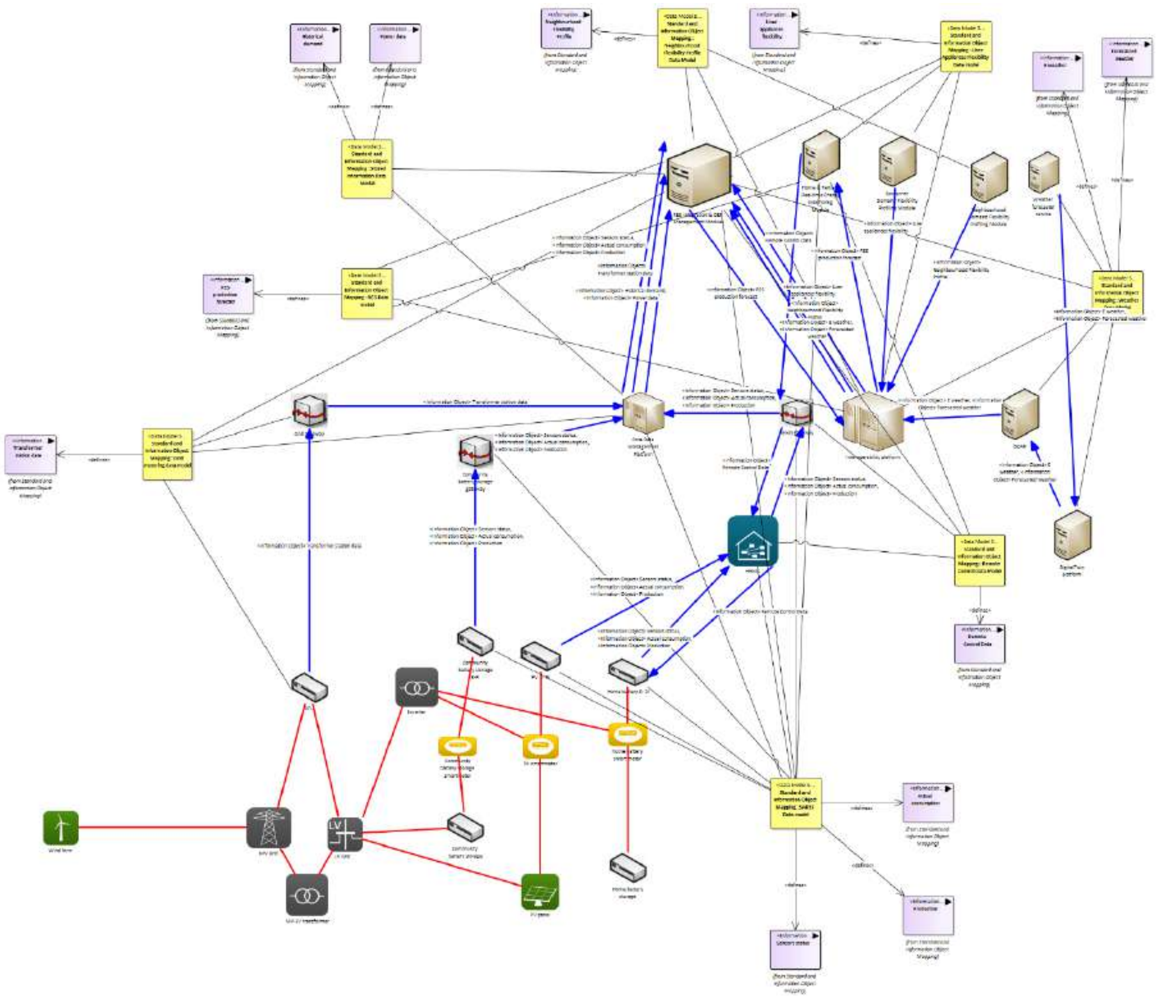

Figure 163: SGAM Standards and Information Object Mapping PUC05.01

Table 97: List of Information Objects PUC05.01

Information Objects	Data Models
Actual consumption	SAREF Data model
Sensor status	SAREF Data model
Production	SAREF Data model
Transformer station data	Grid metering data model
RES production forecast	RES Data model
Historical consumption	Stored Information Data Model
Power data	Stored Information Data Model

Neighbourhood Flexibility Profile	Neighbourhood Flexibility Profile Data Model
User appliances flexibility	User Appliances Flexibility Data model
E weather	Weather Data Model
Forecasted weather	Weather Data Model
Remote Control Data	Remote Control Data Model

9.1.8. Activity Diagram

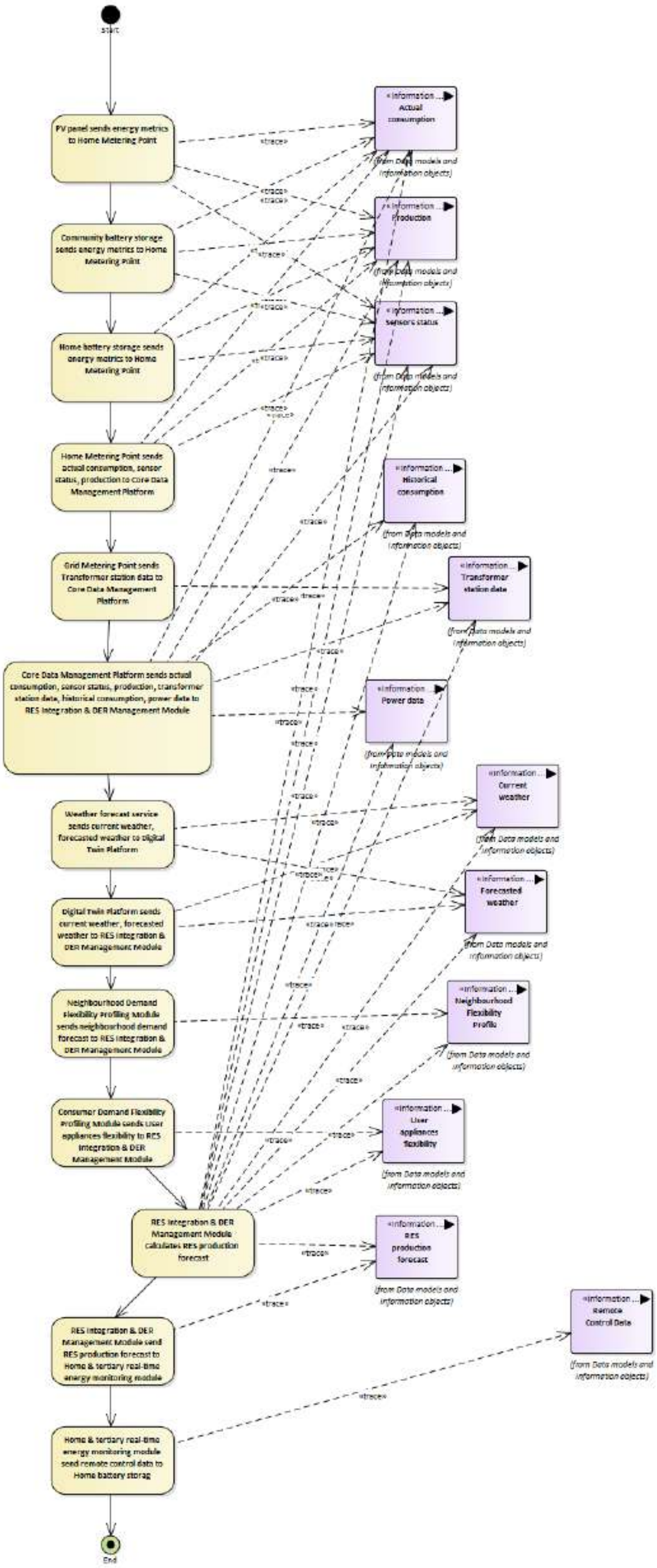

Figure 164: SGAM Activity Diagram PUC05.01

Twinergy has received funding from the European Union's Horizon 2020 research and innovation programme under grant agreement No. 957736

9.1.9. Sequence Diagram

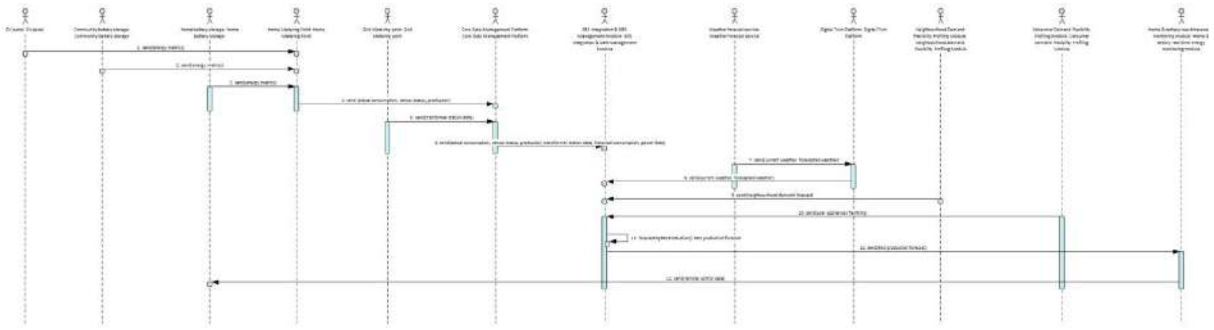

Figure 165: SGAM Sequence Diagram PUC05.01

9.2. PUC05.02. Utilizing the Virtual-Power-Plant

9.2.1. Use Case Description

The use case begins on a sunny day.

1. While it is still early just before dawn, the PV-systems in Hagedorn have not yet begun any production. Still, some people have already woken up and are preparing themselves for work. At this time, the first rooms are lit and appliances such as coffee machines are started for breakfast. Because it is still dark, the PV systems on the roofs cannot contribute to the energy production, yet. However, during the past day and with help of wind turbines, they were able to charge the energy storages in the village, which can now be used to power the households.

2. As the sun rises, the production of solar energy is also increasing until there is a balance between the demand and the production of energy. Any excess energy produced from this point on, is used to charge the battery storages at the pilot site, since they were used up to some extent in the morning and during the night.

3. When the sun begins to set, the storages are sufficiently charged to support the households with enough power throughout the upcoming evening and night. This is supplemented with additional power reserves coming from wind power, which is not dependent on sunlight.

4. The whole process is repeated the next day.

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9.2.2. SGAM Function Layer

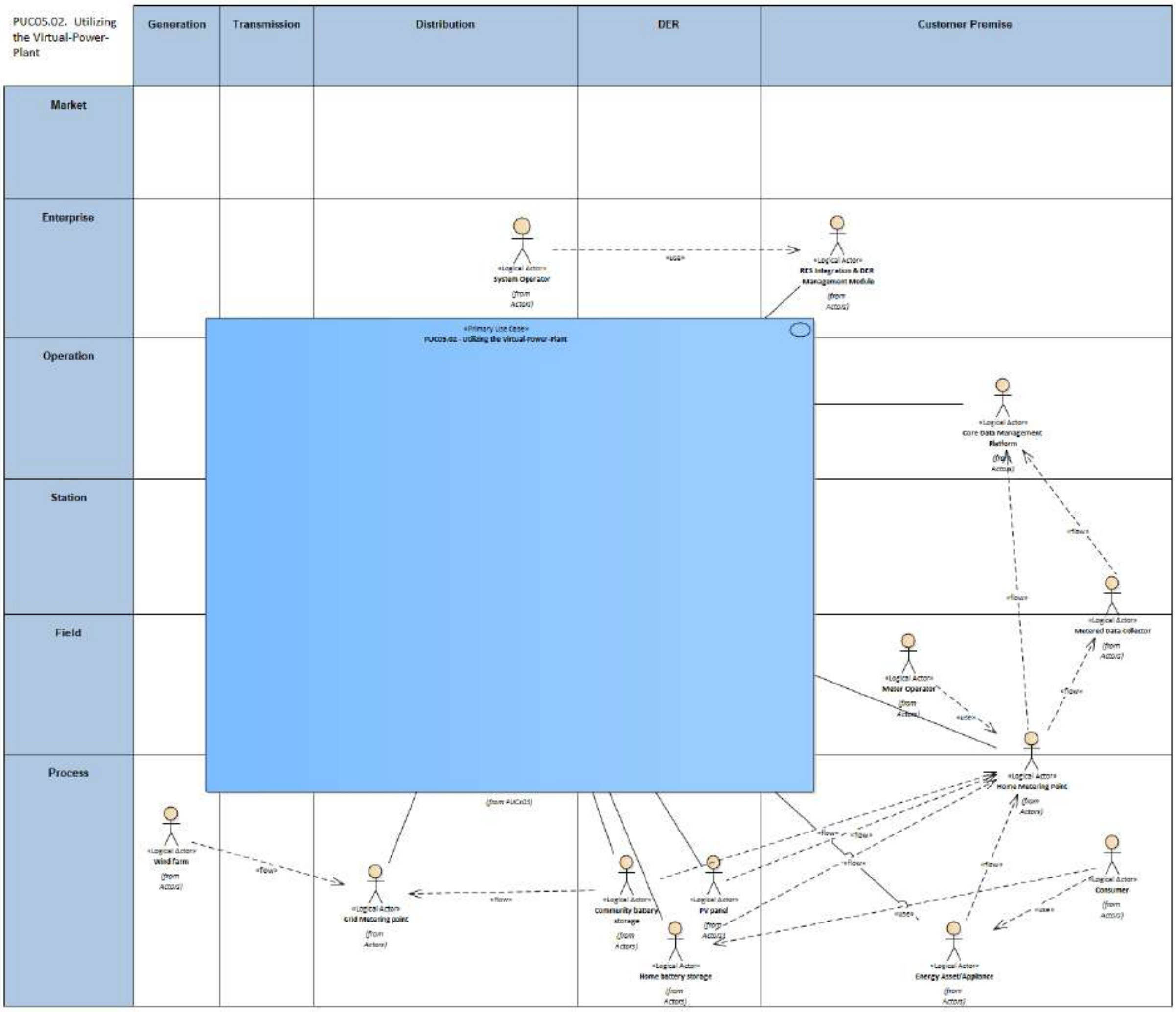

Figure 166: SGAM Function Layer PUC05.02

Table 98: List of Actors Involved PUC05.02

Actor Name	Actor Type
System Operator	Organization
RES integration & DER Management Module	Application
Core Data Management Platform	Application
Metered Data Collector	Device
Meter Operator	Device
Home Metering Point	Device

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Wind Farm	Device
Grid Metering Point	Device
Home Battery Storage	Device
Community Battery storage	Device
PV panel	Device
Energy asset/appliance	Device
Consumer	Logical actor role

9.2.3. SGAM Component Layer

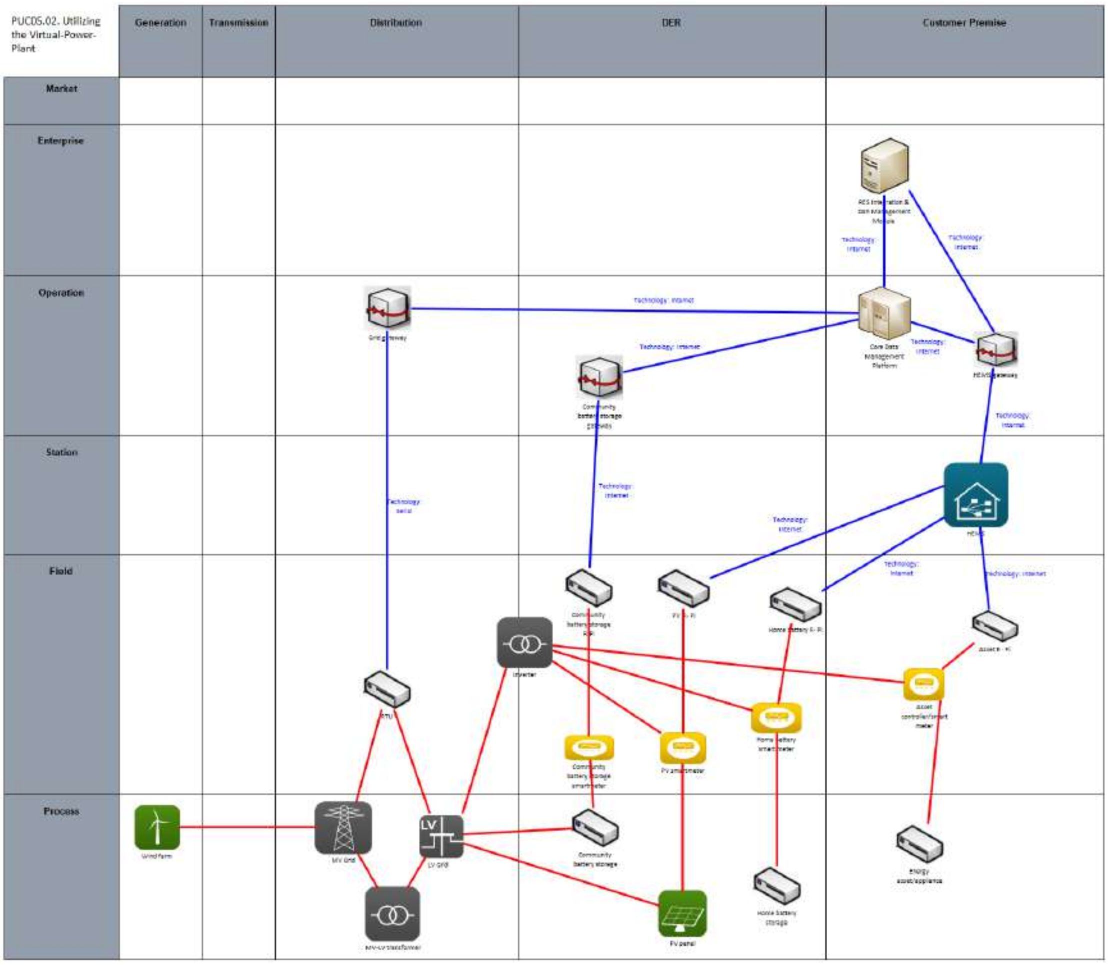

Figure 167: SGAM Component Layer PUC05.02

Table 99: List of Components PUC05.02

Component	Component Type
Wind Farm	Physical asset
MV Grid	Physical asset
MV-LV Transformer	Physical asset
LV Grid	Physical asset
RTU	Physical asset
Grid Gateway	External application
Inverter	Physical asset
Community Battery Storage	Physical asset
PV Panel	Physical asset
Home Battery Storage	Physical asset
Community Battery Storage Smartmeter	Physical asset
PV Panel Smartmeter	Physical asset
Home Battery Storage Smartmeter	Physical asset
Energy asset/appliance	Physical asset
Asset controller/ Smart Meter	Physical asset
Raspberry-Pi	Physical asset
Community Battery Storage Gateway	External application
Core Data Management Platform	TwinERGY application
HEMS	External application
HEMS gateway	External application
RES Integration & DER Management Module	TwinERGY application

9.2.4. SGAM Communication Layer

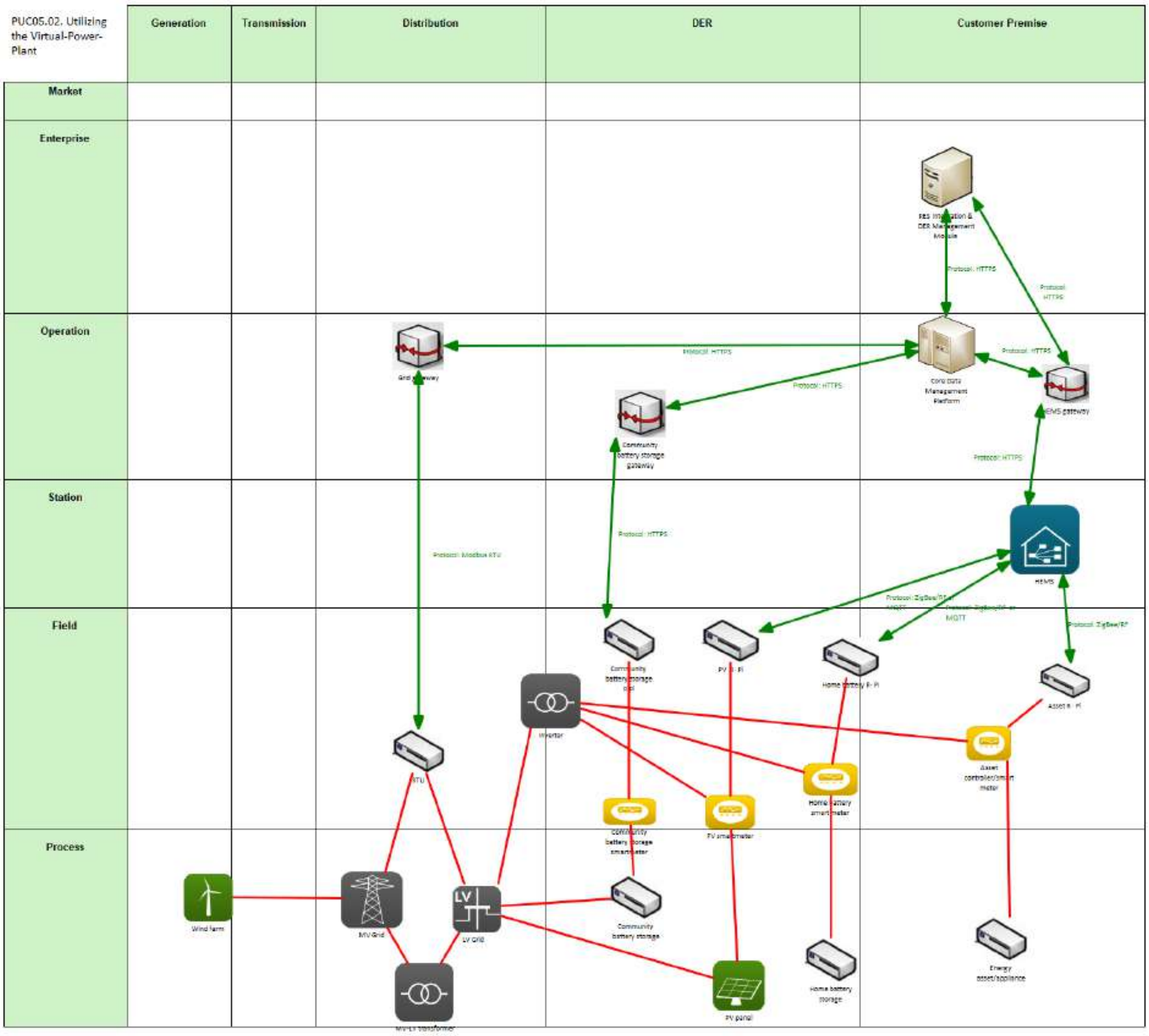

Figure 168: SGAM Communication Layer PUC05.02

Table 100: List of Communication technologies involved in PUC05.02

Communication Technology	Description
Modbus RTU	Data communications protocol for using with programmable logic controllers (PLCs), where devices are connected to the same cable or Ethernet network. It is used on industrial environments
HTTPS	HyperText Transfer Protocol Secure. It is an extension of the Hypertext Transfer Protocol (HTTP), used for secure communication over a computer network. In HTTPS, the communication protocol is encrypted using Transport Layer Security (TLS) or, formerly, Secure Sockets Layer (SSL). The

	protocol is therefore also referred to as HTTP over TLS, or HTTP over SSL.
ZigBee/RF	Protocol IEEE 802.15.4, designed to communicate data through noisy RF environments. This standard operates on the physical radio specification and operates in unlicensed bands including 2.4 GHz, 900 MHz and 868 MHz.
MQTT	MQ Telemetry Transport. It is an open OASIS standard and an ISO recommendation (ISO/IEC 20922) over TCP/IP, being a lightweight, publish-subscribe network protocol that transports messages between devices.

9.2.5. SGAM Information Layer

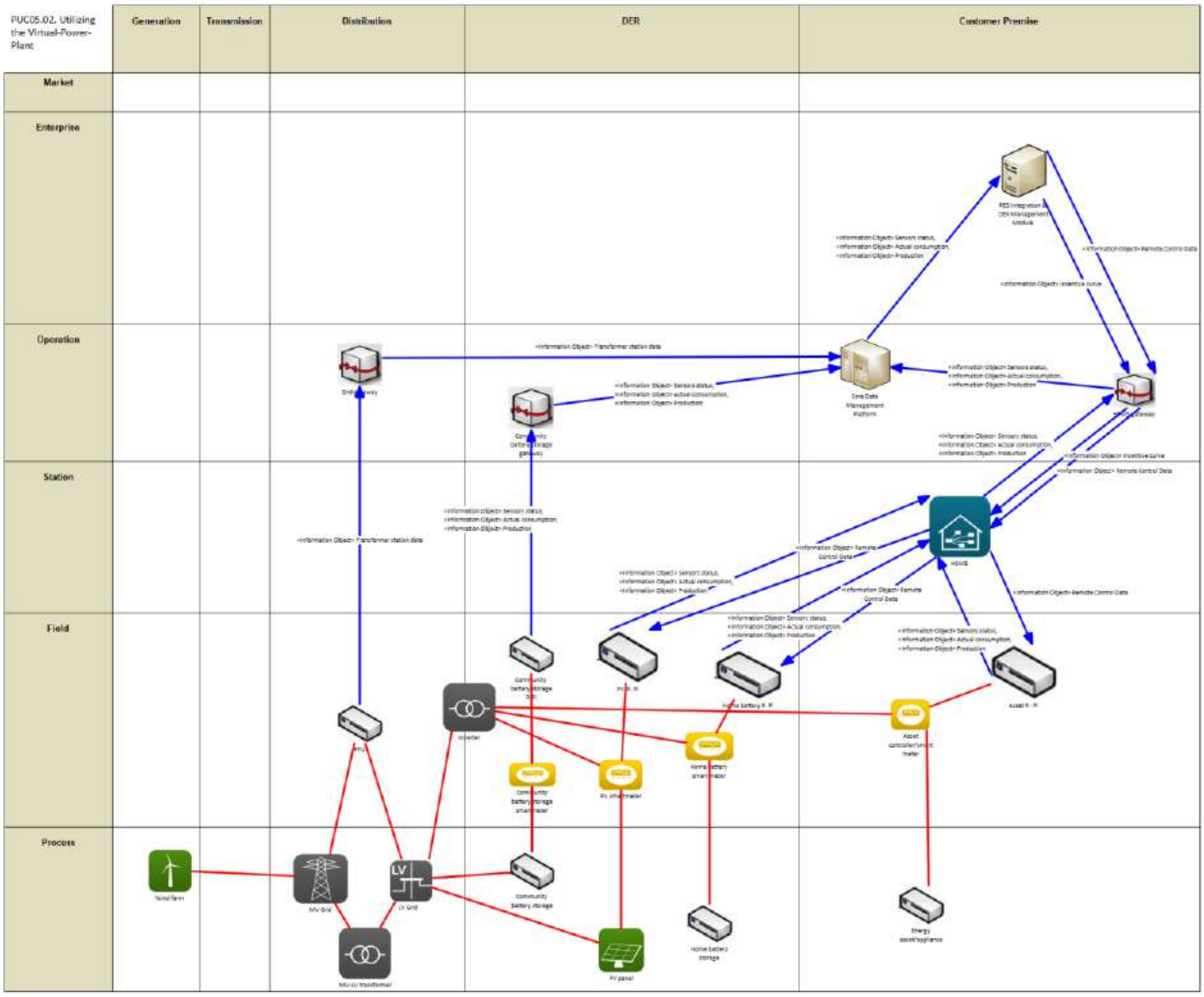

Figure 169: SGAM Information Layer PUC05.02

9.2.6. Canonical Data Model

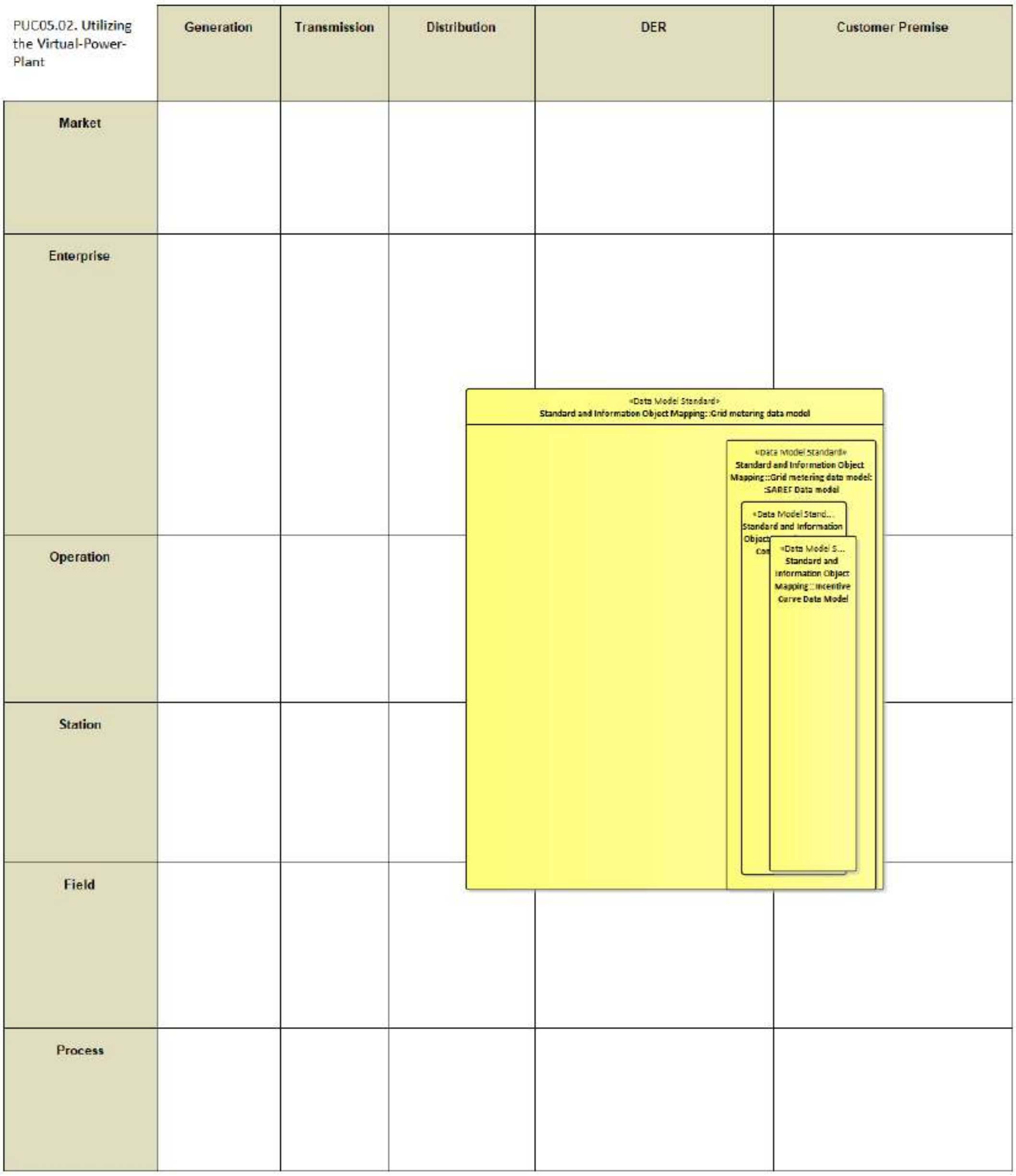

Figure 170: SGAM Canonical Data Model PUC05.02

Table 101: List of Data Models PUC05.02

Data Models
Grid metering Data Model
SAREF Data Model
Remote Control Data Model
Incentive Curve Data Model

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9.2.7. Standards and Information Object Mapping

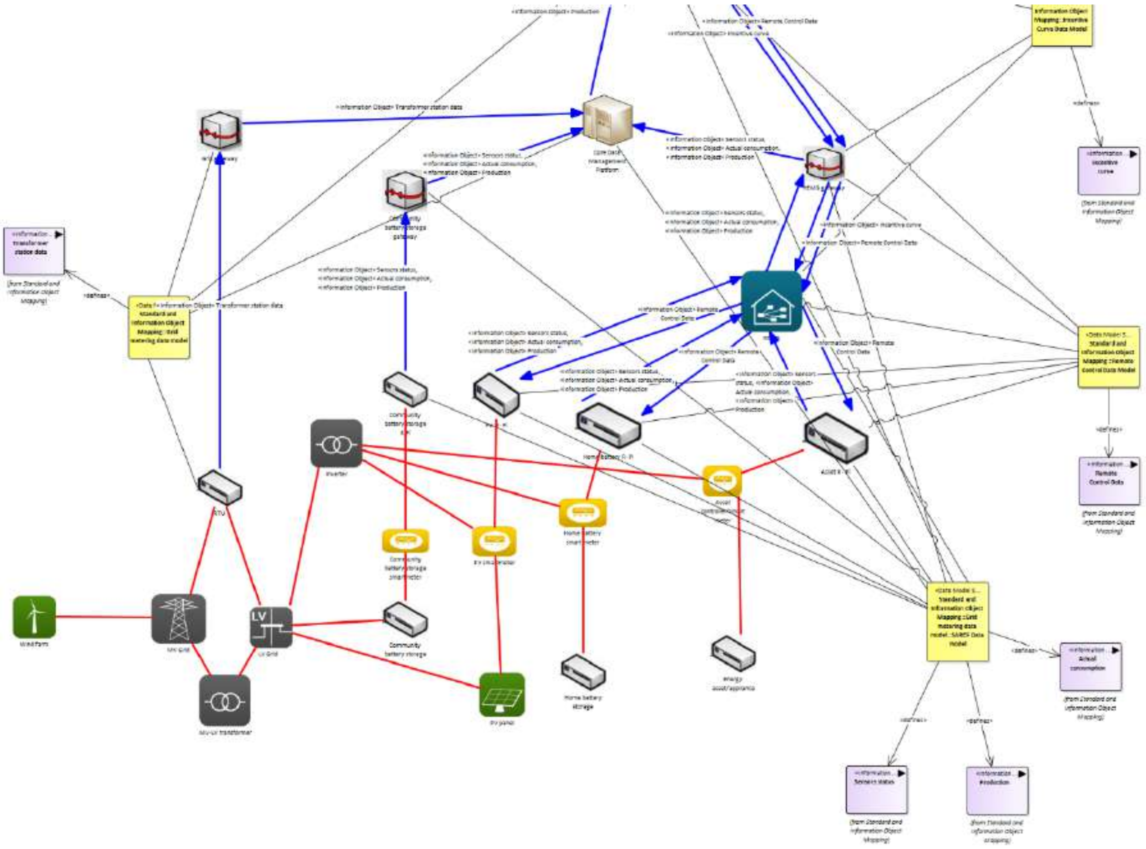

Figure 171: SGAM Standards and Information Object Mapping PUC05.02

Table 102: List of Information Objects PUC05.02

Information Objects	Data Models
Actual consumption	SAREF Data model
Sensor status	SAREF Data model
Production	SAREF Data model
Transformer station data	Grid metering data model
Remote Control Data	Remote Control Data Model
Incentive curve	Incentive Curve Data Model

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9.2.8. Activity Diagram

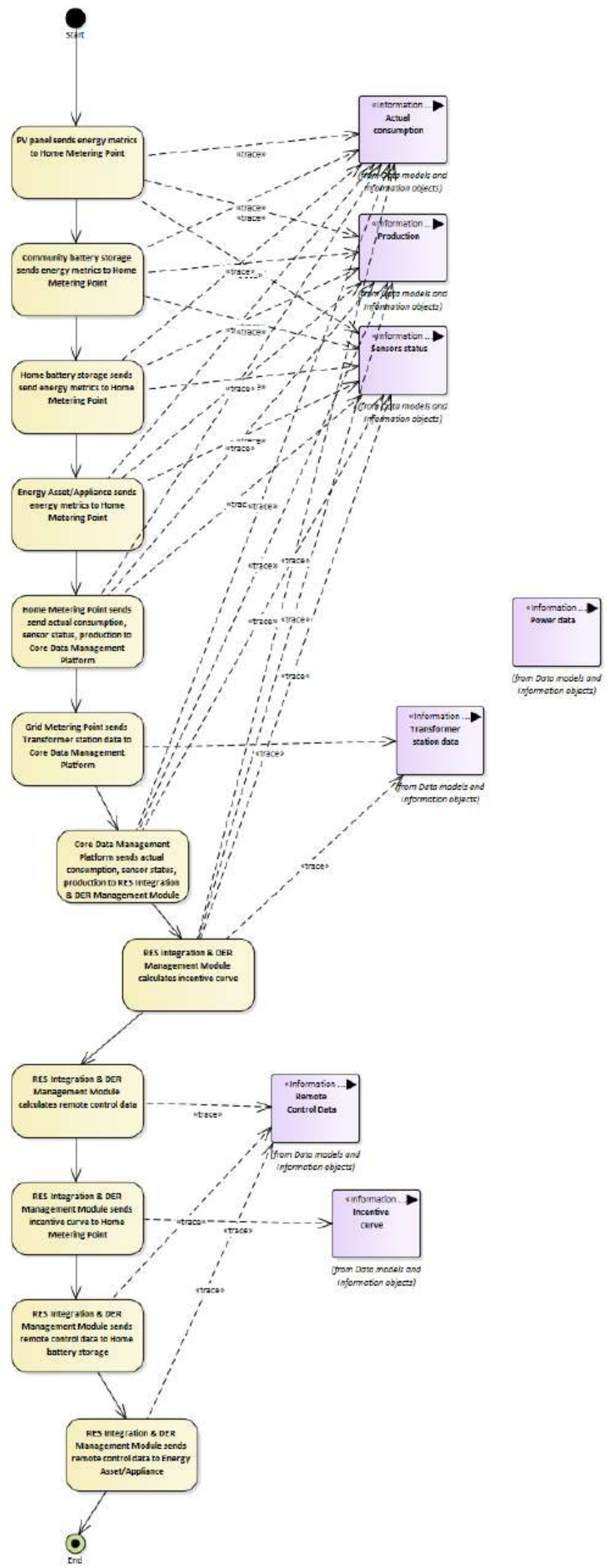

Figure 172: SGAM Activity Diagram PUC05.02

Twinergy has received funding from the European Union's Horizon 2020 research and innovation programme under grant agreement No. 957736

9.2.9. Sequence Diagram

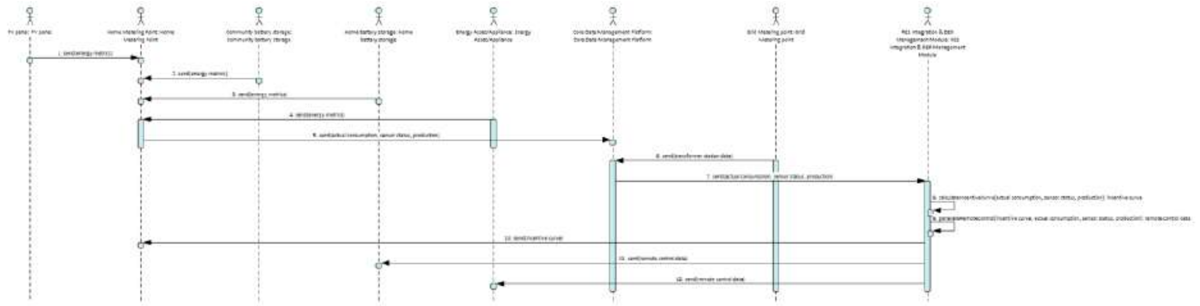

Figure 173: SGAM Sequence Diagram PUC05.02

9.3. SUC05.01. Grid status calculation and bottleneck detection

9.3.1. Use Case Description

This use case starts when the last calculation ends or in an appropriate task runtime. It is a monitoring process. This process will be calculated within the RES Integration and DER Management module. All necessary data will be collected from the database placed in TwinERGY Storage System, so the information about the grid will be obtained from there.

The process in this use case is defined as follows:

1. The DSO collects all relevant data from smart meters and grid-integrated sensors at various specified nodes. This includes voltage-levels, currents, power, power factor and overload conditions.

2. The DSO estimates the grid state of all other nodes that were not directly measured by interpolating the existing measured data and using the available specification information of individual hardware components within the grid (network model).

3. The DSO examines the measurements and calculated data for all nodes and checks whether they are within their specified thresholds or if certain nodes are experiencing bottlenecking.

4. If there are bottlenecks detected, the DSO starts the local countermeasure procedure. The countermeasure procedure depends on the availability of controllable loads, it could be interlinking two grids, the control of a battery storage for auxiliary services or the control of public charging infrastructure.

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9.3.2. SGAM Function Layer

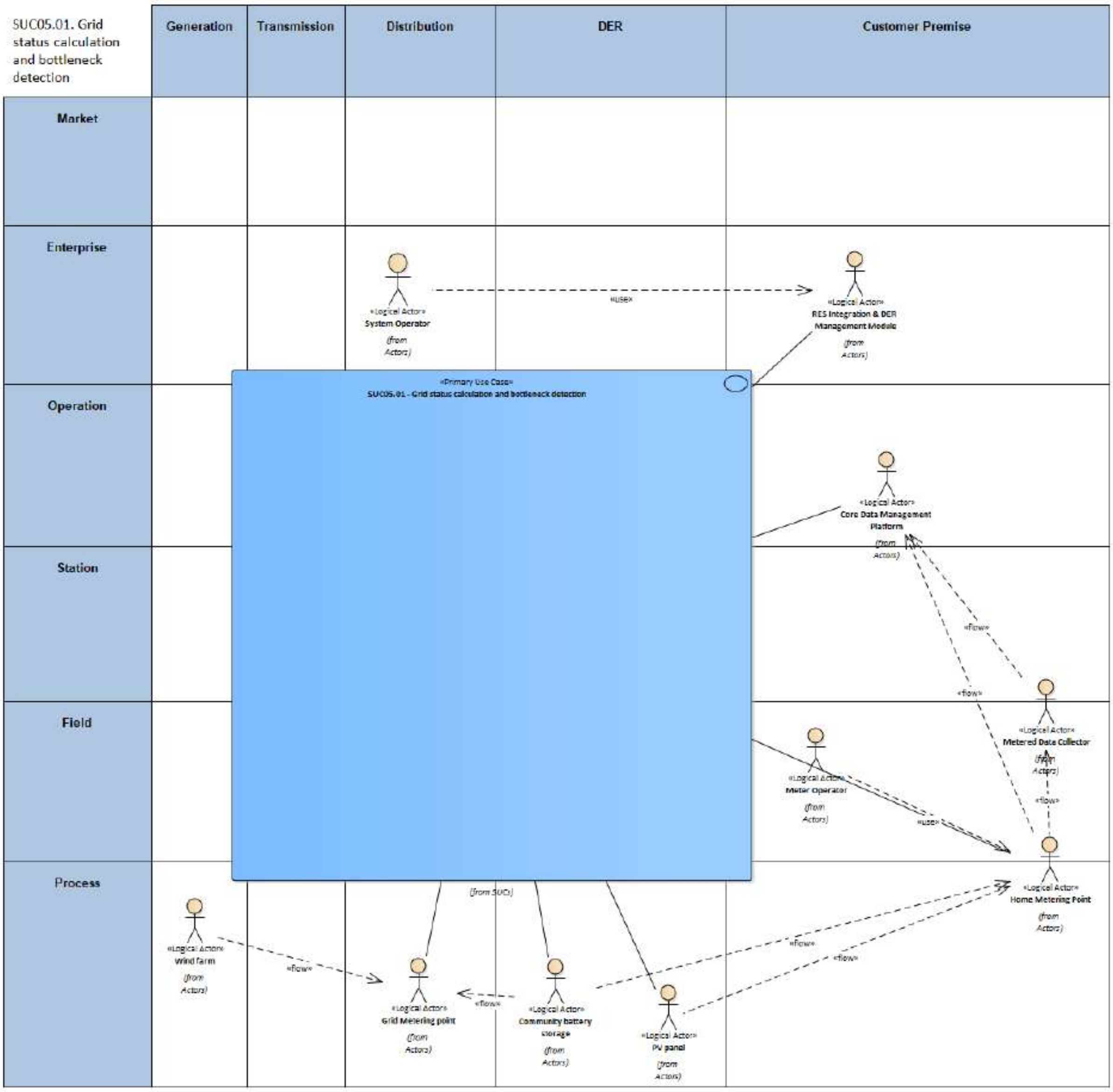

Figure 174: SGAM Function Layer SUC05.01

Table 103: List of Actors Involved SUC05.01

Actor Name	Actor Type
System Operator	Organization
RES integration & DER Management Module	Application
Core Data Management Platform	Application
Metered Data Collector	Device

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Meter Operator	Device
Home Metering Point	Device
Wind Farm	Device
Grid Metering Point	Device
Community Battery storage	Device
PV panel	Device

9.3.3. SGAM Component Layer

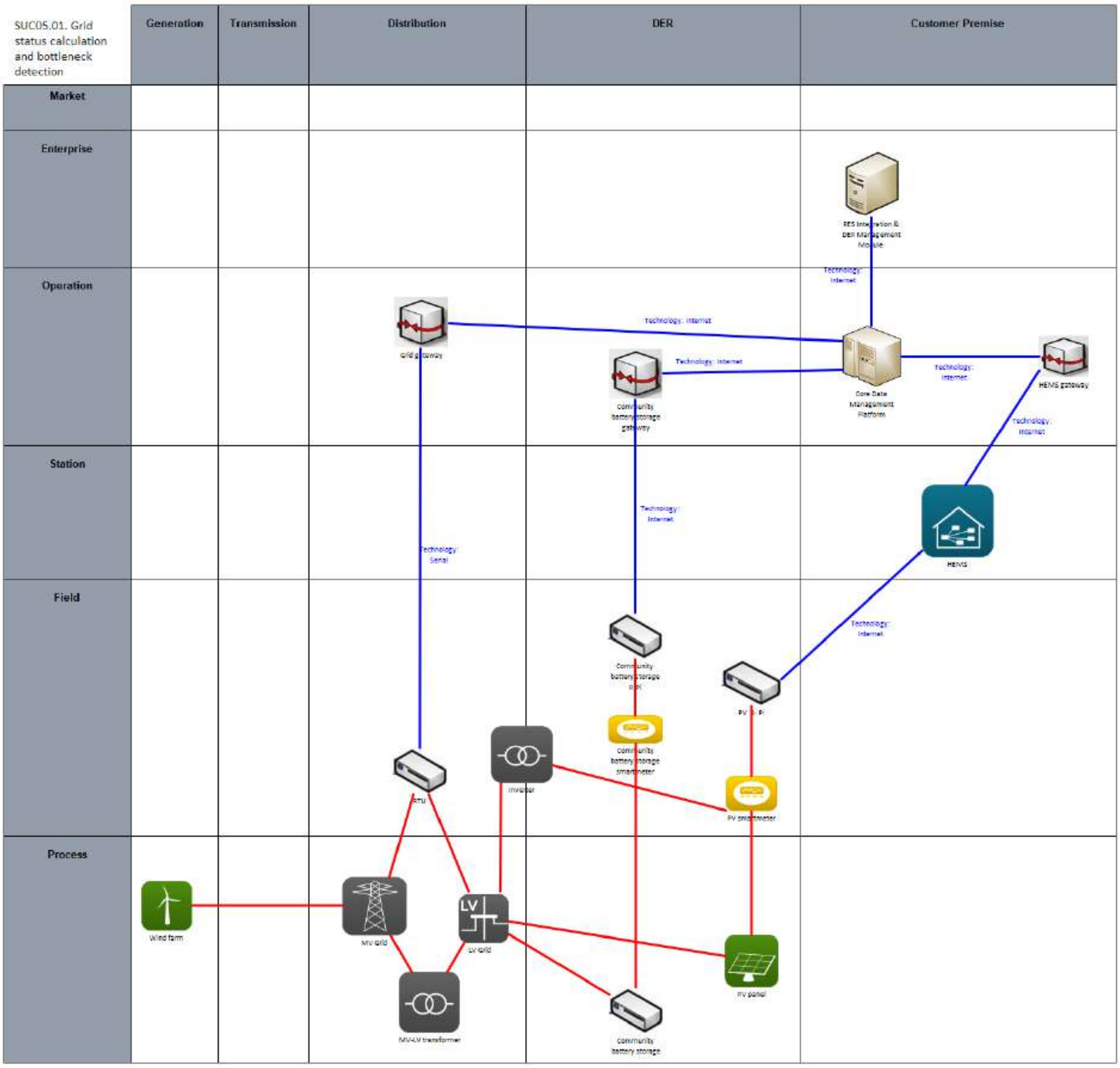

Figure 175: SGAM Component Layer SUC05.01

Table 104: List of Components SUC05.01

Component	Component Type
Wind Farm	Physical asset
MV Grid	Physical asset
MV-LV Transformer	Physical asset
LV Grid	Physical asset
RTU	Physical asset
Grid Gateway	External application
Inverter	Physical asset
Community Battery Storage	Physical asset
PV Panel	Physical asset
Community Battery Storage Smartmeter	Physical asset
PV Panel Smartmeter	Physical asset
Raspberry-Pi	Physical asset
Community Battery Storage Gateway	External application
Core Data Management Platform	TwinERGY application
HEMS	External application
HEMS gateway	External application
RES Integration & DER Management Module	TwinERGY application

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9.3.4. SGAM Communication Layer

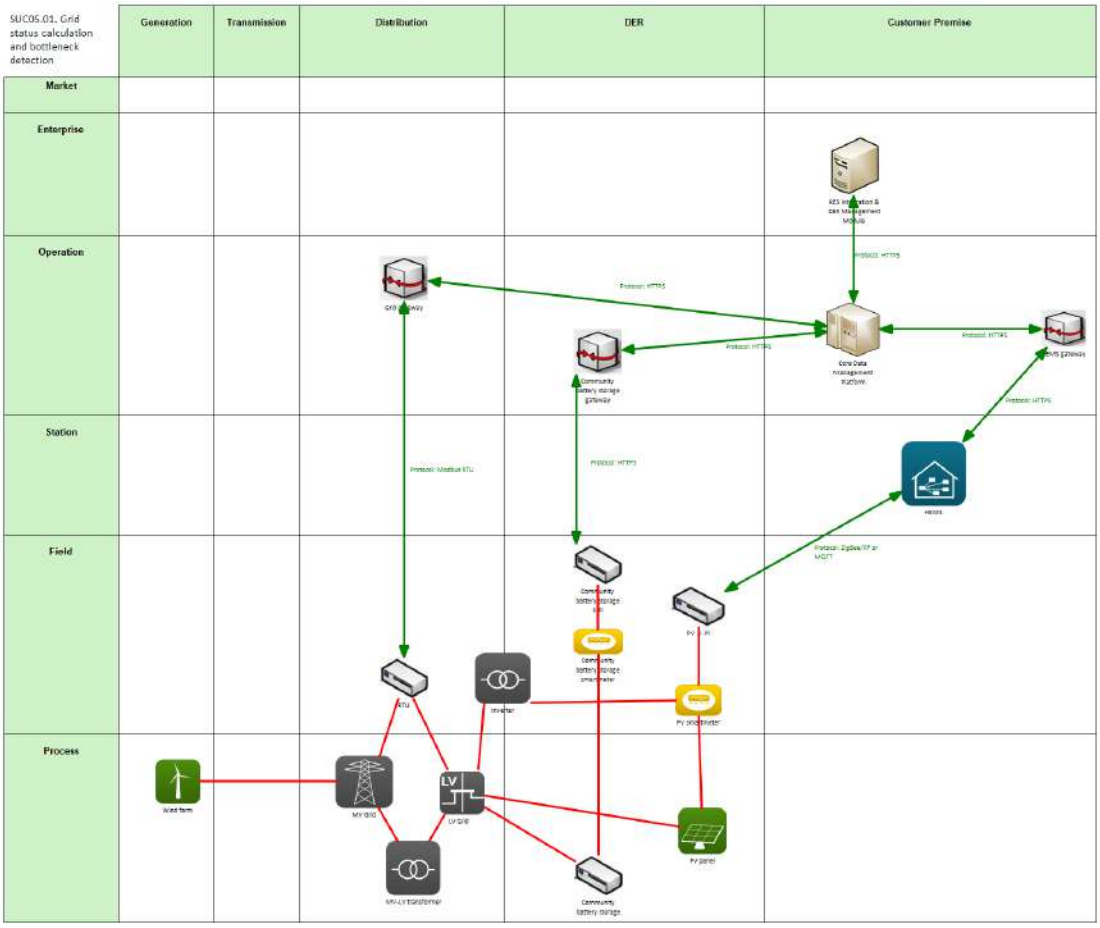

Figure 176: SGAM Communication Layer SUC05.01

Table 105: List of Communication technologies involved in SUC05.01

Communication Technology	Description
Modbus RTU	Data communications protocol for using with programmable logic controllers (PLCs), where devices are connected to the same cable or Ethernet network. It is used on industrial environments
HTTPS	HyperText Transfer Protocol Secure. It is an extension of the Hypertext Transfer Protocol (HTTP), used for secure communication over a computer network. In HTTPS, the communication protocol is encrypted using Transport Layer Security (TLS) or, formerly, Secure Sockets Layer (SSL). The protocol is therefore also referred to as HTTP over TLS, or HTTP over SSL.
ZigBee/RF	Protocol IEEE 802.15.4, designed to communicate data through noisy RF environments. This standard operates on the physical

	radio specification and operates in unlicensed bands including 2.4 GHz, 900 MHz and 868 MHz.
MQTT	MQ Telemetry Transport. It is an open OASIS standard and an ISO recommendation (ISO/IEC 20922) over TCP/IP, being a lightweight, publish-subscribe network protocol that transports messages between devices.

9.3.5. SGAM Information Layer

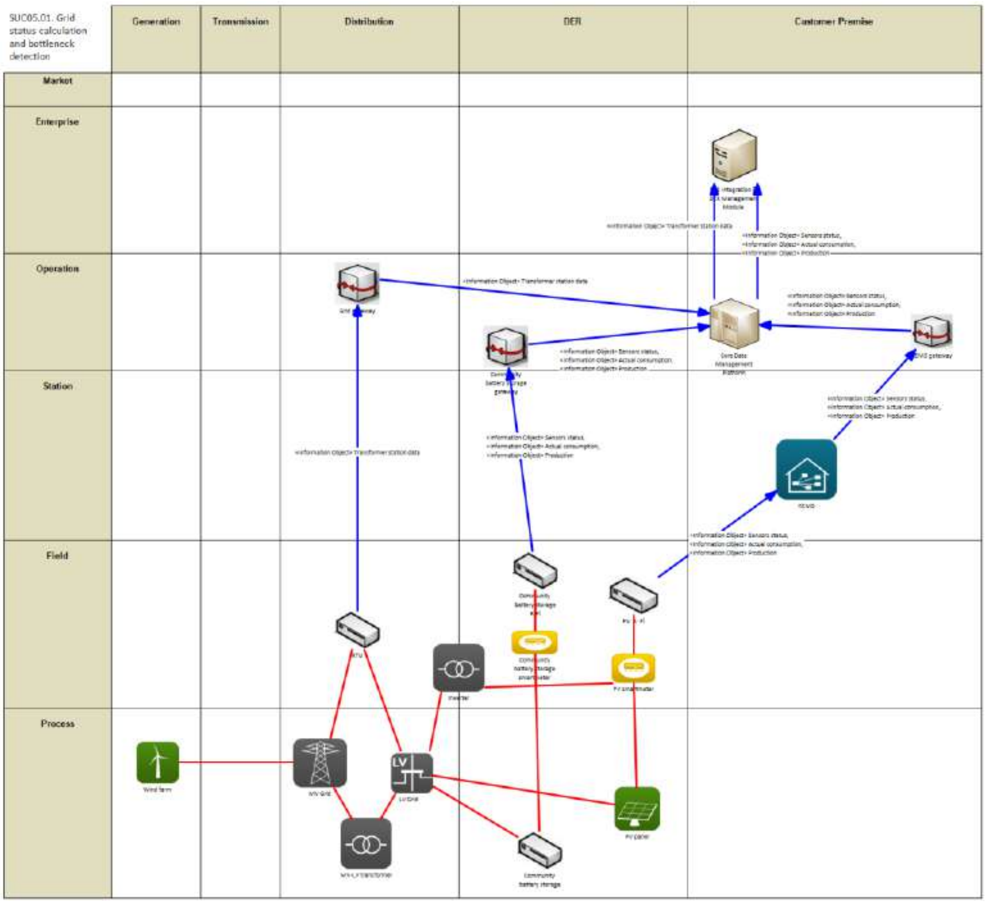

Figure 177: SGAM Information Layer SUC05.01

9.3.6. Canonical Data Model

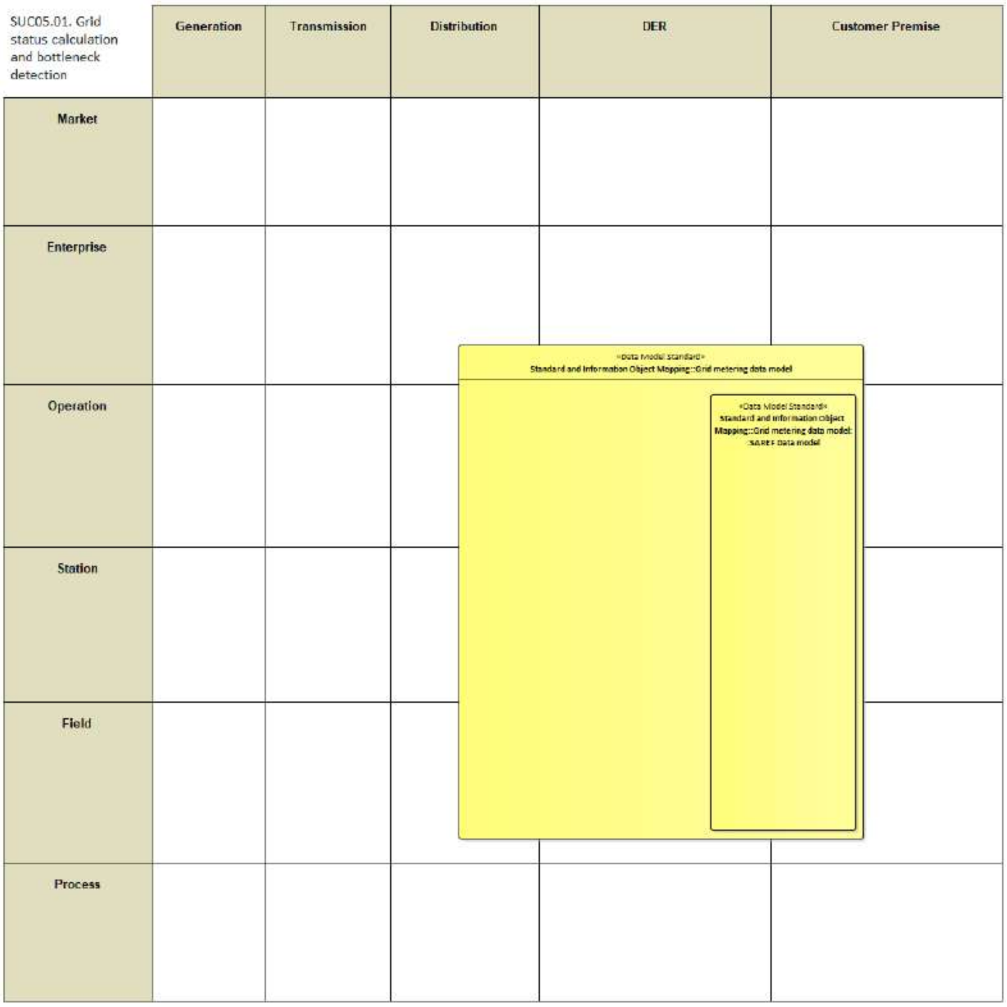

Figure 178: SGAM Canonical Data Model SUC05.01

Table 106: List of Data Models SUC05.01

Data Models
Grid Metering Data Model
SAREF Data Model

9.3.7. Standards and Information Object Mapping

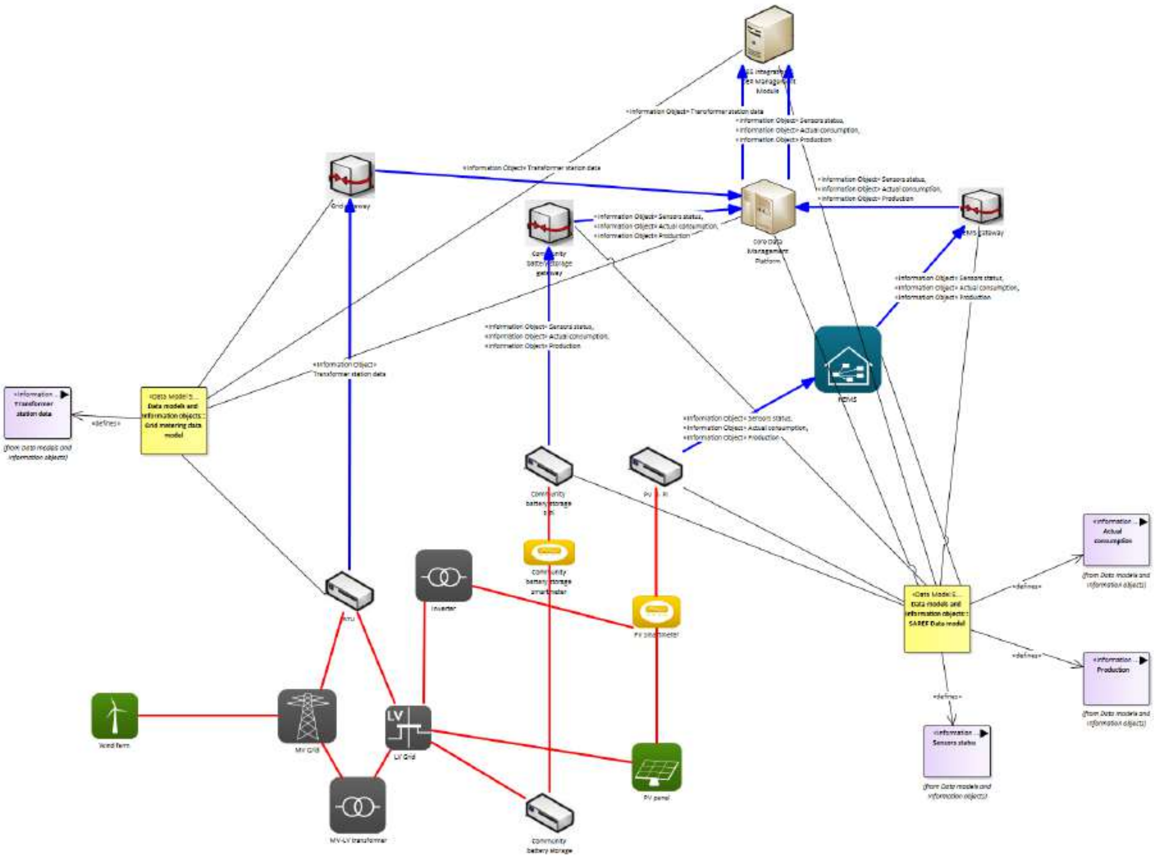

Figure 179: SGAM Standards and Information Object Mapping SUC05.01

Table 107: List of Information Objects SUC05.01

Information Objects	Data Models
Actual consumption	SAREF Data model
Sensor status	SAREF Data model
Production	SAREF Data model
Transformer station data	Grid metering data model

9.3.8. Activity Diagram

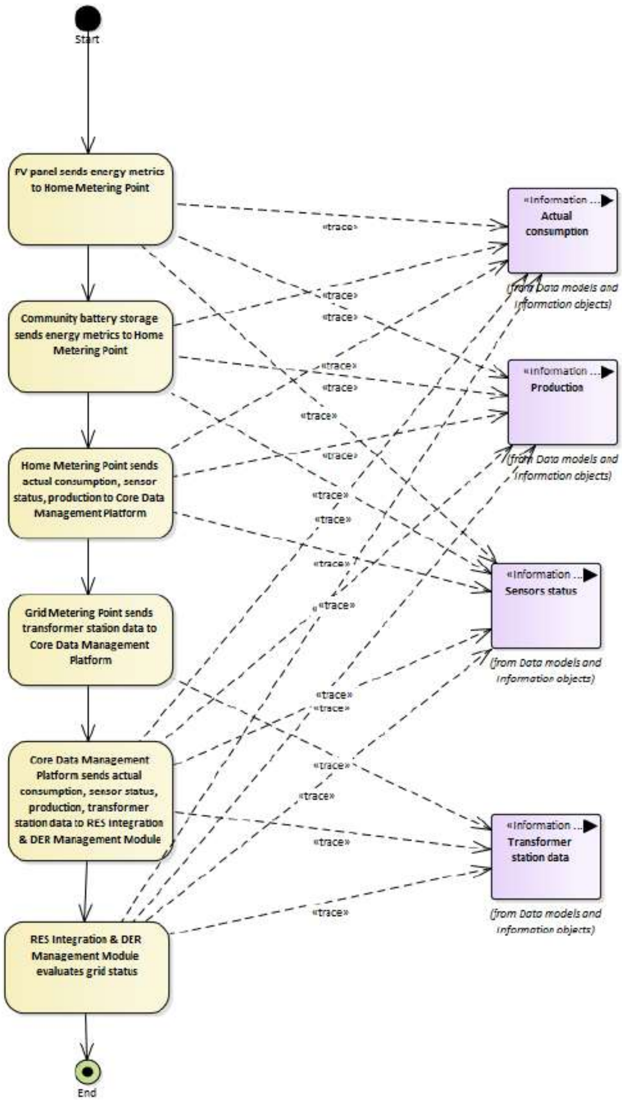

Figure 180: SGAM Activity Diagram SUC05.01

9.3.9. Sequence Diagram

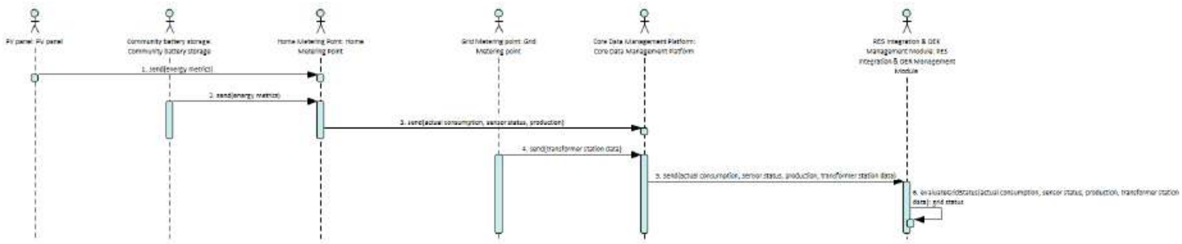

Figure 181: SGAM Sequence Diagram SUC05.01

9.4. SGAM Business Layer

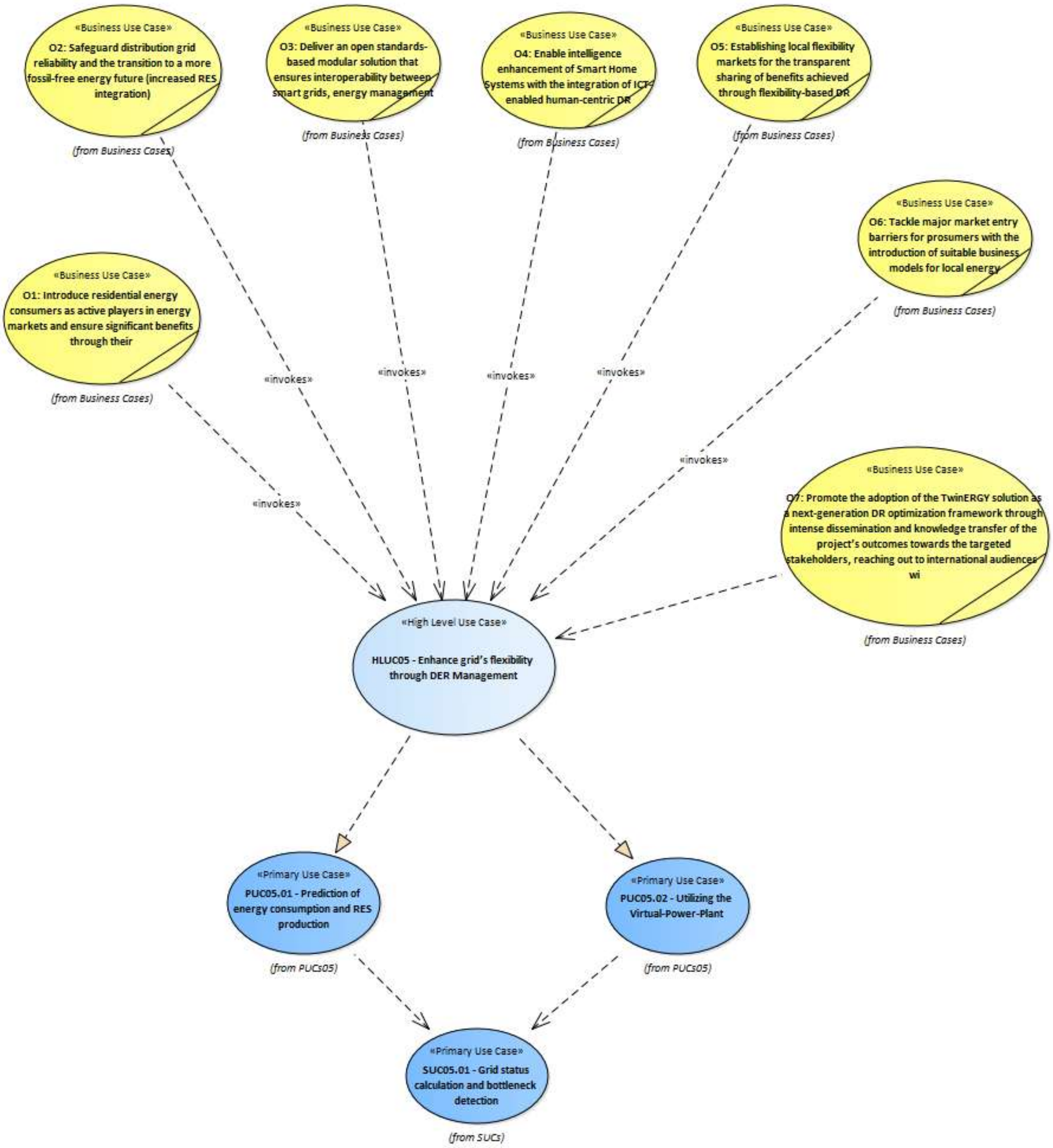

Figure 182: SGAM Business Layer HLUC05

10. HLUC06. Consumers engagement in Demand Side Management Programs utilizing feedback mechanisms

10.1. PUC06.01. Increase residential demand flexibility

10.1.1. Use Case Description

The use case "Increase residential demand flexibility" is a permanent task.

The description below is based on an interaction between the DSO and the consumer. However, it could also represent an interaction between the energy supplier and the consumer or the DSO and energy supplier together with the consumer. The process in this use case is the following:

1. The DSO has information on times with grid bottlenecks and local energy surplus and wants to encourage residents to shift their energy consumption to a more beneficial time slot.

2. The DSO sends a signal to the residential HEMS (Home Energy Monitoring System) which operates as an HMI via and displays the signal in an appropriate way.

3. The consumer gets informed by the HEMS and plans his actions accordingly to adapt his energy demand as signalled.

4. The consumer uses his appliances as planned.

5. The DSO collects demand information and rewards the consumer(s) of the local market for his/their efforts in complying with the demand response actions. This could be a monetary benefit, a bonus point system with local benefits (voucher for shops, parking, sport events, free time activities) or some form of gamification between local distribution systems.

10.1.2. SGAM Function Layer

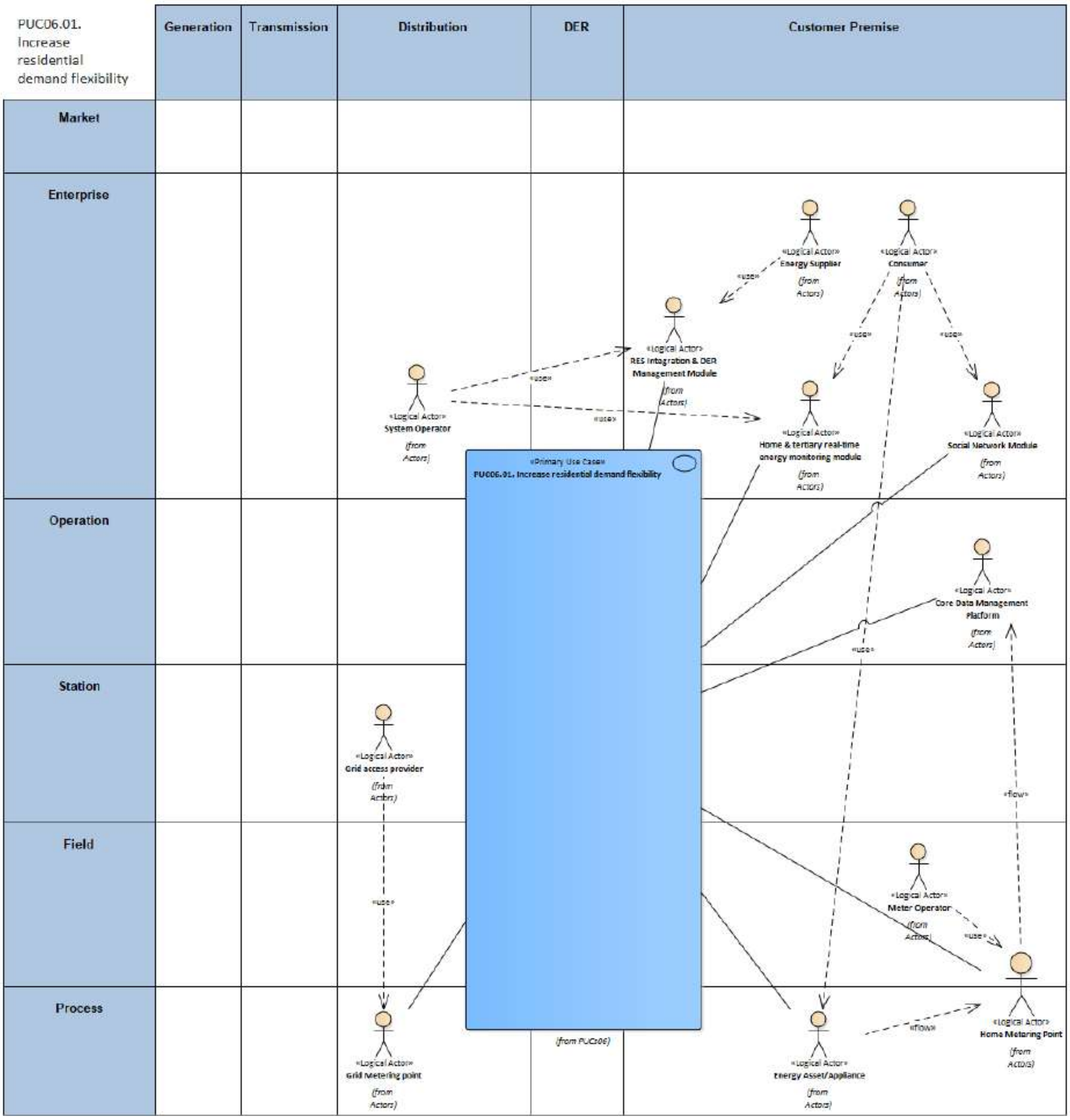

Figure 183: SGAM Function Layer PUC06.01

Table 108: List of Actors Involved PUC06.01

Actor Name	Actor Type
Grid Access Provider	Organization
Grid Metering Point	Device
Energy Asset/appliance	Device
Home Metering Point	Device

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Meter Operator	Device
Core Data Management Platform	Application
System Operator	Organization
RES integration & DER Management Module	Application
Home & Tertiary real-time energy monitoring module	Application
Energy supplier	Organization
Consumer	Logical Actor Role
Social Network module	Application

10.1.3. SGAM Component Layer

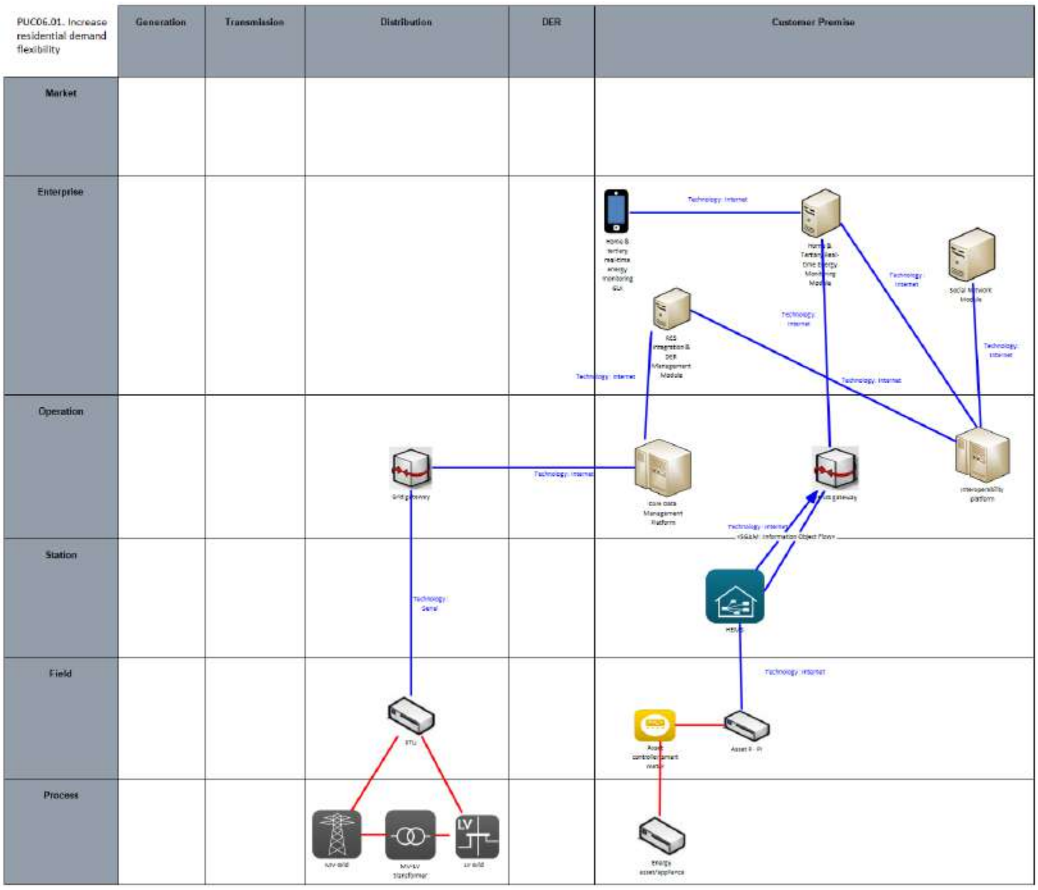

Figure 184: SGAM Component Layer PUC06.01

Twinergy has received funding from the European Union's Horizon 2020 research and innovation programme under grant agreement No. 957736

Table 109: List of Components PUC06.01

Component	Component Type
MV Grid	Physical asset
MV-LV Transformer	Physical asset
LV Grid	Physical asset
RTU	Physical asset
Grid gateway	External application
Energy asset/appliance	Physical asset
Asset Controler/ Smart Meter	Physical asset
Raspberry-Pi	Physical asset
HEMS	External application
HEMS gateway	External application
Core Data Management Platform	TwinERGY application
RES integration & DER Management Module	TwinERGY application
Interoperability Platform	TwinERGY application
Home & Tertiary Real-time Energy Monitoring Module	TwinERGY application
Social Network Module	TwinERGY application
Home & Tertiary real-time energy monitoring GUI	TwinERGY application

10.1.4. SGAM Communication Layer

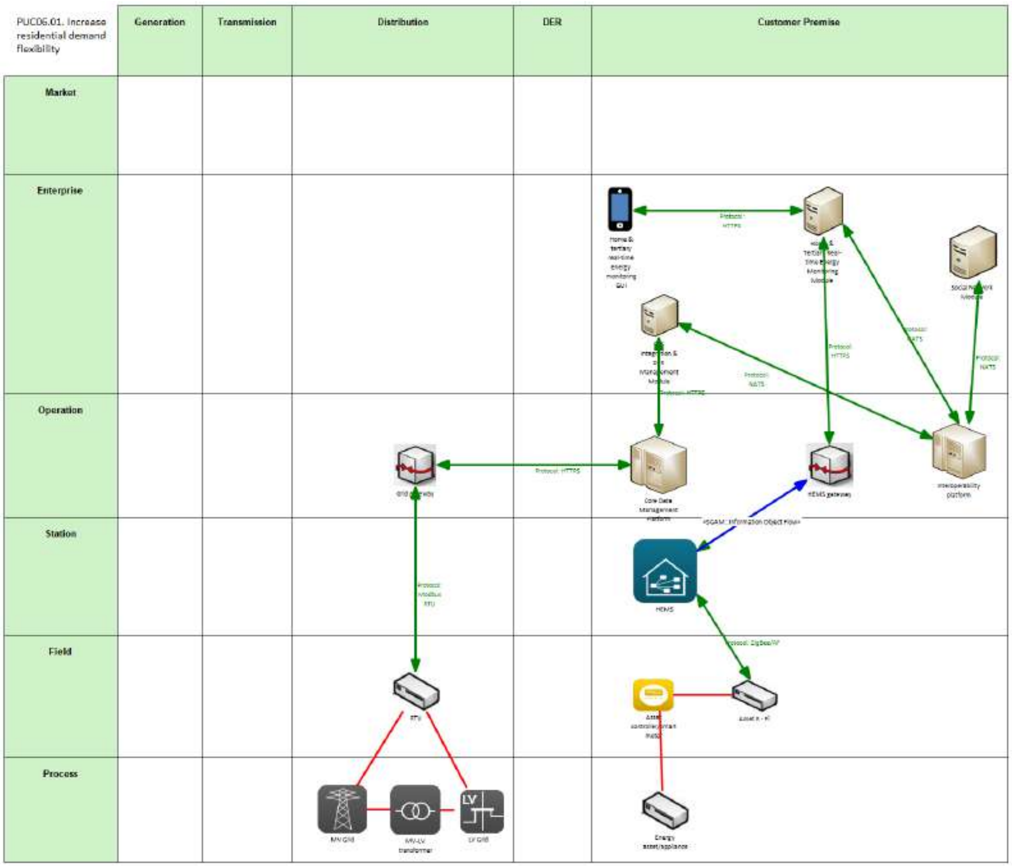

Figure 185: SGAM Communication Layer PUC06.01

Table 110: List of Communication technologies involved in PUC06.01

Communication Technology	Description
Modbus RTU	Data communications protocol for using with programmable logic controllers (PLCs), where devices are connected to the same cable or Ethernet network. It is used on industrial environments
HTTPS	HyperText Transfer Protocol Secure. It is an extension of the Hypertext Transfer Protocol (HTTP), used for secure communication over a computer network. In HTTPS, the communication protocol is encrypted using Transport Layer Security (TLS) or, formerly, Secure Sockets Layer (SSL). The protocol is therefore also referred to as HTTP over TLS, or HTTP over SSL.
NATS	Protocol of messaging that enables the exchange of messages among computer applications and services, not depending on the network location.

ZigBee/RF	Protocol IEEE 802.15.4, designed to communicate data through noisy RF environments. This standard operates on the physical radio specification and operates in unlicensed bands including 2.4 GHz, 900 MHz and 868 MHz.
MQTT	MQ Telemetry Transport. It is an open OASIS standard and an ISO recommendation (ISO/IEC 20922) over TCP/IP, being a lightweight, publish-subscribe network protocol that transports messages between devices.

10.1.5. SGAM Information Layer

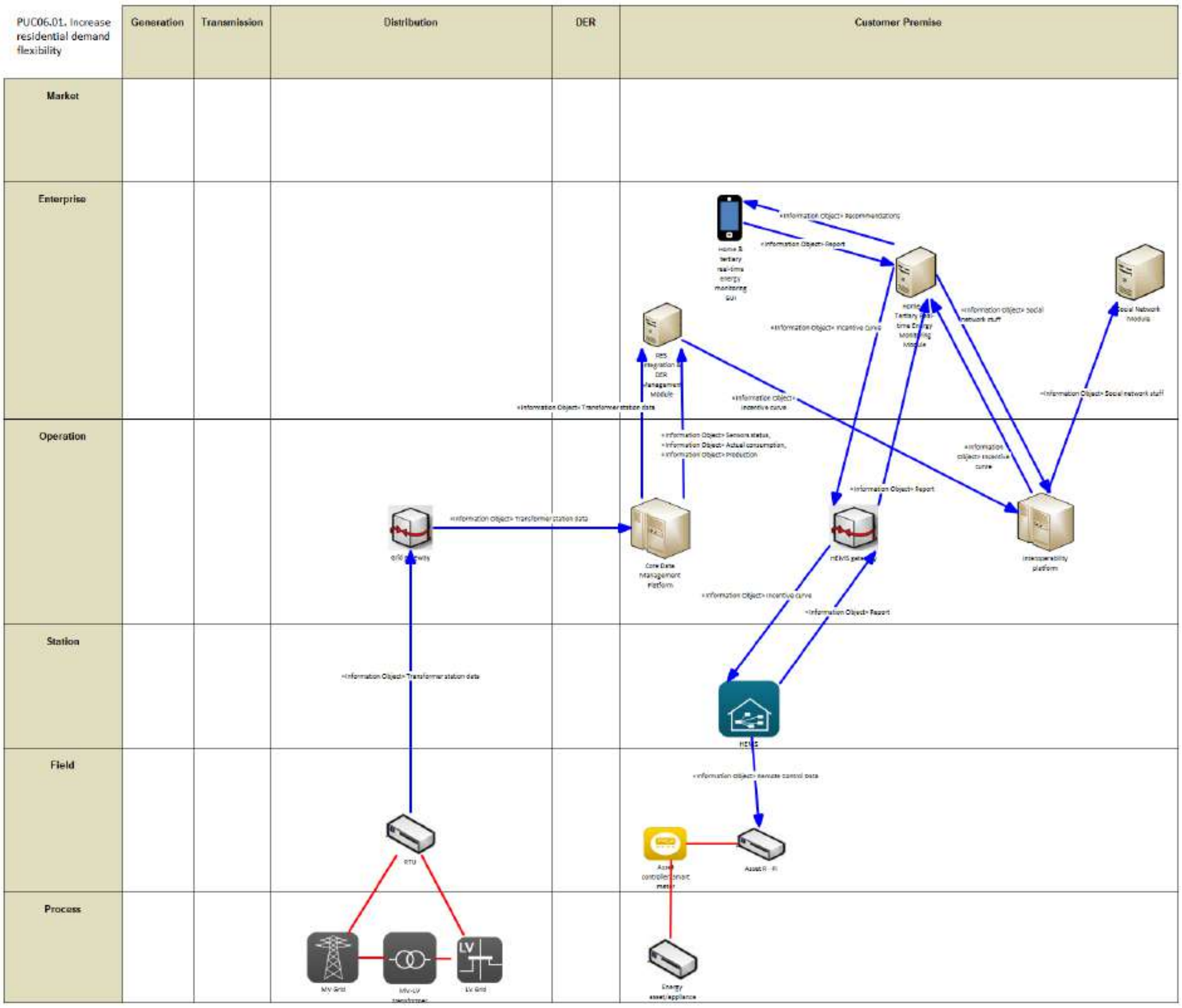

Figure 186: SGAM Information Layer PUC06.01

10.1.6. Canonical Data Model

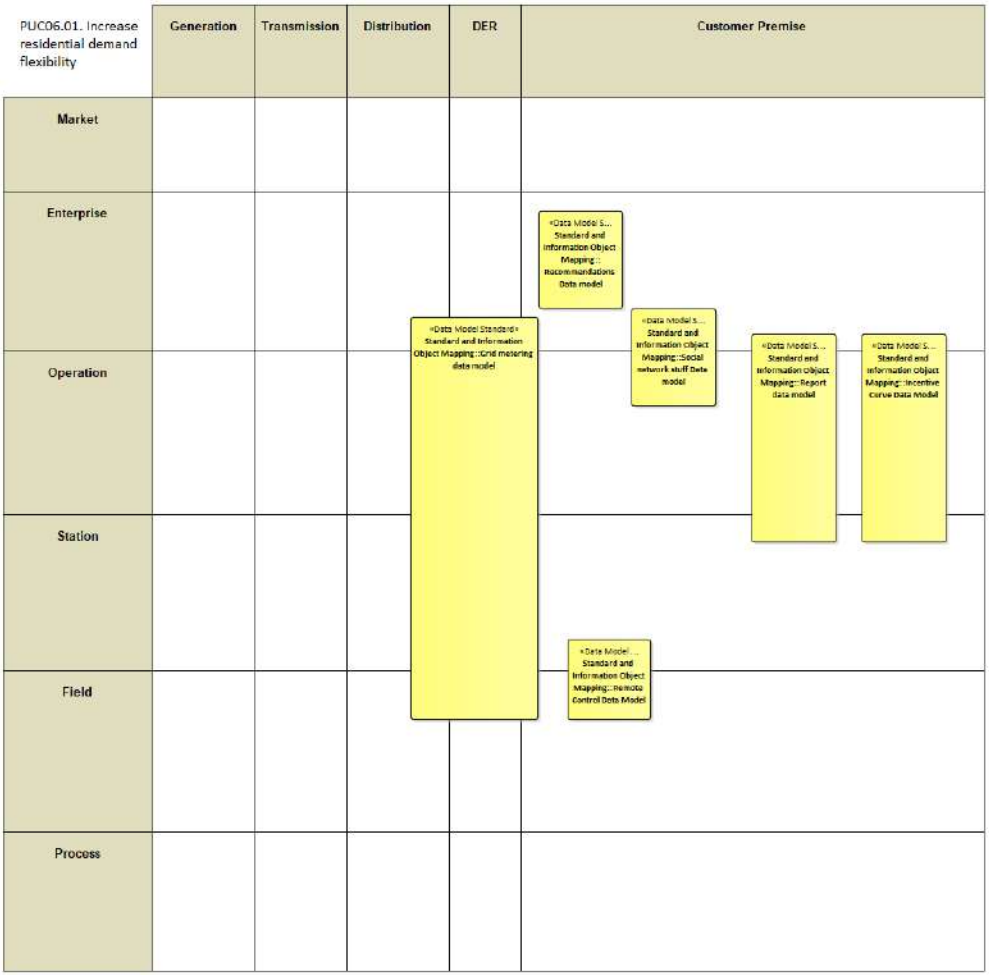

Figure 187: SGAM Canonical Data Model PUC06.01

Table 111: List of Data Models PUC06.01

Data Models
Grid Metering Data Model
Recommendations Data Model
Remote Control Data Model
Social Network stuff Data Model
Report Data Model
Incentive Curve Data Model

10.1.7. Standards and Information Object Mapping

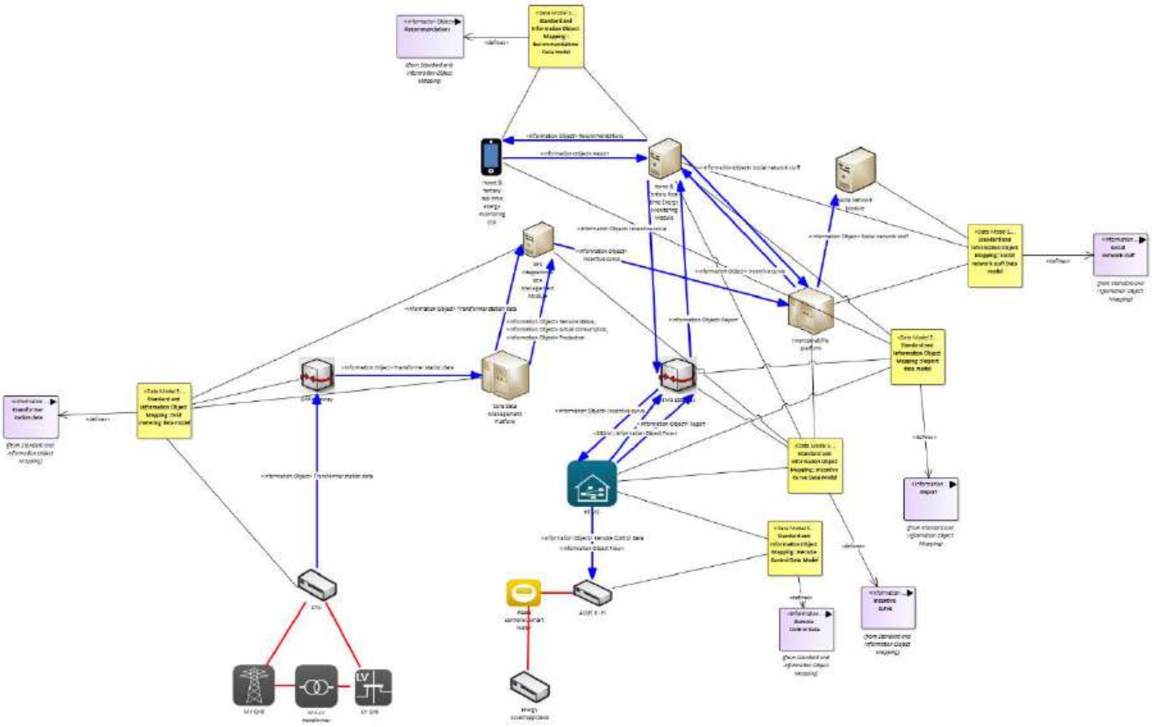

Figure 188: SGAM Standards and Information Object Mapping PUC06.01

Table 112: List of Information Objects PUC06.01

Information Objects	Data Models
Actual consumption	SAREF Data model
Sensor status	SAREF Data model
Production	SAREF Data model
Transformer station data	Grid metering data model
Recommendations	Recommendations Data model
Social network stuff	Social network stuff Data model
Report	Report data model
Incentive curve	Incentive Curve Data Model
Remote Control Data	Remote Control Data Model

10.1.8. Activity Diagram

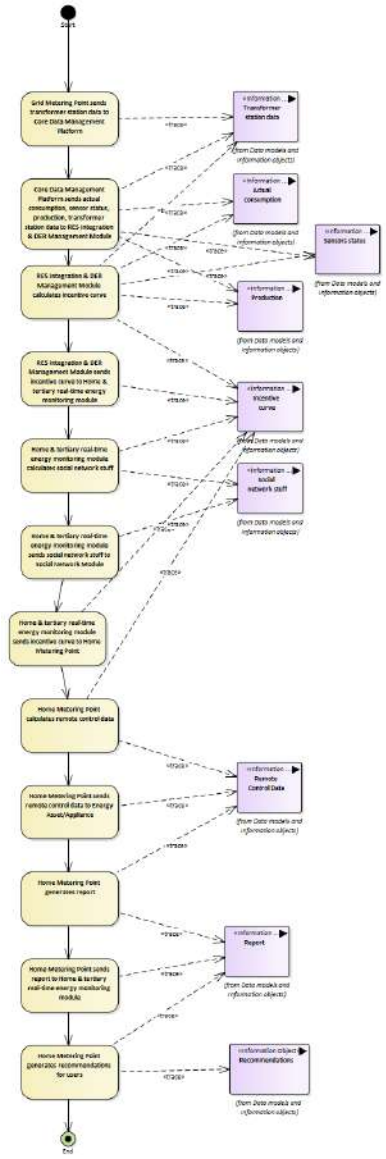

Figure 189: SGAM Activity Diagram PUC06.01

10.1.9. Sequence Diagram

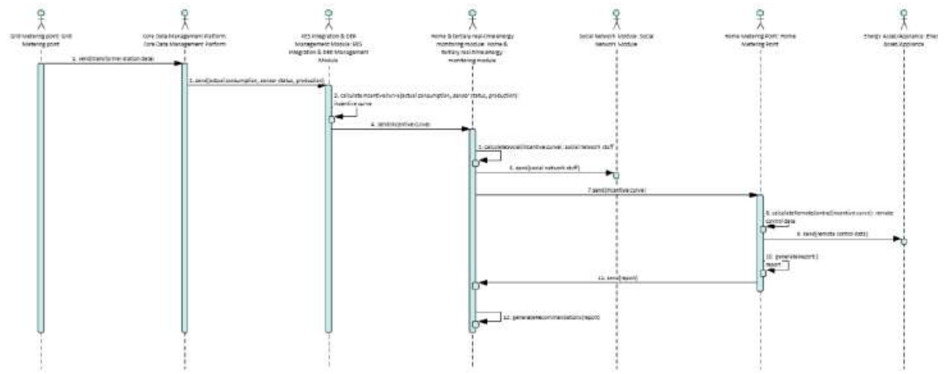

Figure 190: SGAM Sequence Diagram PUC06.01

10.2. PUC06.02. Decrease residential energy use

10.2.1. Use Case Description

The use case "decrease residential demand" is a permanent task. The description below is based on an interaction between the DSO and the consumer. However, it could also represent an interaction between the energy supplier and the consumer or the DSO and energy supplier together with the consumer. The process in this use case is the following:

1. The DSO has information on the historical and current energy consumption and can identify anomalies in energy usage (e.g., an unusually high uninterrupted energy demand at night) for individual consumers based on their known energy profiles.
2. If it unusually high energy consumption is detected, which does not fit into the associated consumer's energy profile, the DSO sends a message to the residential HEMS (Home Energy Monitoring System) which operates as an HMI and displays the message in an appropriate way.
3. The HEMS informs the consumer, who is asked to identify the appliances that could be responsible for the unusually high energy consumption. This could be an idling washing machine that was not fully turned off. If an appliance was identified and currently does not need to be operated, it is turned off by the consumer.

10.2.2. SGAM Function Layer

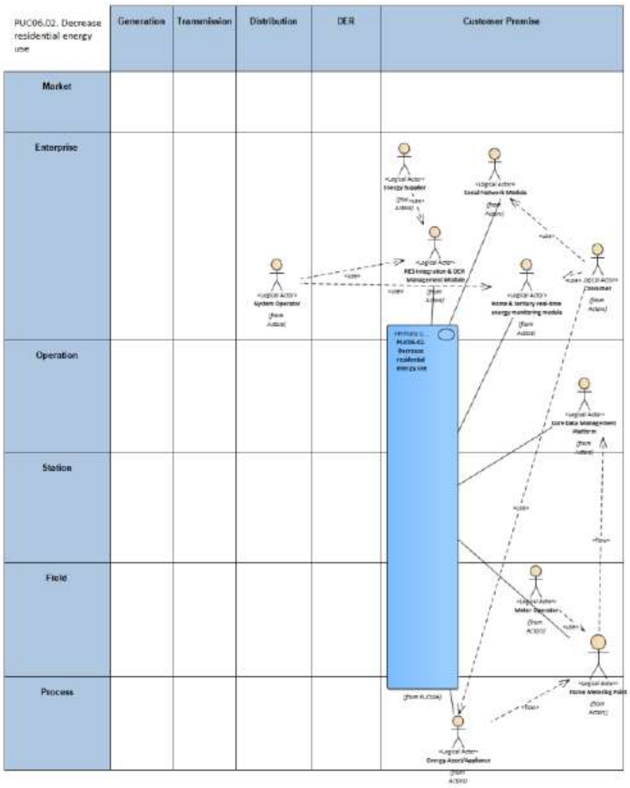

Figure 191: SGAM Function Layer PUC06.02

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Table 113: List of Actors Involved PUC06.02

Actor Name	Actor Type
Energy Asset/appliance	Device
Home Metering Point	Device
Meter Operator	Device
Core Data Management Platform	Application
System Operator	Organization
RES integration & DER Management Module	Application
Home & Tertiary real-time energy monitoring module	Application
Energy supplier	Organization
Consumer	Logical Actor Role
Social Network module	Application

10.2.3. SGAM Component Layer

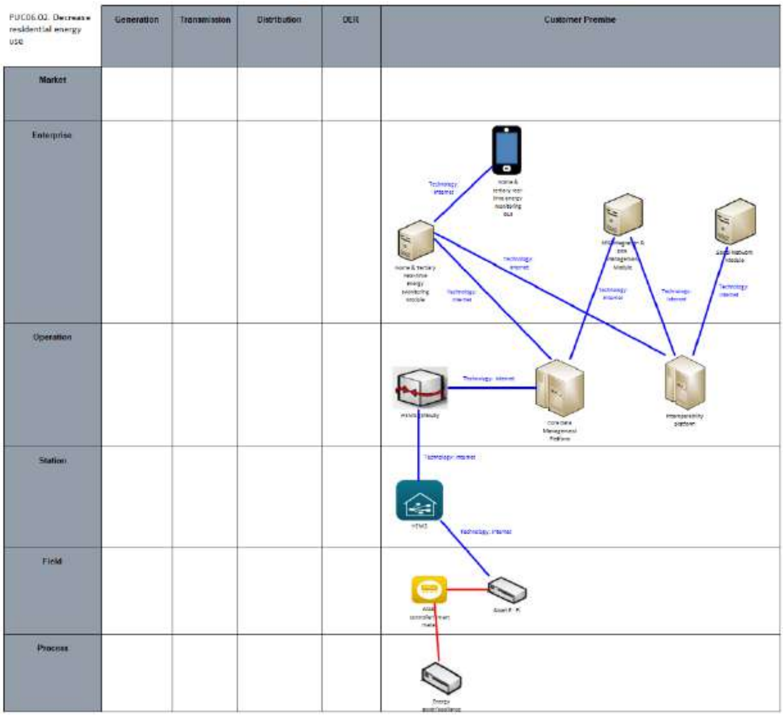

Figure 192: SGAM Component Layer PUC06.02

Table 114: List of Components PUC06.02

Component	Component Type
Energy asset/appliance	Physical asset
Asset Controler/ Smart Meter	Physical asset
Raspberry-Pi	Physical asset
HEMS	External application
HEMS gateway	External application
Core Data Management Platform	TwinERGY application
RES integration & DER Management Module	TwinERGY application
Interoperability Platform	TwinERGY application
Home & Tertiary Real-time Energy Monitoring Module	TwinERGY application
Social Network Module	TwinERGY application
Home & Tertiary real-time energy monitoring GUI	TwinERGY application

Twinergy has received funding from the European Union's Horizon 2020 research and innovation programme under grant agreement No. 957736

10.2.4. SGAM Communication Layer

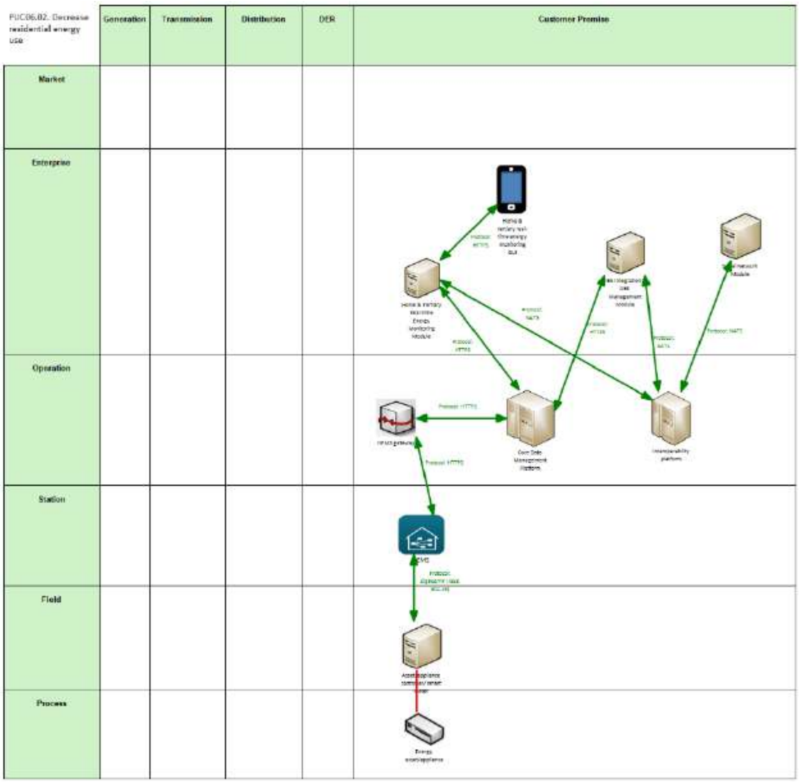

Figure 193: SGAM Communication Layer PUC06.02

Table 115: List of Communication technologies involved in PUC06.02

Communication Technology	Description
HTTPS	HyperText Transfer Protocol Secure. It is an extension of the Hypertext Transfer Protocol (HTTP), used for secure communication over a computer network. In HTTPS, the communication protocol is encrypted using Transport Layer Security (TLS) or, formerly, Secure Sockets Layer (SSL). The protocol is therefore also referred to as HTTP over TLS, or HTTP over SSL.
NATS	Protocol of messaging that enables the exchange of messages among computer applications and services, not depending on the network location.
ZigBee/RF	Protocol IEEE 802.15.4, designed to communicate data through noisy RF environments. This standard operates on the physical radio specification and operates in unlicensed bands including 2.4 GHz, 900 MHz and 868 MHz.

10.2.5. SGAM Information Layer

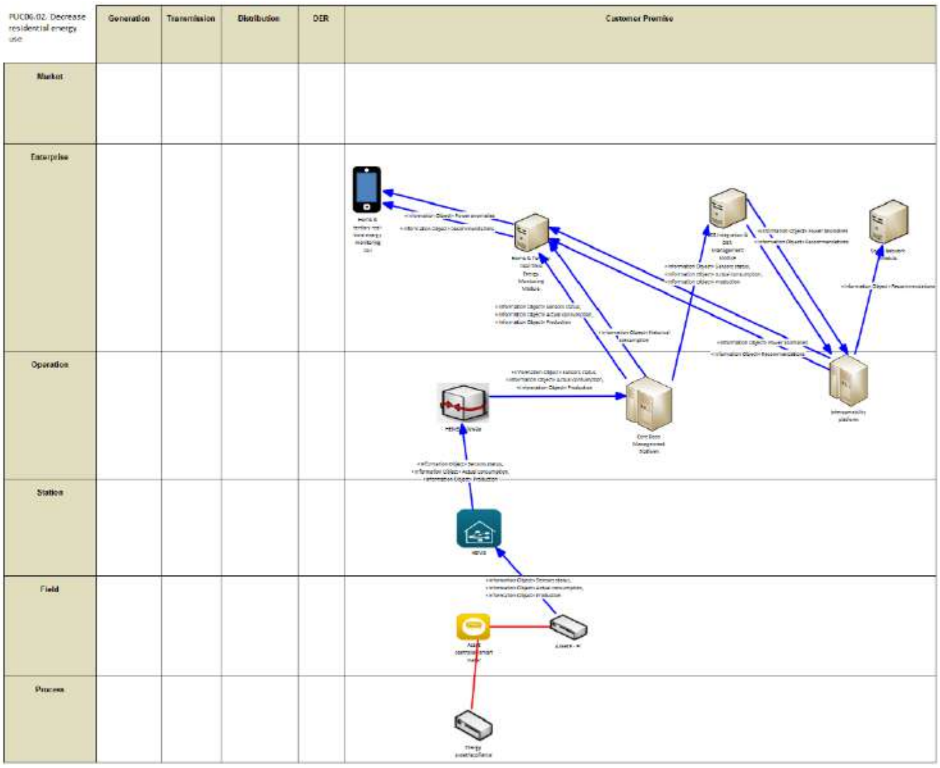

Figure 194: SGAM Information Layer PUC06.02

10.2.6. Canonical Data Model

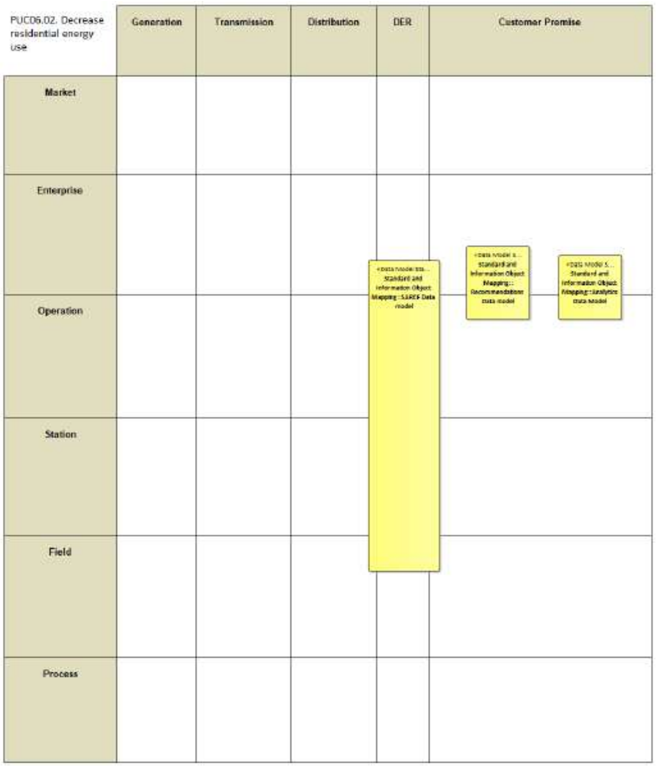

Figure 195: SGAM Canonical Data Model PUC06.02

Twinergy has received funding from the European Union's Horizon 2020 research and innovation programme under grant agreement No. 957736

Table 116: List of Data Models PUC06.02

Data Models
SAREF Data Model
Recommendations Data Model
Analytics Data Model

10.2.7. Standards and Information Object Mapping

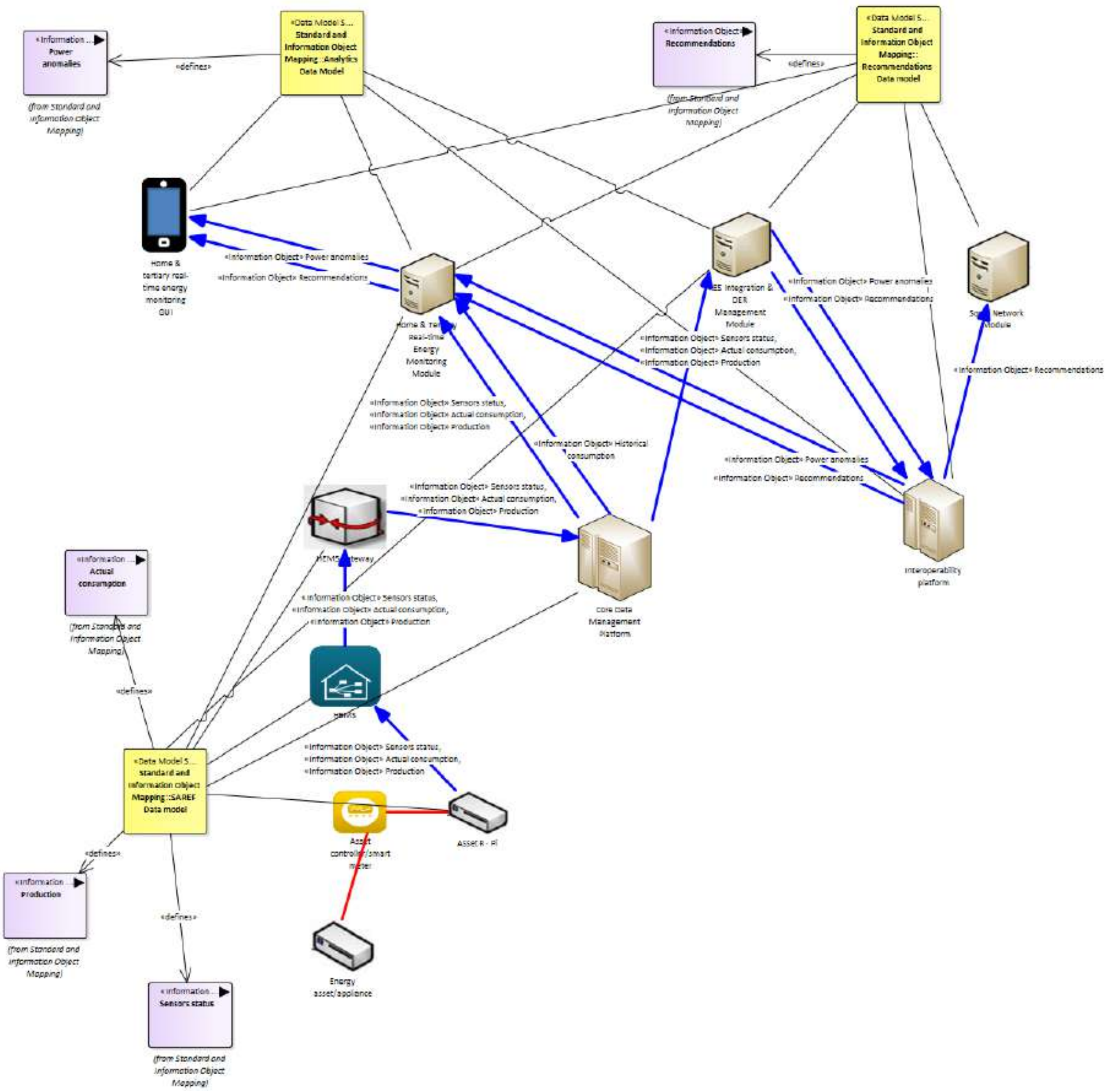

Figure 196: SGAM Standards and Information Object Mapping PUC06.02

Table 117: List of Information Objects PUC06.02

Information Objects	Data Models
Actual consumption	SAREF Data model
Sensor status	SAREF Data model
Production	SAREF Data model
Power anomalies	Analytics Data Model
Recommendations	Recommendations Data model
Historical consumption	Stored Information Data Model

10.2.8. Activity Diagram

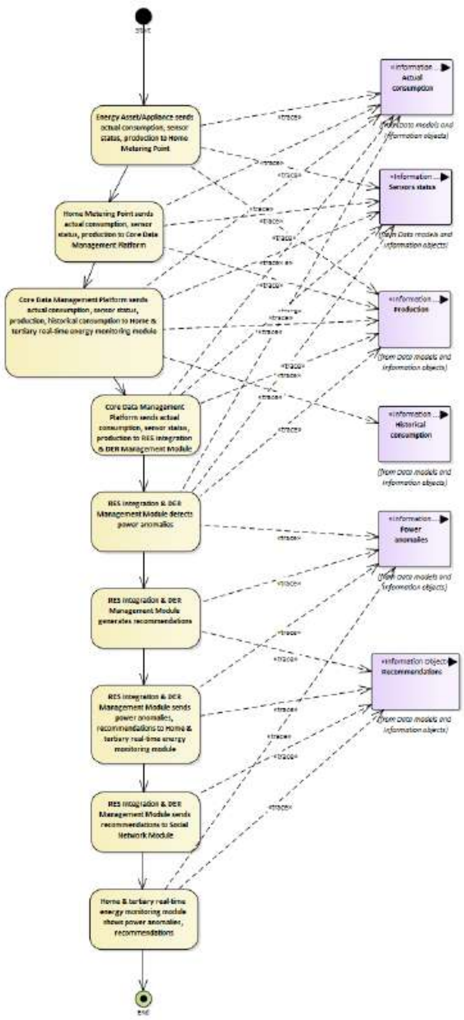

Figure 197: SGAM Activity Diagram PUC06.02

10.2.9. Sequence Diagram

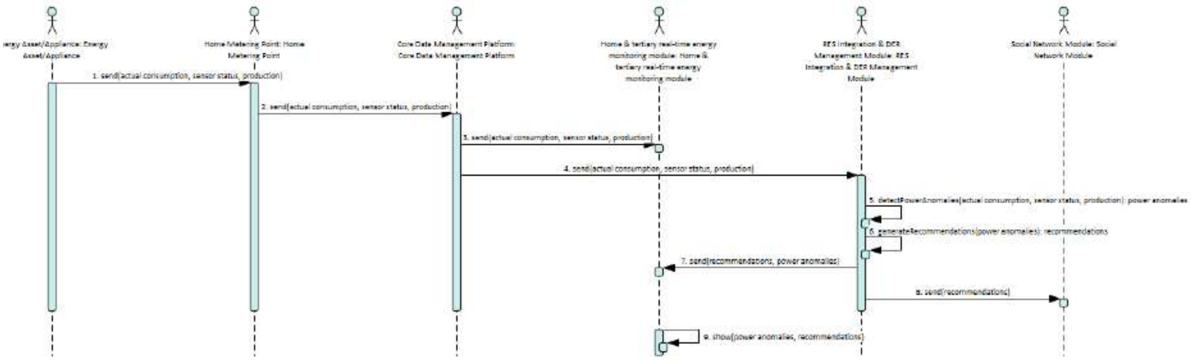

Figure 198: SGAM Sequence Diagram PUC06.02

10.3. SGAM Business Layer

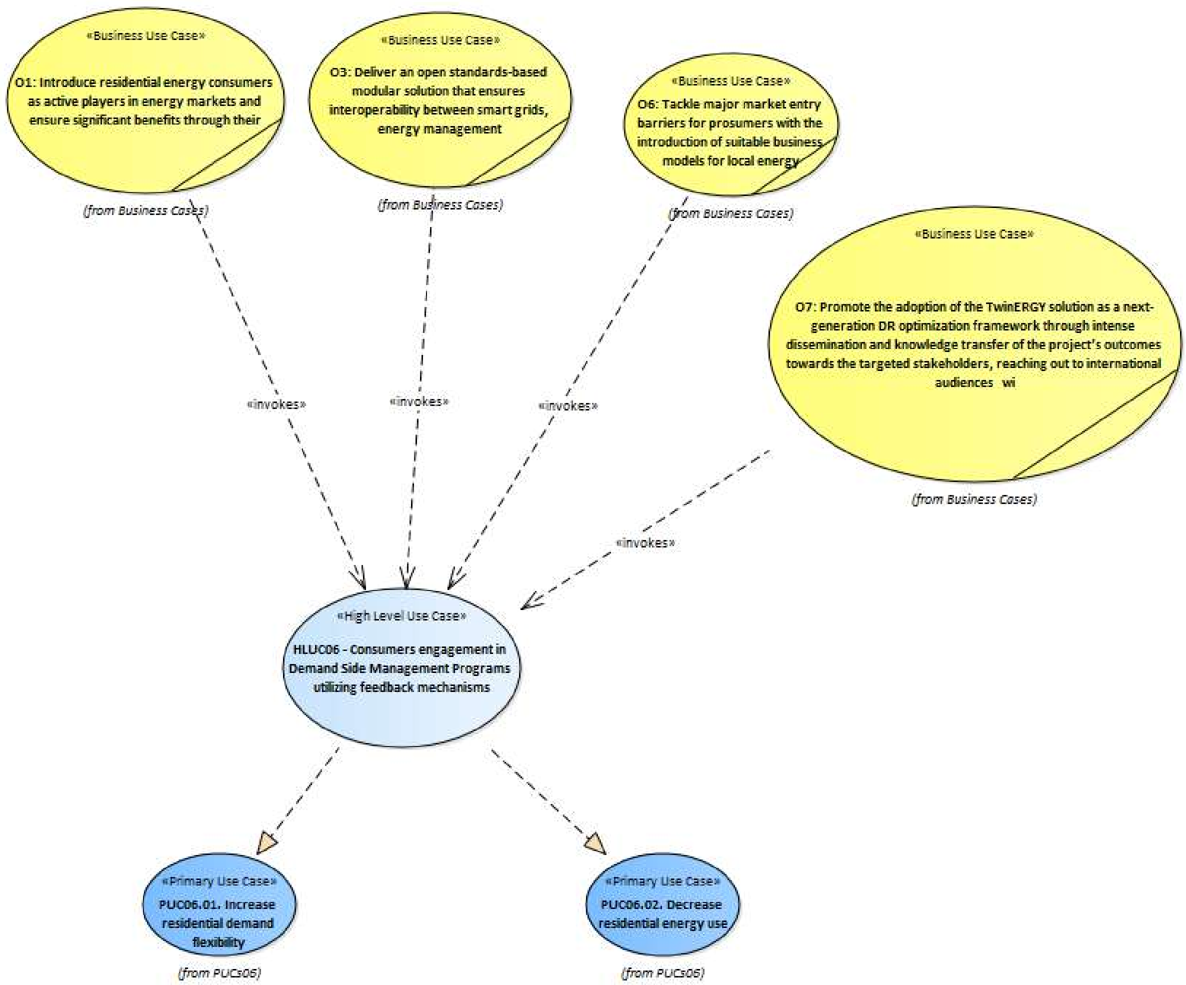

Figure 199: SGAM Business Layer HLUC06

11. HLUC07. Consumer's engagement in demand response programs utilizing a socio-economic context

11.1. PUC07.01. Social marketing to engage customers via competition.

11.1.1. Use Case Description

This PUC aims to validate the gradual engagement of end-users via social competition. The enhanced awareness of end-users (i.e., monitoring and understanding their consumption profiles) that will be performed with a comprehensive dashboard on the Social Network Module. Therefore, this PUC contains all the necessary preconditions to perform the social competition (steps 1-3).

This PUC is triggered each time a user accepts to participate in end-users' competition, where the Social Network Module initiates the process of evaluation of end-users' net consumption behaviours.

The steps are the following, presuming that a user account/profile has already been created on the Social Network Module:

1. The Social Network Module invokes information from Digital Twin Platform and the Comfort - Wellbeing Module via the Interoperability Platform. Such information:
    - Might refer to the user's consumption profile (aggregated and disaggregated at device level), generation profiles, status of DER (e.g., SoC of a BESS), optimized net profile etc.
    - Is comprehensively presented to the end-user to increase her/his awareness on consumption habits.
2. The Social Network Module interacts with the user proposing challenges to participate in several energy competition as a matter gaining TwinERGY points.
3. The Social Network Module will propose consumption improvements so that the user may achieve better results in the competition
4. At the end of the competition the user will be informed for the TwinERGY points that gained.

The user will dynamically build a profile of TwinERGY points based on the commitment attended (i.e., daily/weekly/monthly). Accordingly, the user will collect badges based on multiple available achievements that will be challenged.

11.1.2. SGAM Function Layer

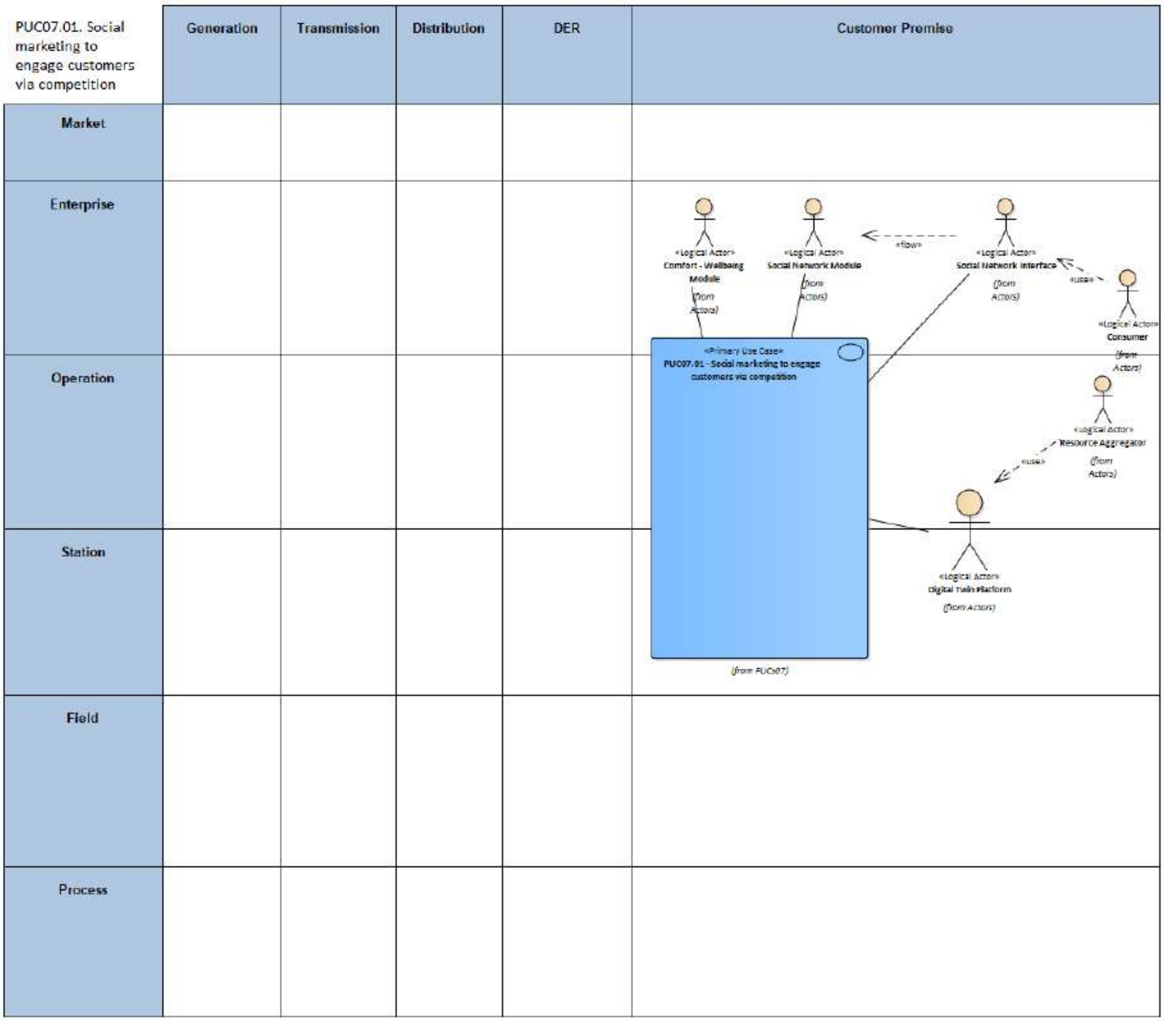

Figure 200: SGAM Function Layer PUC07.01

Table 118: List of Actors Involved PUC07.01

Actor Name	Actor Type
Comfort – Wellbeing Module	Application
Social Network Module	Application
Social Network Interface	Application
Consumer	Logical actor role
Resource aggregator	Logical actor role
Digital Twin Platform	Application

11.1.3. SGAM Component Layer

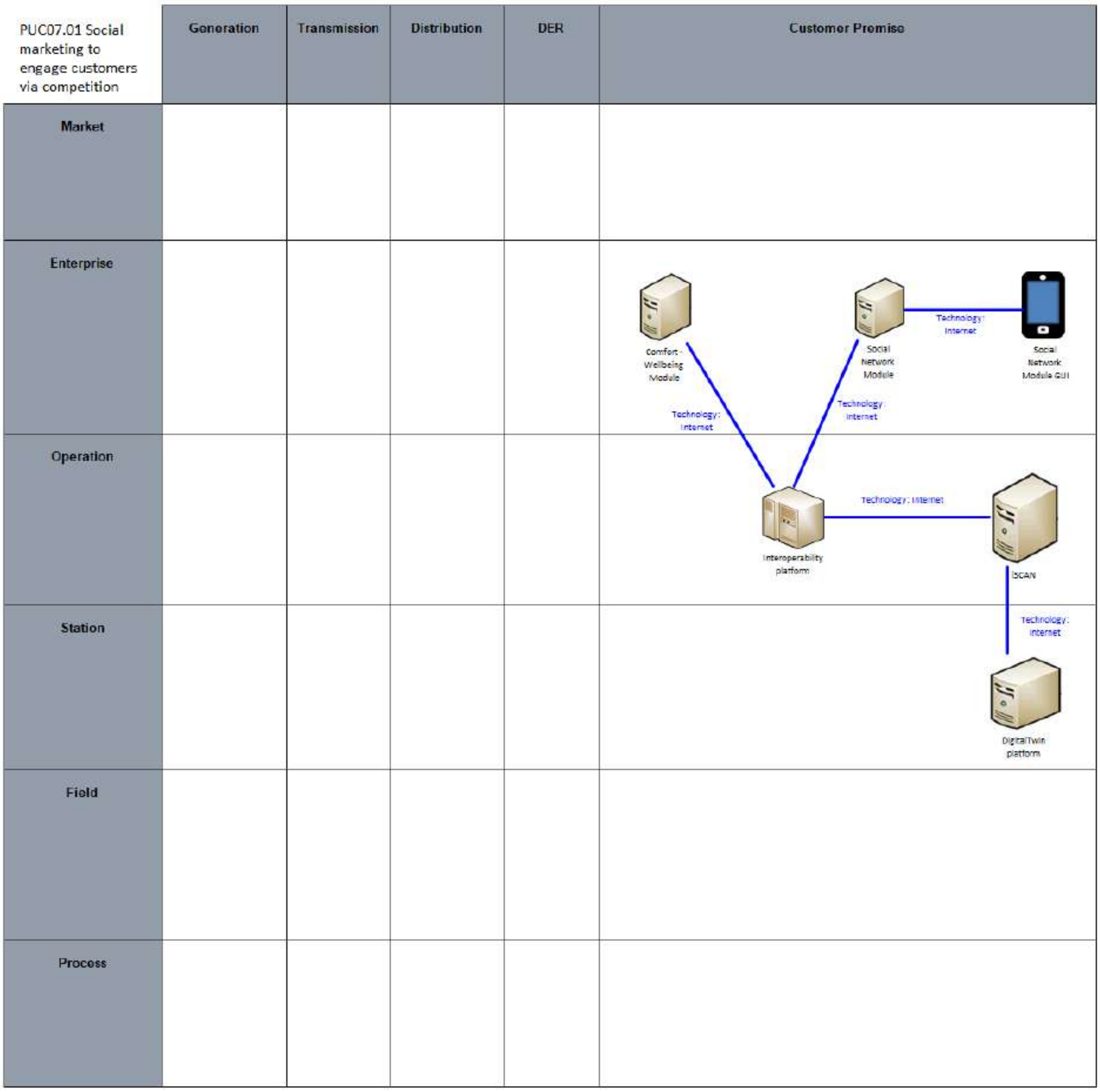

Figure 201: SGAM Component Layer PUC07.01

Table 119: List of Components PUC07.01

Component	Component Type
Digital Twin Platform	TwinERGY application
iSCAN	External application
Interoperability platform	TwinERGY application
Comfort Well-being module	TwinERGY application

Social Network Module	TwinERGY application
Social Network Module GUI	TwinERGY application

11.1.4. SGAM Communication Layer

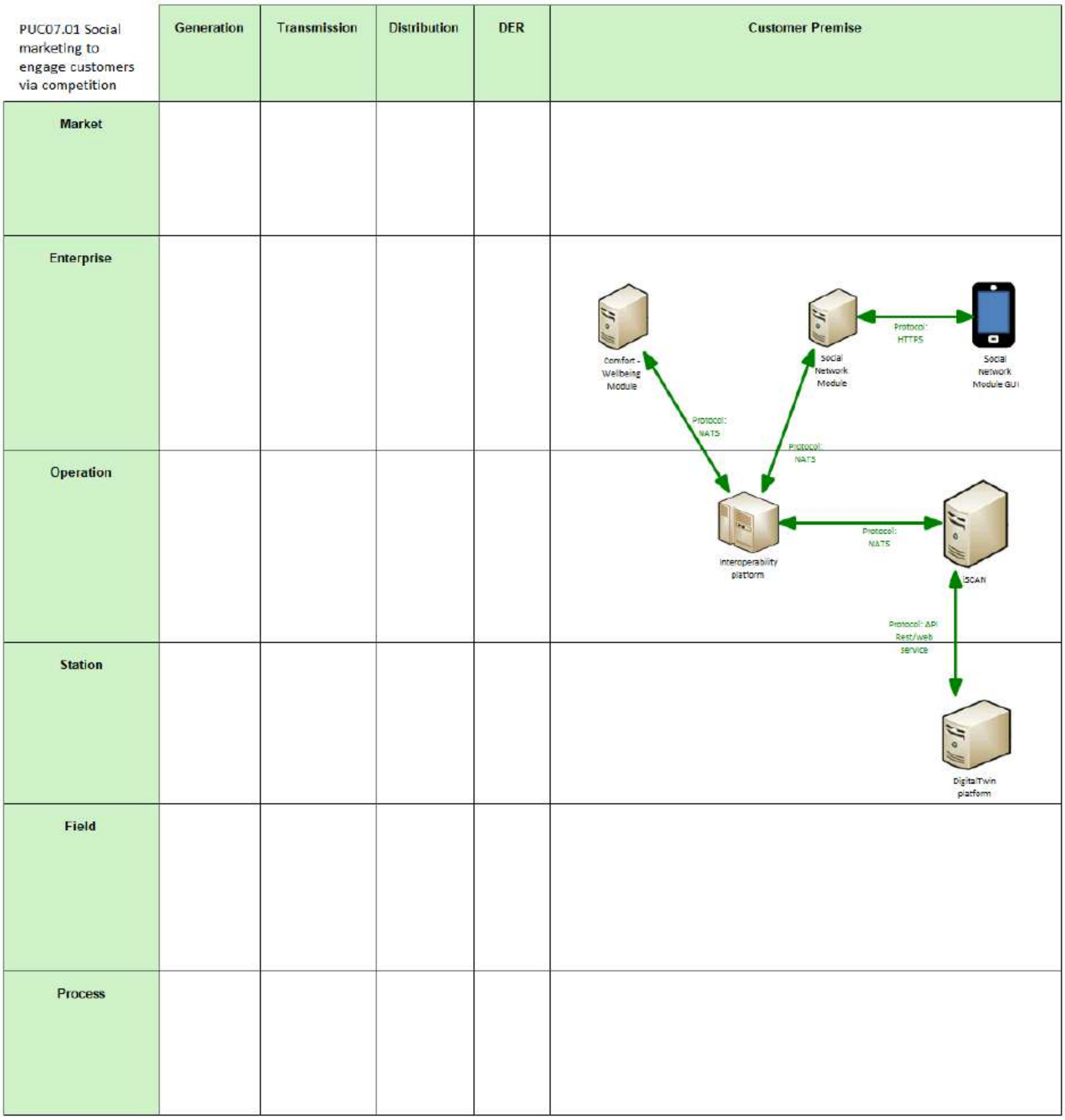

Figure 202: SGAM Communication Layer PUC07.01

Table 120: List of Communication technologies involved in PUC07.01

Communication Technology	Description

API Rest	Application Programming Interface for REpresentational State Transfer. API is a software intermediary that allows two applications to talk to each other, whilst REST is an architectural style for distributed hypermedia systems, working stateless. Both define a set of distributed resources accessible and manipulable through a set of public functions.
HTTPS	HyperText Transfer Protocol Secure. It is an extension of the Hypertext Transfer Protocol (HTTP), used for secure communication over a computer network. In HTTPS, the communication protocol is encrypted using Transport Layer Security (TLS) or, formerly, Secure Sockets Layer (SSL). The protocol is therefore also referred to as HTTP over TLS, or HTTP over SSL.
NATS	Protocol of messaging that enables the exchange of messages among computer applications and services, not depending on the network location.

11.1.5. SGAM Information Layer

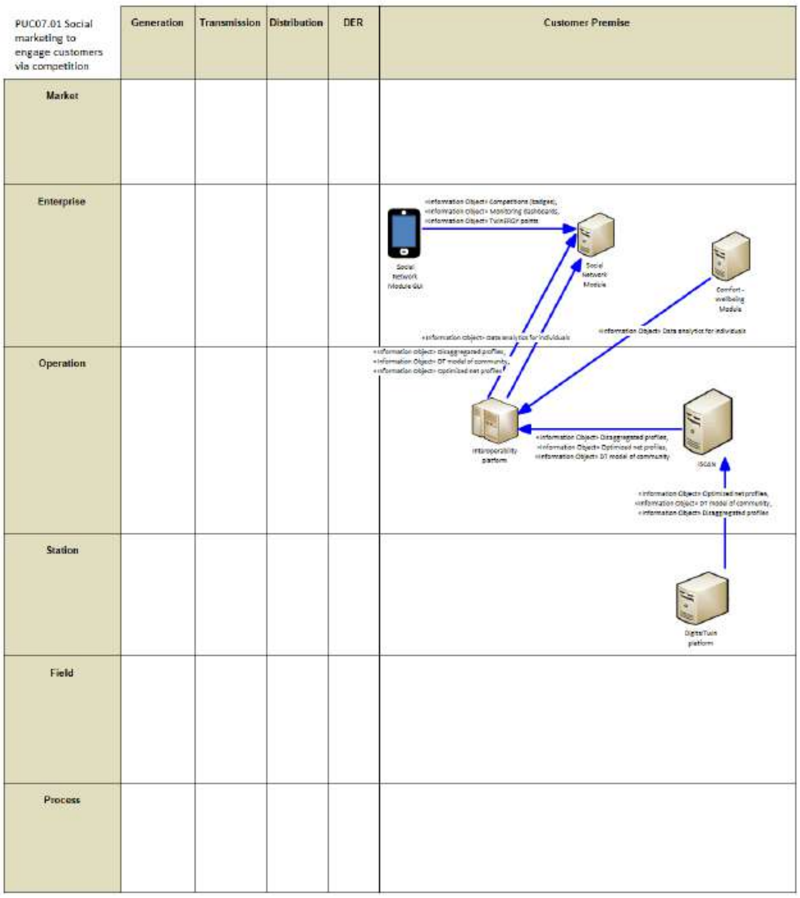

Figure 203: SGAM Information Layer PUC07.01

11.1.6. Canonical Data Model

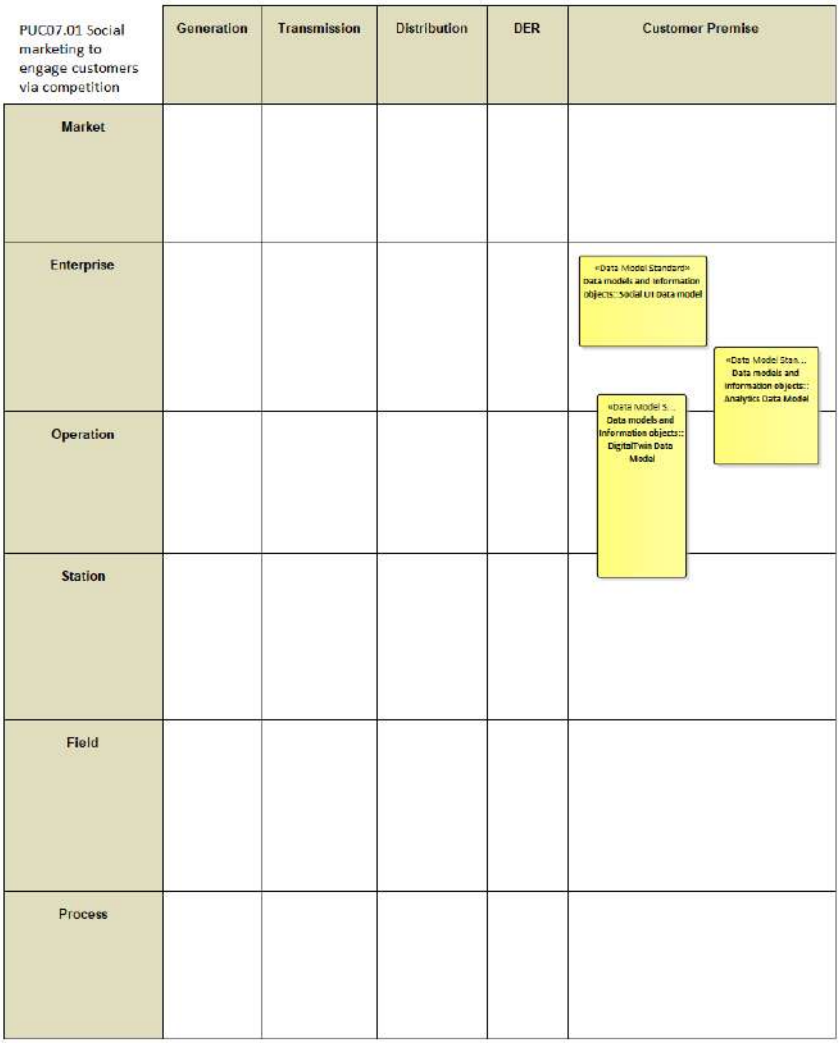

Figure 204: SGAM Canonical Data Model PUC07.01

Table 121: List of Data Models PUC07.01

Data Models
Social UI Data Model
Digital Twin Data Model
Analytics Data Model

11.1.7. Standards and Information Object Mapping

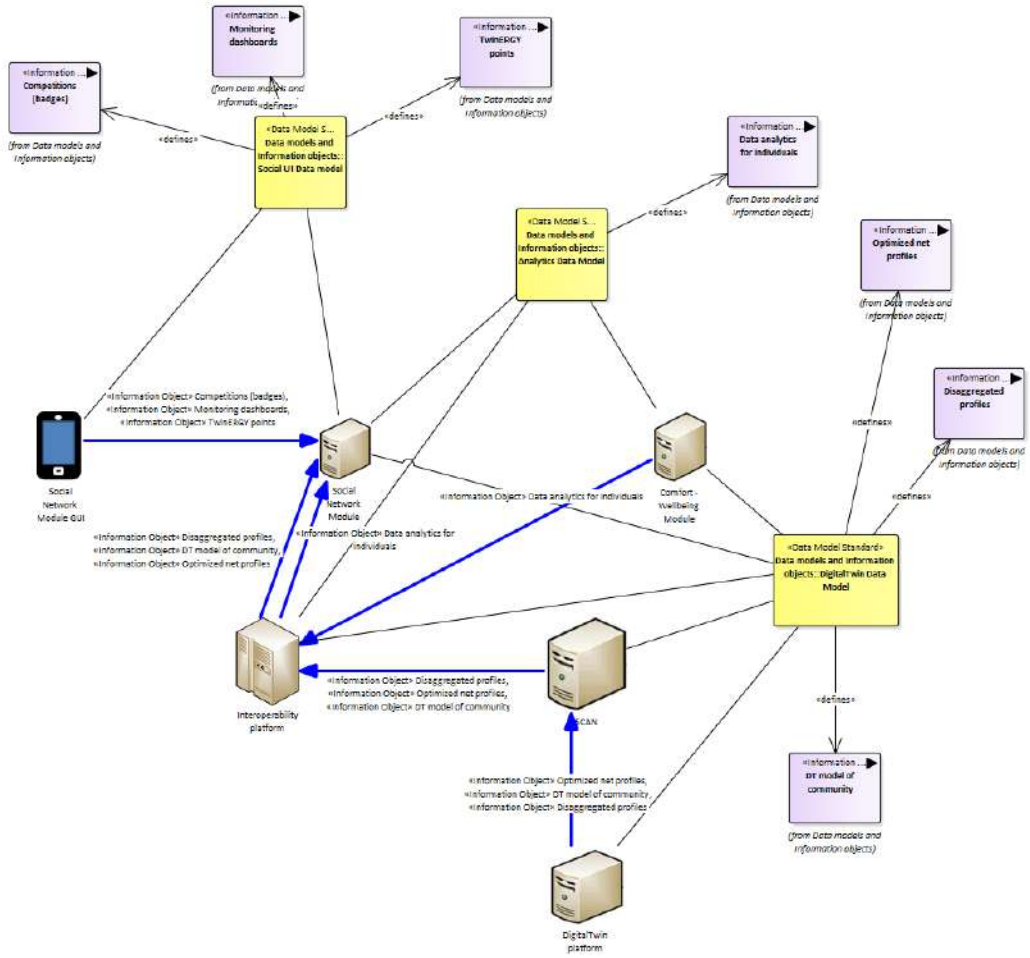

Figure 205: SGAM Standards and Information Object Mapping PUC07.01

Table 122: List of Information Objects PUC07.01

Information Objects	Data Models
Competitions (badges)	Social UI Data model
Monitoring dashboards	Social UI Data model
TwinERGY points	Social UI Data model
Data analytics for individuals	Analytics Data Model
Optimized net profiles	Digital Twin Data Model
Disaggregated profiles	Digital Twin Data Model
DT model of community	Digital Twin Data Model

11.1.8. Activity Diagram

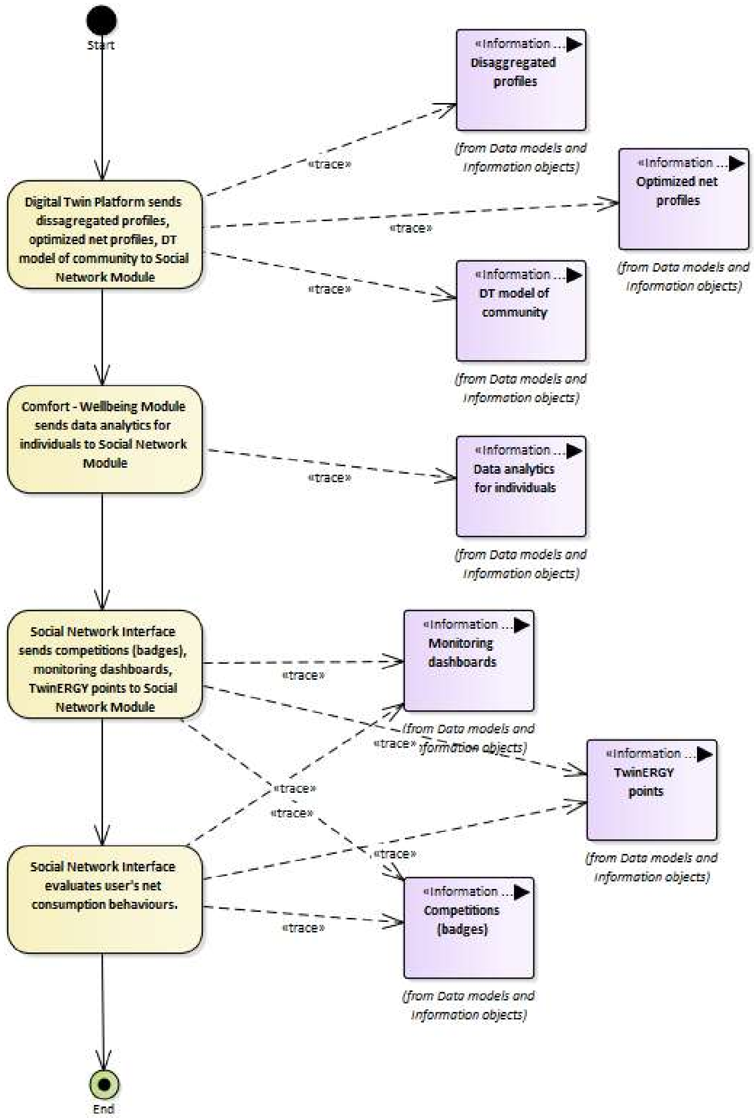

Figure 206: SGAM Activity Diagram PUC07.01

11.1.9. Sequence Diagram

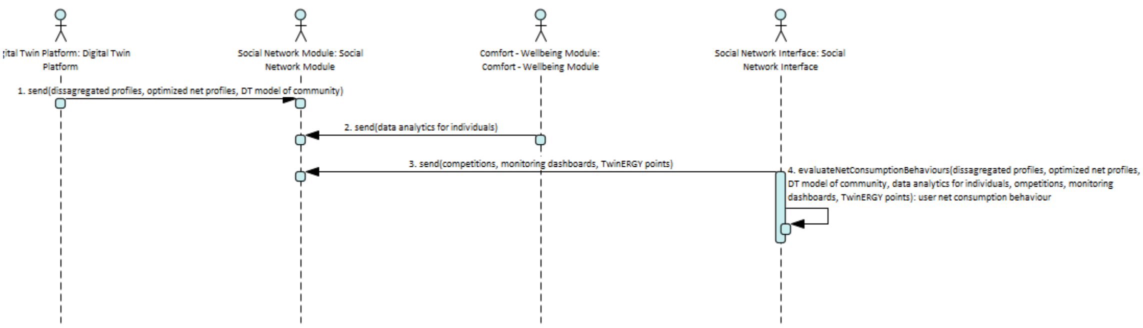

Figure 207: SGAM Sequence Diagram PUC07.01

11.2. PUC07.02. End-users' engagement on utilization of shared DERs.

11.2.1. Use Case Description

This use case aims at exploring the utilization of shared DER in a building or community.

This PUC is triggered each time a user accepts to participate in end-users competition, where the Social Network Module will initiate the process of evaluation of end-users' net consumption behaviours.

The steps are the following ones, presuming that the user has already created an account/profile on the Social Network Module and shared DER are already registered:

1. The Social Network Module invokes information from the Digital Twin Platform and the Comfort - Wellbeing Module via the Interoperability Platform. Such information:
   . Might refer to the user's consumption profile (aggregated and disaggregated at device level), generation profiles, status of DER (e.g., SoC of a BESS), optimized net profile etc.
   a. Is comprehensively presented to the end-user to increase her/his awareness on consumption habits. More specifically, there will be a comprehensive dashboard with the aid of Digital Twin Platform with graphic representation of the shared assets to illustrate the current status/conditions.
2. The Social Network Module interacts with the user proposing challenges to adapt the consumption needs given the predicted and current status of the share DER assets. The user will be challenged to follow specific recommendations and will compete with other neighbouring users that are sharing the same DER assets.
3. The Social Network Module will propose consumption improvements so that the user may achieve better results in the competition
4. At the end of the competition the user will be informed for the TwinERGY points that gained.
5. The user will dynamically build a profile of TwinERGY points based on the commitment attended (i.e., daily/weekly/monthly). Accordingly, the user will collect badges based on multiple available achievements that will be challenged.

11.2.2. SGAM Function Layer

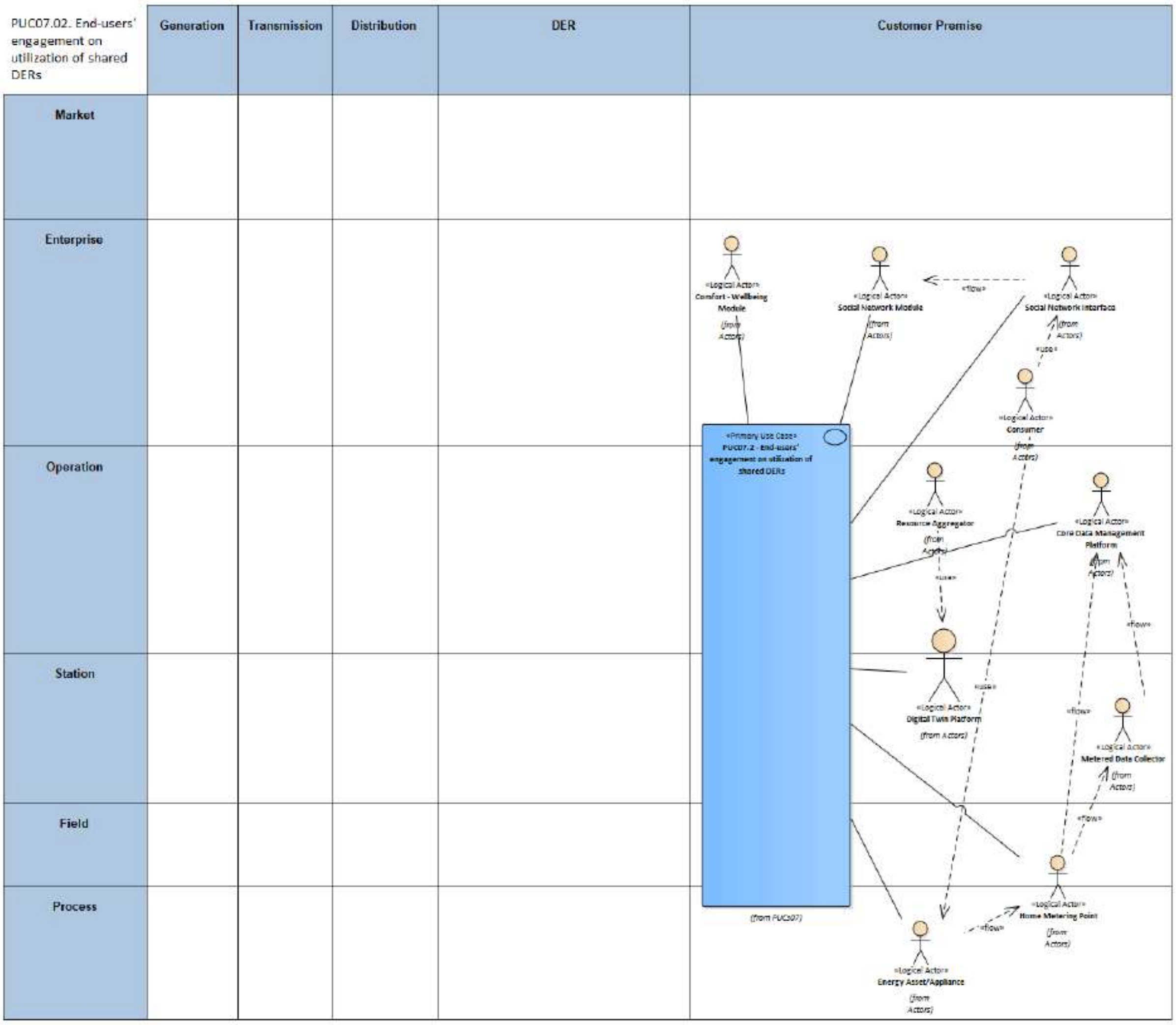

Figure 208: SGAM Function Layer PUC07.02

Table 123: List of Actors Involved PUC07.02

Actor Name	Actor Type
Comfort – Wellbeing Module	Application
Social Network Module	Application
Social Network Interface	Application
Consumer	Logical actor role
Resource aggregator	Logical actor role
Digital Twin Platform	Application

Core Data Management Platform	Application
Metered Data Collector	Device
Home Metering Point	Device
Energy Asset/appliance	Device

11.2.3. SGAM Component Layer

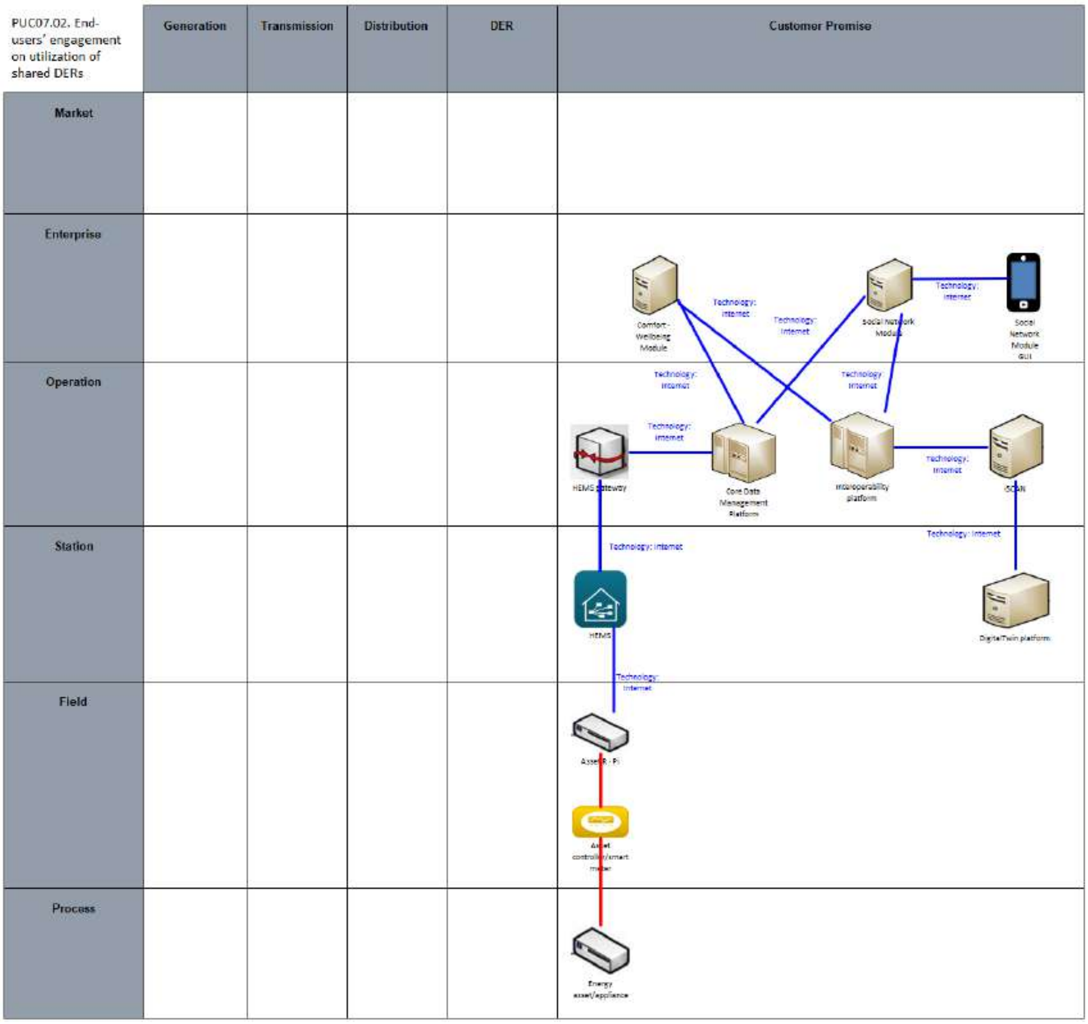

Figure 209: SGAM Component Layer PUC07.02

Table 124: List of Components PUC07.02

Component	Component Type
Energy asset/appliance	Physical asset
Asset Controler/ Smart Meter	Physical asset

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Raspberry-Pi	Physical asset
HEMS	External application
HEMS gateway	External application
Core Data Management Platform	TwinERGY application
Interoperability Platform	TwinERGY application
Social Network Module	TwinERGY application
Comfort Well-being Module	TwinERGY application
Social Network Module GUI	TwinERGY application
Digital Twin Platform	TwinERGY application
iSCAN	External application

11.2.4. SGAM Communication Layer

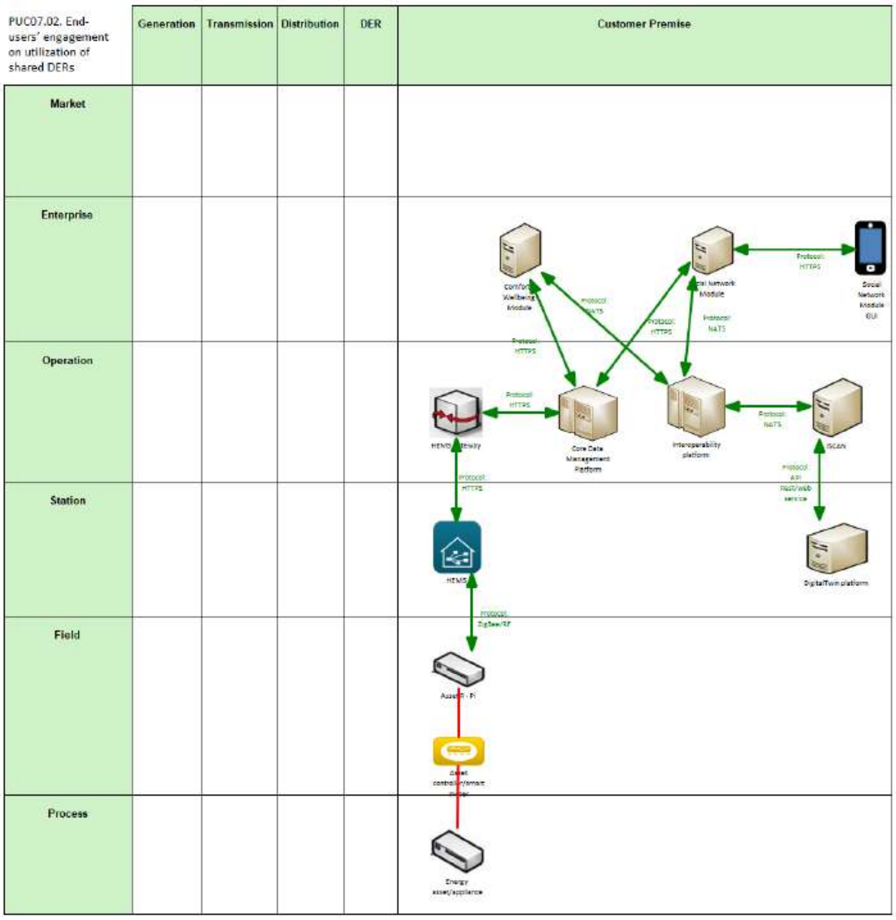

Figure 210: SGAM Communication Layer PUC07.02

Table 125: List of Communication technologies involved in PUC07.02

Communication Technology	Description
ZigBee/RF	Protocol IEEE 802.15.4, designed to communicate data through noisy RF environments. This standard operates on the physical radio specification and operates in unlicensed bands including 2.4 GHz, 900 MHz and 868 MHz.
HTTPS	HyperText Transfer Protocol Secure. It is an extension of the Hypertext Transfer Protocol (HTTP), used for secure communication over a computer network. In HTTPS, the communication protocol is encrypted using Transport Layer Security (TLS) or, formerly, Secure Sockets Layer (SSL). The protocol is therefore also referred to as HTTP over TLS, or HTTP over SSL.
REST API	
NATS	Protocol of messaging that enables the exchange of messages among computer applications and services, not depending on the network location.

11.2.5. SGAM Information Layer

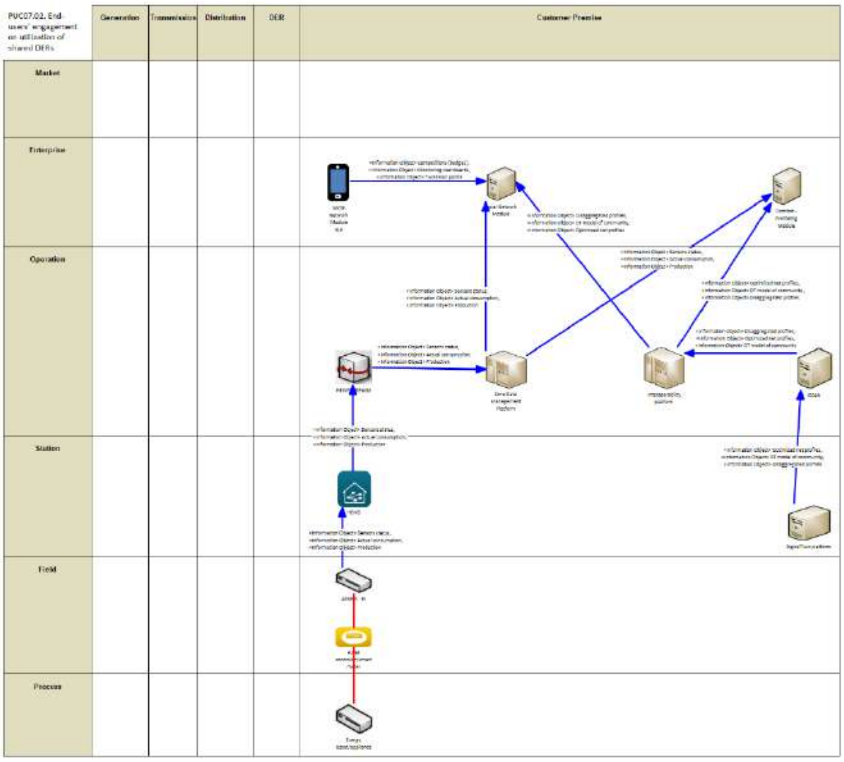

Figure 211: SGAM Information Layer PUC07.02

11.2.6. Canonical Data Model

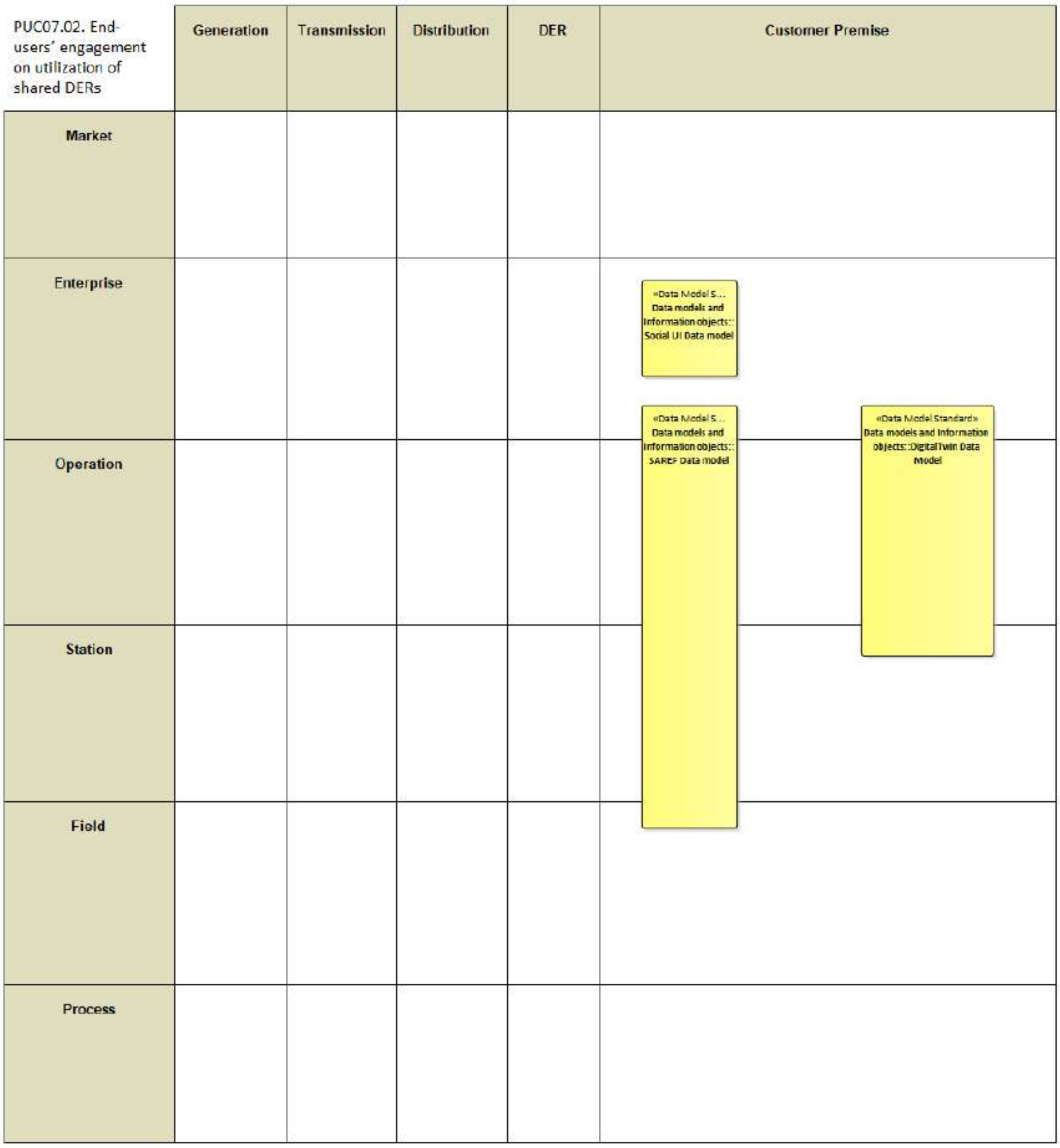

Figure 212:SGAM Canonical Data Model PUC07.02

Table 126: List of Data Models PUC07.02

Data Models
Social UI Data Model
SAREF Data Model
Digital Twin Data Model

11.2.7. Standards and Information Object Mapping

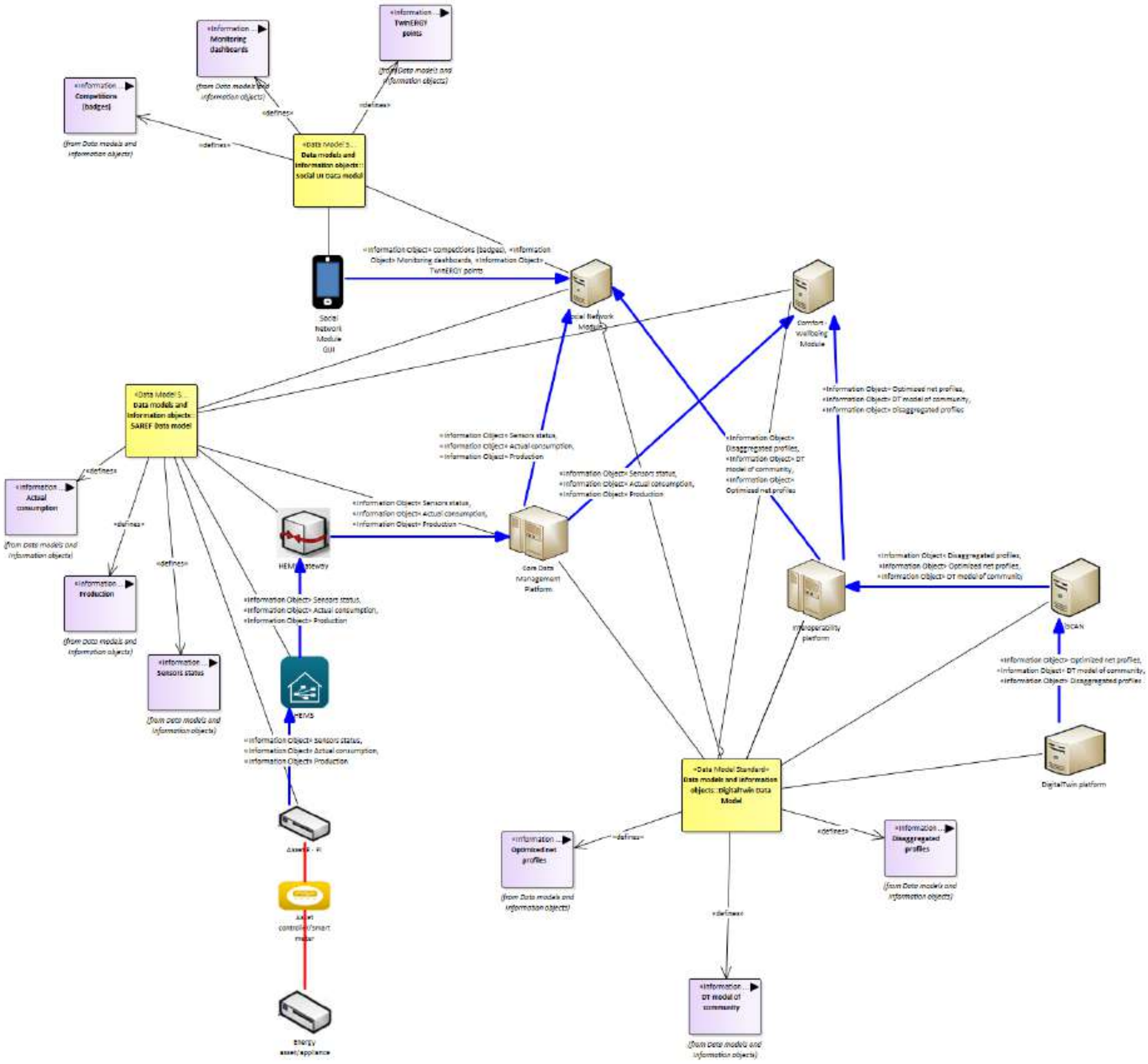

Figure 213: SGAM Standards and Information Object Mapping PUC07.02

Table 127: List of Information Objects PUC07.02

Information Objects	Data Models
Competitions (badges)	Social UI Data model
Monitoring dashboards	Social UI Data model
TwinERGY points	Social UI Data model
Actual consumption	SAREF Data model
Sensor status	SAREF Data model
Production	SAREF Data model

Optimized net profiles	DigitalTwin Data Model
Disaggregated profiles	DigitalTwin Data Model
DT model of community	DigitalTwin Data Model

11.2.8. Activity Diagram

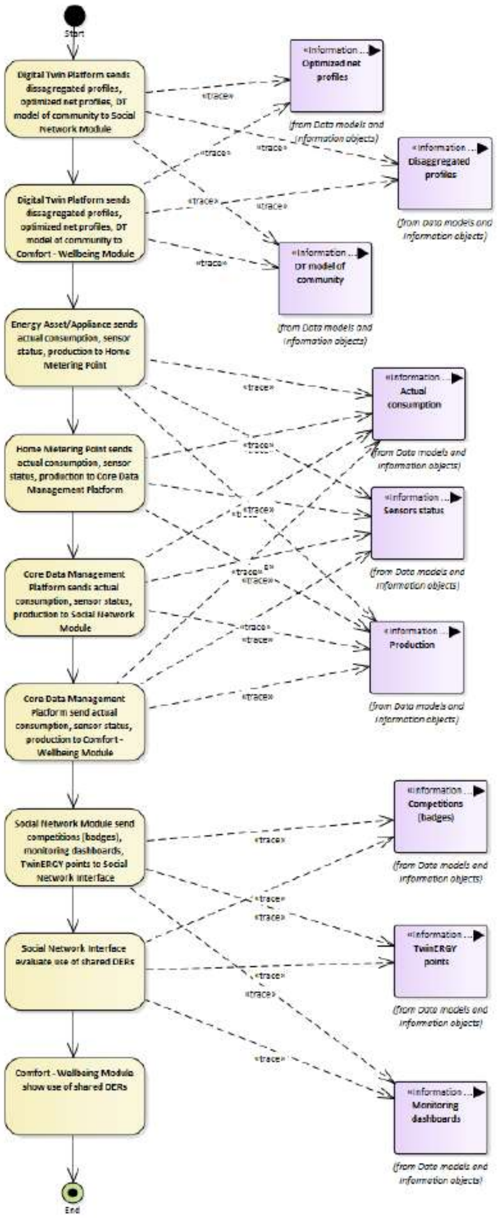

Figure 214: SGAM Activity Diagram PUC07.02

Twinergy has received funding from the European Union's Horizon 2020 research and innovation programme under grant agreement No. 957736

11.2.9. Sequence Diagram

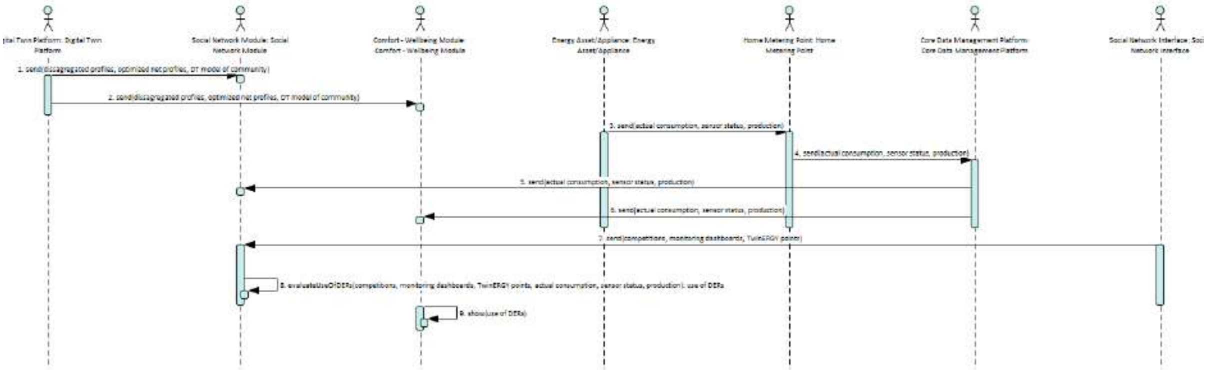

Figure 215: SGAM Sequence Diagram PUC07.02

11.3. PUC07.03. Enable co-creation for end consumers, prosumers and public authorities.

11.3.1. Use Case Description

This use case aims at exploiting the functionality to enable the co-creation among several different neighbouring end-users and flexibility actors via the Social Network Module. A type of portal will be in place within the Social Network Module for all users (i.e., end-users, authorities, buildings) to commonly discuss and resolve issues of common interest. The use case starts when a user creates a new issue on the social portal.

It should be stated that this use case essentially prescribes an internal procedure of the Social Network Module, raising an interaction between the users of the Social Network Module; hence, no interaction is deemed necessary with other modules. The steps are outlined as follows, presuming that the user has already created an account/profile on the Social Network Module:

1. Any user might utilize the Social Network Module to view social portal.
2. The user might check important issues/updates for topics of interest of the community that is participating in (e.g., incident declared on a shared asset).
3. Create/register and discuss topics of common interest with other members of an energy community/condominium.

11.3.2. SGAM Function Layer

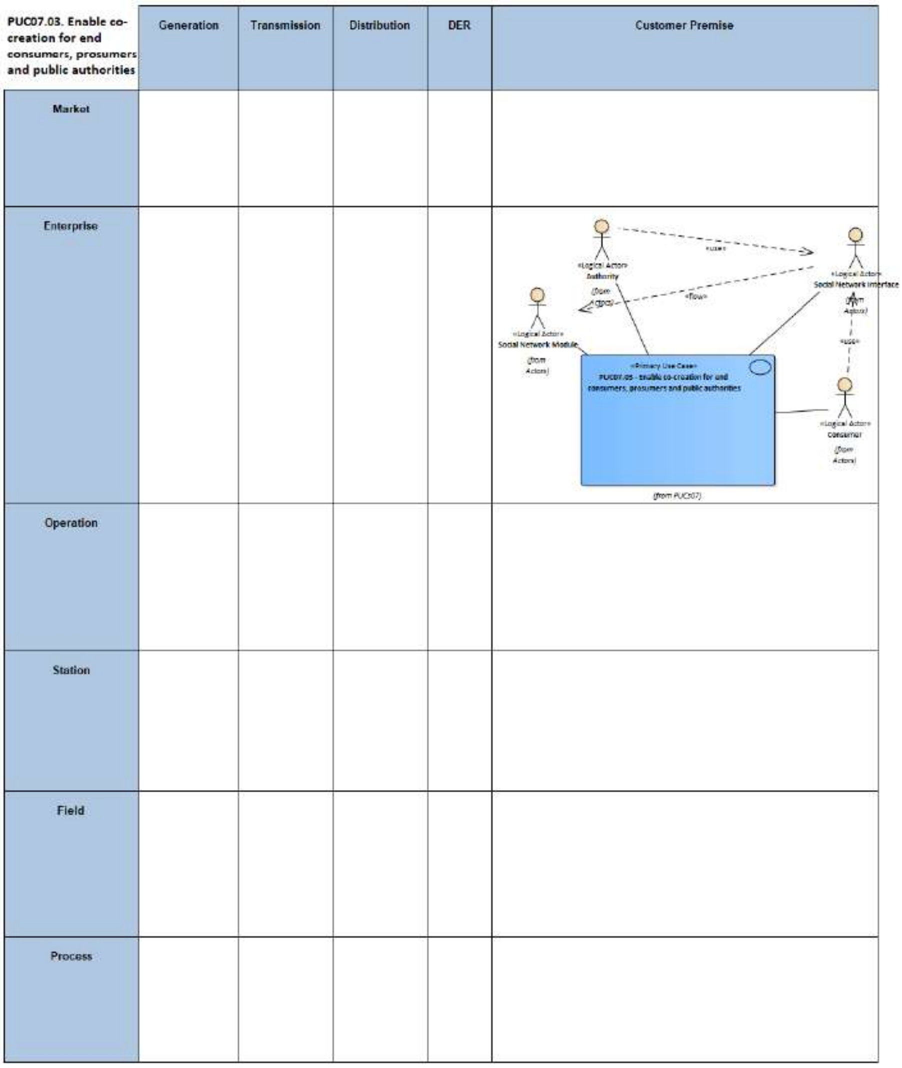

Figure 216: SGAM Function Layer PUC07.03

Table 128: List of Actors Involved PUC07.03

Actor Name	Actor Type
Social Network Module	Application
Authority	Logical actor role
Social Network Interface	Application
Consumer	Logical actor role

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11.3.3. SGAM Component Layer

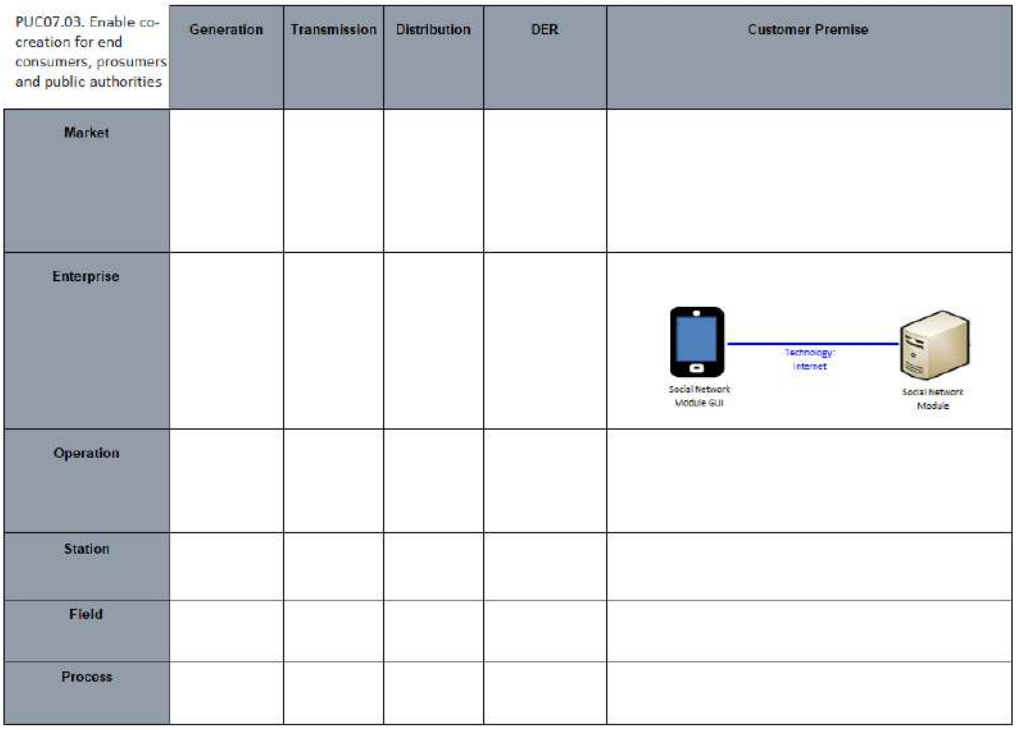

Figure 217: SGAM Component Layer PUC07.03

Table 129: List of Components PUC07.03

Component	Component Type
Social Network Module GUI	TwinERGY application
Social Network Module	TwinERGY application

11.3.4. SGAM Communication Layer

Figure 218:SGAM Communication Layer PUC07.03

Table 130: List of Communication technologies involved in PUC07.03

Communication Technology	Description
HTTPS	HyperText Transfer Protocol Secure. It is an extension of the Hypertext Transfer Protocol (HTTP), used for secure communication over a computer network. In HTTPS, the communication protocol is encrypted using Transport Layer Security (TLS) or, formerly, Secure Sockets Layer (SSL). The protocol is therefore also referred to as HTTP over TLS, or HTTP over SSL.

11.3.5. SGAM Information Layer

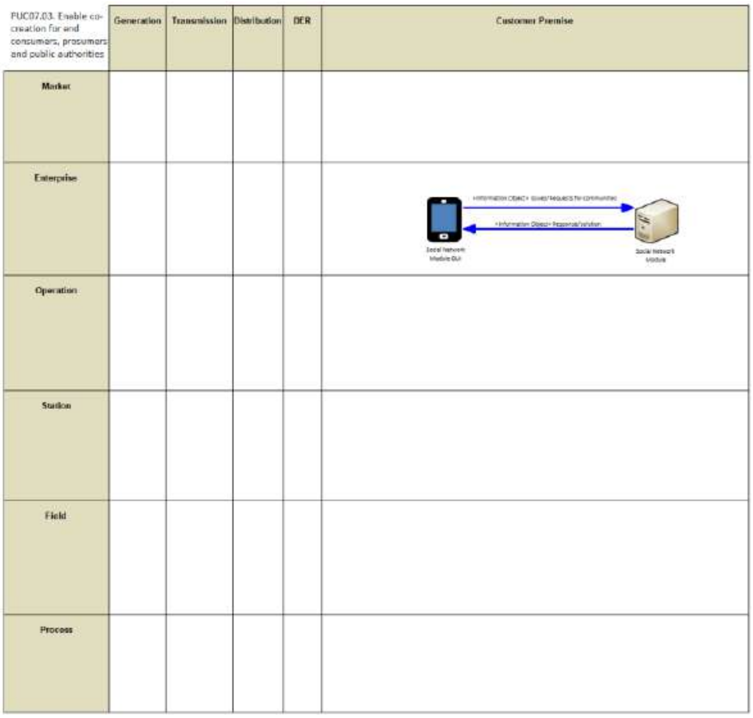

Figure 219: SGAM Information Layer PUC07.03

11.3.6. Canonical Data Model

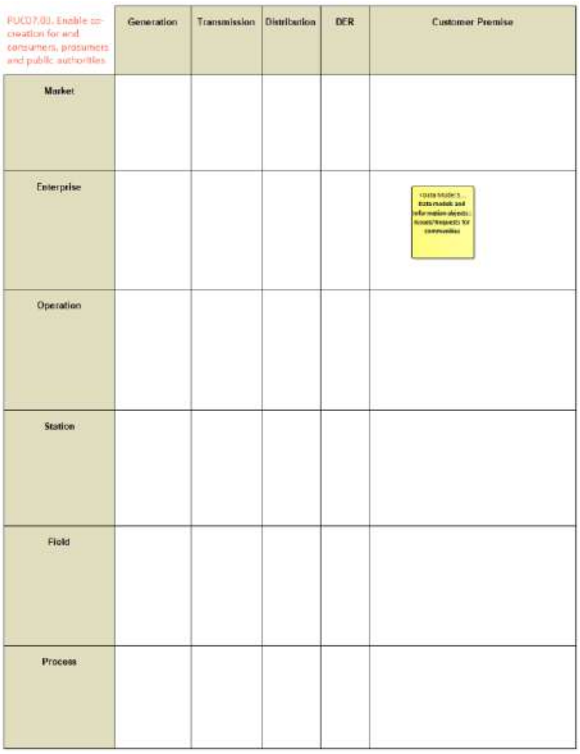

Figure 220: SGAM Canonical Data Model PUC07.03

Table 131: List of Data Models PUC07.03

Data Models
Issues/Requests for Communities

11.3.7. Standards and Information Object Mapping

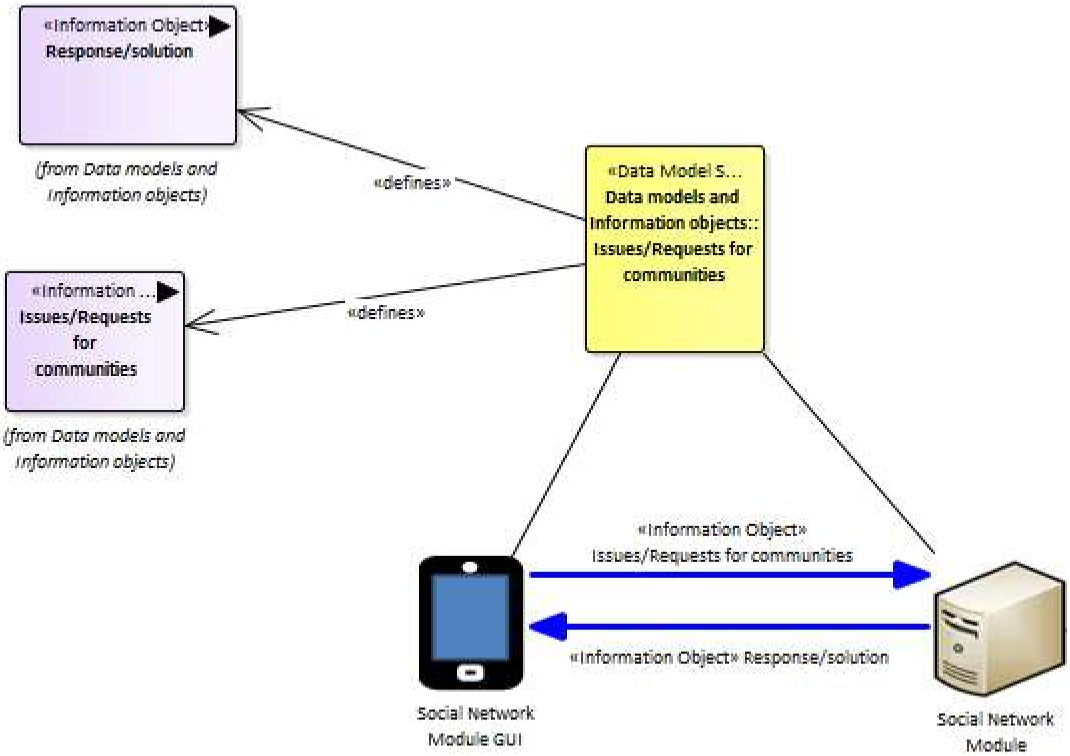

Figure 221: SGAM Standards and Information Object Mapping PUC07.03

Table 132: List of Information Objects PUC07.03

Information Objects	Data Models
Response/solution	Issues/Requests for communities Data model
Issues/Requests for communities	Issues/Requests for communities Data model

11.3.8. Activity Diagram

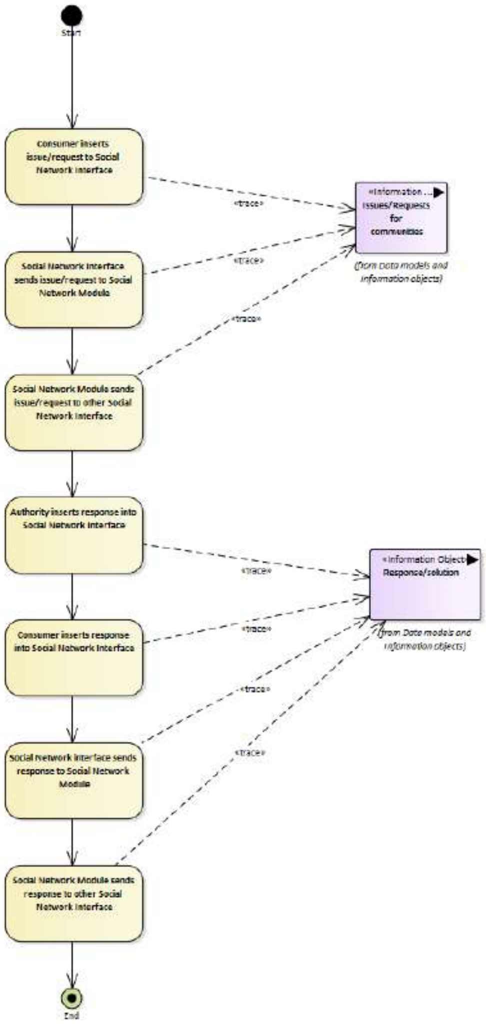

Figure 222: SGAM Activity Diagram PUC07.03

11.3.9. Sequence Diagram

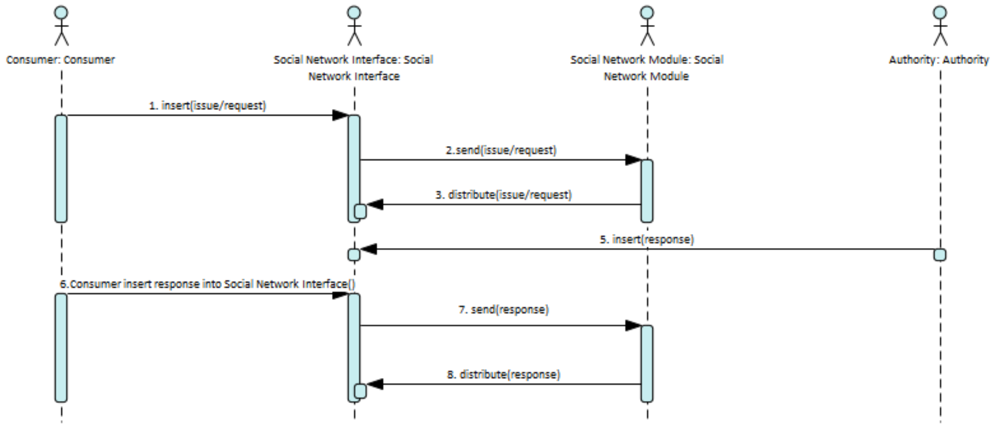

Figure 223: SGAM Sequence Diagram PUC07.03

11.4. SGAM Business Layer

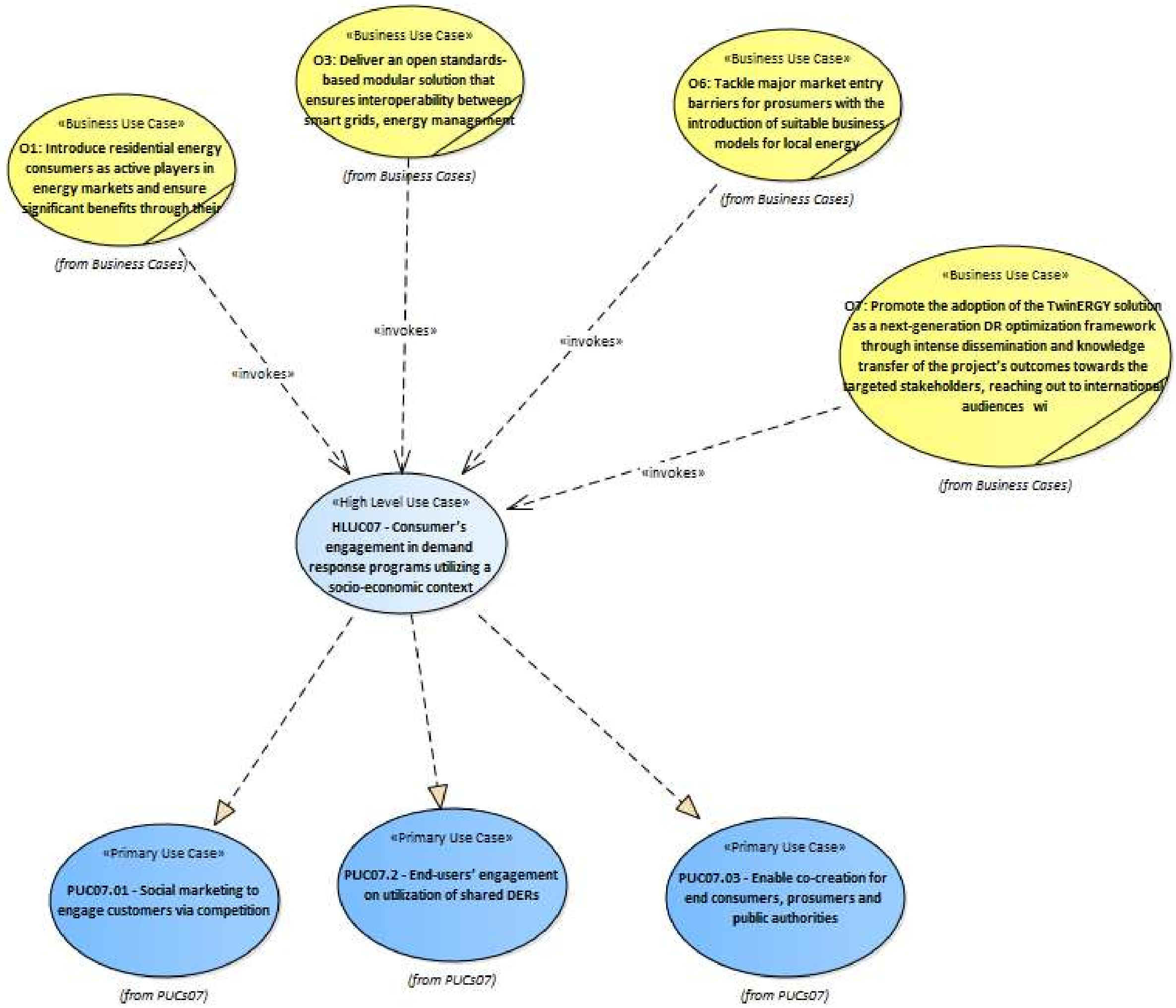

Figure 224: SGAM Business Layer HLUC07

12. HLUC08. Consumer's engagement in demand response programs utilizing personalized comfort/health-oriented services

12.1. PUC08.01. Wellbeing best practice for indoor environment conditions

12.1.1. Use Case Description

This use case aims to show the feasibility of making optimal decisions of energy consumption allocation while preserving acceptable Thermal comfort level and well-being Status and taking into account the occupant's preferences.

The Comfort - Wellbeing Module processes a set of Indoor Air Quality parameters (Air Temperature, Relative Humidity, Visual, Acoustic and concentration of Indoor Air Pollutants), Outdoor environmental parameters (Air Temperature, Relative Humidity), Physiological parameters, Motion status and Clothing Insulation in order to continuously assess the occupant's Thermal comfort level – Well-being status, which eventually is pushed to the Consumer Digital Twin (CDT). Moreover, the occupant inserts a set of preferences in the form of constraints, which can change at any time through a friendly Graphical User Interface provided by the CDT. These preferences are mainly related to the desired range of Thermal comfort level and Well-being status but could include the eco – friendliness level as shown in the figures below.

Figure 225: Thermal Comfort Well-being Module

Figure 226: Thermal Comfort Well-being Module (2)

Twinergy has received funding from the European Union's Horizon 2020 research and innovation programme under grant agreement No. 957736

Figure 227: Thermal Comfort Well-being Module(3)

Thanks to the TwinERGY Interoperability Platform, the occupant's assessed Thermal comfort level and Wellbeing status as well as the corresponding preferences can be diffused from the CDT to the appropriate TwinERGY modules, namely the Consumer and Neighbourhood Demand Flexibility Profiling modules and the Home & Tertiary Real-time Energy Monitoring Module for further elaboration regarding achieving optimal energy consumption. Then, actions related to the distribution of the power loads during the full day in order to achieve the setting target (s) shall be provided to the occupant.

As the CDT is constantly updated with the status and the consumption details of the related loads (e.g., HVAC) and the occupant's Thermal comfort level and Wellbeing status, an evaluation assessment regarding the degree of occupants' preferences accomplishment shall be generated accompanied possibly by related remarks.

12.1.2. SGAM Function Layer

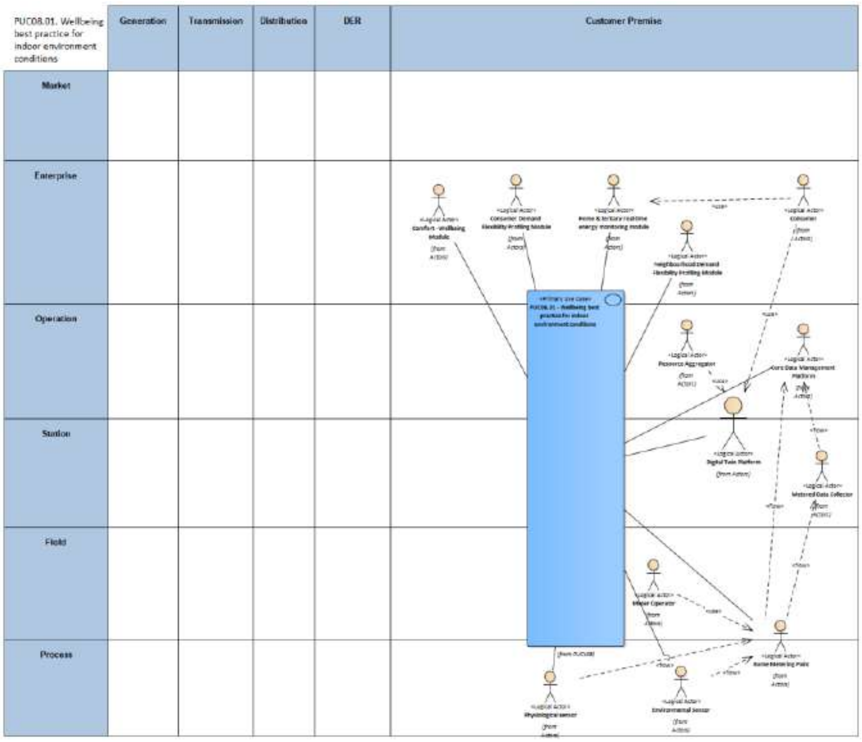

Figure 228: SGAM Function Layer PUC08.01

Twinergy has received funding from the European Union's Horizon 2020 research and innovation programme under grant agreement No. 957736

Table 133: List of Actors Involved PUC08.01

Actor Name	Actor Type
Comfort- Well being Module	Application
Consumer Demand Flexibility Profiling Module	Application
Home & Tertiary real-time energy monitoring module	Application
Consumer	Local actor role
Neighbourhood Demand Flexibility Profiling Module	Application
Resource aggregator	Local actor role
Core Data Management Platform	Application
Digital Twin Platform	Application
Metered Data Collector	Device
Meter Operator	Device
Home Metering Point	Device
Environmental Sensor	Device
Physiological sensor	Device

12.1.3. SGAM Component Layer

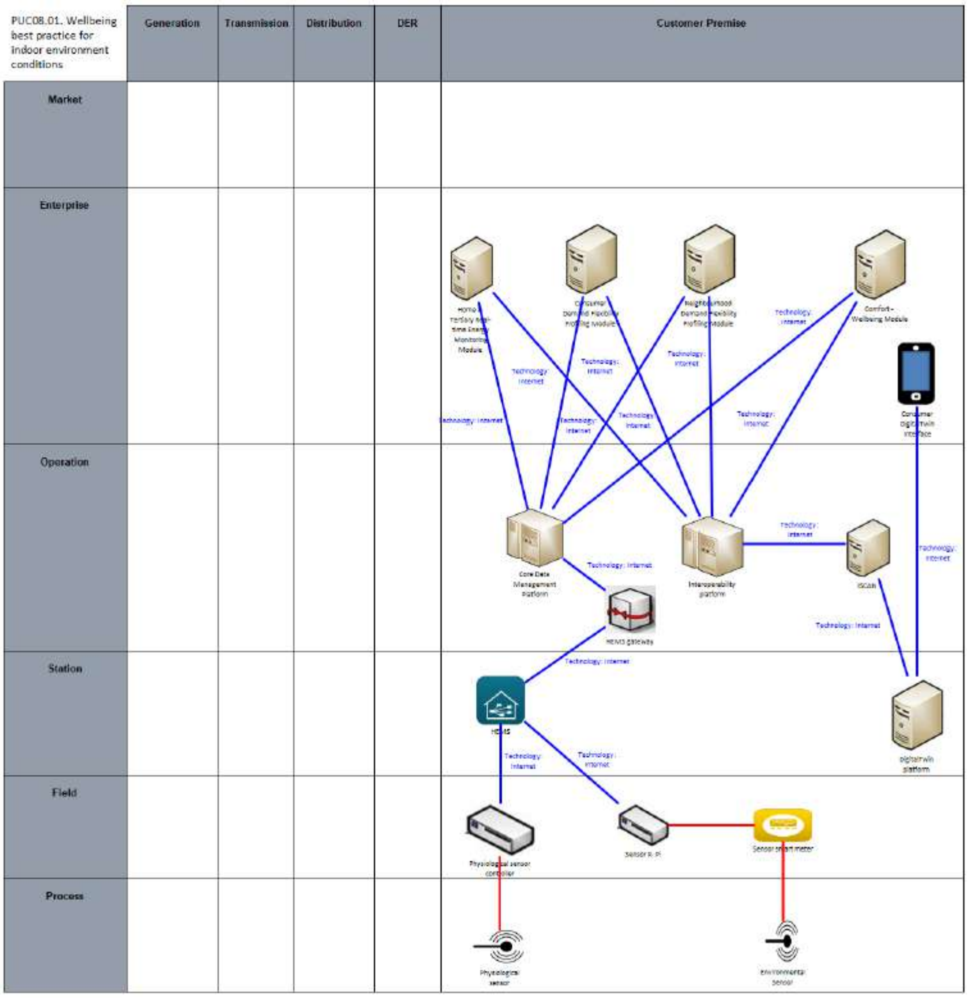

Figure 229: SGAM Component Layer PUC08.01

Table 134: List of Components PUC08.01

Component	Component Type
Physiological sensor	Physical asset
Environmental sensor	Physical asset
Physiological sensor controller	Physical asset
Sensor Smart Meter	Physical asset
Raspberry-Pi	Physical asset
HEMS	External application
HEMS gateway	External application

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Core Data Management Platform	TwinERGY application
Consumer Digital Twin Platform	TwinERGY application
Digital Twin Platform	TwinERGY application
iSCAN	External application
Interopereability Platform	TwinERGY application
Home & Tertiary Real-time Energy Monitoring Module	TwinERGY application
Consumer Demand Flexibility Profiling Module	TwinERGY application
Neighbourhood Demand Flexibility Profiling Module	TwinERGY application
Comfort Well-being Module	TwinERGY application

12.1.4. SGAM Communication Layer

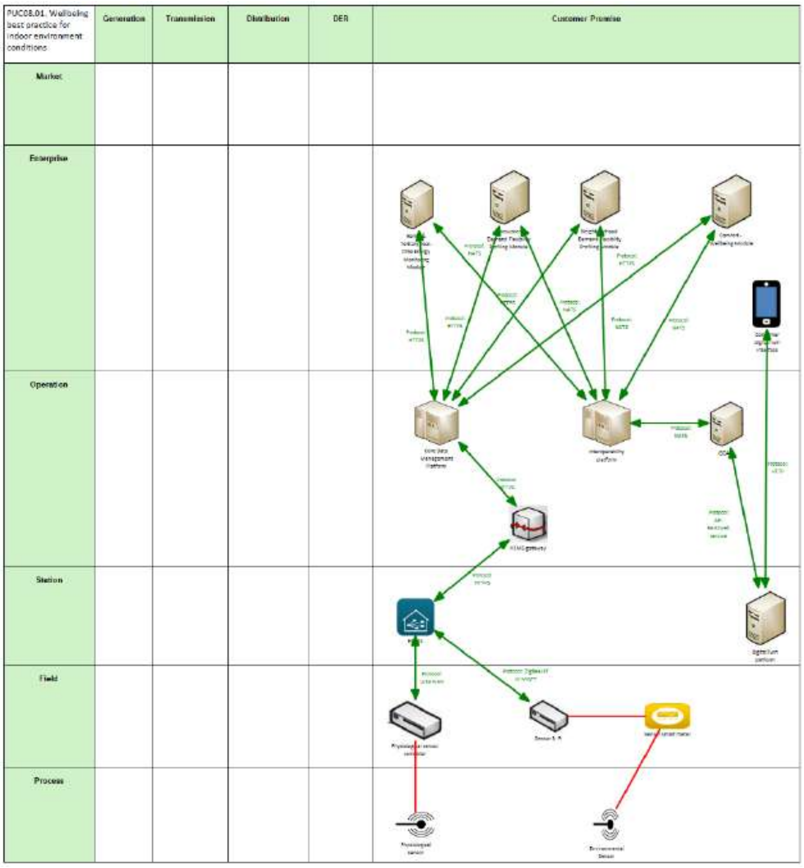

Figure 230:SGAM Communication Layer PUC08.01

Twinergy has received funding from the European Union's Horizon 2020 research and innovation programme under grant agreement No. 957736

Table 135: List of Communication technologies involved in PUC08.01

Communication Technology	Description
LoRaWAN	Long Range over WAN. It defines the communication protocol and system architecture for the network.
ZigBee/RF	Protocol IEEE 802.15.4, designed to communicate data through noisy RF environments. This standard operates on the physical radio specification and operates in unlicensed bands including 2.4 GHz, 900 MHz and 868 MHz.
MQTT	MQ Telemetry Transport. It is an open OASIS standard and an ISO recommendation (ISO/IEC 20922) over TCP/IP, being a lightweight, publish-subscribe network protocol that transports messages between devices.
HTTPS	HyperText Transfer Protocol Secure. It is an extension of the Hypertext Transfer Protocol (HTTP), used for secure communication over a computer network. In HTTPS, the communication protocol is encrypted using Transport Layer Security (TLS) or, formerly, Secure Sockets Layer (SSL). The protocol is therefore also referred to as HTTP over TLS, or HTTP over SSL.
HTTP	Stand for Hypertext Transfer Protocol. It is an application layer protocol in the Internet protocol suite model for distributed, collaborative, hypermedia information systems
NATS	Protocol of messaging that enables the exchange of messages among computer applications and services, not depending on the network location.
API REST	Application Programming Interface for REpresentational State Transfer. API is a software intermediary that allows two applications to talk to each other, whilst REST is an architectural style for distributed hypermedia systems, working stateless. Both define a set of distributed resources accessible and manipulable through a set of public functions.

12.1.5. SGAM Information Layer

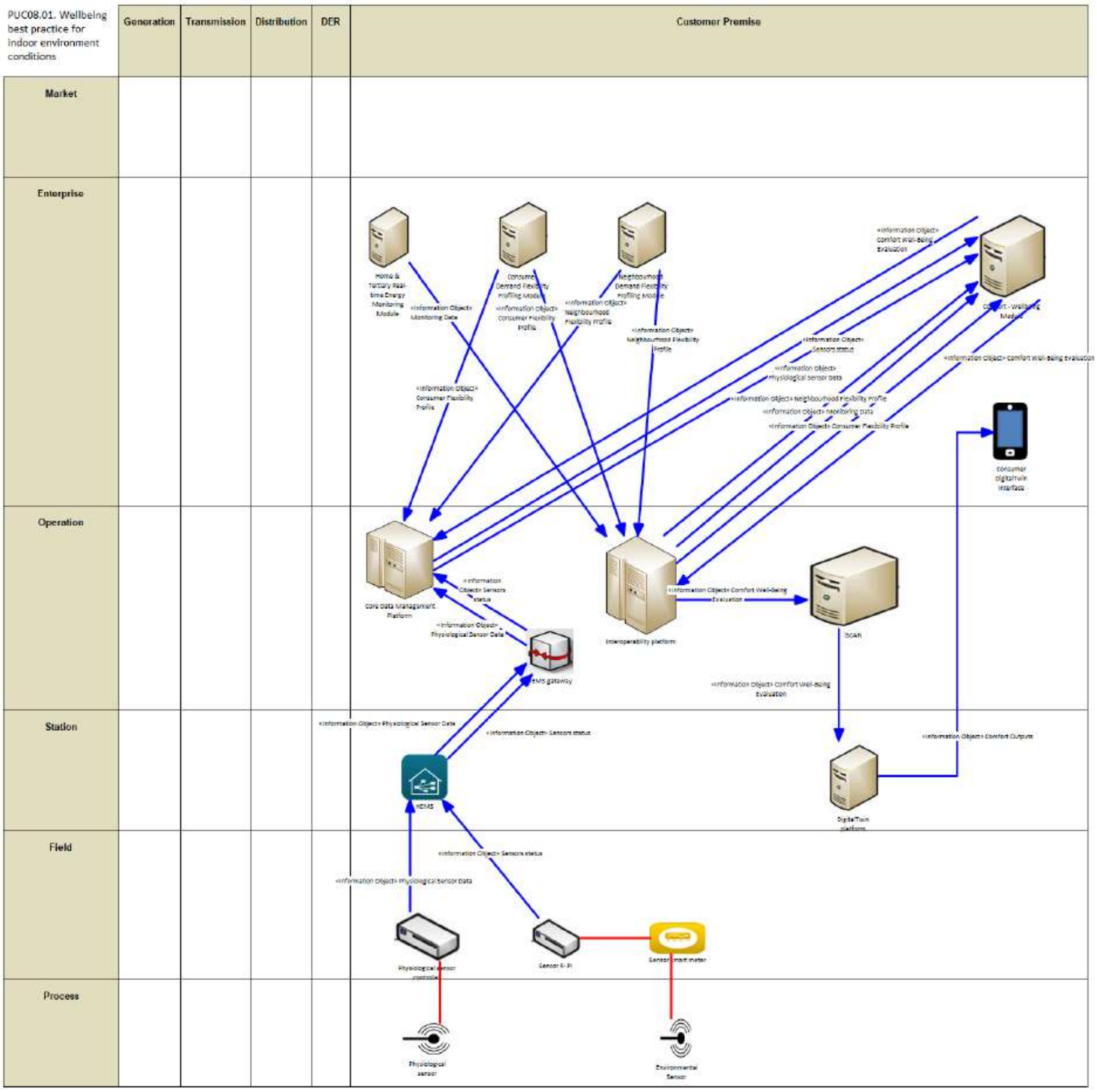

Figure 231: SGAM Information Layer PUC08.01

12.1.6. Canonical Data Model

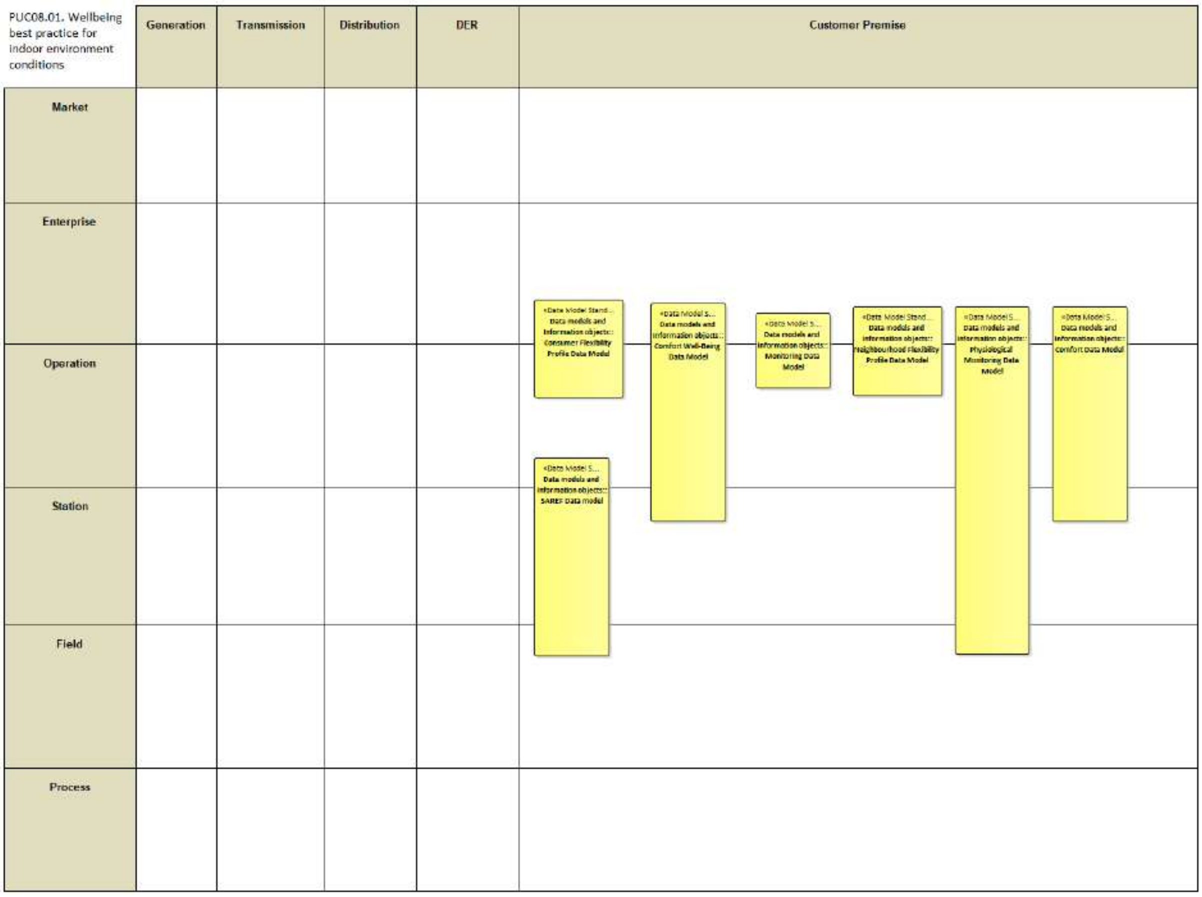

Figure 232: SGAM Canonical Data Model PUC08.01

Table 136: List of Data Models PUC08.01

Data Models
Consumer Flexibility Profile Data Model
SAREF Data Model
Comfort Well-being Data Model
Energy Data Model
Neighbourhood Flexibility Profile Data Model
Physiological Monitoring Data Model
Comfort Data Model

Twinergy has received funding from the European Union's Horizon 2020 research and innovation programme under grant agreement No. 957736

12.1.7. Standards and Information Object Mapping

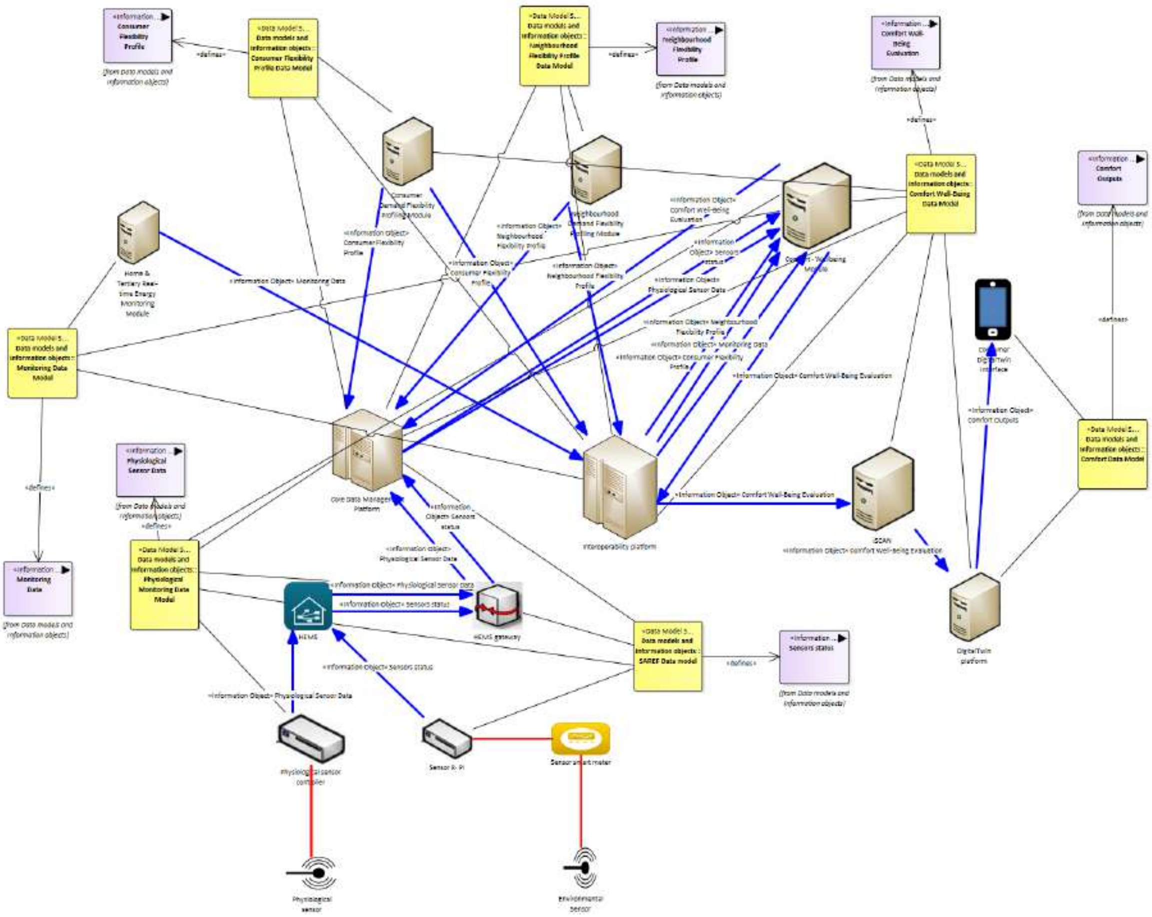

Figure 233: SGAM Standards and Information Object Mapping PUC08.01

Table 137: List of Information Objects PUC08.01

Information Objects	Data Models
Energy Data	Energy Data Model
Consumer Flexibility Profile	Consumer Flexibility Profile Data Model
Neighbourhood Flexibility Profile	Neighbourhood Flexibility Profile Data Model
Comfort Well-Being Evaluation	Comfort Well-Being Data Model
Comfort Outputs	Comfort Data Model
Sensors status	SAREF Data model
Physiological Sensor Data	Physiological Monitoring Data Model

12.1.8. Activity Diagram

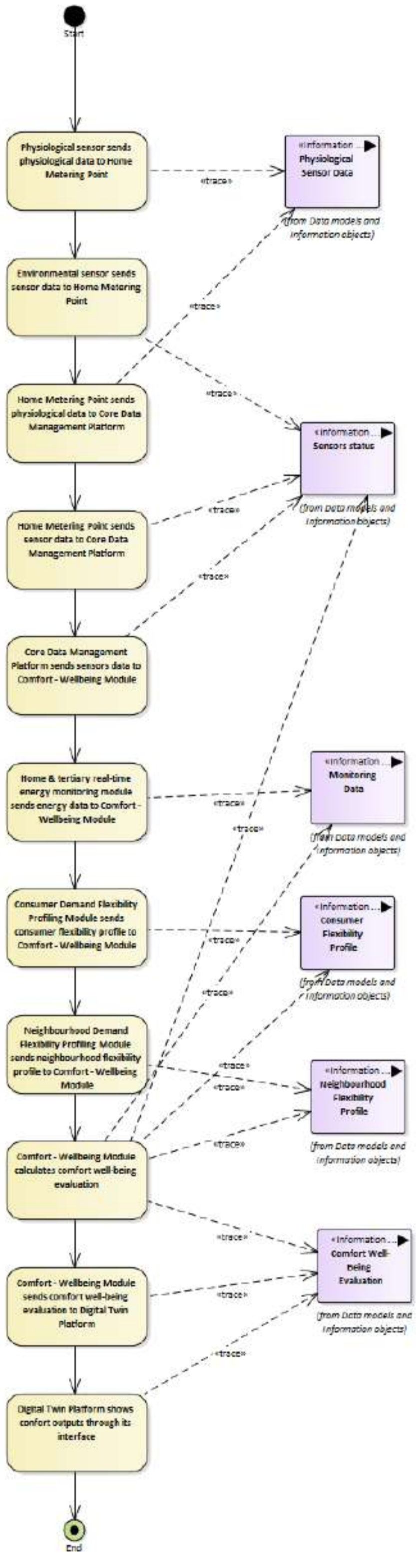

Figure 234: SGAM Activity Diagram PUC08.01

Twinergy has received funding from the European Union's Horizon 2020 research and innovation programme under grant agreement No. 957736

12.1.9. Sequence Diagram

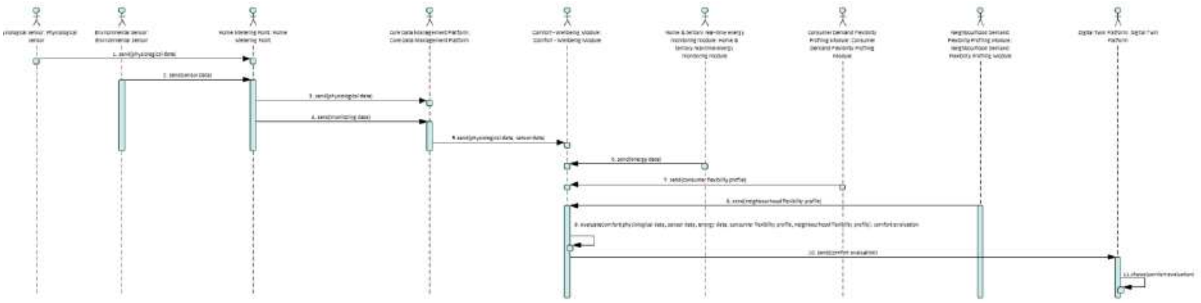

Figure 235: SGAM Sequence Diagram PUC08.01

12.2. PUC08.02. Physiological parameter and comfort feedback monitoring

12.2.1. Use Case Description

This use case aims to show the feasibility of making optimal decisions of energy consumption allocation while preserving occupant's acceptable comfort.

The Comfort -Wellbeing module pushes the occupant's assessed thermal comfort to the Consumer Digital Twin (CDT) as shown in the figure below.

Figure 236: Thermal Comfort Well-being Module (4)

Alongside this, the CDT will provide the opportunity to occupants to provide their feedback regarding thermal sensation by vote, as can be seen in the following Figure 237. Occupants can vote multiple times during the day and these data shall be used for validating the estimated thermal comfort.

Figure 237: Thermal Comfort Well-being Module(6)

Thanks to the TwinERGY Interoperability Platform, data related to the occupant's physiological parameters and thermal comfort levels shall be available by the Comfort -

Wellbeing module and presented by the CDT along with the vote feedback regarding thermal sensation.

12.2.2. SGAM Function Layer

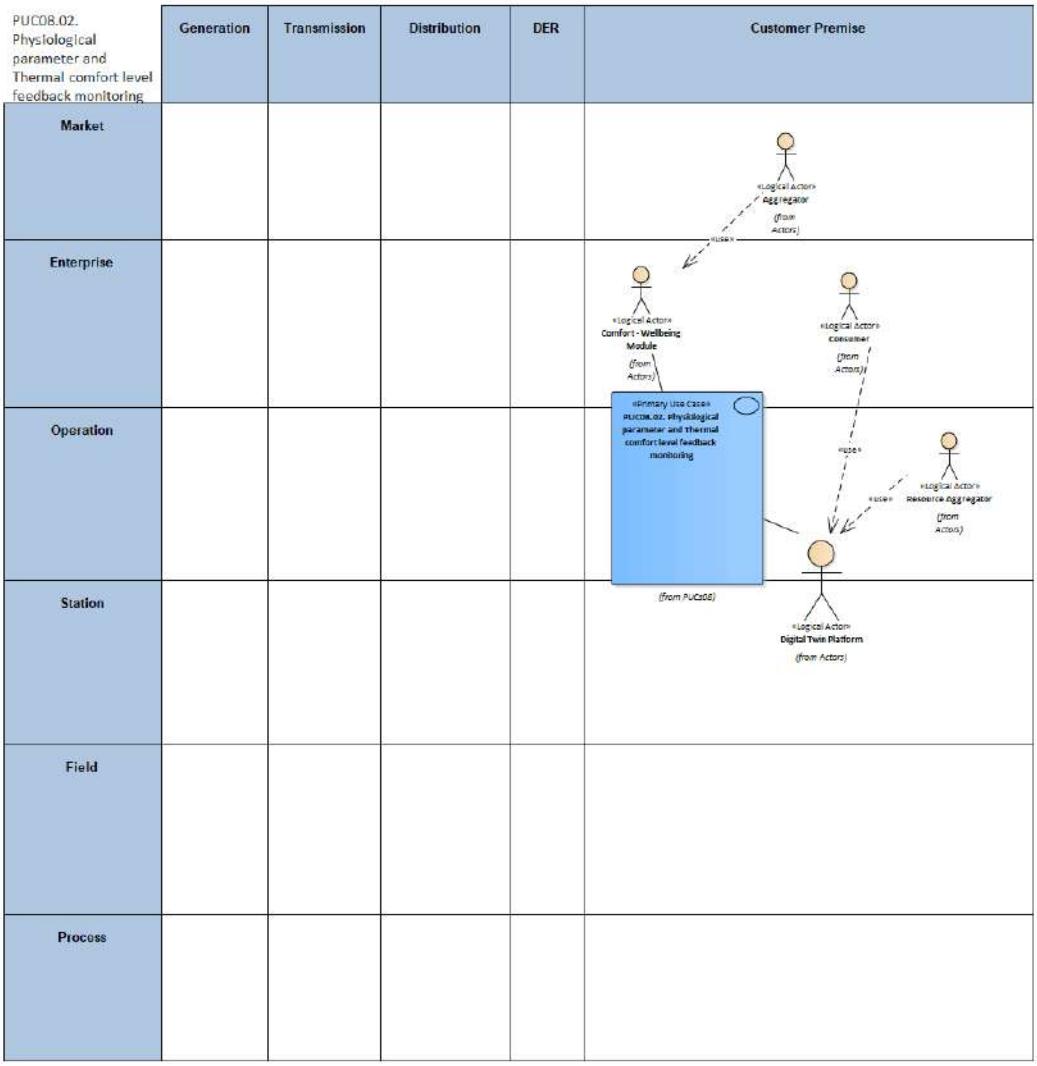

Figure 238: SGAM Function Layer PUC08.02

Table 138: List of Actors Involved PUC08.02

Actor Name	Actor Type
Comfort Wellbeing Module	Application
Aggregator	Local actor role
Consumer	Local actor role
Resource Aggregator	Local actor role
Digital Twin Platform	Application

Twinergy has received funding from the European Union's Horizon 2020 research and innovation programme under grant agreement No. 957736

12.2.3. SGAM Component Layer

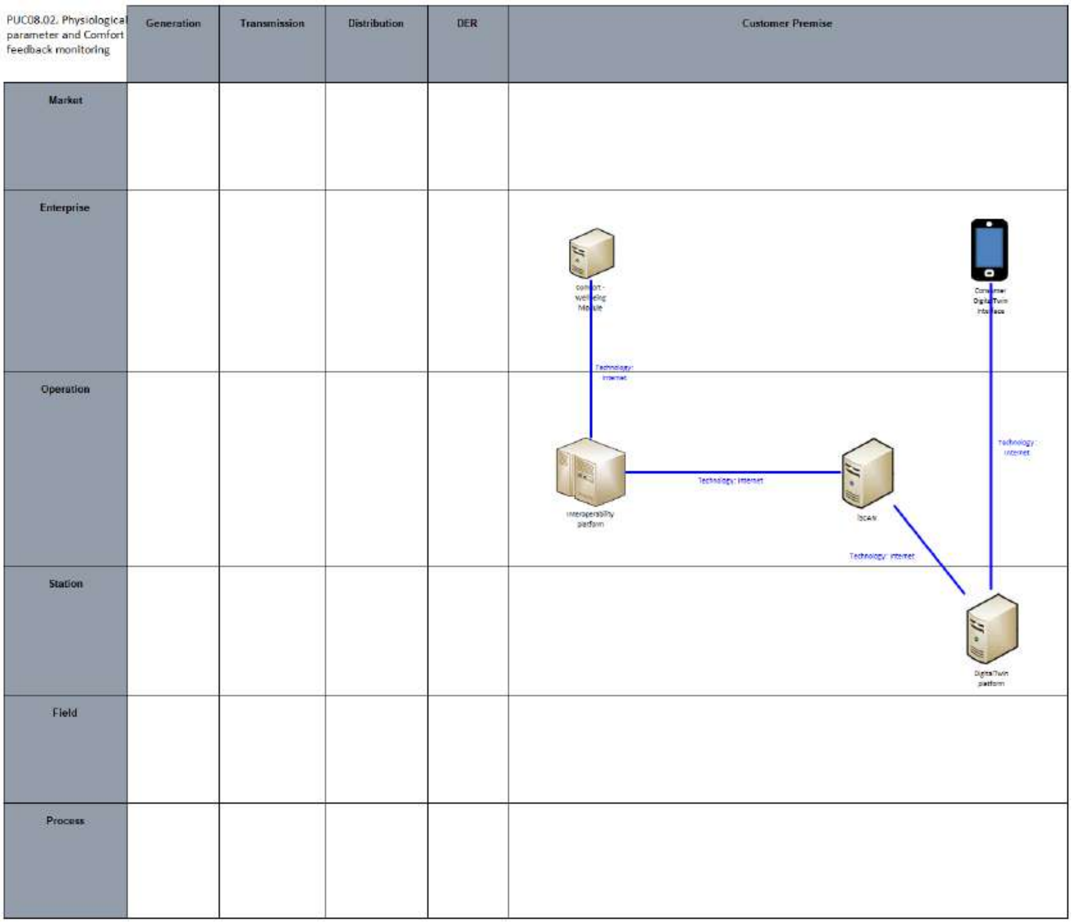

Figure 239: SGAM Component Layer PUC08.02

Table 139: List of Components PUC08.02

Component	Component Type
Consumer Digital Twin Interface	TwinERGY application
Digital Twin Platform	TwinERGY application
iSCAN	External application
Interoperability Platform	TwinERGY application
Consumer Well-being Module	TwinERGY application

Twinergy has received funding from the European Union's Horizon 2020 research and innovation programme under grant agreement No. 957736

12.2.4. SGAM Communication Layer

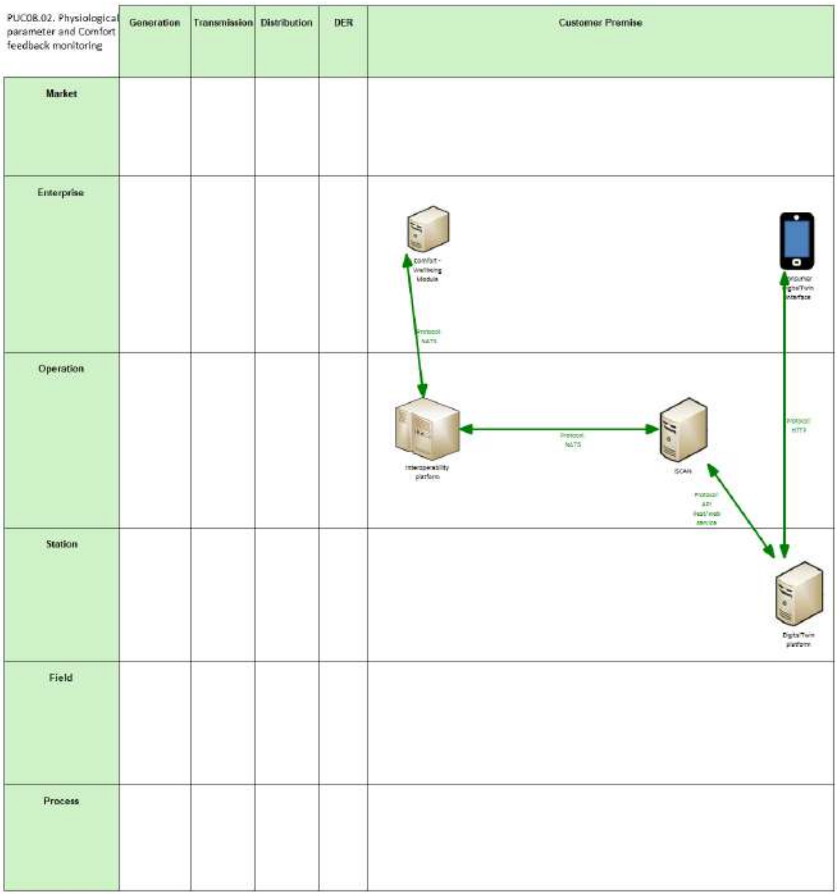

Figure 240: SGAM Communication Layer PUC08.02

Table 140: List of Communication technologies involved in PUC08.02

Communication Technology	Description
NATS	Protocol of messaging that enables the exchange of messages among computer applications and services, not depending on the network location.
HTTP	Stand for Hypertext Transfer Protocol. It is an application layer protocol in the Internet protocol suite model for distributed, collaborative, hypermedia information systems
API REST	Application Programming Interface for REpresentational State Transfer. API is a software intermediary that allows two applications to talk to each other, whilst REST is an architectural style for distributed hypermedia systems, working stateless. Both define a set of distributed resources accessible and manipulable through a set of public functions.

12.2.5. SGAM Information Layer

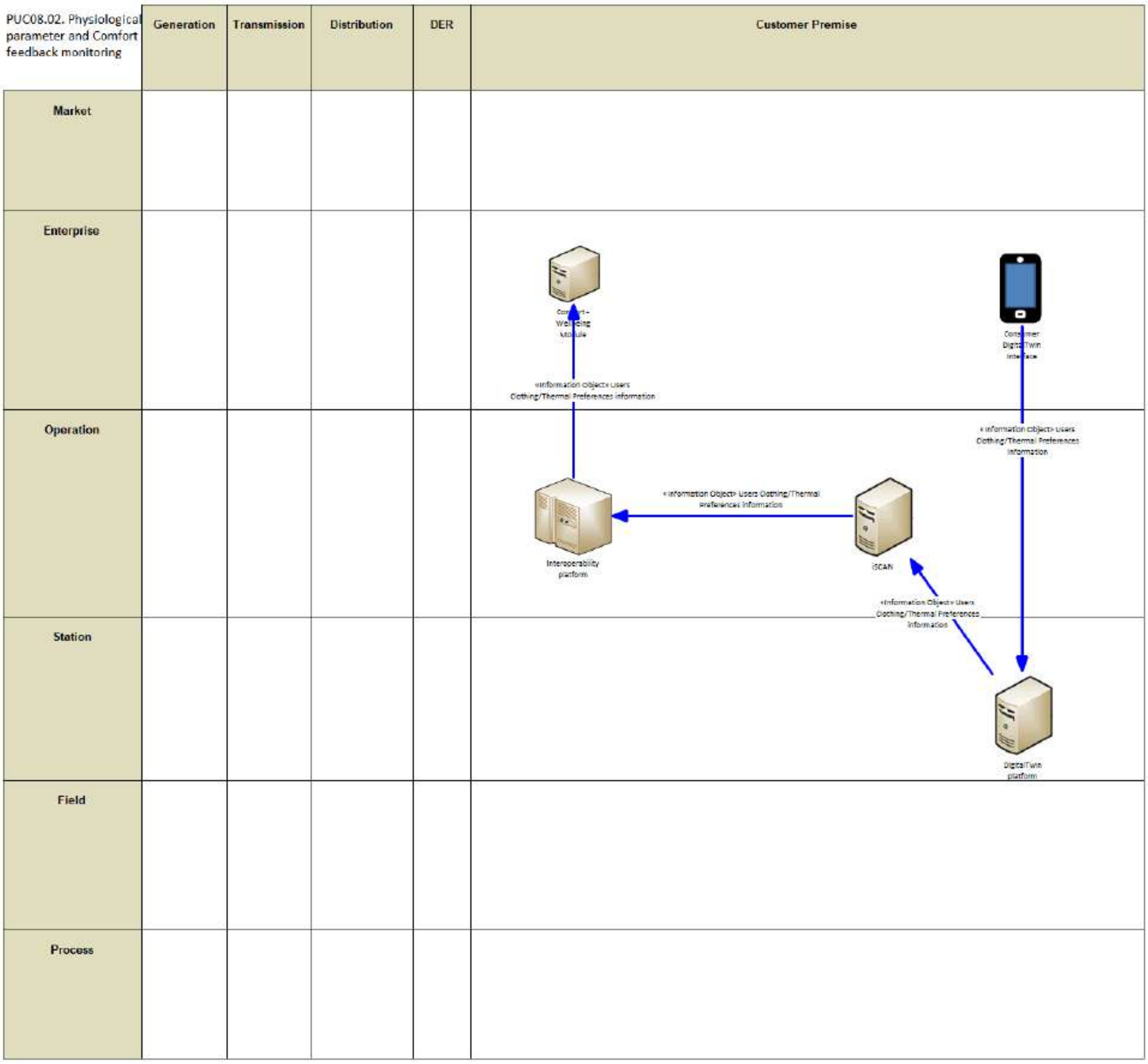

Figure 241:SGAM Information Layer PUC08.02

12.2.6. Canonical Data Model

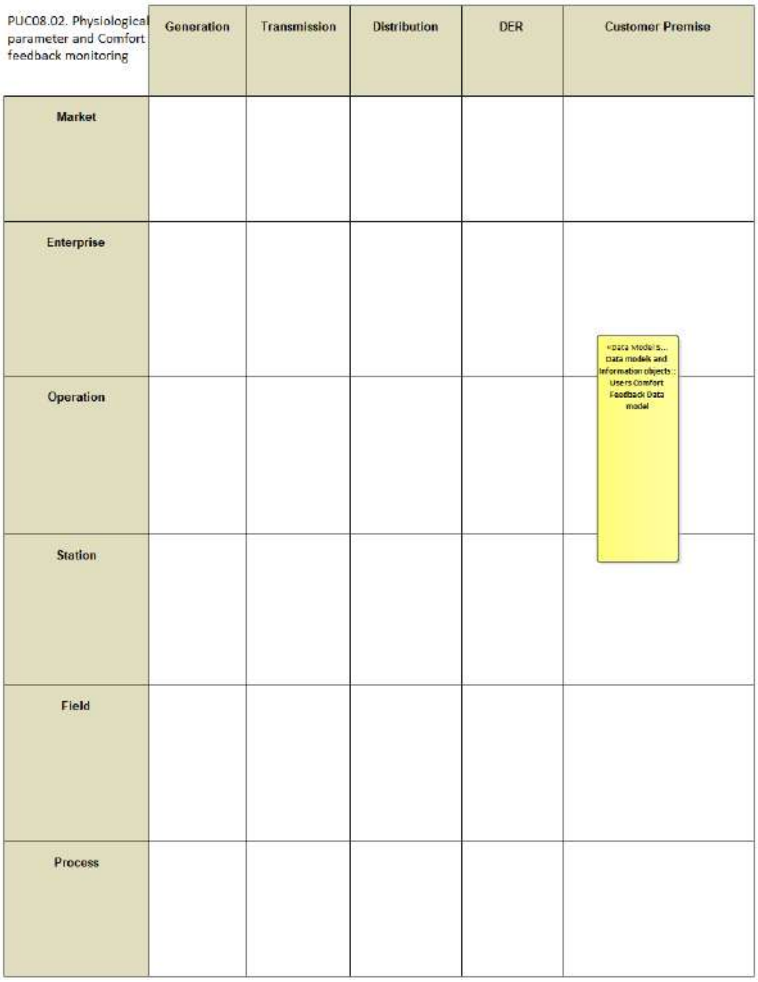

Figure 242: SGAM Canonical Data Model PUC08.02

Table 141: List of Data Models PUC08.02

Data Models
Users Comfort Feedback Data Model

12.2.7. Standards and Information Object Mapping

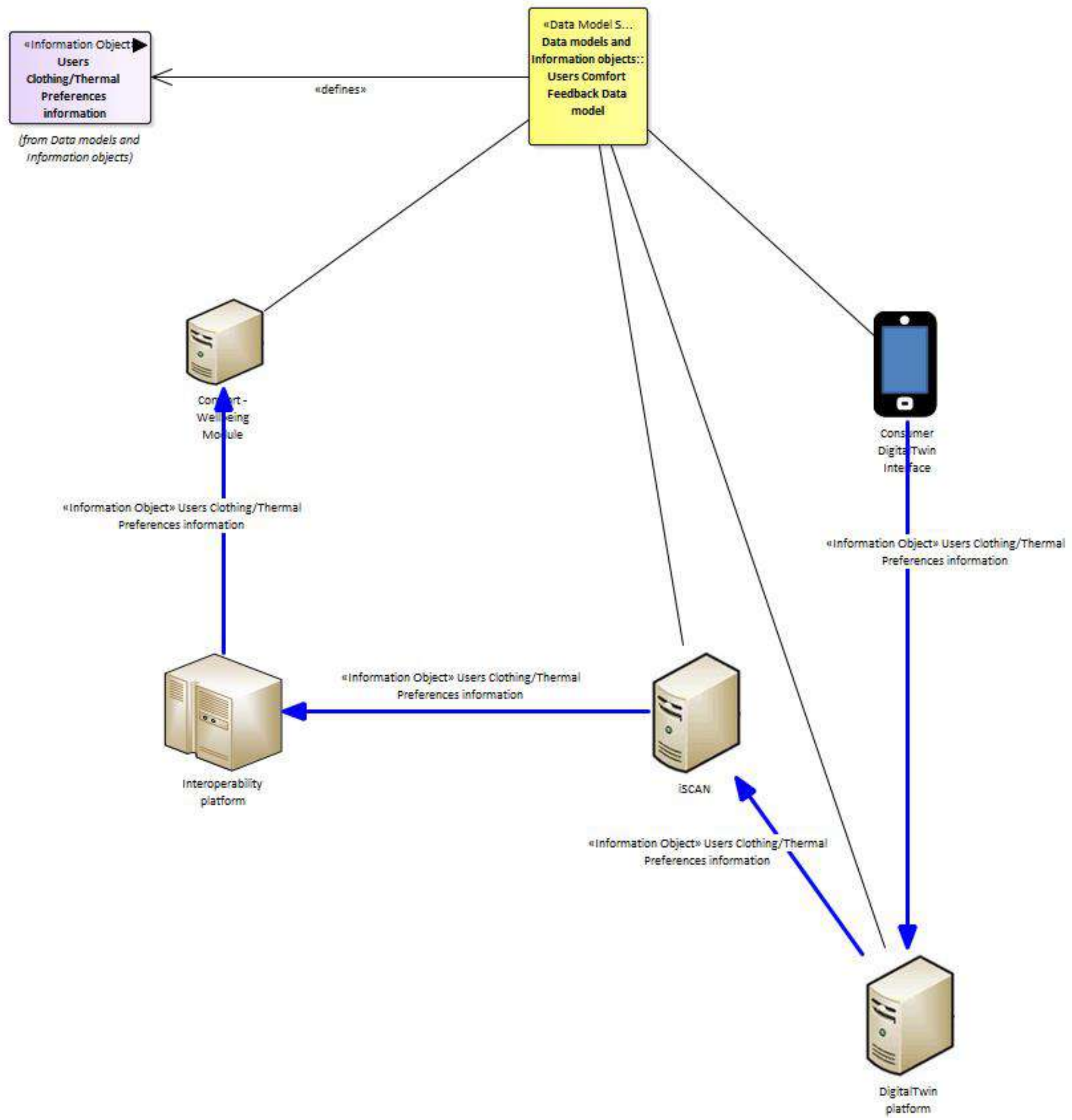

Figure 243: SGAM Standards and Information Object Mapping PUC08.02

Table 142: List of Information Objects PUC08.02

Information Objects	Data Models
Users Clothing/Thermal Preferences information	Users Comfort Feedback Data model

12.2.8. Activity Diagram

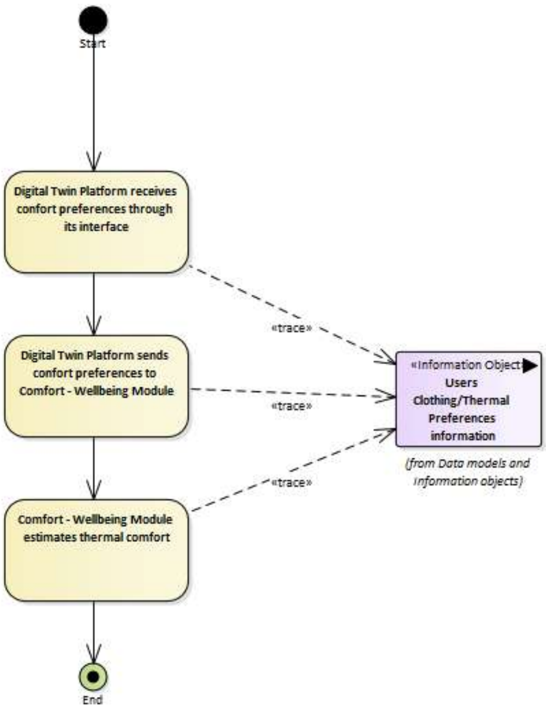

Figure 244: SGAM Activity Diagram PUC08.02

12.2.9. Sequence Diagram

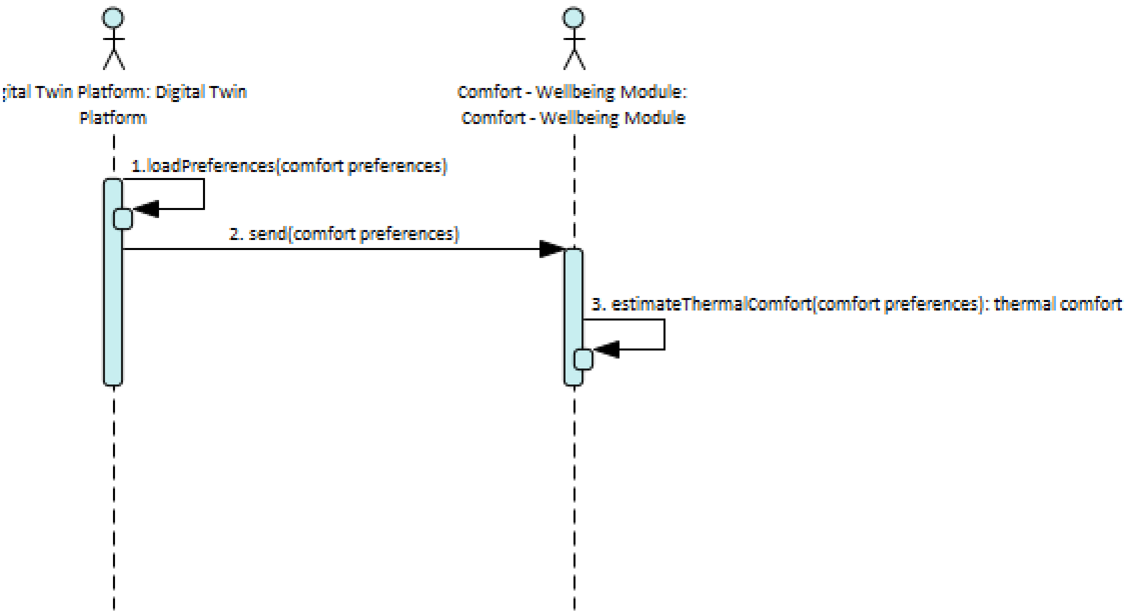

Figure 245: SGAM Sequence Diagram PUC08.02

Twinergy has received funding from the European Union's Horizon 2020 research and innovation programme under grant agreement No. 957736

12.3. PUC08.03. Comfort relation within Demand Response optimal solution

12.3.1. Use Case Description

The use case aims to show the feasibility of making decisions regarding energy consumption allocation according to the occupant's energy consumption flexibility, while also accounting for the occupant's preferences.

In order to continuously assess the occupant's thermal comfort level and well-being status, the Comfort - Wellbeing Module processes a set of:

- Indoor Air Quality parameters (Air Temperature, Relative Humidity, Visual, Acoustic and concentration of Indoor Air Pollutants),
- Outdoor environmental parameters (Air Temperature, Relative Humidity),
- Physiological parameters,
- Motion status, and
- Clothing Insulation,

Which is eventually pushed to the Consumer Digital Twin (CDT).

Moreover, the occupant inserts a set of preferences in the form of constraints, which can change at any time through a friendly Graphical User Interface provided by the CDT. These preferences are mainly related to the desired range of thermal comfort level and well-being status but could include the upper and lower monthly billing limits and the eco – friendliness level as shown in the figures below.

Figure 246: Thermal Comfort Well-being Module(7)

Figure 247: Thermal Comfort Well-being Module (8)

Figure 248: Thermal Comfort Well-being Module (9)

Figure 249: Thermal Comfort Well-being Module

Thanks to the TwinERGY interoperability platform, the occupant's calculated Thermal comfort level and Wellbeing status as well as the corresponding preferences can be diffused from the CDT to the appropriate TwinERGY modules, namely Consumer and Neighbourhood Demand Flexibility Profiling modules and the Home & Tertiary Real-time Energy Monitoring Module, so they can undertake any proper Demand Response action service.

As the CDT is constantly updated with the status and the consumption details of the related loads (e.g., HVAC) and the occupant's thermal comfort level and wellbeing status, an evaluation assessment regarding the degree of occupants' preferences accomplishment shall be generated accompanied possibly by related remarks.

12.3.2. SGAM Function Layer

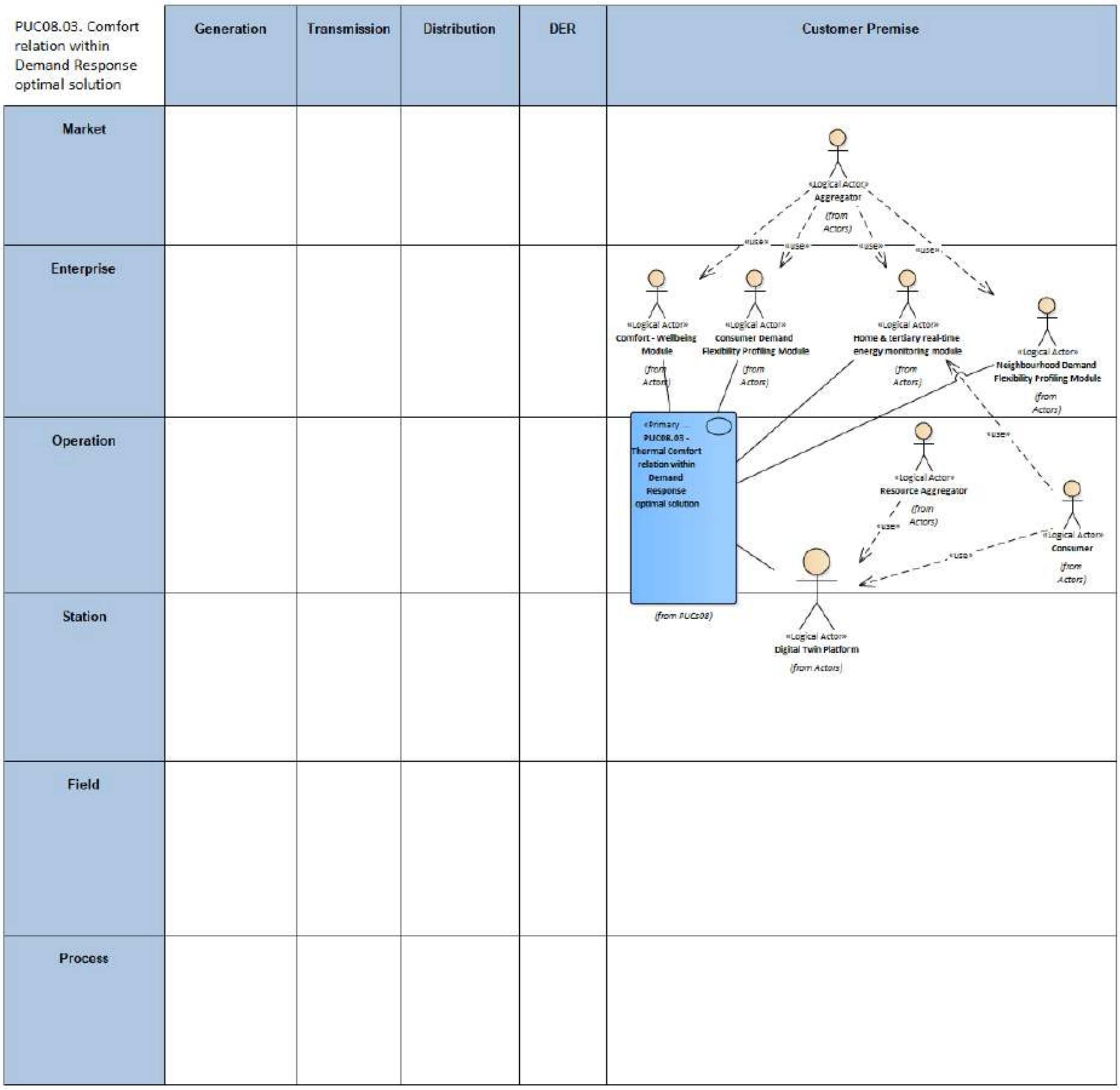

Figure 250: SGAM Function Layer PUC08.03

Table 143: List of Actors Involved PUC08.03

Actor Name	Actor Type
Aggregator	Local actor role
Comfort – Wellbeing Module	Application
Consumer Demand Flexibility Profiling Module	Application
Home & Tertiary real-time energy monitoring module	Application

Neighbourhood Demand Flexibility Profiling Module	Application
Resource Aggregator	Local actor role
Consumer	Local actor role
Digital Twin Platform	Application

12.3.3. SGAM Component Layer

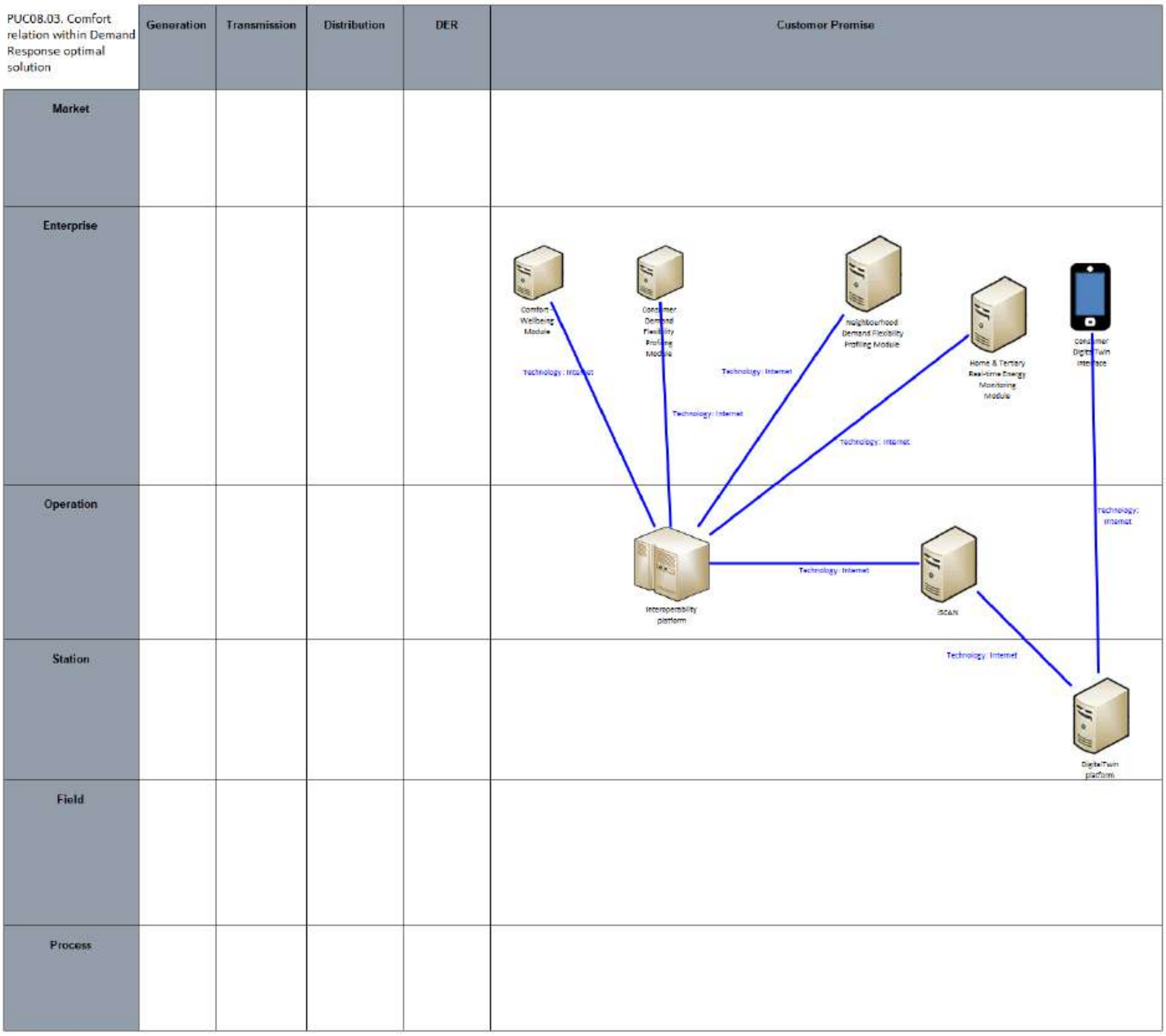

Figure 251: SGAM Component Layer PUC08.03

Table 144: List of Components PUC08.03

Component	Component Type

Twinergy has received funding from the European Union's Horizon 2020 research and innovation programme under grant agreement No. 957736

Consumer Digital Twin Interface	TwinERGY application
Digital Twin Platform	TwinERGY application
iSCAN	External application
Interoperability platform	TwinERGY application
Comfort-Wellbeing Module	TwinERGY application
Consumer Demand Flexibility Profiling Module	TwinERGY application
Neighbourhood Demand Flexibility Profiling Module	TwinERGY application
Home & Tertiary Real-time Energy Monitoring Module	TwinERGY application

12.3.4. SGAM Communication Layer

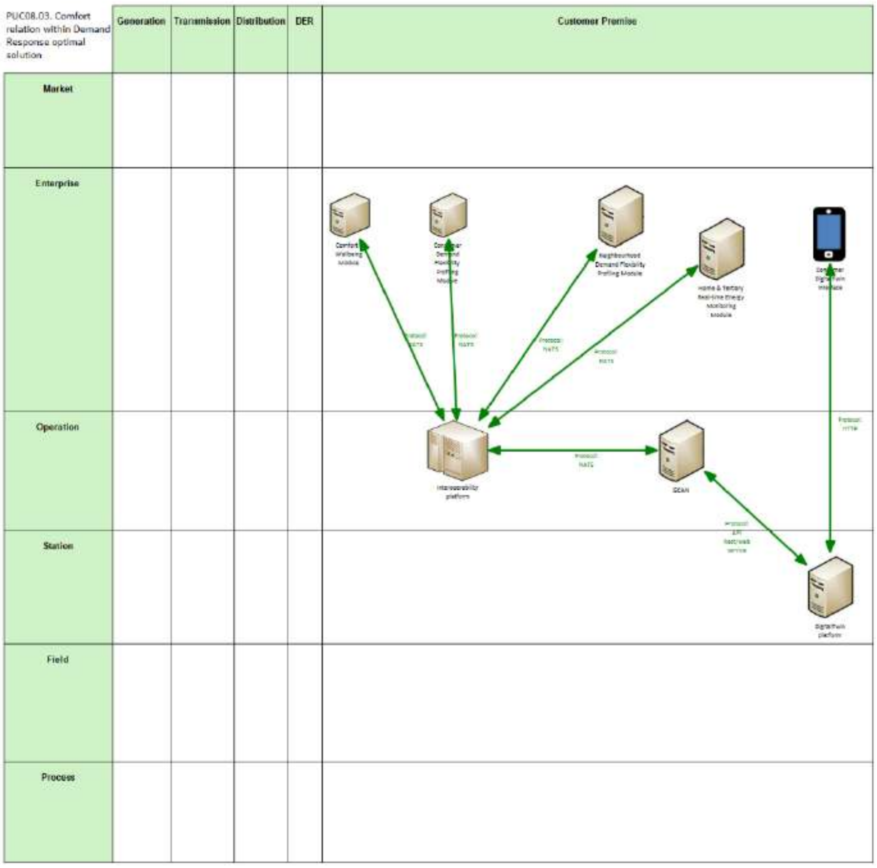

Figure 252: SGAM Communication Layer PUC08.03

Twinergy has received funding from the European Union's Horizon 2020 research and innovation programme under grant agreement No. 957736

Table 145: List of Communication technologies involved in PUC08.03

Communication Technology	Description
NATS	Protocol of messaging that enables the exchange of messages among computer applications and services, not depending on the network location.
HTTP	Stand for Hypertext Transfer Protocol. It is an application layer protocol in the Internet protocol suite model for distributed, collaborative, hypermedia information systems
API REST	Application Programming Interface for REpresentational State Transfer. API is a software intermediary that allows two applications to talk to each other, whilst REST is an architectural style for distributed hypermedia systems, working stateless. Both define a set of distributed resources accessible and manipulable through a set of public functions.

12.3.5. SGAM Information Layer

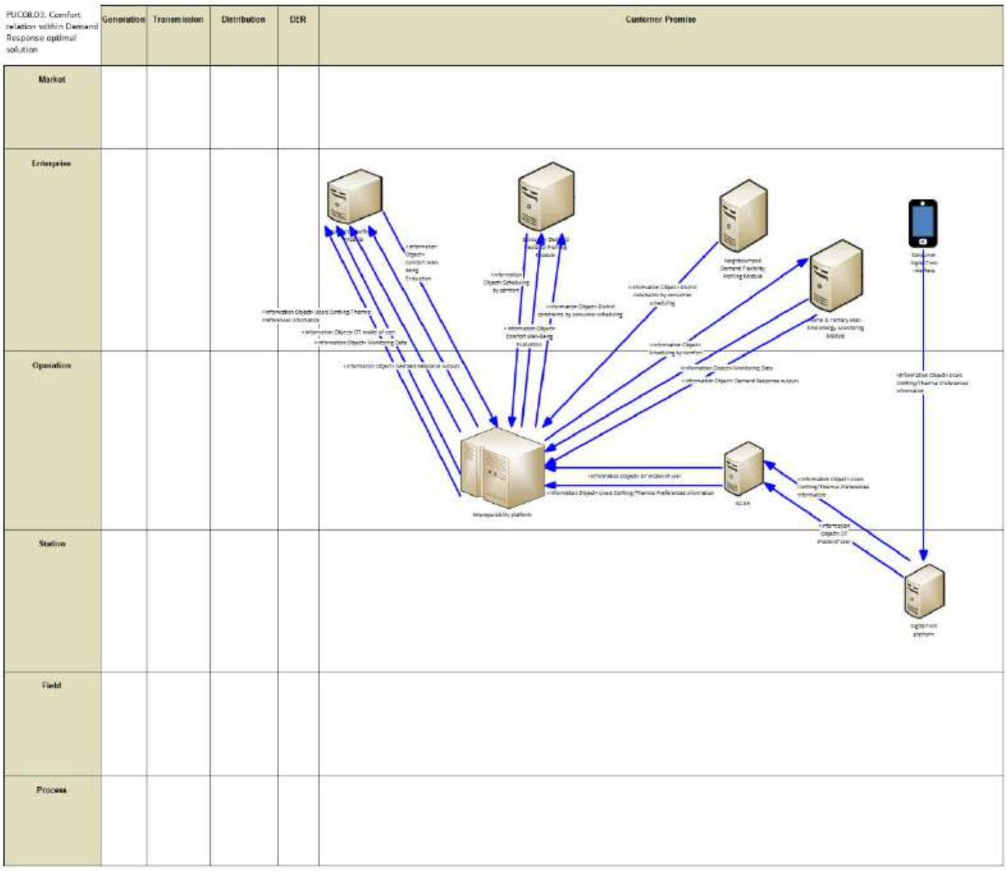

Figure 253: SGAM Information Layer PUC08.03

Twinergy has received funding from the European Union's Horizon 2020 research and innovation programme under grant agreement No. 957736

12.3.6. Canonical Data Model

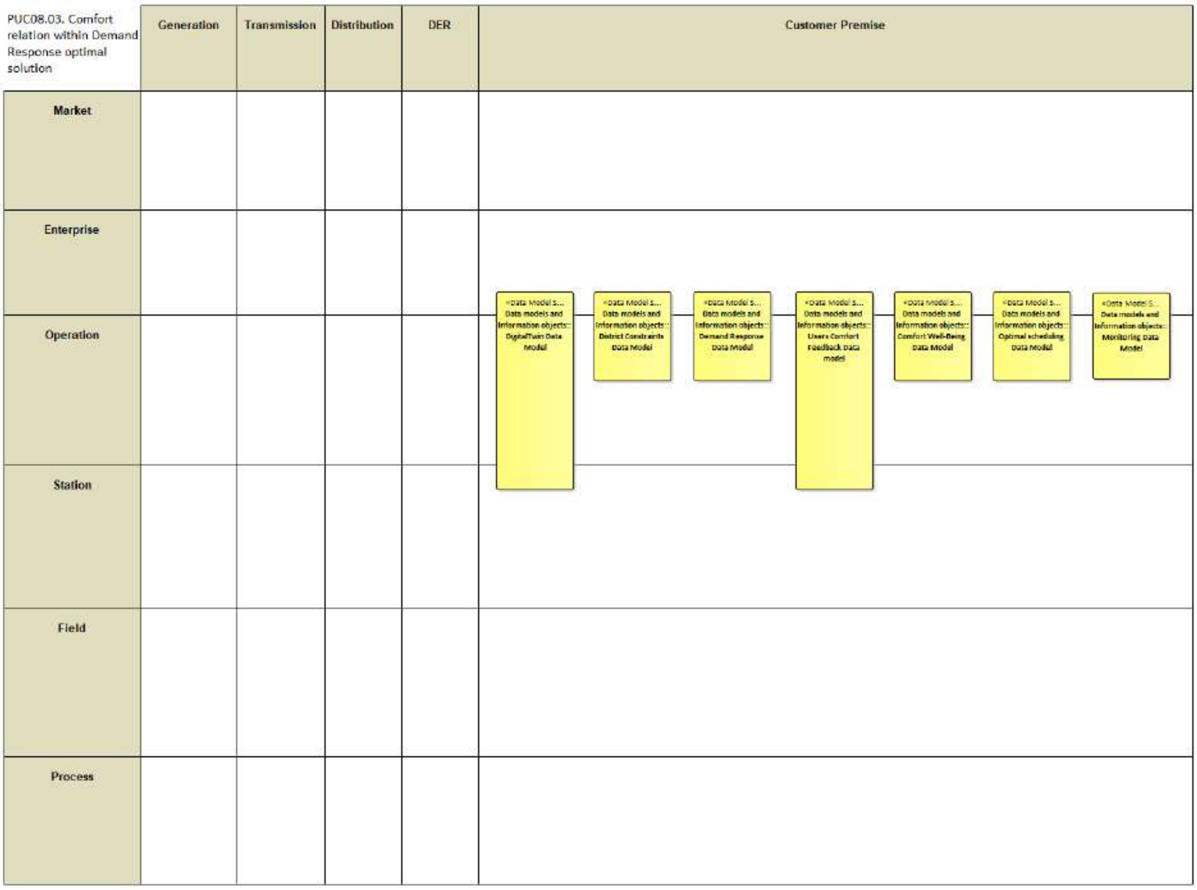

Figure 254: SGAM Canonical Data Model PUC08.03

Table 146: List of Data Models PUC08.03

Data Models
Digital Twin Data Model
District Constraints Data Model
Demand Response Data Model
User Comfort Feedback Data Model
Comfort Well-being Data Model
Optimal Scheduling Data Model
Energy Data Model

12.3.7. Standards and Information Object Mapping

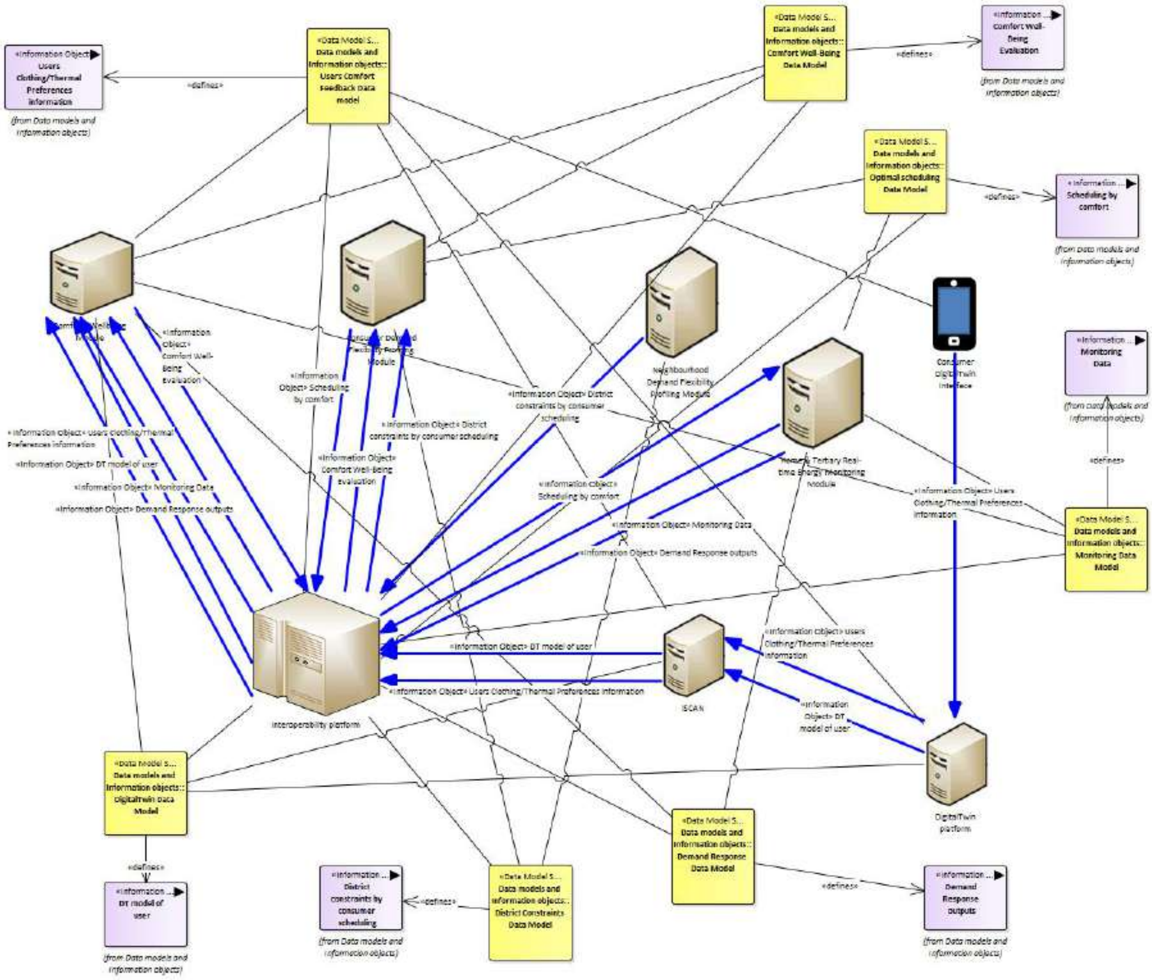

Figure 255: SGAM Standards and Information Object Mapping PUC08.03

Table 147: List of Information Objects PUC08.03

Information Objects	Data Models
Users Clothing/Thermal Preferences information	Users Comfort Feedback Data model
Comfort Well-Being Evaluation	Comfort Well-Being Data Model
Scheduling by comfort	Optimal scheduling Data Model
Energy Data	Energy Data Model
Demand Response outputs	Demand Response Data Model
District constraints by consumer scheduling	District Constraints Data Model

DT model of user	DigitalTwin Data Model

12.3.8. Activity Diagram

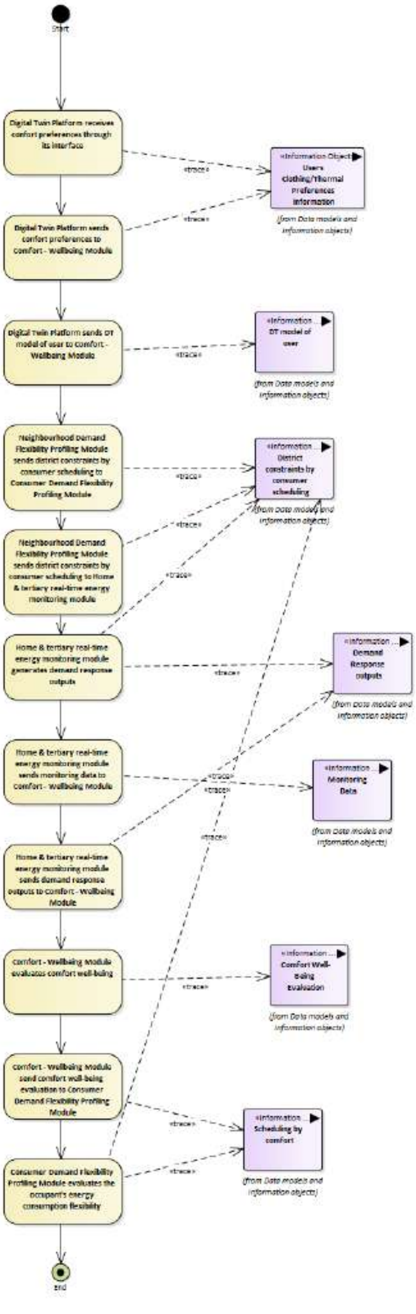

Figure 256: SGAM Activity Diagram PUC08.03

12.3.9. Sequence Diagram

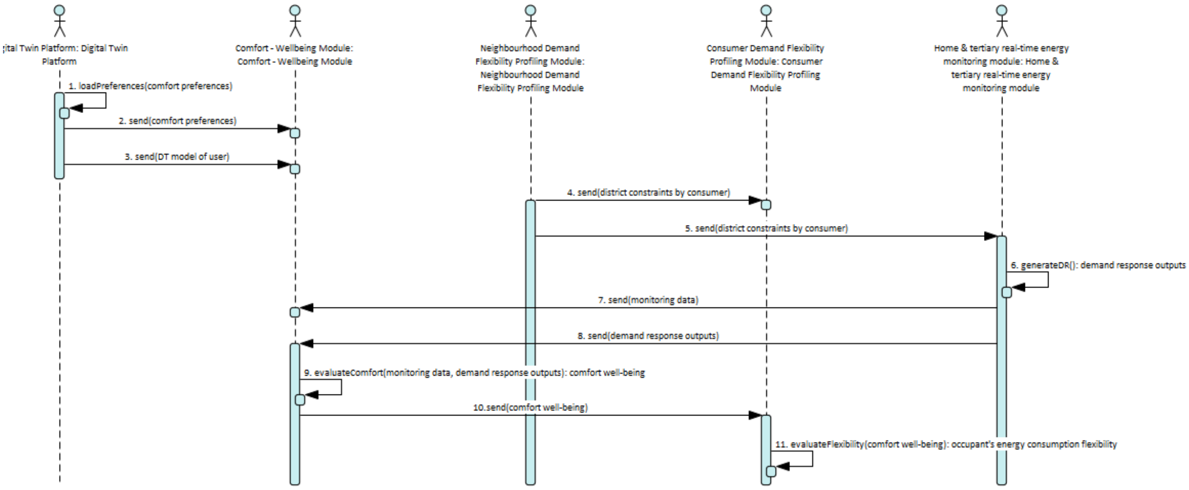

Figure 257: SGAM Sequence Diagram PUC08.03

12.4. SGAM Business Layer

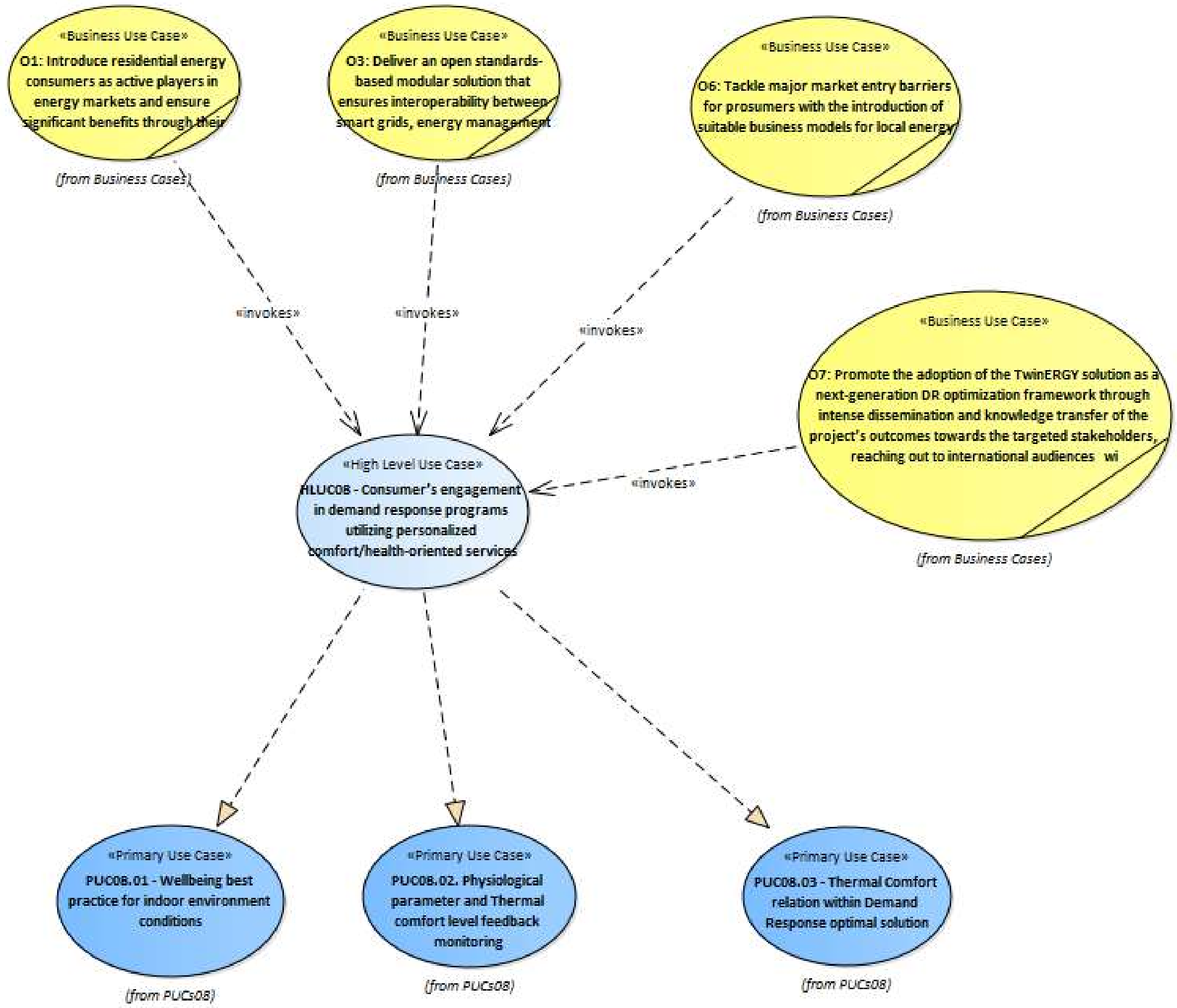

Figure 258: SGAM Business Layer HLUC08

13. HLUC09. Consumer Engagement in Demand Response Programs Utilizing Digital Twin Prediction Capabilities for Dynamic VPPs

13.1. PUC09.01 Explicit Demand Response Automation and display at a consumer and community level.

13.1.1. Use Case Description

The optimisation algorithm within the Digital Twins Platform (that form the basis of both Consumer and Neighbourhood Demand Flexibility Profiling Modules) is used to identify flexible loads and determines when is the best time to shift them to. The optimisation algorithm is based on:

- Renewable generation forecasts (from RES integration & DER management Module),
- Predicted building and community demand, and
- Associated energy prices (retrieved from ENTSO-e).

Once calculated, this flexible load capacity can then be used to enact explicit demand response actions in the buildings of the communities as permitted by end users. This information can also be used after the fact by community/town planners to evaluate future solutions for their community, by DSO planners and operators to plan future expansion and upgrade of the network as required and can also feed into the pricing calculation by community aggregators if required.

13.1.2. SGAM Function Layer

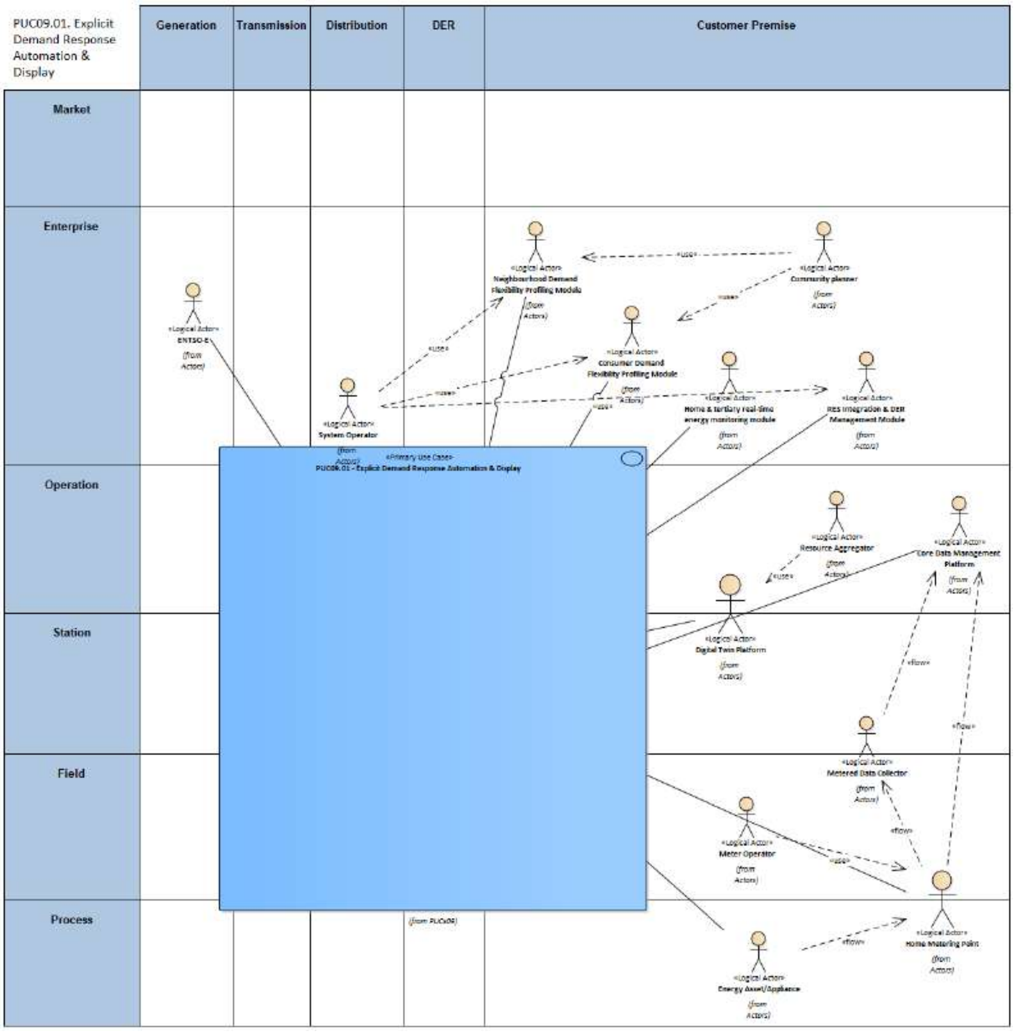

Figure 259: SGAM Function Layer PUC09.01

Table 148: List of Actors Involved PUC09.01

Actor Name	Actor Type

ENTSO-E	Application
System Operator	Organization
Neighbouhood Demand Flexibility Profiling Module	Application
Consumer Demand Flexibility Profiling Module	Application
Community planner	Logical actor role
Home & Tertiary real-time energy monitoring module	Application
RES integration & DER Management Module	Application
Digital Twin Platform	Application
Resource Aggregator	Logical actor role
Core Data Management Platform	Application
Metered Data Collector	Device
Meter Operator	Device
Home Metering Point	Device
Energy asset/appliance	Device

13.1.3. SGAM Component Layer

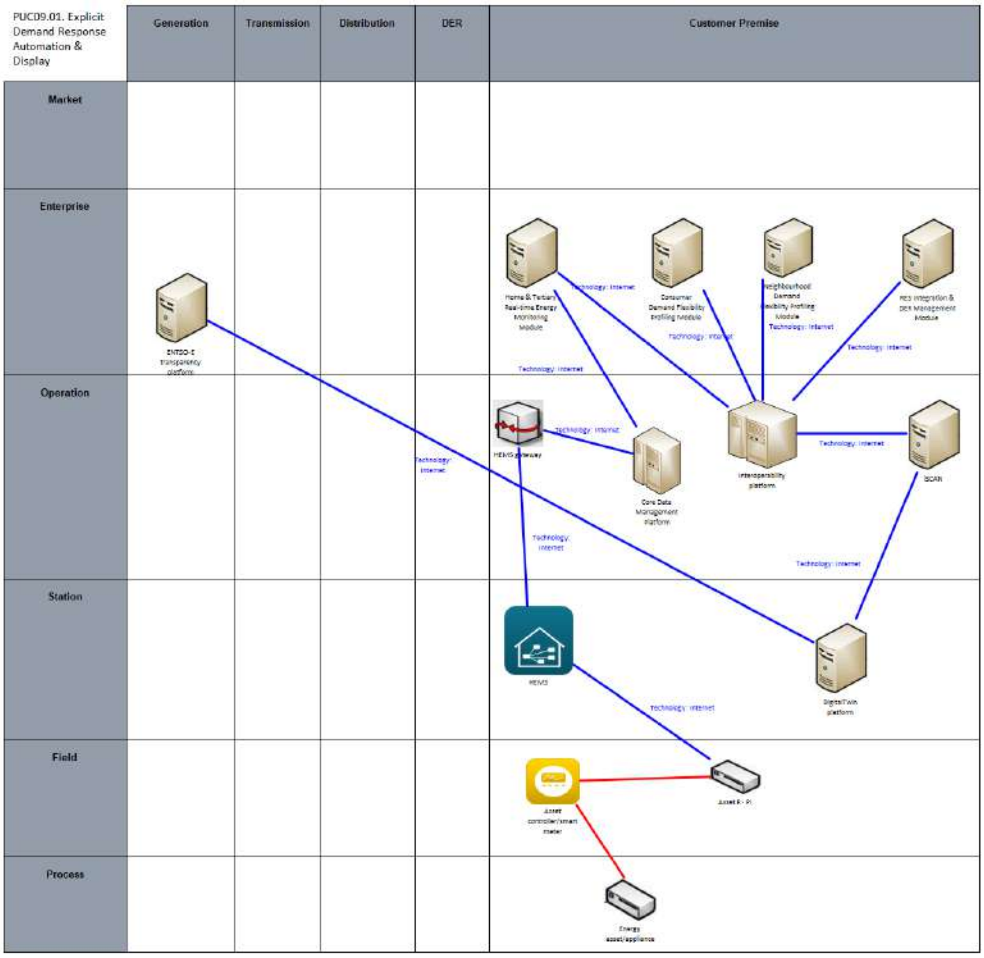

Figure 260: SGAM Component layer PUC09.01

Table 149: List of Components PUC09.01

Component	Component Type
Energy asset/appliance	Physical asset
Asset Controler/ Smart Meter	Physical asset
Raspberry-Pi	Physical asset
HEMS	External application
HEMS gateway	External application
Core Data Management Platform	TwinERGY application
Interoperability Platform	TwinERGY application

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Home & Tertiary Real-time Energy Monitoring Module	TwinERGY application
Consumer Demand Flexibility Profiling Module	TwinERGY application
Neighbourhood Demand Flexibility Profiling Module	TwinERGY application
RES integration & DER Management Module	TwinERGY application
ENTSO-E transparency platform	External application
Digital Twin Platform	TwinERGY application
iSCAN	External application

13.1.4. SGAM Communication Layer

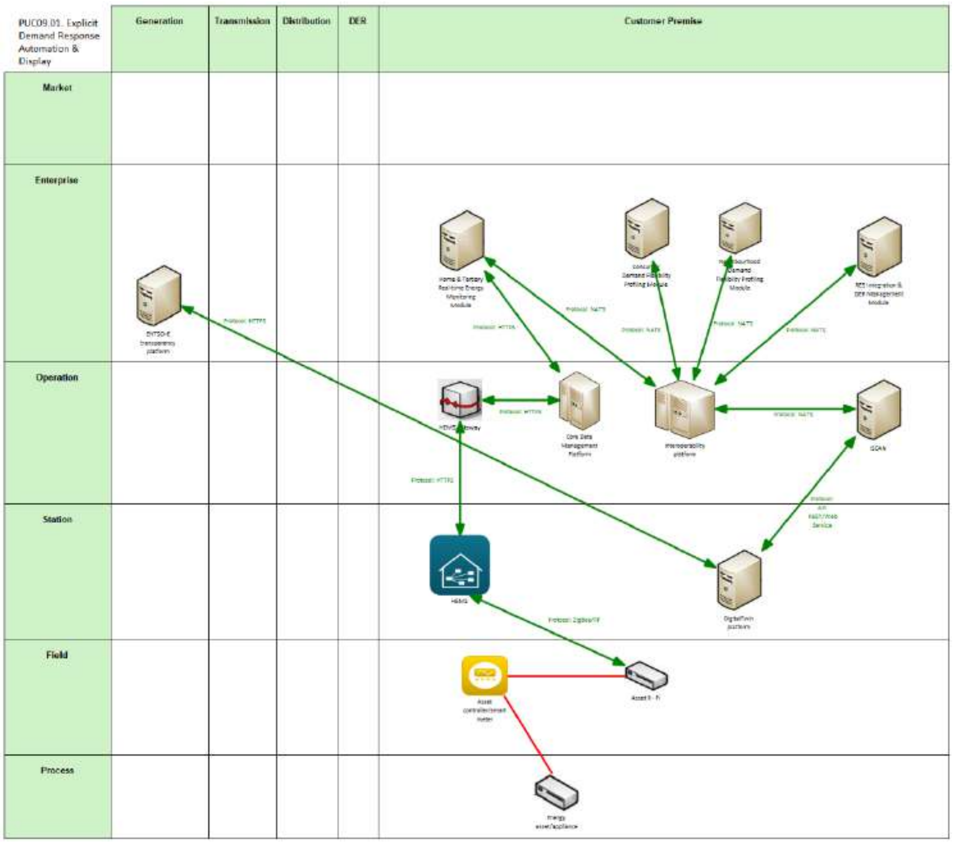

Figure 261: SGAM Communication Layer PUC09.01

Twinergy has received funding from the European Union's Horizon 2020 research and innovation programme under grant agreement No. 957736

Table 150: List of Communication technologies involved in PUC09.01

Communication Technology	Description
ZigBEE/RF	Protocol IEEE 802.15.4, designed to communicate data through noisy RF environments. This standard operates on the physical radio specification and operates in unlicensed bands including 2.4 GHz, 900 MHz and 868 MHz.
HTTPS	HyperText Transfer Protocol Secure. It is an extension of the Hypertext Transfer Protocol (HTTP), used for secure communication over a computer network. In HTTPS, the communication protocol is encrypted using Transport Layer Security (TLS) or, formerly, Secure Sockets Layer (SSL). The protocol is therefore also referred to as HTTP over TLS, or HTTP over SSL.
NATS	Protocol of messaging that enables the exchange of messages among computer applications and services, not depending on the network location.

13.1.5. SGAM Information Layer

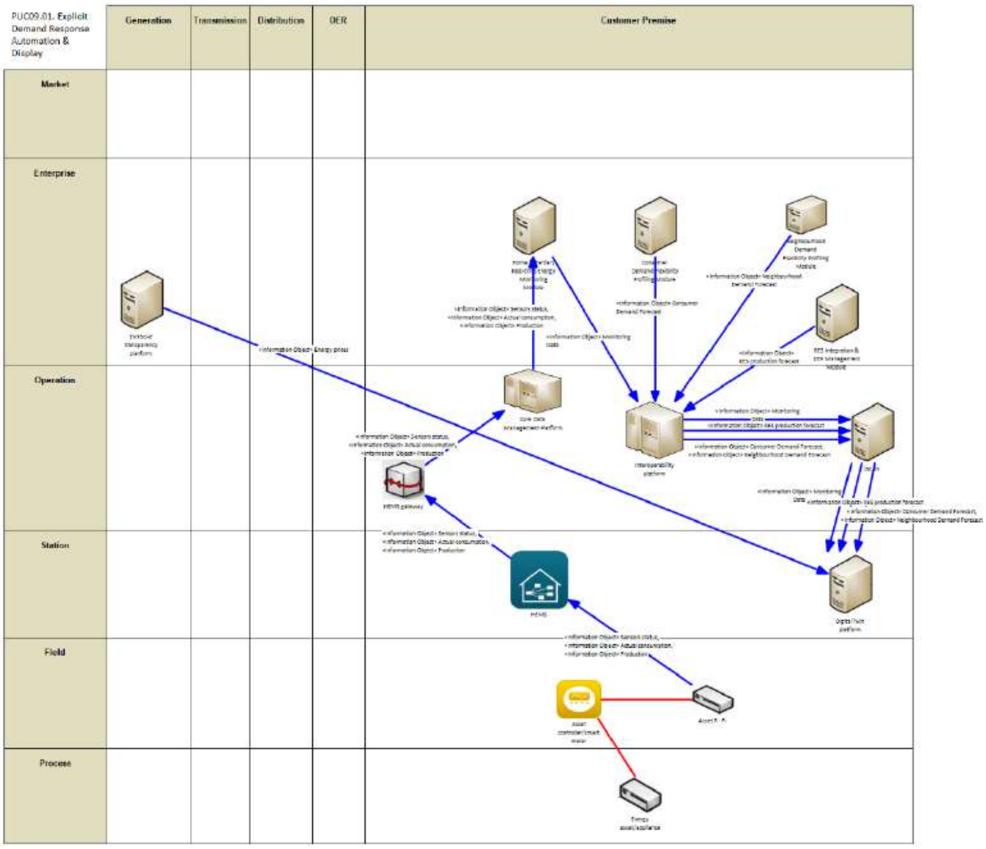

Figure 262: SGAM Information Layer PUC09.01

13.1.6. Canonical Data Model

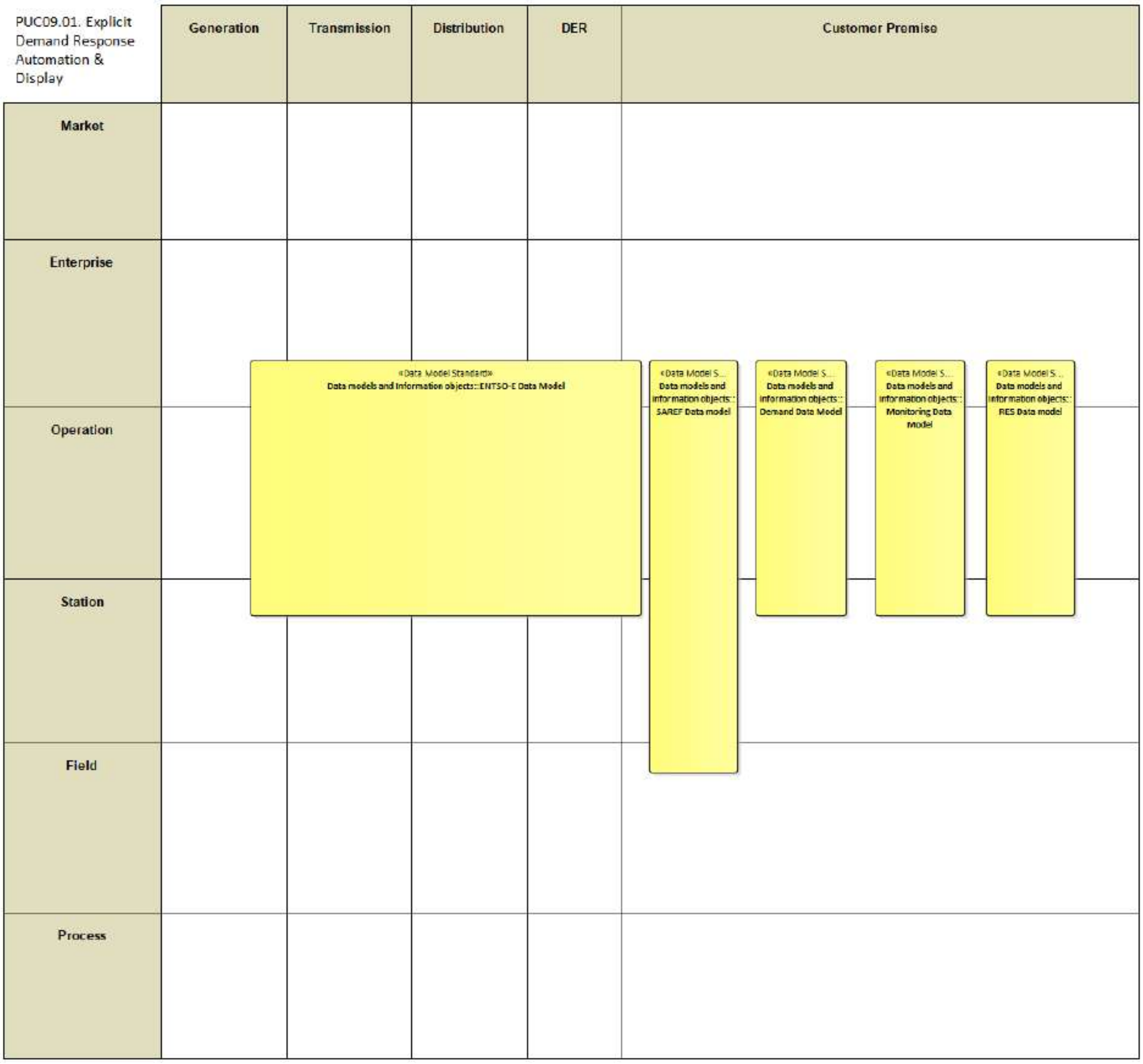

Figure 263: SGAM Canonical Data Model PUC09.01

Table 151: List of Data Models PUC09.01

Data Models
ENTSO-E Data Models
SAREF Data Model
Demand Data Models
Energy Data Models
RES Data Model

13.1.7. Standards and Information Object Mapping

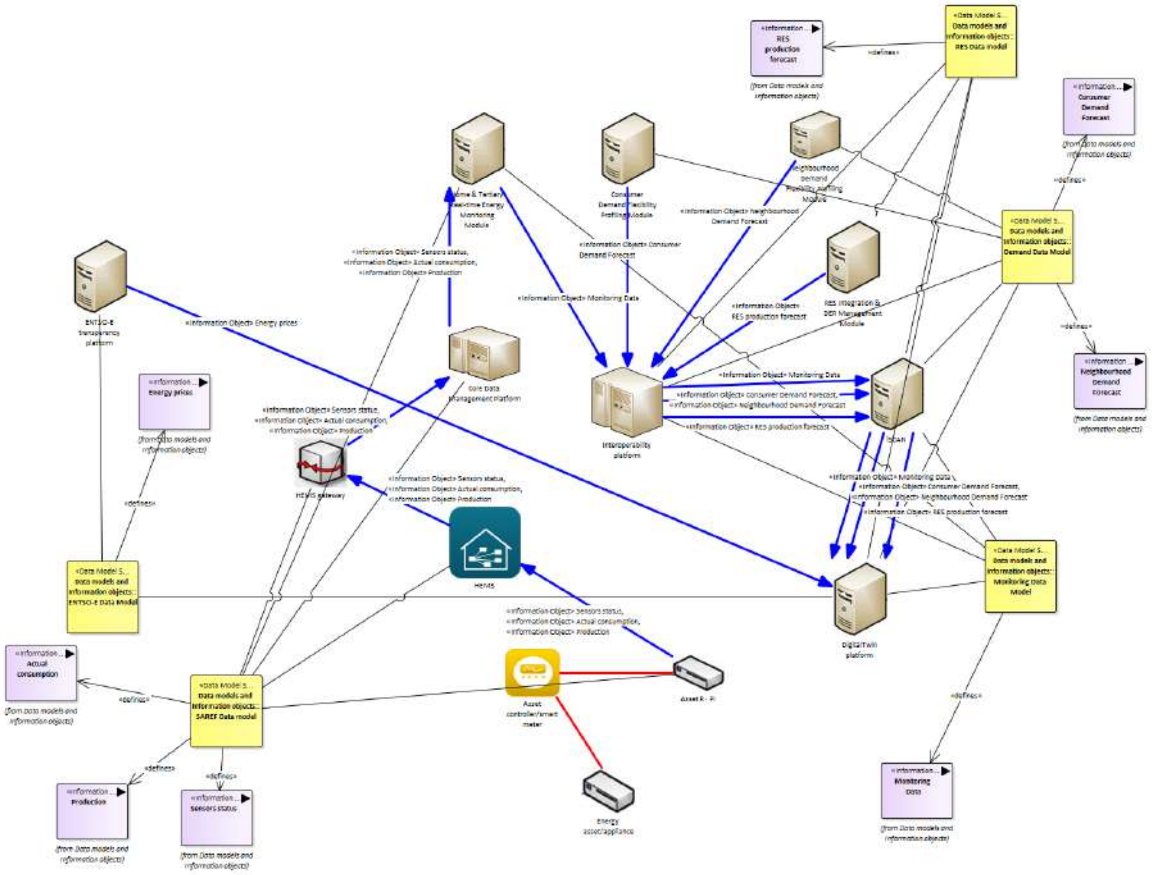

Figure 264: SGAM Standards and Information Object Mapping PUC09.01

Table 152: List of Information Objects PUC09.01

Information Objects	Data Models
Actual consumption	SAREF Data model
Sensor status	SAREF Data model
Production	SAREF Data model
Energy prices	ENTSO-E Data Model
RES production forecast	RES Data model
Consumer Demand Forecast	Demand Data Model
Neighbourhood Demand Forecast	Demand Data Model
Energy Data	Energy Data Model

13.1.8. Activity Diagram

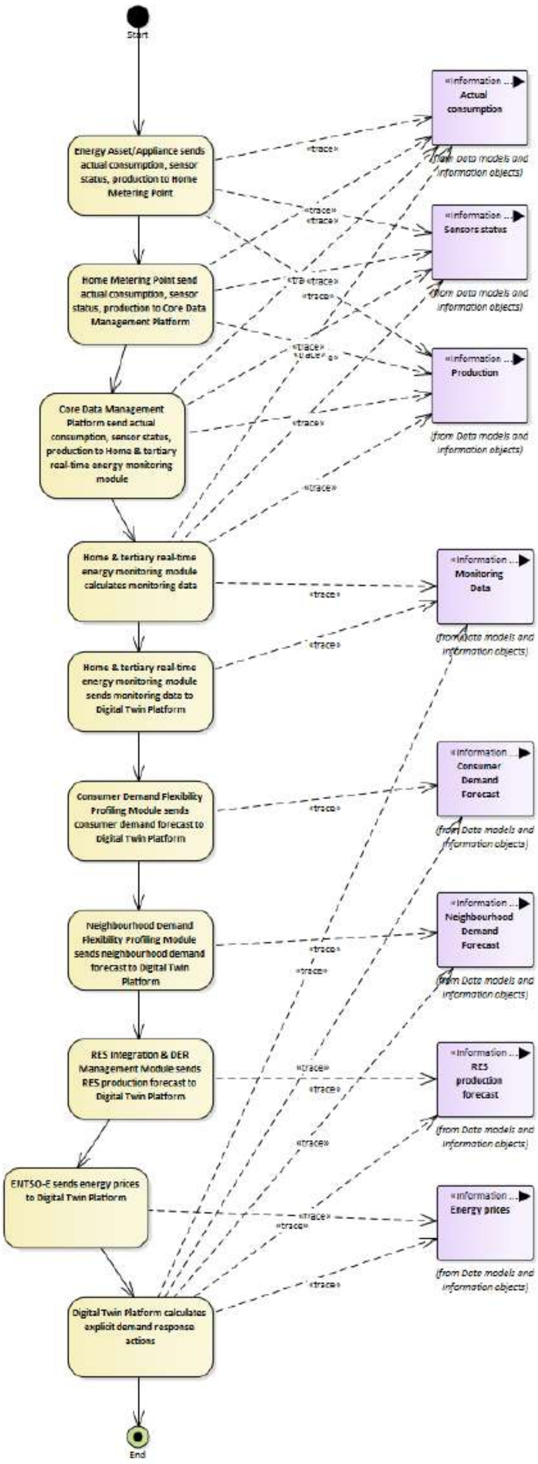

Figure 265: SGAM Activity Diagram PUC09.01

Twinergy has received funding from the European Union's Horizon 2020 research and innovation programme under grant agreement No. 957736

13.1.9. Sequence Diagram

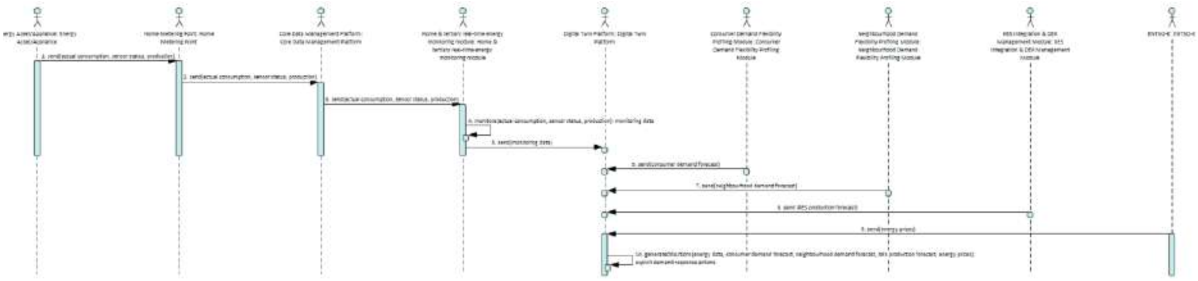

Figure 266: SGAM Sequence Diagram PUC09.01

13.2. PUC09.02 Implicit Demand Response Calculation and Communication to the end-user at both a community and consumer level.

13.2.1. Use Case Description

The optimisation algorithm within the Digital Twin Platform (that form the basis of both Consumer and Neighbourhood Demand Flexibility Profiling Modules) is used to identify flexible loads and determines when the best time is to shift them to. The optimisation algorithm is based on:

- Renewable generation forecasts (from RES integration & DER management Module),
- Predicted building and community demand, and
- Associated energy prices (retrieved from ENTSO-e).

The output of this process will be recommended actions for the user to carry out (such as delaying the switching on of their washing machine, for example) that are communicated through online dashboards. The response will then be captured by the metering of the pilot sites and will feed into the next iteration of the optimisation algorithm. This information can also be used after the fact by community/town planners to evaluate future solutions for their community, by DSO planners and operators to plan future expansion and upgrade of the network as required and can also feed into the pricing calculation by community aggregators if required.

13.2.2. SGAM Function Layer

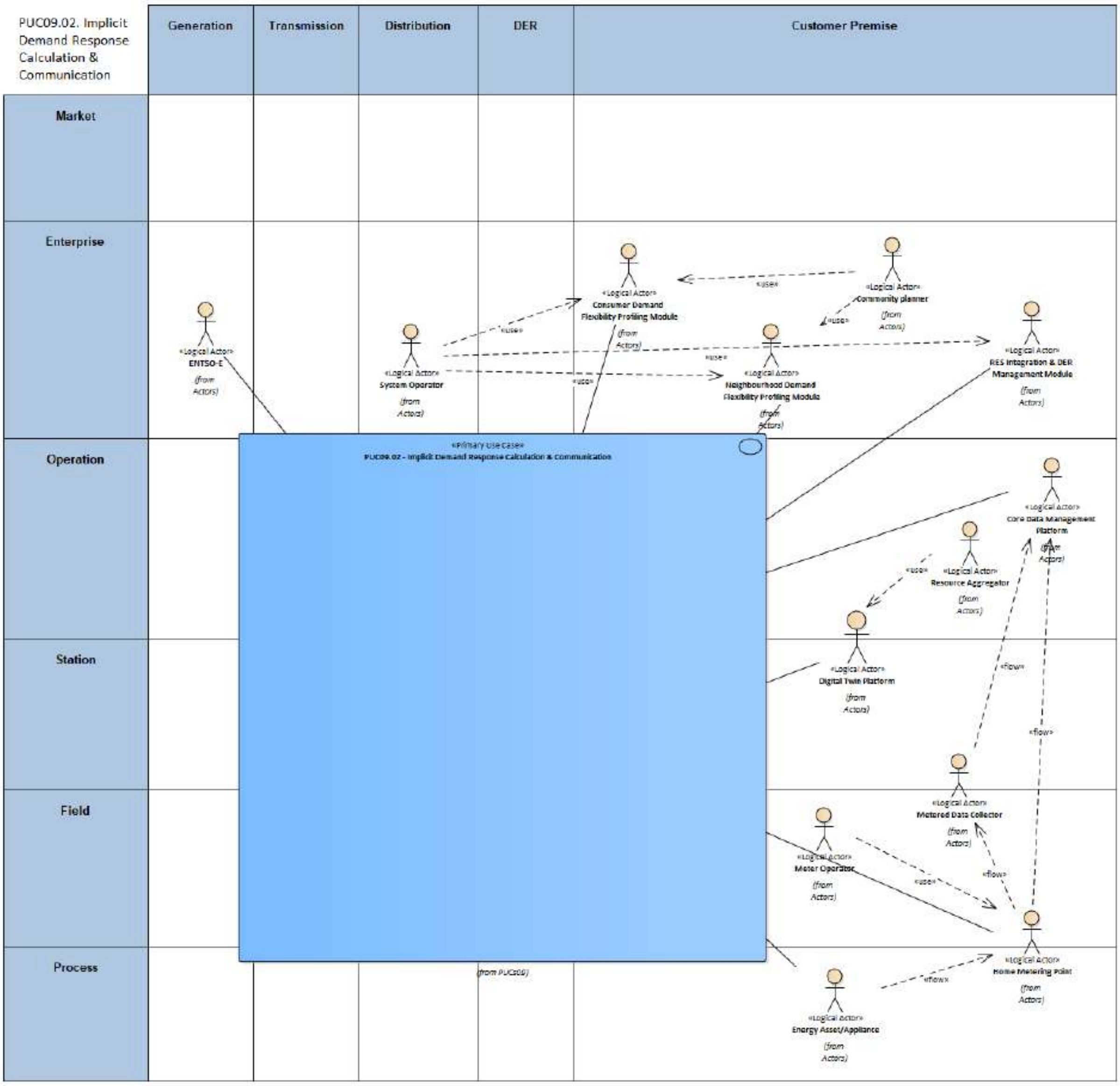

Figure 267: SGAM Function Layer PUC09.02

Table 153: List of Actors Involved PUC09.02

Actor Name	Actor Type
ENTSO-E	Application
System Operator	Organization
Neighbouhood Demand Flexibility Profiling Module	Application

Consumer Demand Flexibility Profiling Module	Application
Community planner	Logical actor role
Home & Tertiary real-time energy monitoring module	Application
RES integration & DER Management Module	Application
Digital Twin Platform	Application
Resource Aggregator	Logical actor role
Core Data Management Platform	Application
Metered Data Collector	Device
Meter Operator	Device
Home Metering Point	Device
Energy asset/appliance	Device

13.2.3. SGAM Component Layer

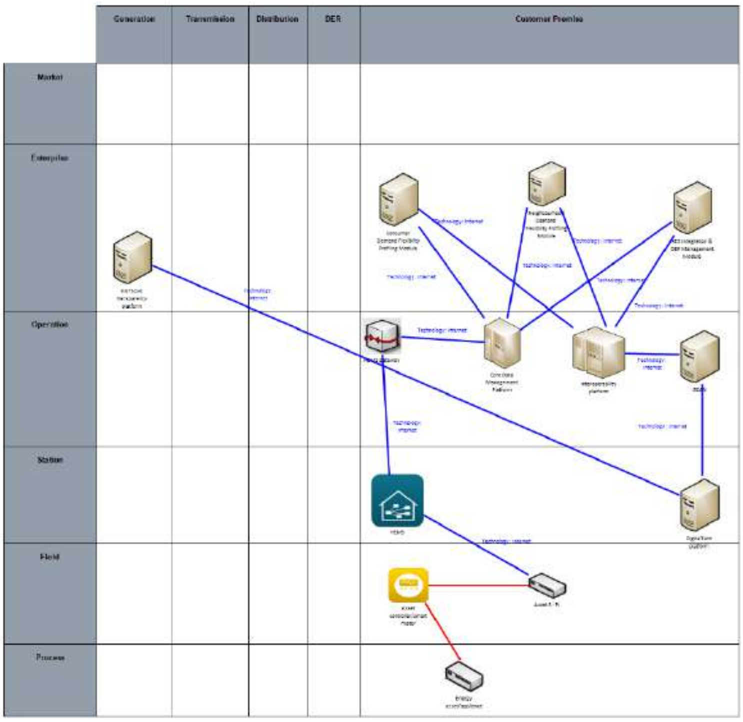

Figure 268: SGAM Component layer PUC09.02

Table 154: List of Components PUC09.02

Component	Component Type
Energy asset/appliance	Physical asset
Asset Controler/ Smart Meter	Physical asset
Raspberry-Pi	Physical asset
HEMS	External application
HEMS gateway	External application
Core Data Management Platform	TwinERGY application
Interoperability Platform	TwinERGY application
Consumer Demand Flexibility Profiling Module	TwinERGY application
Neighbourhood Demand Flexibility Profiling Module	TwinERGY application
RES integration & DER Management Module	TwinERGY application
ENTSO-E transparency platform	External application
Digital Twin Platform	TwinERGY application
iSCAN	External application

13.2.4. SGAM Communication Layer

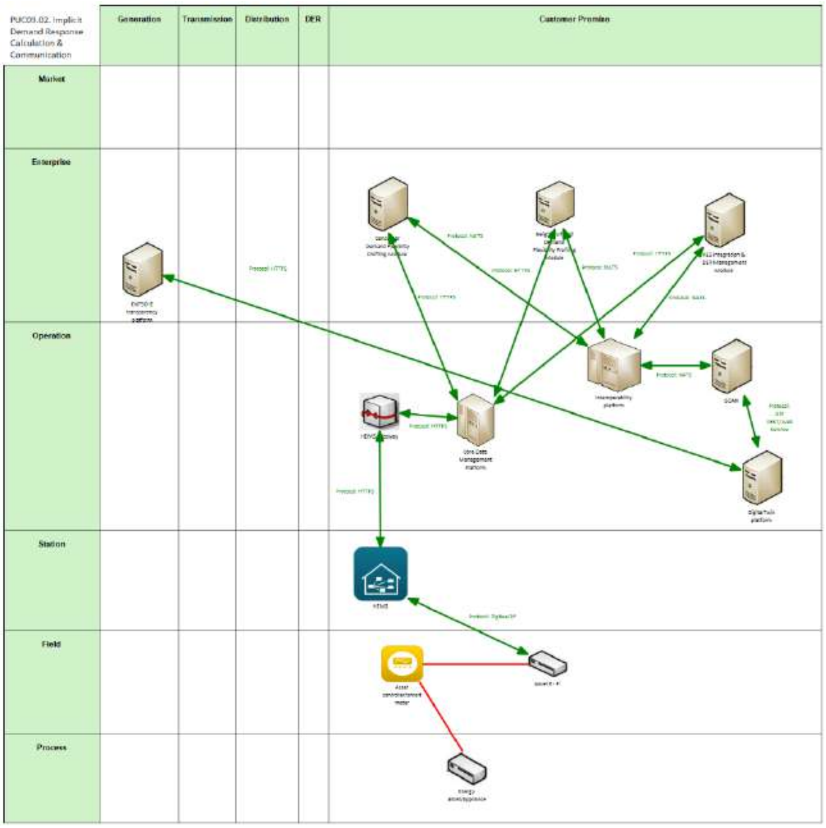

Figure 269: SGAM Communication Layer PUC09.02

Table 155: List of Communication technologies involved in PUC09.02

Communication Technology	Description
HTTPS	HyperText Transfer Protocol Secure. It is an extension of the Hypertext Transfer Protocol (HTTP), used for secure communication over a computer network. In HTTPS, the communication protocol is encrypted using Transport Layer Security (TLS) or, formerly, Secure Sockets Layer (SSL). The protocol is therefore also referred to as HTTP over TLS, or HTTP over SSL.
NATS	Protocol of messaging that enables the exchange of messages among computer applications and services, not depending on the network location.
API REST	Application Programming Interface for REpresentational State Transfer. API is a software intermediary that allows two applications to talk to each other, whilst REST is an architectural style for distributed hypermedia systems, working stateless. Both define a set of distributed resources accessible and manipulable through a set of public functions.

ZigBee/RF	Protocol IEEE 802.15.4, designed to communicate data through noisy RF environments. This standard operates on the physical radio specification and operates in unlicensed bands including 2.4 GHz, 900 MHz and 868 MHz.

13.2.5. SGAM Information Layer

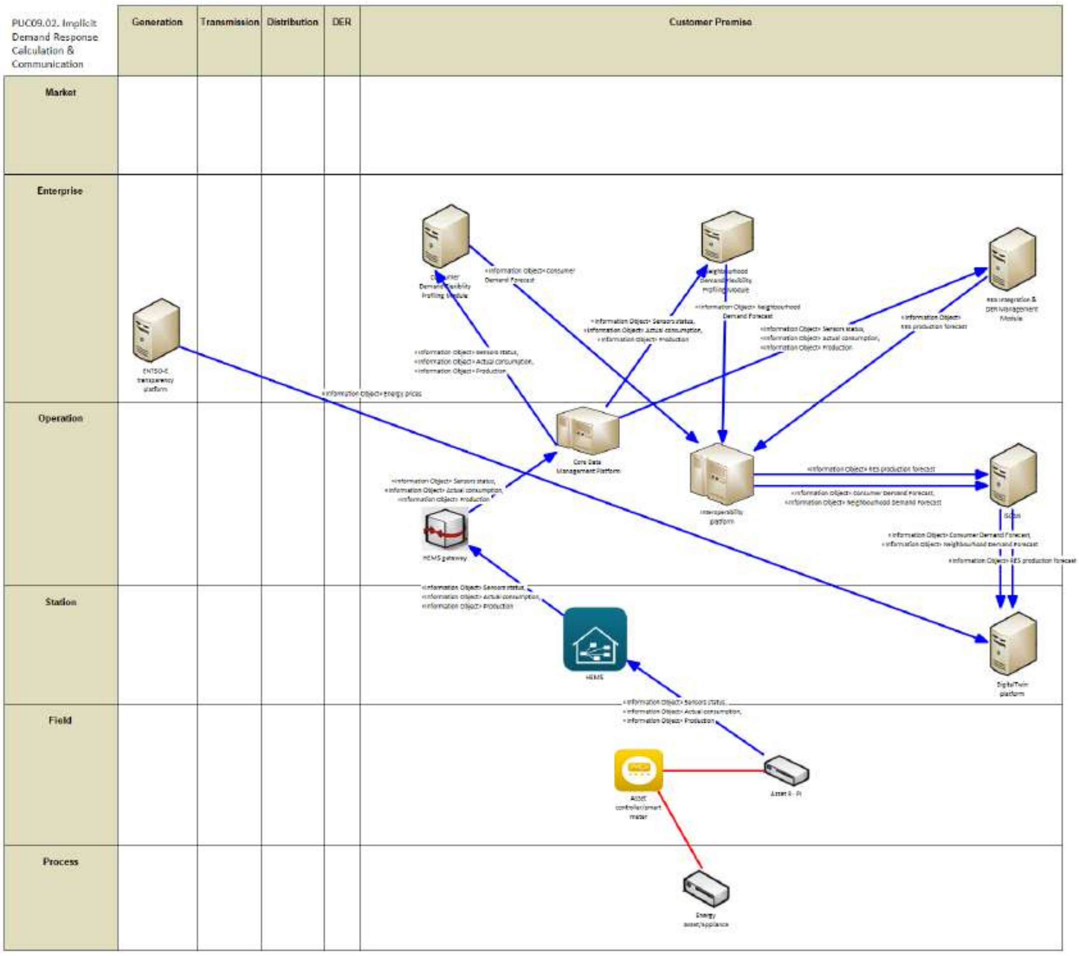

Figure 270: SGAM Information Layer PUC09.02

13.2.6. Canonical Data Model

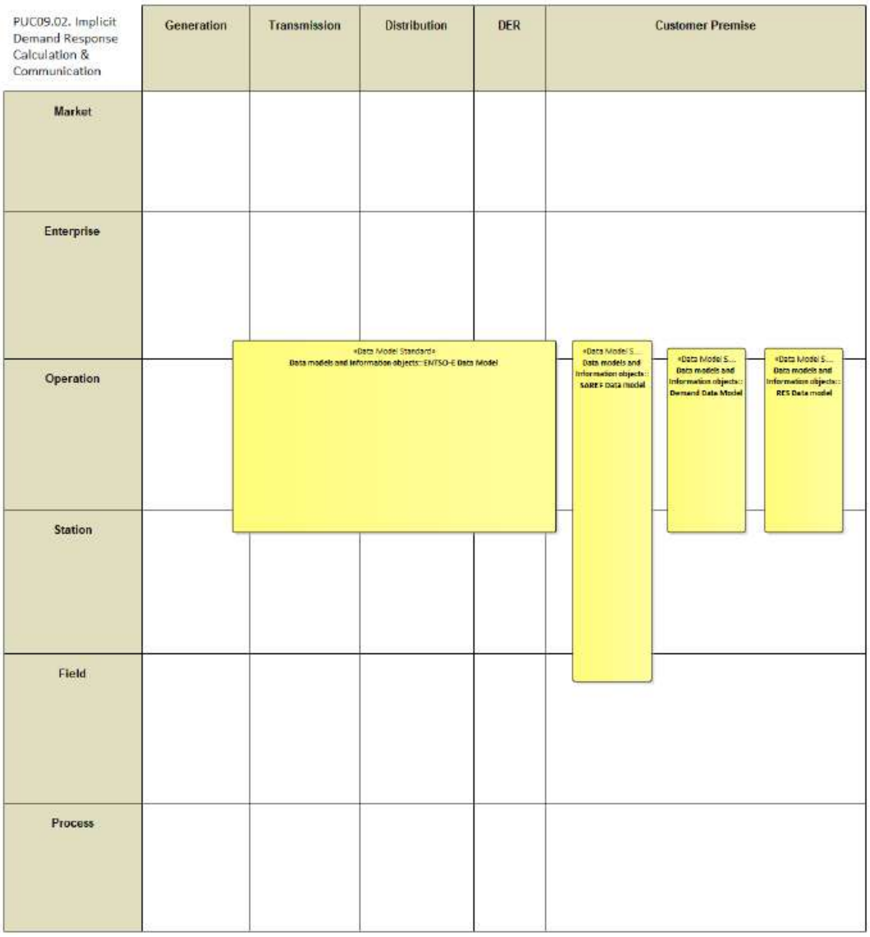

Figure 271: SGAM Canonical Data Model PUC09.02

Table 156: List of Data Models PUC09.02

Data Models
ENTSO-E Data Model
SAREF Data Model
Demand Data Model
RES Data Model

13.2.7. Standards and Information Object Mapping

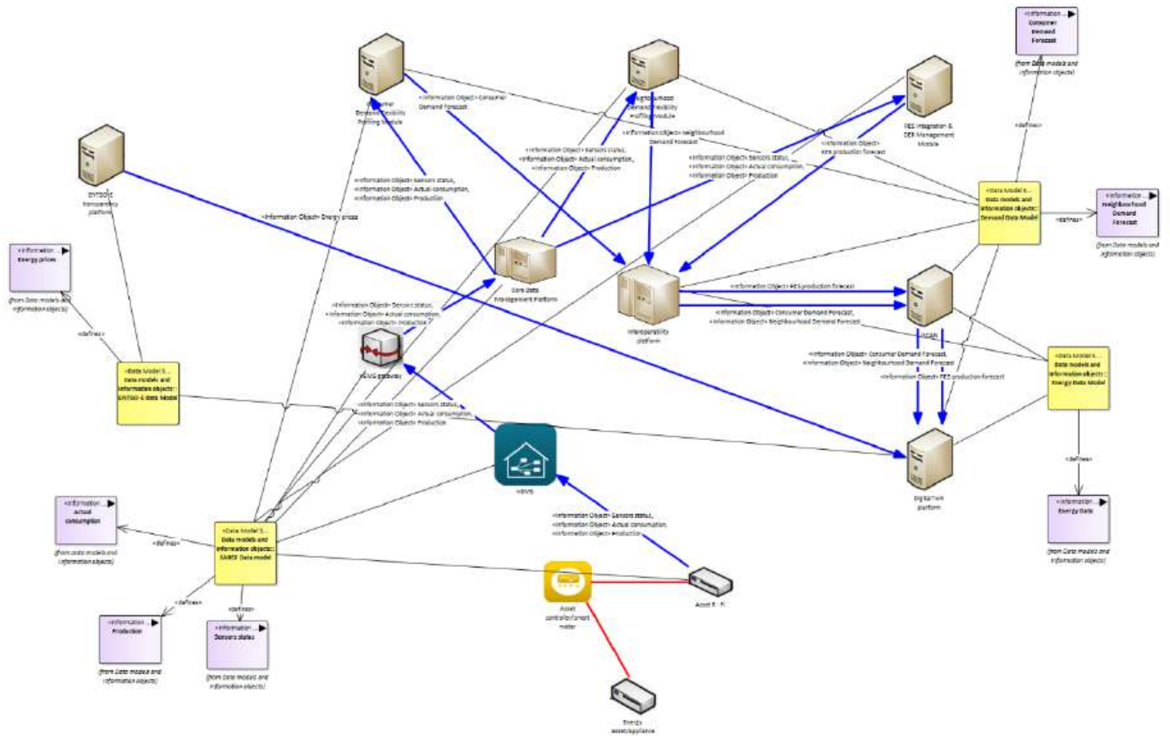

Figure 272: SGAM Standards and Information Object Mapping PUC09.02

Table 157: List of Information Objects PUC09.02

Information Objects	Data Models
Actual consumption	SAREF Data model
Sensor status	SAREF Data model
Production	SAREF Data model
Energy prices	ENTSO-E Data Model
Consumer Demand Forecast	Demand Data Model
Neighbourhood Demand Forecast	Demand Data Model
RES production forecast	RES Data model

13.2.8. Activity Diagram

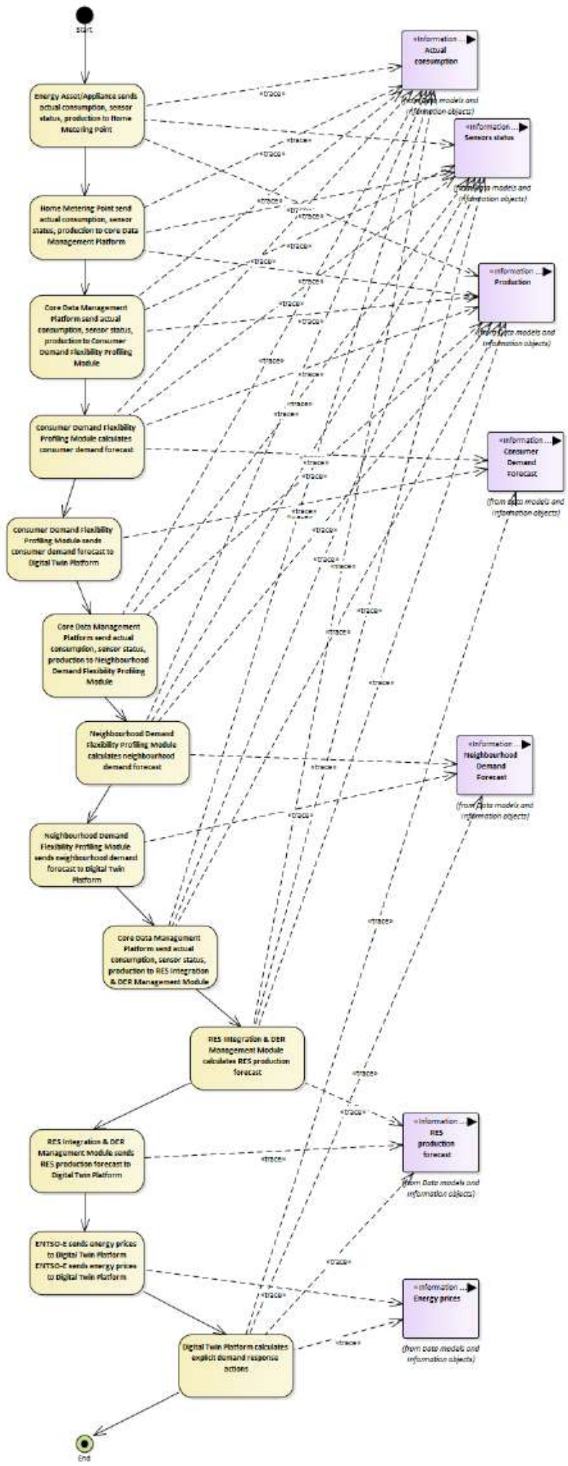

Figure 273: SGAM Activity Diagram PUC09.02

13.2.9. Sequence Diagram

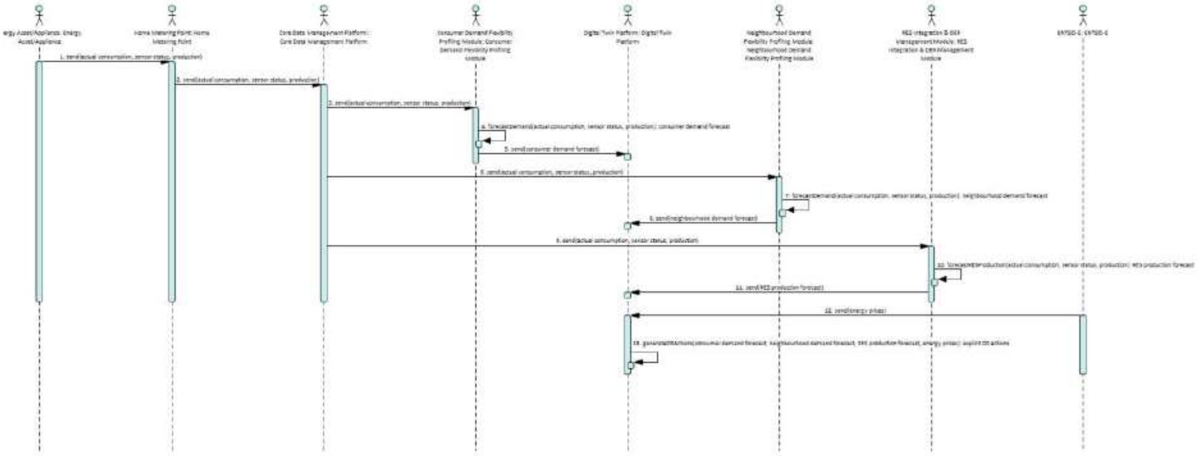

Figure 274: SGAM Sequence Diagram PUC09.02

13.3. SGAM Business Layer

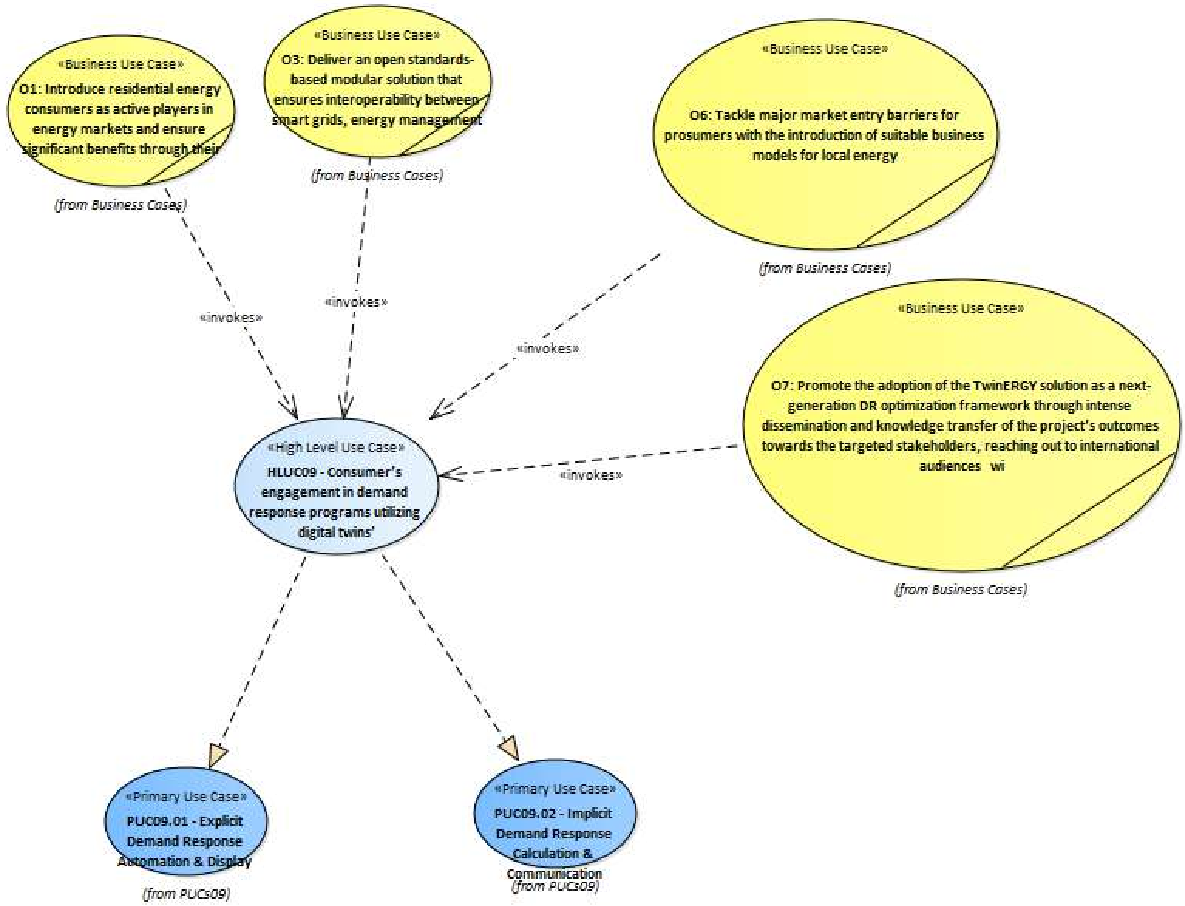

Figure 275: SGAM Business Layer HLUC09

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14. Conclusions

This deliverable presents the outcomes of the work carried out under "Task 4.4: System Architecture". Its purpose is to model in a systematic and homogenised manner the different HLUC in the TwinERGY project. Their analysis, alongside their associated PUCs and SUCs using the Smart Grid Architecture Model framework has provided all the necessary information for the subsequent development phase of the nine different modules integrated within the TwinERGY ecosystem. As an outcome of information modelled and analysed through the SGAM modelling of the UCs in this deliverable, a set of different information objects, assets, protocols and actors have been identified to be part of the TwinERGY environment.

Furthermore, in regards of the HLUC definition, this deliverable has contributed as well to the breakdown structure and complementation of the already introduced HLUC within Task 2.2 "Stakeholders Requirements". In Task 4.4. "System Architecture", HLUCs have been further analysed based on the SGAM methodology requirements so that they can fulfil the different needs.

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Annex I: High Level Use Cases

HLUC01: Home Energy Management

Scope

The scope of this UC is the energy management in residential consumer premises to monitor the energy flows, maximize self-consumption and self-sufficiency, reduce the costs for the users also enhancing their active role into the energy efficiency process.

A bottom-up approach is envisaged focusing on the power grid at the buildings level. The traditionally monodirectional power system saw the network change to bidirectional, thus making the consumer an active part of the process and above all it would contribute to greater control of power, voltage and frequency in the distribution level.

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

Data gathering is crucial in the energy efficiency process and energy management; depending on the data available, different actions can be taken, and eventually, the existing monitoring system is going to be improved.

The static parameters regard many aspects of the facility such as:

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

The dynamic parameters refer to:

- Energy demand
- Photovoltaic production
- Electrical Storages state of charge
- Indoor parameters (such as temperature and humidity)
- Weather conditions

The monitoring data will be achieved through a monitoring system on edge and through online monitoring services. Many of them are going to be made available through an online graphical interface to improve the users' awareness about their energy patterns.

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Starting from the main electrical appliances inventory and their daily usage habits is going to deliver the optimal loads distribution during the day.

In relation to the energy monitoring and forecasts and the energy costs information, this data can be used to find and shape the optimal load profile, reducing costs in the energy bill and maximizing self-consumption.

Features under study:

- Smart and remote monitoring in the GUI - STAM
- Forecast Photovoltaic production - THOWL
- Neighbourhood Flexibility estimation - IES
- Building Energy Cost curves estimation - WEC
- Home Flexibility Optimization - STAM
- Bills checking - STAM
- Power consumption anomaly detection _STAM

Networks/Markets under study:

- MV Network
- LV Network
- Energy markets

Objectives

This Use Case is focused on the energy management of residential consumer premises and their ability of monitoring and controlling electrical loads taking into account the PV generation and energy storage, in order to maximize self-consumption and self-sufficiency.

To carry out this purpose, the energy scenario would be analysed through this UC by:

- Increase the observability of the facilities through the information gathering and the improvement of the energy monitoring system.
- Graphic flexibility modelling so that the tenants can actively participate in demand response programs.
- Employment of load management system provided by the smart plugs on/off control, considering dynamic tariffs to minimize energy cost to the end-user and to improve their self-consumption from PV

Actors & Roles, Names and Types

- Aggregator/Flexibility Operator
- Service Provider
- Distributed System Operator (DSO)

- End consumers (MV/LV)/Prosumers

Short Description

HLUC01- Home Energy Management can be further depicted into these Primary Use Cases (PUCs):

1. PUC01.01. Increase the building observability - Data gathering from the home monitoring system
2. PUC01.02. Data analysis. Behavioural rules analysis, minimization of the energy costs and increase the self-consumption from PV
3. PUC01.03. Optimal flexibility management system - Analysis of the optimal electrical appliances flexibility management
4. PUC01.04. Control of the smart devices

HLUC02: RES generation in domestic and tertiary buildings

Scope

This use case has the goal to create further renewable sources and infrastructure to increase the RES share in public and private buildings. The use case is being applied to three of the pilot sites for the TwinERGY project, with different aims for each specific to the location in question:

1. Bristol: Community investment in local energy infrastructure, focusing on local RES (both present and future potential) both from an energy production point of view and also taking into account how they would operate in any future local energy market/community grid framework etc.
2. Hagedorn Village: Increased uptake of locally produced renewable energy, enabling increased flexibility of the local microgrid and increased social engagement in the use of RES.
3. Benetutti Smart Community: Increased integration of RES in the community grid, which will enable optimisation of building energy consumption through DR and participate in a new local energy trading platform.

Objectives in each of pilot sites are quite similar in the context of this use case, but the plan will be still to be as flexible as possible to allow for any specific requirements of one location so that the optimal solution can be found for local RES in the community.

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Objectives

As mentioned, this use case is aimed at maximising both the present and future RES generation and usage in public and private buildings across three of the four pilot sites. In line with this overall goal, the objectives of the use case are as follows:

- Minisimising energy costs for the end user through optimal use of the local renewable energy production
- Minimising the overall carbon emissions produced by the community
- Maximising the use of the local RES through supporting infrastructure, such as battery storage and demand response algorithms.

Actors & Roles, Names and Types

- Aggregator
- Retailer
- Building/asset owner

End users

Short Description

HLUC02 can be divided into these Primary Use Cases (PUCs):

- PUC02.01 Dispatch of existing RES in domestic and tertiary buildings to minimise cost/carbon emissions
- PUC02.02 Optimal future energy storage to maximise RES production
- PUC02.03 Maximum future RES capacity according to the physical constraints (e.g. roof space, cable sizes) of the pilot site, as well as present/future V2G capacity as determined by the TwinEV module
- PUC02.04 Optimal CHP solution specific to the pilot site in terms of capital costs and network capacity
- PUC02.05 Optimal scenario of future energy storage and RES to minimise energy costs for the end user/carbon emissions
- PUC02.06 Optimal domestic and tertiary demand response, based on RES, to minimise cost/carbon emissions

There are no Secondary Use Cases (SUCs) related to UC02.

HLUC03. Grid capacity enhancement utilizing e-mobility

Scope

Electrical Vehicles (EV) have a dual nature. In the first place, they act as a transport mean when they are on the move. In the second place, they can also be a grid-connected battery when they are parked and plugged. Taking advantage of their second nature, EVs are able to transform the stress on the electric grid into the opportunity to act as a flexible asset. Smart Charging through an external control system, accompanied by Vehicle-to-Grid connexion would be leading the EV owners to participate in specific markets that could generate relevant benefits for the energy sector, not only in terms of grid management but also in environmental terms since the transport sector in Europe is responsible for over 25% of greenhouse gas emissions. The adoption of EVs as a distributed storage asset would be leading to a more decarbonized infrastructure. Furthermore, managing the charging process though time schedule and power profiles will be opening new opportunities to not only EV owners but also to flexibility markets: smart EV charging can integrate a large share of Renewable Energy Sources (RES) throughout the modification of the power demand curve, reducing the system costs and supporting as well the decarbonization of neighbourhoods. Consequently, EV will enable improved system management in terms of voltage control and grid congestions.

Through the application and study of this Use Case in two of the TwinERGY project pilot sites (Athens in Greece and Hagedorn Village in Germany), EVs would be analysed as a distributed storage asset for grid purposes. EV smart charging in collaboration to Vehicle-to-Grid connection, would allow the grid to stabilize through the integration of RES and the possibility to participate in energy flexible markets. Additionally, Smart Charging would benefit EV users in terms of economic performance, by the reduction of energy cost when charging, though the scheduling of their charging sessions. EVs as a distributed storage asset could also have influence in the performance of Distributed System Operators (DSO). Batteries could help these entities in the congestion and the voltage management taking advantage of the flexibility that batteries can provide when they are connected through V2G connectors in charging points. In addition, the use of Smart Charging in EV would lead to a more decarbonized neighbourhoods, throughout the integration of RES from the energy mix or from renewable surpluses detected in the charging processes.

Features under study:

- Smart Charging
- Vehicle-to-Grid (V2G) Capability
- Participation in Demand Response campaigns
- Participation in Energy Markets
- Participation in Local flexibility markets
- Voltage Control and Grid Congestions through DSO
- Integration of RES and surpluses
- Reduction of CO2 emissions

Networks/Markets under study:

- MV Network
- LV Network
- Energy markets
- Local Flexibility Markets

Objectives

This Use Case is focused on analysing the potential implementation of electromobility to use EVs as distributed assets in the benefit of the grid performance. To carry out this purpose, electromobility would be analysed through this UC by:

- Use of EVs batteries as a distributed asset to offer ancillary services to the DSO (Congestion and Voltage Management) through the integration by V2G connexion.

- Develop a smart charging scheme for EV owners from which EV charging could focus on the use of green energy (both from the Renewable sources in the energy mix or from the renewable surpluses from renewable generating assets) as well as focus on minimizing the costs of the charging sessions.

- The use of EV batteries for the participation in flexible energy markets using demand response campaigns.

- Using smart charging profiles to generate charging curves to EVs that would lead the integration of RES helping to the decarbonization of neighbourhoods.

Actors & Roles, Names and Types

- Aggregator
- Retailer
- Distributed System Operator (DSO)
- MV/LV End consumers / Prosumers
- Electric vehicle driver (EV driver)
- Electric Vehicle Supply Equipment operator or charging stations operator (EVSE operator)
- Public Authorities

VPP operator

Short Description

HLUC03 "Grid capacity enhancement utilizing e-mobility" can be further depicted into these Primary Use Cases (PUCs):

- PUC03.01. Booking a charge session
- PUC03.02. Smart Charging to follow grid requests
- PUC03.03. Smart Charging to maximize RES integration (green electricity)

- PUC03.04. Smart Charging to minimize charge costs
- PUC03.05. Smart Charging to minimize time of charge
- PUC03.06. Grid management

Despite there is no any Secondary Use Cases (SUCs) related to HLUC03, the PUC03.06 is related to SUC05.01 - Grid status calculation and bottleneck detection.

HLUC04. Prosumer's empowerment in local energy trading markets

Scope

The scope of this use case is to provide solutions to transactive energy uses cases and enables grid decentralization and democratization by connecting the micro-grid operators to the DER managers and their customers. It aims for an integrated energy business model through energy service expansion, customer engagement and financial inclusion. It allows them to balance the grid and provide solutions to a number of grid problems, such as grid power quality and reliability. The core of this use case is a transactional platform that offers its participants to sell their flexible energy loads and excess capacity on an open market to the (micro) grid operators or to each other. Microgrid operators provide balancing and grid services at a local and micro-grid level.

A micro-grid could be a collection of a) IoT devices, b) buildings, c) neighbourhoods/substations, and d) regions that operate at a regional level to balance multiple neighbourhoods, districts and/or substations. It could potentially include the high voltage grid. Each component of the system (e.g., device, building, neighbourhood, distribution grid and transmission grid) is a self-contained ecosystem, replicated and nested within the next layer of the system, like in a fractal configuration. All components operate with identical information and control models and each have operational decision-making capabilities. This platform offers a path to grid decentralization, energy democratization, and a way to effectively leverage and monetize the emerging DER infrastructure.

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

Through the application and study of this use case in two of the TwinERGY project pilot sites (Bristol in the United Kingdom and Benetutti in Italy), grid infrastructures would be analysed to implement state-of-the-art equipment that can monitor and track energy consumption and distribution.

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Pilot sites, consisting of apartment buildings and individual houses will be equipped with smart meters, local and public storage facilities and IOT devices such as smart plugs. These are integrated with the Transactive Energy Module giving prosumers a powerful insight of their power consumption and redistribution to the local energy market (LEM).

The TEM will allow for prosumers to buy and sell energy from the LEM. It will also allow TE participants to transact in a P2P configuration outside an organized LEM/DSO or an ISO/TSO market. These transactions are stored as an immutable record on the blockchain specifying the actors participating in the transaction and the origin of the energy.

To further support the LEM, the TEM will process and broadcast price forecasting of the DNO and LEM. Other TwinERGY modules will be able to listen to the broadcast and make energy consumption or discharge decisions on behalf of the prosumer.

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

Features under study:

- Granular monitoring of energy consumption behind the meter
- Use of private and public storage facilities within a concealed grid infrastructure
- Technical limitations of tracing electrons (units of energy)
- LEM Price calculation and forecasting
- Social incentivisation for delivering energy to the LEM

Networks/Markets under study:

- Regulatory limitations of peer-to-peer transacting of energy
- Regulatory limitations of financial transactions for energy without involvement of a DNO or DSO

Summary of Benetutti pilot site:

- The Benetutti pilot site consists of a neighbourhood of 120 buildings of which 20 participate. Two of the participants are public places being a primary school and a nursery.
- Every participating house will have a PV installation. The kWh output of each installation is different.
- 1 participating house has a battery.
- Every participating house will be installed with a shelly cloud smart meter
- Every participating house will be provisioned with smart plugs

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Summary Bristol pilot site:

- The Bristol pilot site consists of 1 campus building and 10 residential homes. participants are yet to be selected.
- Every home will be provisioned with a smart sub meter.
- There will be a few houses with a PV installation.
- There will be 1 or 2 houses that will receive a Tesla battery.
- All participants will receive smart plugs.
- There will be no public storage facility.

Objectives

This Use Case is focused on analysing the potential implementation of Transactive Energy in the benefit of the grid performance. Also, to empower prosumers by allowing them to trade the energy they produce. The use case is also focused on creating a Local Energy Market (LEM) and calculate dynamic energy pricing for the same. To carry out this purpose, Transactive Energy would be analysed through this UC by:

1. Participating houses and apartment buildings on the pilot sites are / or will be equipped with smart meters. Behind the meter a combination of IOT devices are available such as smart sockets, HVAC systems and so forth. This also includes PV systems, home turbines, electric vehicles and other appliances that can generate or discharge energy. These are connected to the TwinERGY data modules
2. The data generated by the aforementioned devices can be used by other modules in order to make decisions on the behaviour of appliances. This includes the decision to distribute energy back into the grid, move the energy to public storage facility or to provide the energy to another prosumer in the TwinERGY ecosystem.
3. All energy transactions are recorded on a private permissioned blockchain (PPB)

Actors & Roles, Names and Types

- Aggregator
- Consumers / Prosumers
- Prosumer Consortium

Short Description

HLUC04 Prosumer's empowerment in local energy trading markets can be further depicted into these level actions:

Primary Use Cases (PUC):

- PUC04.01. Recording transactions of energy: Recording transactions of energy from a RES to a private or public storage facility, recording transactions of energy between prosumers and Recording transactions of energy between prosumer consortia. In addition, DR events are simulated and prosumers are rewarded for their positive response.

- PUC04.02. Calculation and broadcasting of LEM pricing compared to DNO/DSO pricing.

There are no secondary use cases (SUCs)

Besides, this Use Case is support by the following functionalities:

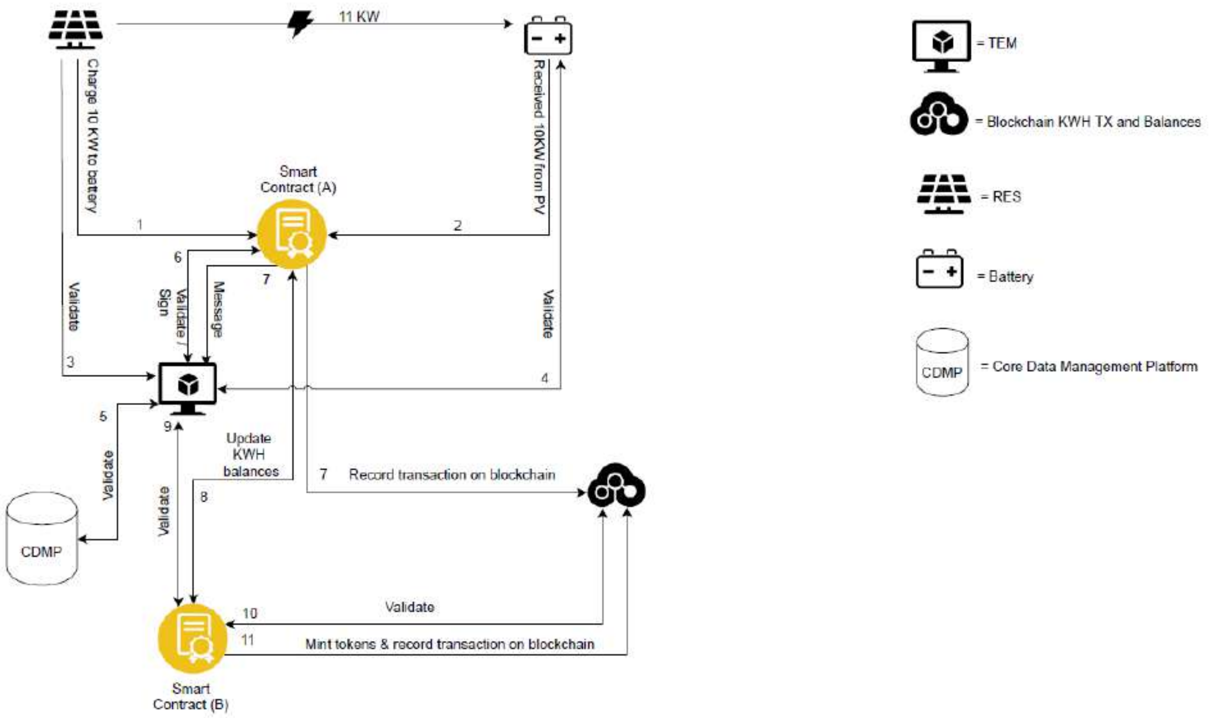
1. Create account:
    - Prosumer joins TwinERGY project
    - Receive signal from other TwinERGY module to create prosumer account
    - TEM confirms account created
2. Register Device:
    - New device joins TwinERGY ecosystem
    - Receive Signal from other TwinERGY module to register a device (PV, HVAC etc.)
    - Signal includes owner and TEM creates relation between prosumer and device
    - TEM confirms device is registered and relation created
    - (2) Function to remove devices
3. Register Consortium:
    - New prosumer consortium is formed
    - Receive Signal from other TwinERGY module to register a consortium
    - Signal includes participants and devices creates consortium relations
    - (2) Function to add and remove prosumers and devices
4. Calculate and broadcast LEM and DSO/DNO Pricing:
    - TEM receives input data from other TwinERGY modules
    - TEM receives input data from DSO/DNO
    - TEM calculates LEM pricing
    - TEM broadcasts LEM/DSO/DNO pricing on set interval
    - TEM records pricing on the blockchain
5. Process energy transaction:

Scenario 1: Transfer KWH to Public or Private battery

In this scenario a transaction of energy is created between a PV, turbine or other system to a public or private battery.

1. At the end of a charging session or on a set time interval the RES confirms to the battery that the charging session has completed and confirms to Smart contract "A" that it has delivered 11 KWH to the battery;
2. The battery confirms to the Smart Contract that it has received 11 KWH of which 10 KWH is usable;
3. The RES confirms information communicated in step 1 to the TEM;
4. The battery confirms the information communicated in step 2 to the TEM;

5. TEM validates with the CDMP database that the data received from the RES and the battery matches;
6. The TEM acts as a validator by signing the transaction on Smart Contract "A";
7. Smart Contract "A" executes and records the transaction on the blockchain ledger;
    a. Send a confirmation message to the TEM to confirm execution
8. Smart Contract "A" sends a message to Smart Contract "B". The message includes the transaction hash, an order to mint tokens and the wallet addresses to which these tokens must be send;
9. Smart Contract "B" validates the transaction wit the TEM and the TEM signs the transaction;
10. Smart contract "B" validates the transaction hash in the blockchain ledger;
11. Smart Contract "B" mints the KWH tokens and distributes them equally to the wallet addresses It received from Smart Contract "A".

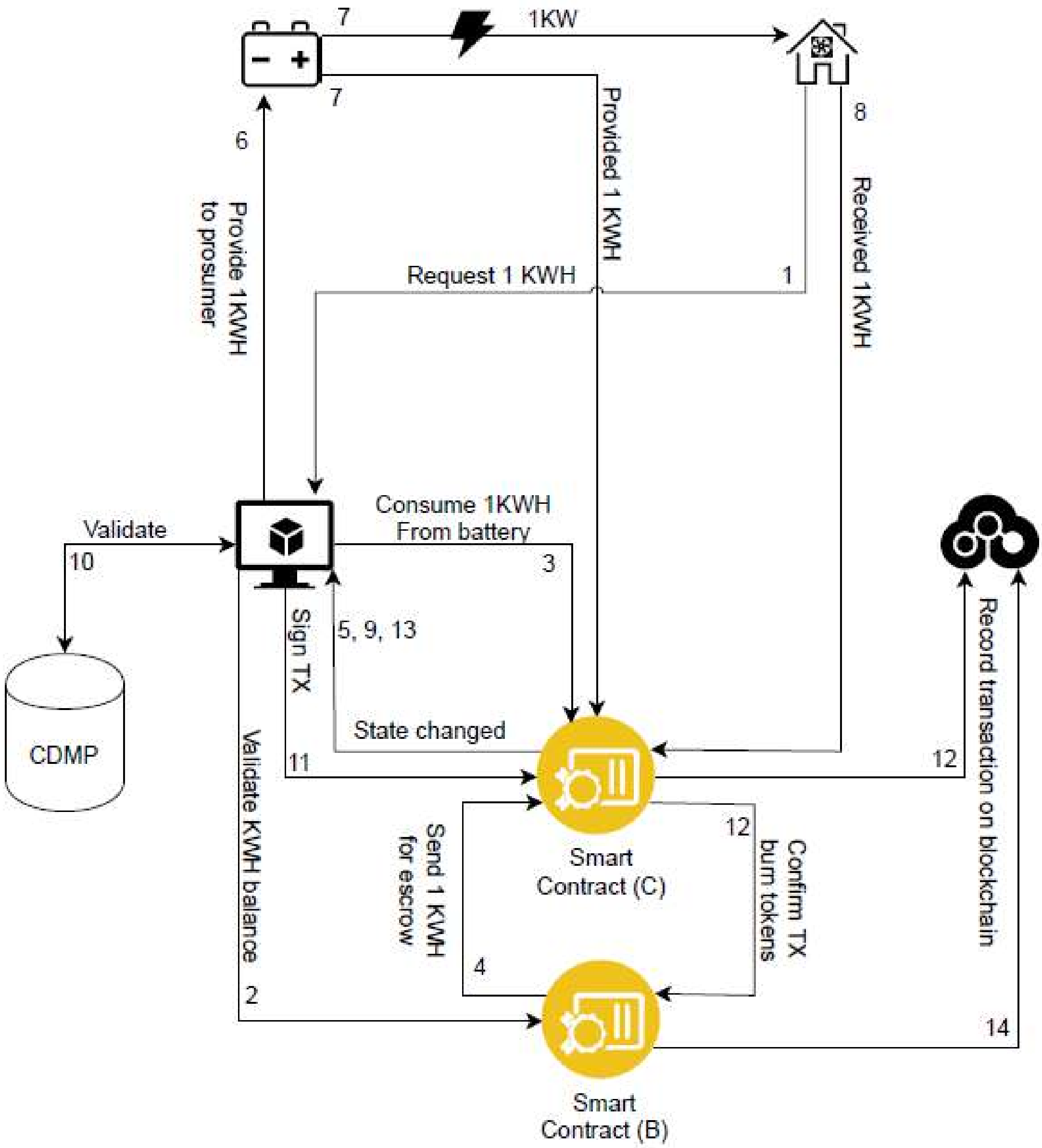


Scenario 2: Consume own KWH from Public battery

In this scenario a transaction of Energy is created between a battery and a consumable and where the KWH is owned by the prosumer that consumes the energy.

1. Dwelling requests the TEM to receive X KWH from the battery;

2. TEM validates the KWH balance of the prosumer wallet though interaction with Smart Contract "B" function "Balance Of";
3. TEM invokes Smart Contract "C" and updates dwelling of approval and includes an address for a state update to the contract;
4. If balance is sufficient the TEM instructs Smart Contract "B" to send x KWH tokens to a wallet controlled by Smart Contract "C" for escrow;
5. The TEM receives a message from Smart Contract "C" regarding its state change and that x KWH is in escrow;
6. TEM instructs battery to provide X KWH to dwelling during the requested time;
7. The battery supplies the energy to dwelling and updates Smart Contract "C" once completed;
8. Dwelling validates that it has received X KWH and updates Smart Contract "C";
9. TEM receives an update regarding the state changes of Smart Contract "C";
10. TEM validates with the CDMP database that the data received from the battery and the dwelling matches;
11. TEM signs the transaction;
12. Smart contract "C" executes the transaction, records the transaction on the dedicated blockchain ledger and sends the KWH token with the that were in escrow together with the transaction hash to Smart Contract "B" for burning;
13. Smart Contract "C" sends a confirmation message to the TEM to confirm execution;
14. Smart Contract "B" burns the KWH token and records this transaction on the ledger
    a. Al transaction hashes of the process are included in the meta data.



Scenario 3: Purchase KWH from other prosumer (1) - battery to battery

In this scenario a transaction of Energy is created between the batteries of prosumers. Where one prosumer offers their stored energy for sale and where another prosumer wishes to buy the energy.

1. Prosumer offers X KWH when the LEM price is between X&X and specifies the minimum contract sale
    a. For example, if the total KWH is 10 and the minimum contract sale is 2, then the contract can sell the KWH in partitions of 2 or more, until the contracts

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hold less than 2 KWH. In this event the remaining KWH in the contract is returned to the address of the contract owner;

2. TEM validates the KWH balance of the prosumer wallet though interaction with Smart Contract "B" function "Balance Of";
3. TEM invokes Smart Contract "D" provides prosumer currency token wallet address, details of the transfer and instructs Smart Contract "B" to send X KWH token for escrow with Smart Contract "D";
4. Smart Contract "B" validates the KWH balance of the prosumer and requests TEM to sign;
5. Smart Contract "B" sends X KWH token of prosumer to Smart Contract "D";The Smart Contract "D" is now discoverable for the TEM when the LEM price is within the specified range.
6. Prosumer sends a request to the TEM with the request to buy X KWH before X date and X time when the LEM price is not larger than X;
7. The TEM matching service queries the blockchain for contracts that match the buy order when the LEM price is in the specified range.
    a. If there is no matching contract hen the TEM will continue to listen until a contract becomes available;
    b. If no contract becomes available before the specified end time of the order, then the buy order expires;
    c. If a contract becomes available before the specified end time of the order, then the TEM validates the currency balance of the prosumer through interaction with Smart Contract "E" function "Balance Of";
8. The TEM validates the LEM price and posts the order ID, LEM price hash, KWH on the order, ID of the receiving battery and KWH token wallet address of prosumer to Smart Contract "D"
9. TEM instructs Smart Contract "E" to transfer the currency tokens to Smart Contract "D" including the order ID in the meta data
10. Smart Contract "D" instructs the battery of the prosumer selling (A) to start the transfer of KWH to the battery (B) of the prosumer buying
11. Battery A confirms to Smart Contract "D" and the TEM that the transfer has completed
12. Battery B confirms to Smart Contract "D" and the TEM that the transfer has completed
13. Smart Contract "D" requests the TEM to validate that the transaction has completed
14. TEM validates with the CDMP database that the data received from the batteries match
15. TEM signs the transaction with Smart Contract "D"
16. Smart Contract "D" sends the KWH tokens to the KWH wallet address of the buying prosumer

17. Smart Contract "D" sends the currency tokens to the currency wallet address of the selling prosumer
18. If the KWH tokens remaining in Smart Contract "D" is less than the minimum contract sale, then the remaining KWH tokens are returned to the KWH token wallet address of the contract owner

HLUC05: Enhance grid flexibility through DER Management

Scope

The generation of renewable energy sources (RES) can, in most cases, is not controlled and it is therefore crucial to find ways to harvest these types of energy when they are available. For this, it is necessary to utilize methods that make the energy accessible for longer periods of time and be able to make accurate forecasts about the estimated energy generation so the energy consumption and distribution can be planned accordingly.

Currently, there is a big imbalance between the production and the consumption of RES, especially in regions that generate large amounts of RES power. Over the course of a day there may be periods where wind turbines or PV-systems generate more energy than is needed or can be consumed at the time. In order to keep the power grid stable, these energy sources have to be temporarily shut down, leading to an unused RES-potential of several TWh per year (e.g. 6,3 TWh in 2019 in Germany).

It is therefore essential to find intelligent ways of making the power demand more flexible and store the excess of produced energy, so that potential RES power is not wasted and the energy production sector in Europe can profit from further decarbonization. Another potential advantage of such intelligent energy storages is their very fast response time that can help stabilizing the power grid by reacting to temporary energy shortages in a timely manner.

Features under study:

- Real-time grid status calculation
- Real-time grid bottleneck detection
- Real-time consumption level prediction.
- Real-time RES production level prediction.
- Real-time testing and evaluation of changes to grid switching behaviour.
- Electric battery storage
- Home energy management system

Networks/Markets under study:

- Low-Voltage (LV) Network
- Medium-Voltage (MV) Network

Objectives

In this Use Case congestion management is operated and tested. Specifically, different forecasts for loads and RES production are tested to measure combined network data and calculate the network status in real time. This includes testing the feedback- and switching- behaviour as well as reactions of the HEMS towards changes of the network state.

- Improve grid flexibility and stability by utilizing demand response mechanisms and energy storage capabilities.
- Increase local RES share by increasing their usage in times of higher production, thus avoiding temporary shutdowns of RES facilities.
- Optimize VPP through services offered to DSOs.

Actors & Roles, Names and Types

- Aggregator/Flexibility Operator
- Distribution System Operator (DSO)
- End-users/consumers with and without electrical storage
- Battery storage operator

Short Description

HLUC05 "Enhance grid flexibility through DER Management" can be further depicted into these Primary Use Cases (PUCs):

- PUC05.01. Prediction of energy consumption and RES production
- PUC05.02. Utilizing the Virtual-Power-Plant

These PUCs are based on a Secondary Use Case (SUC):
SUC05.01. Grid status calculation and bottleneck detection

HLUC06: Consumer's engagement in Demand Side Management Programs utilizing feedback mechanisms

Scope

The scope of this use case is limited to feedback-based demand-side intervention strategies applied at the residential level. It describes how the DSO and/or Retailer provides a feedback mechanism in a context that is relevant to the needs of the households, and thereby increases residential awareness and engagement to demand side management programs in order to: Increase residential demand flexibility and decrease residential energy use.

Features under study:

- Residential flexibility
- Use of energy

Networks/Markets under study:

- MV Network
- Local Flexibility Markets

Objectives

The main objectives in this use case are two:

- Increase residential demand flexibility.
- Decrease residential energy use.

Actors & Roles, Names and Types

- Distributed Operator System (DSO)
- Retailer
- End consumers/prosumers

Short Description

HLUC06 "Consumers engagement in Demand Side Management Programs utilizing feedback mechanisms" can be further depicted into these Primary Use Cases (PUCs):

- PUC06.01. Increase residential demand flexibility
- PUC06.02. Decrease residential energy use

There is no any Secondary Use Cases (SUCs) related to UC06.

HLUC07: Consumer's engagement in demand response programs utilizing a socio-economic context

Scope

This UC entails to enable a set of social context drivers for energy-related behaviour changes by exploiting social interaction and cultural values. The aim is to influence efficient energy exchanges between households relying on consumer attitudes towards benefit and comfort. The latter is foreseen to take place based on qualitative and quantitative techniques, which have embedded prosumers' contexts.
The main objective will be to validate a social comparison tool by comparing the energy use between several neighbouring end-users focusing particularly on the individuals own behaviour which to some extent has implication on the consumption regular profile.

Twinergy has received funding from the European Union's Horizon 2020 research and innovation programme under grant agreement No. 957736

Features under study:

- Socio-economic variables
- Cultural dimensions (individual- and community-level)
- Behavioural data (e.g., adoption intention, engagement, energy exchanges between households, consumer attitudes (benefit in conjunction with comfort))
- Social competition among end-users
- Co-creation for end consumers, service providers and public authorities

Networks/Markets under study:

- LV Network
- MV Network

Objectives

Enable Social context drivers for energy-related behaviour changes, by utilization of social interactions and cultural values to influence energy exchanges between households, and consumer attitudes towards benefit and comfort. Within this UC the following aspects will be taken under consideration:

- Socio-economic variables
- Cultural aspects, at individual- and community-level (e.g., Hofstede cultural dimension or Schwartz Human Values Theory)
- All of these will be independent variables of attitude and actual users' behaviour (e.g., measuring adoption intention, speed-up engagement, energy exchanges between households, among others)

The main objective of this UC will be to leverage the inputs above by conducting behavioural analysis, as a matter of employing community based social marketing to engage participants through continuing conversation, active debates and organize Living Labs. From the individuals' perspective certain recommendations will be provided by the social network as a matter of improving their consumption profiles and habits. The latter aims to consider a disaggregation algorithm which will allow determining appliance-specific consumption, using merely the aggregate power signal of a household as input. Each appliance relates to a unique energy consumption pattern, characterizing and differentiating appliance's operations from the aggregate signal.

At the community level, competition among neighbouring end-users will take place via the utilization of Social Network Module will be performed based on gamification functionalities. The competition, in turn, will be relying on specific KPIs such as energy efficiency, participation on the local community, utilization of shared assets etc, as a matter of providing the corresponding rewards.

Actors & Roles, Names and Types

- End consumers (MV/LV) / Prosumers
- Public authorities

Short Description

This use case will also focus on the barriers that consumers face when adopting Demand Response, being cultural barriers, knowledge or social limitations like energy vulnerable customers. To gather this customer perspective, smartEn will work together with consumer organizations. The outcome will be a reasoned analysis into all kinds of barriers customers and service providers face and how they can limit the implementation of TwinERGY business models.

Social engagement in this context is foreseen to take place via a gamification scheme based on social comparison among several end-users (i.e., prosumers and consumers). The increased awareness of end-users profiles will be performed via comprehensive dashboards that will provide the monitoring of current and projected load and generation profiles.

The main objective will be to validate a social comparison tool by comparing the energy use between several neighbouring end-users focusing particularly on the individual's own behaviour which to some extent has implication on the consumption regular profile. The social comparison will also lead social competition among within the community or the neighbourhood providing rewards (i.e., TwinERGY points) to the participating households. The competition will be performed based on gamification functionalities which in turn will be relying on specific KPIs such as energy efficiency, participation on the local community, utilization of shared assets etc, as a matter of providing the corresponding rewards.

This use case is realized in the following Primary Use Cases (PUC):

- PUC07.01. Social marketing to engage customers via competition.
- PUC07.02. End-users' engagement on utilization of shared DERs.
- PUC07.03. Enable co-creation for end consumers, prosumers and public authorities.

HLUC08: Consumer's engagement in demand response programs utilizing personalized comfort/health-oriented services

Scope

The scope of this UC is to demonstrate innovative approaches to obtain consumers' realistic comfort / wellbeing level with minimum intervention. More specifically, it will be shown that the utilization of low-cost wearable devices through which specific physiological data can be unobtrusively obtained and advance unsupervised classification techniques comprise an appropriate combination to accurately depict consumers' comfort / wellbeing level. By accurately depicting this level the consumers become predictable energy wise and pertinent personalized feedback notifications can be provided to them.

Innovation often faces matters related to distrust and misunderstanding.

To improve the people participation in DR programs, one of the main tasks to tackle is to increase their awareness of the topic in order to reduce their fear of comforts losses.

The main idea is to let the users aware of their current energy usage routines:

- Are they healthy?
- Are they fine compared to the average of similar facilities?
- Does exists some unidentified energy consumption pattern?

Through a user-friendly Graphic Unit Interface, the energy monitoring information can be shown together with target and good practice threshold of facilities with similar characteristics. Moreover, is going to be suggest to the users, the optimal electrical appliances distribution during the week and the benefits, in terms of costs and energy consumption reduction. Starting from that, it is already possible to drive the users into an autonomous behavioural changing and toward more efficient and healthier energy routines. The next step is the real user's comfort analysis. Comfort is a parameter specific for each person; even married couple can have completely different energy consumption or indoor environment preferences. Because of that, a close-loop with the users is an interesting analysis target.Depending on the availability of the users, this use case aims to gather the comfort feedbacks through the GUI and the physiological data through wearable devices.In relation with the indoor and energy monitoring system data, the comfort analysis will enter in the optimal energy solution for DR.

Features under study:

- Sensing data from consumer premises,
- Physiological parameter monitoring
- Comfort analysis

Networks/Markets under study:

- Low voltage market

Objectives

Show that the utilization of low-cost wearable devices through which specific physiological data can be unobtrusively obtained, and advance unsupervised classification techniques comprise an appropriate combination to accurately depict consumers' comfort / well-being level.

Main objectives:

- Gather the comfort physiological parameters and their feedback from the users
- Increase the users' awareness about healthier energy routines
- Shape optimal load management based on the users' comfort specs

Actors & Roles, Names and Types

- End consumers

Short Description

The TwinERGY services will analyse and promote non-intrusiveness, comfort and well-being preservation, respect of prosumer daily schedules as well as maximization of benefits through transparent and open participation in markets. It will also guarantee easy switching between DR service providers, vendor lock-in avoidance, customized DR service contracts and objective settlement and remuneration, thus establishing an energy democracy context and empowerment of prosumers to become active energy market players.

HLUC08-Consumer's engagement in demand response programs utilizing personalized comfort/health-oriented services the scope of this particular UC is to demonstrate innovative approaches to obtain consumers' realistic comfort / wellbeing level with minimum intervention. More specifically, it will be shown that the utilization of low-cost wearable devices through which specific physiological data can be unobtrusively obtained and advance unsupervised classification techniques comprise an appropriate combination to accurately depict consumers' comfort / wellbeing level. By accurately depicting this level the consumers become predictable energy wise and pertinent personalized feedback notifications can be provided to them.

In this Use Case the "Consumer's engagement in demand response programs utilizing personalized comfort/health-oriented services "is focused on through:

This HLUC is realized in these Primary Use Cases (PUC):

- PUC08.01. Wellbeing best practice for indoor environment conditions
- PUC08.02. Physiological parameter and comfort feedback monitoring
- PUC08.03. Comfort relation within Demand Response optimal solution

There are not Secondary Use Cases (SUC) related.

HLUC09: Consumer's Engagement in Demand Response Programs Utilizing Digital Twin Prediction Capabilities for Dynamic VPPs

Scope

The main focus of consumer engagement in the demand response programs that utilise the digital twins of the TwinERGY pilot sites will be a human-machine interface in the form of an online interactive dashboards. Bespoke dashboards will be created for each of the pilot sites, the design of which will be informed by their specific requirements. Dashboards will be created for both Consumer and Community Digital Twins, with specific users able to interact with and evaluate relevant information about their home/building/community.
In terms of the quality of data that is displayed and the accuracy of the demand response programs, it is very important that the required information and data is provided by each of the pilot site. The quality of performance of this use case is directly proportional to the input data, and so the data collection exercise is a vital pre-requisite to this use case.

Features under study:
•Demand response, both implicit & explicit
Networks/markets under study:
•LV & MV Networks

Objectives

- Define explicit and implicit demand response actions at a building and community level
- Maximise renewable generation use and minimise carbon emissions for all buildings in the community
- Minimise energy costs community-wide

Actors & Roles, Names and Types

- Aggregator
- Retailer

Twinergy has received funding from the European Union's Horizon 2020 research and innovation programme under grant agreement No. 957736

- Building/asset owner
- End users

Short Description

The consumer and community digital twins (and associated demand flexibility profiling modules) will optimise the demand response based off both price and the carbon emission factor of the electricity for a given time period. The output of this process will be recommended actions for the user to carry out (such as delaying the switching on of their washing machine, for example) that are communicated through online dashboards, as well as automated explicit demand response actions as permitted by the end user. The response will then be captured by the metering of the pilot sites, and will feed into the next iteration of the optimisation algorithm.

HLUC09 can be further divided into these Primary Use Cases (PUCs):

- PUC09.01 Explicit Demand Response Automation and display at a consumer and community level.
- PUC09.02 Implicit Demand Response Calculation and Communication to the end-user at both a community and consumer level.

There are no Secondary Use Cases (SUCs) related to HLUC09.

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