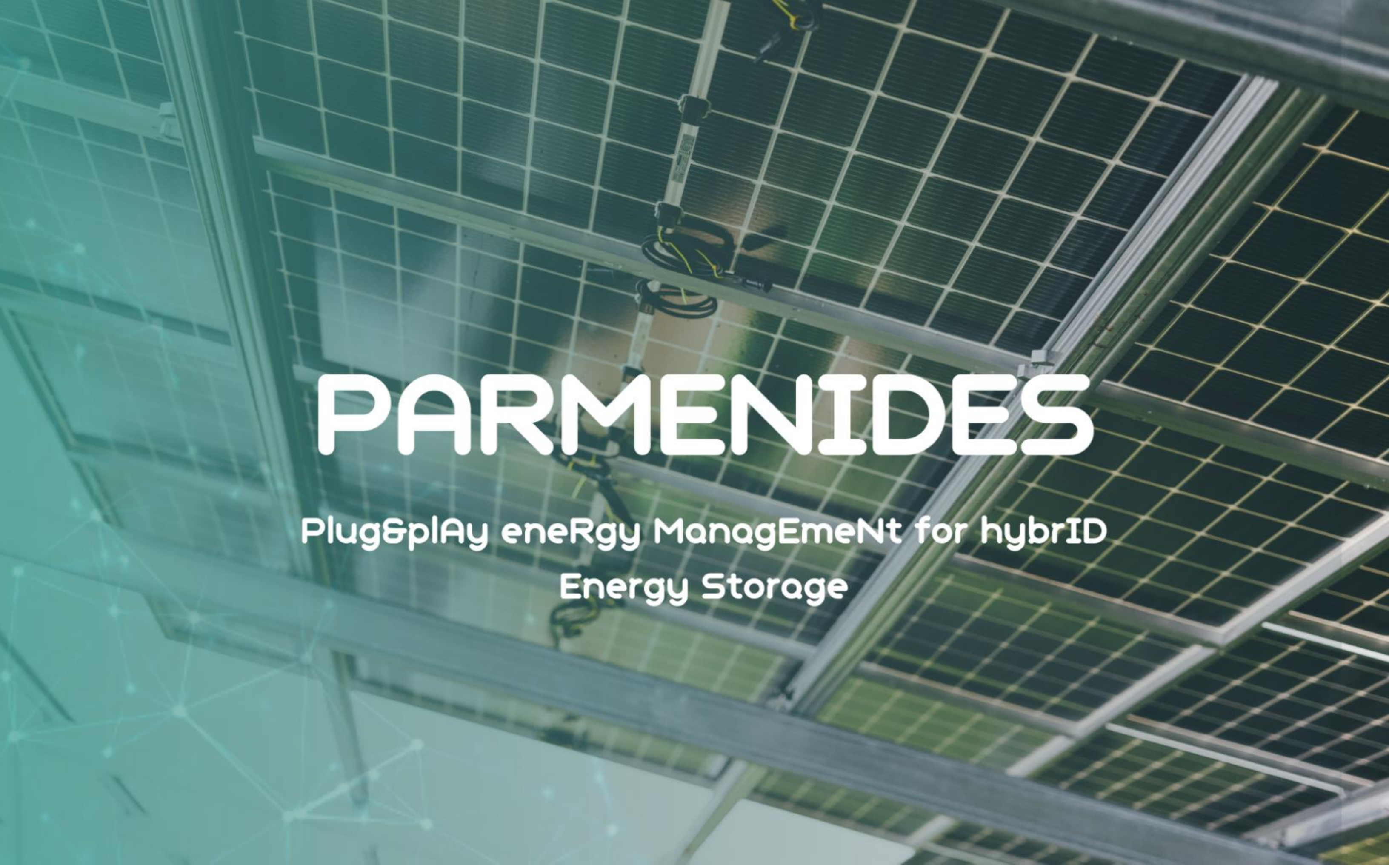


PARMENIDES

Plug&plAy eneRgy ManagEmeNt for hybrID
Energy Storage

Deliverable D3.1

PARMENIDES system architecture

Work Package 3

Disclaimer

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

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

Work package	WP3 - Architecture design, interoperability, and ontology development
Related task	T3.1 - Architecture based on SGAM
Deliverable due date	M12 (31.12.2023)
Actual delivery date	M12 (31.12.2023)
Dissemination level	Public
Deliverable responsible	Trialog

Document Information

Document Version: V1.1

Revision / Status: Submission

All Authors/Partners

Name	Organisation
Dune Sebilleau	Trialog
Léo Cornec	Trialog
Mark Stefan	AIT Austrian Institute of Technology GmbH

Document History

Revision	Content/changes	Resp. partner	Date
0.1	Creation of the structure	Trialog	22.11.2023
0.2	Addition of the content	Trialog	06.12.2023
0.3	Version sent for review	Trialog	07.12.2023
0.4	Update of the version according to project participants review	Trialog	19.12.2023
1.0	Final version	Trialog	20.12.2023
1.1	Review and submission	AIT	22.12.2023

Document Approval

Final approval	Name	Resp. partner	Date
1.0	Mark Stefan	AIT	22.12.2023

Copyright Notice

Executive Summary

This document aims at defining and documenting the architecture of PARMENIDES. It includes a description of the methodology used, a study of the communication protocols to be used, and the architectures, both the generic and the declinations for the different use cases and pilots. This work aims to ensure the interoperability of the components developed in WP4.

Table of contents

Abbreviations

Acronym	Description
aFFR	Automatic Frequency Restoration Reserve
BSP	Balancing Service Provider
CIM	Common Information Model
CSP	Concentrated solar power
DER	Distributed Energy Resources
DERA	Data Exchange Reference Architecture
DMS	Distribution Management System
DSO	Distribution System Operator
EC	Energy Community
EDI	Electronic Data Interchange
EMS	Energy Management System
EMS4HESS	EMS for HESS
ERRP	ENTSO-E Reserve Resource Process
ESCo	Energy Service Company
EU	European Union
EV	Electric Vehicle
FCR	Frequency Containment Reserve
GBP	Generic Business Process
GCM	Grid Capacity Management
GMD	Grid Monitoring Devices
HEMS	Home Energy Management System
HESS	Hybrid Energy Storage System
HVAC	Heating, Ventilation, and Air Conditioning
ICS	Information and Configuration System
IoT	Internet of Things
mFRR	Manual Frequency Restoration Reserve
NIST	National Institute of Standards and Technology
PECO	PARMENIDES Energy Community Ontology
PV	Photovoltaic
SCADA	Supervisory Control And Data Acquisition
SGAM	Smart Grid Architecture Model

Acronym	Description
SHBIRA	Smart Home and Building IoT Reference Architecture
SIF	Semantic Interoperability Framework
SM	Smart Meters
TSO	Transmission System Operator
UFTP	USEF Flexibility Trading Protocol
USEF	Universal Smart Energy Framework
Vlab	AIT Virtual Verification Laboratory
XML	Extensible Markup Language

1. Introduction

1.1. PARMENIDES project introduction and summary

The ongoing transition of the energy system is accompanied by digitalization activities, enabling new applications. This results in a fragmentation of existing platforms, protocols, and standards. Therefore, interoperability among various platforms as well as cross-domain interoperability must be ensured.

The usage of ontologies provides an opportunity to address cross-platform and cross-domain interoperability. PARMENIDES aims to develop a new ontology by extending existing ontologies to provide a knowledge base, with a focus on the electricity and heating domain for buildings, customers, and energy communities. It will support different use cases, focusing on the utilization of Hybrid Energy Storage Systems (HESS). Besides the representation of storage technologies, information about energy community customers, their behaviours, and components including their relation will be part of the ontology, providing a standardized vocabulary of the domain of energy communities. This further includes technical, economic, regulatory, behavioural, and social constraints to be considered in operation.

To support a number of use cases, a new generation of innovative Energy Management Systems (EMS) will be developed. This system will be capable of using ontology as a knowledge base. This will enable a very generic software design and ensures the scalability and replicability of the solution.

As a framework for the integration of the EMS, PARMENIDES will define an information and communication architecture, enabling an interoperable, reliable, and secure exchange of data and instructions. The developed EMS will be demonstrated in very diverse pilots in Austria and Sweden. The Austrian pilot will address energy communities with different storage technologies, the Swedish pilot will focus on flexibility from a very short time scale through innovative heat pump control to electrical and thermal batteries and seasonal storage through geothermal borehole heat exchangers.

1.2. Work Package 3 (WP3) introduction

The objectives of this work package are to design an interoperability and secured system architecture to support the use cases defined in WP2 and develop the required components in WP4. It will rely on existing references (e.g., standards, reports, etc.) and results from previous projects (e.g., InterConnect, BRIDGE, etc.). Furthermore, the PARMENIDES Energy Community Ontology (PECO) will be developed, based on existing ontologies to act as a knowledge base for the new generation of energy management applications (WP4) and to utilize the flexibility of different storage technologies.

1.3. Deliverable 3.1 (D3.1) introduction

The following deliverable presents the project architecture studied and defined within WP3. It describes the various interactions required between the project's material but also non-material elements. Thus, it is a definition of its structure, and this work will be the foundation for the following steps of the project.

The architecture of the PARMENIDES project has been defined within the task 3.1. It aims at refining the findings of the task 2.2 [1] on the use cases in terms of interactions between actors and systems. A generic architecture is defined for the whole project, encompassing the main functions and objectives of the project. The resulting architecture is then declined to fit the specificities of the use cases and pilot implementations. This work was moreover preformed in close collaboration with the task 3.2 to ensure the coherence of the data exchanges depicted in the architecture with the development of the ontology.

The solution developers were moreover involved to be able to properly comprehend the functions and interactions of the components to be developed. Pilot leaders were also involved in the discussions to understand the specificities of the local assets.

Moreover, the elaboration of the architecture lead to identify a gap in the identification of communication standards, as the standard to be use for flexibility exchanges was not yet chosen. A focussed study of existing protocols and their relevance for the PARMENIDES project therefore enabled to fill this gap.

The architecture was developed based on frameworks and methodologies. These includes the Smart Grid Architecture Model (SGAM), the Data Exchange Reference Architecture (DERA) developed by Bridge, the Smart Home and Building IoT Reference Architecture (SHBIRA), and the Semantic Interoperability Framework (SIF) developed by Interconnect.

The innovation brought by PARMENIDES through its infrastructure is the integration of hybrid system storages, to be structured around an Energy Community (EC) and the creation of an EC dedicated ontology. This architecture will be used directly by the Australian and Swedish pilots of the project.

2. Methodology

The methodology for the definition of the architecture of the Parmenides project will be based on a methodology developed by Trialog through previous innovation projects. It relies on a range of frameworks, that complete each other to get a complete vision of the architecture. The SGAM framework is used as a basis for the relations between the components and is used for the instantiations of the architectures. The DERA 3.0 framework [2] is used to identify the generic components used in Parmenides. In particular, the recommendations included in the DERA report were examined to integrate the relevant recommendations in the Parmenides activities. The SHBIRA [3] was used to detail the architecture in the customer premises area, which is very important in the scope of energy communities. Finally, the SIF framework [4] was used to define the architecture of the ontology.

Based on these frameworks, a generic architecture of the overall project is first defined. The generic architecture is then instantiated to define a specific architecture for each use-case, and for each pilot. The use-cases architectures will show the details of the functions implemented and components used in each use-case, and the pilot-specific architectures will show the details of local assets and their communications.

2.1. SGAM

The architecture of the system developed and implemented in the Parmenides project was designed using the SGAM. It is a unified standard allowing for the representation of a smart grid architecture, described in [5]. It consists of five interoperability layers, each subdivided in electrical domains and information management zones.

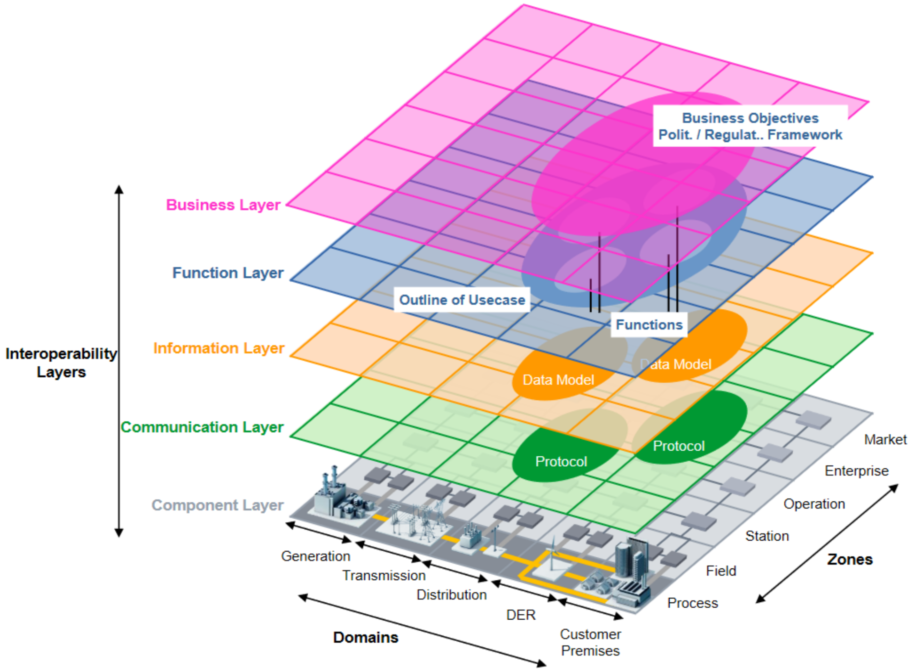


Figure 1: SGAM framework

Each layer focuses on a different level of abstraction:

- **The business layer:** is used to map regulatory and economic structures as well as policies, business models, business portfolios (products & services) of market parties involved.
- **The function layer:** describes functions performed by the system as well as their relationship to one another.
- **The information layer:** describes the information that is being exchanged between functions, services and components. It contains information objects and can specify the underlying canonical data models.
- **The communication layer:** describes protocols and mechanisms for the interoperable exchange of information between components in the context of the underlying use case, function or service and related information objects or data models.
- **The component layer:** describes the physical distribution of all participating components in the smart grid context. This includes system actors, applications, power system equipment (typically located at process and field level), protection and tele-control devices, network infrastructure (wired / wireless communication connections, routers, switches, servers) and any kind of computers.

Each of these layers is mapped on the Smart Grid Plane. This Plane distinguishes electrical process and information management viewpoints. These viewpoints can be partitioned into the physical *domains* of the electrical energy conversion chain and the hierarchical *zones* for the management of the electrical process.

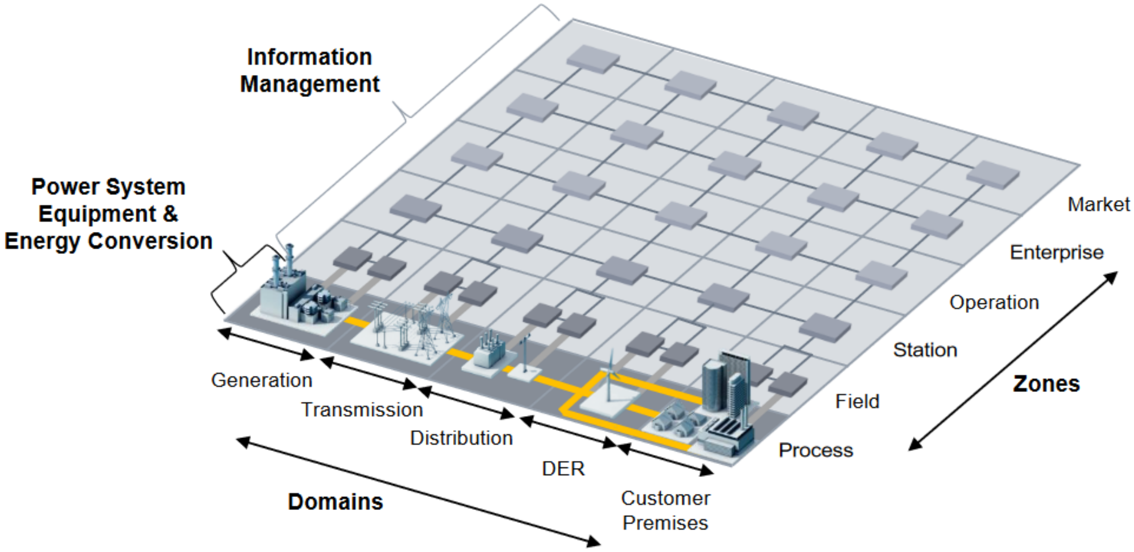


Figure 2 : Smart Grid Plane – Domains and hierarchical zones

These domains are arranged according to the electrical energy conversion chain. They are defined as follows:

- **Bulk Generation:** Representing generation of electrical energy in bulk quantities, such as by fossil, nuclear and hydro power plants, off-shore wind farms, large scale solar power plant (i.e., PV, CSP)– typically connected to the transmission system.
- **Transmission:** Representing the infrastructure and organization which transports electricity over long distances.
- **Distribution:** Representing the infrastructure and organization which distributes electricity to customers.
- **Distributed Electrical Resources (DER):** Representing distributed electrical resources directly connected to the public distribution grid, applying small-scale power generation technologies (typically in the range of 3 kW to 10.000 kW). These distributed electrical resources may be directly controlled by the DSO.
- **Customer Premises:** Hosting both end users of electricity and producers of electricity. The premises include industrial, commercial and home facilities (e.g. chemical plants, airports, harbours, shopping centres, homes). Also, generation in form of e.g. photovoltaic generation, electric vehicles storage, batteries, micro turbines, etc. are hosted.

The SGAM zones represent the hierarchical levels of power system management. They are defined as follows:

- **Process:** Including the physical, chemical, or spatial transformations of energy (electricity, solar, heat, water, wind ...) and the physical equipment directly involved. (e.g., generators, transformers, circuit breakers, overhead lines, cables, electrical loads any kind of sensors and actuators which are part or directly connected to the process, ...).
- **Field:** Including equipment to protect, control and monitor the process of the power system, e.g., protection relays, bay controllers, any kind of intelligent electronic devices which acquire and use process data from the power system.
- **Station:** Representing the areal aggregation level for the field level, e.g., for data concentration, functional aggregation, substation automation, local SCADA systems, plant supervision...
- **Operation:** Hosting power system control operation in the respective domain, e.g., distribution management systems (DMS), energy management systems (EMS) in generation and transmission systems, microgrid management systems, virtual power plant management systems (aggregating several DER), electric vehicle (EV) fleet charging management systems.
- **Enterprise:** Includes commercial and organizational processes, services and infrastructures for enterprises (utilities, service providers, energy traders ...), e.g., asset management, logistics, work force management, staff training, customer relation management, billing and procurement, ...
- **Market:** Reflecting the market operations possible along the energy conversion chain, e.g., energy trading, mass market, retail market, …

2.2. Data Exchange Reference Architecture (DERA)

The Data Exchange Reference Architecture (DERA) has been developed by the Bridge Data Management Working Group to facilitate cross-sector interoperability. It includes the data exchanges involving any stakeholders and divides the different aspects of these data exchanges on the basis of the SGAM layers. A third version of this reference architecture has been produced in 2023 [2] to aggregate and simplify the modules, include the Data Space concept, and to conform to the EU action plan on Digitalising the energy system [6]. It highlights the transversal concepts associated with each module of the architecture, such as security, user acceptance or interoperability.

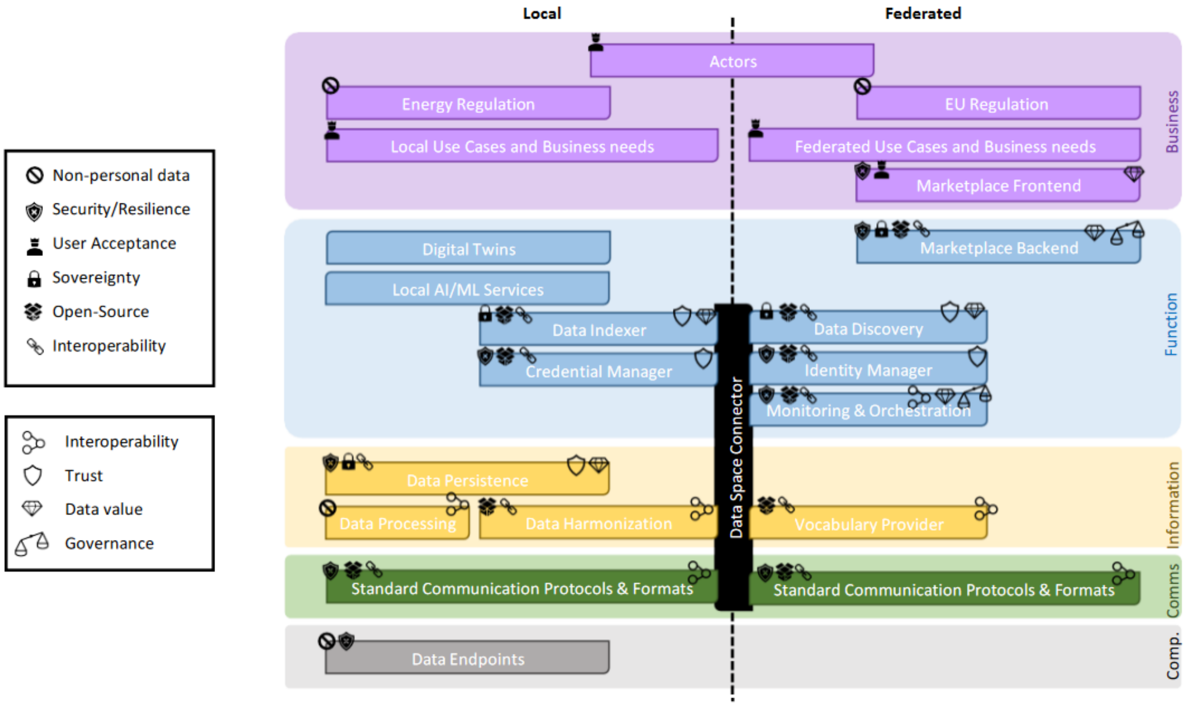


Figure 3: Data exchange reference architecture 3.0

The DERA reports moreover provide a set of recommendations with regards to the design and implementation of the architecture in smart grid projects.

The applicable modules of the DERA and relevant recommendations are described in section 4.2.

2.3. Smart Home and Building IoT Reference Architecture (SHBIRA)

The goal of the Smart Home and Building IoT Reference Architecture (SHBIRA) is to provide a unified architecture viewpoint capable of describing how different components relate to each other in an easy, affordable, and trustworthy manner, allowing for the interconnection of services and devices in the connected Smart Homes and Buildings.

A complete description of the SHBIRA, as well as the methodology followed for its definition, can be found in InterConnect Deliverable 2.1 [3]. The high-level reference architecture is shown below.

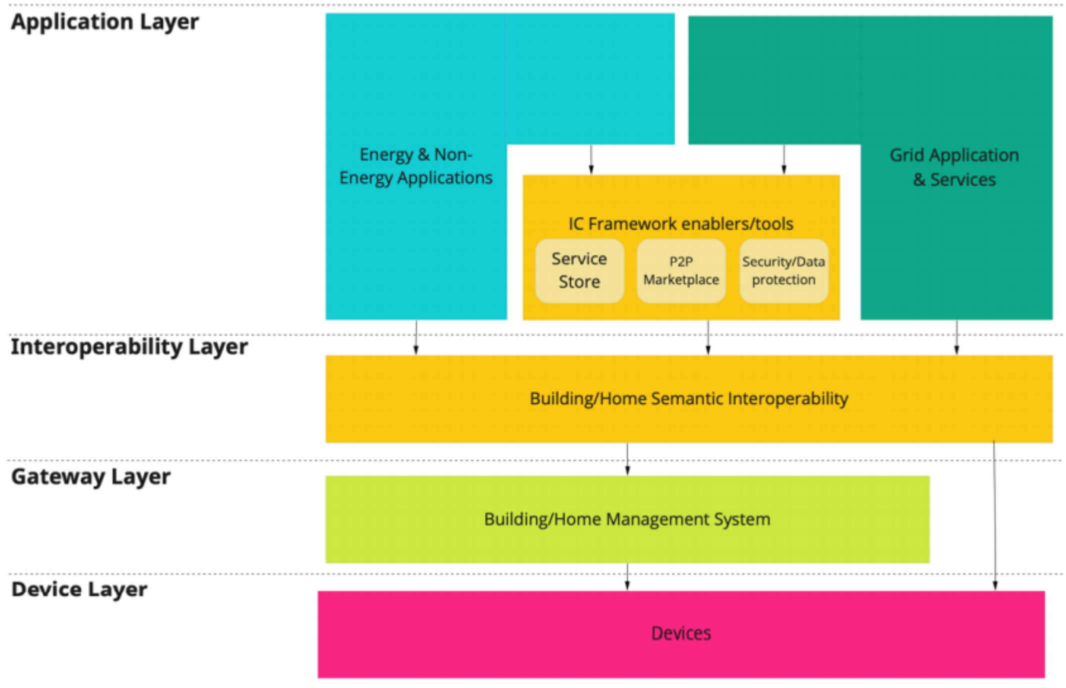


Figure 4: InterConnect's Smart Home and Building IoT Reference Architecture (SHBIRA)

This reference architecture includes four different layers, as described in InterConnect Deliverable 2.1 [3]:

The **Device layer**, consisting of all connected devices and appliances that are installed in the house or in the building. These devices interact with their environment by collecting the information provided by embedded sensors, actuators, processors, and transceivers. In essence, this layer cumulates two functions:

- **Perception**, which is provided by built-in sensors (e.g., environmental sensors, location sensors, light sensors, movement sensors) capable of detecting environmental changes or any other relevant information within its reach.
- **Actuation**, defined as the ability to mechanically control physical devices and appliances.

The **Gateway layer**, including home and building management systems, deployed on site. This layer encompasses communication technologies and protocol gateways bridging the devices and higher-level applications and services.

The **Interoperability layer** allows the establishment of semantic interoperability. This layer provides all the necessary mechanisms and components to facilitate interworking between IoT devices, digital platforms, the energy infrastructure and energy/non-energy applications.

The **Application layer**, which includes all interoperable services (energy, non-energy and grid-related) as well as applications built for the realization of the project's use cases. Applications have been divided into three categories:

- The **Energy and Non-Energy Applications**. Examples of these services include energy efficiency, smart metering, flexibility management, surveillance, amongst others and mainly benefit consumers.
- The **Grid Application and Services** which refer to services that can be proposed to system operators or markets agents to help at the operation of the electricity system.
- The **IC Framework enablers/tools** that gather a collection of tools and enablers that describes and prescribes how to interconnect devices from different vendors and services from different providers, enabling interoperability and the intelligent interaction of many devices and services from different domains.

This framework was moreover modified on the model of the Sender project [7] to include transversal concerns, such as cybersecurity or interoperability.

2.4. Semantic Interoperability Framework (SIF)

The Semantic Interoperability Framework (SIF) [4] was developed by the project Interconnect to structure the implementation of ontologies. It is based on a central knowledge engine and uses generic adapters to be interfaced with external systems. It enables categories 3 and 4 of interoperability in the GWAC Framework [8]. The Figure 5 shows the structure of the framework.

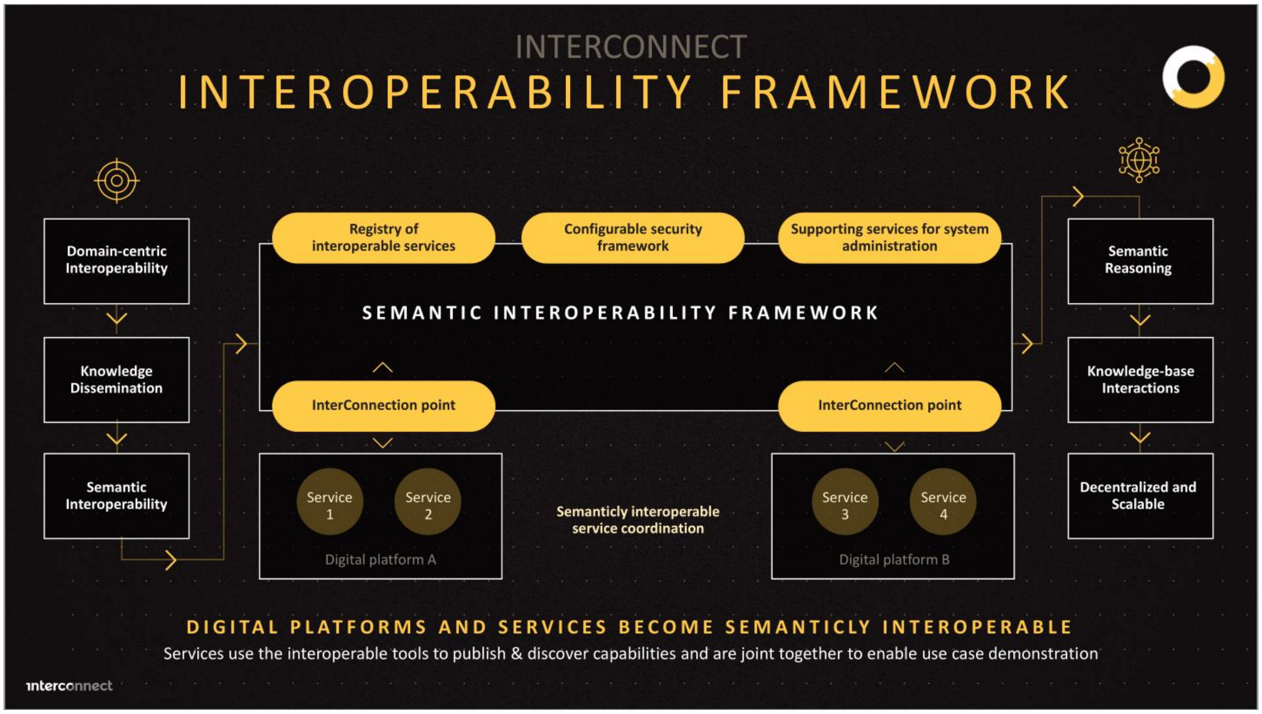


Figure 5: The semantic interoperability Framework from Interconnect [3]

This framework has been used to define the structure of the ontology implementation in PARMENIDES, as shown in the interoperability layer of the SGAM.

3. Selection of communication protocols

Within the development of the architecture, the specification of the communication protocols to be used by each interface is an important part. Most communications are processed through the gateways. The following section will describe the remaining interface to be designed, which is the relation between the PARMENIDES system and the DSO in the Austrian Pilot. Furthermore, the mechanisms for the flexibility offers, negotiations and activations will be detailed.

3.1. Bridge Generic business processes

The 2019 Bridge data management working group report on the main findings and recommendations [9] mentions that new systems should rely on existing standards. However, no recommendations are made on a specific standard to be used.

The 2022 Bridge data management working group report on the interoperability of flexibility assets 2.0 [10] categorizes the flexibility processes into five generic business processes. Given the architecture of PARMENIDES and the participants, the most relevant processes are the GBP 2 for the Austrian Pilot (recommendations including a DSO), and the GBP 4 for the Swedish pilot (energy community optimisation).

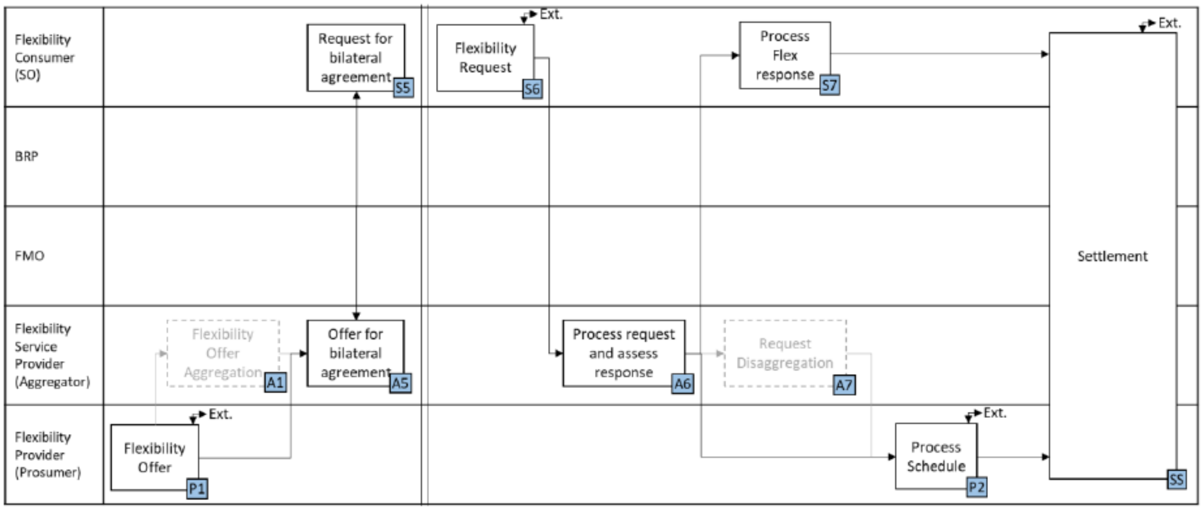


Figure 6: Bridge Generic business process 2

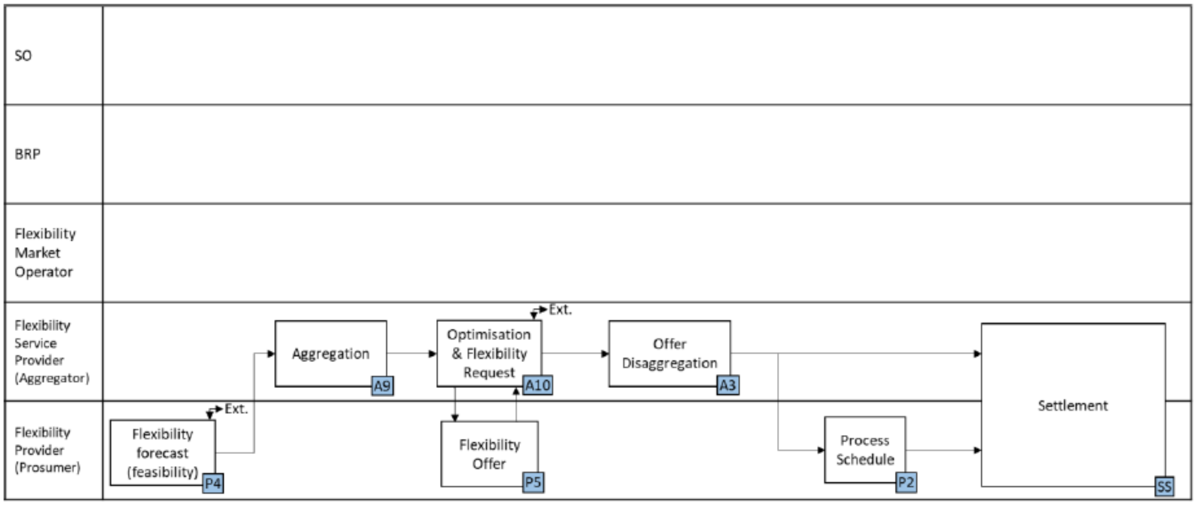


Figure 7: Bridge Generic business process 4

The details of the functions and interfaces purposes are detailed in the report. Additionally, the protocols used in the different interfaces are included in section 4.2.1. The protocols listed as relevant by previous projects are:

- FlexOffer
- USEF
- Modbus
- OCPP
- IEC 60870-5-104
- DLMS/COSEM
- IEC 61850
- CIM
- OpenADR
- EQUIGY
- ERRP
- Z-Wave

3.2. Relevant protocols for flexibility

Not all these protocols are relevant for Parmenides, as some are focussed on one type of flexibility and therefore does not allow for handling the hybrid energy storage that is at the core of the Parmenides system (OCPP for electric vehicles, Z-wave for home devices), or are focussed on the communication with grid assets instead of EMS communications (IEC 60870-5-104, DLMS/COSEM). Moreover, some of these protocols are quite generic, and not focus on the flexibility aspects, as is needed in PARMENIDES (Modbus), or are focused on the data models (CIM).

The most relevant protocols are therefore the following:

- FlexOffer
- USEF
- OpenADR
- EQUIGY
- ERRP

Moreover, the IEEE 2030.5 has also been identified as relevant, and will therefore be added to the studied protocols. All these protocols have been studied in MAESHA’s deliverable D1.4. The main findings with regards to these protocols are detailed in the following paragraphs.

3.1.2 Electricity Balancing Process (ex ERRP)

The Electricity Balancing Process (derived from the ENTSO-E Reserve Resource Process, ERRP [11]) is defined in the Electronic Data Interchange (EDI) library of ENTSO-E. It is a set of conceptual and assembly models, based on the IEC 62325 series (CIM) and developed for reserve resource tendering, planning and activation within the balance management process, as displayed in Figure 8 below. IEC 62325-451-7 defines the Balancing processes, contextual and assembly models for European style market. The system implementation is based on the following ENTSO-E documents:

- ENTSO-E Reserve Resource Process (ERRP) Implementation Guide v5r0 or later versions
- IEC 62325-451-1: Acknowledgement business process and contextual model for CIM European Market
- ENTSO-E Code lists v50 and later versions
- ENTSO-E CIM XSD Schemas

The Electricity Balancing Process defines schemas for:

- Historical activation
- Planned resource schedule
- Redispatch
- Reserve allocation result
- Resource schedule anomaly report
- Resource schedule confirmation
- Bid availability

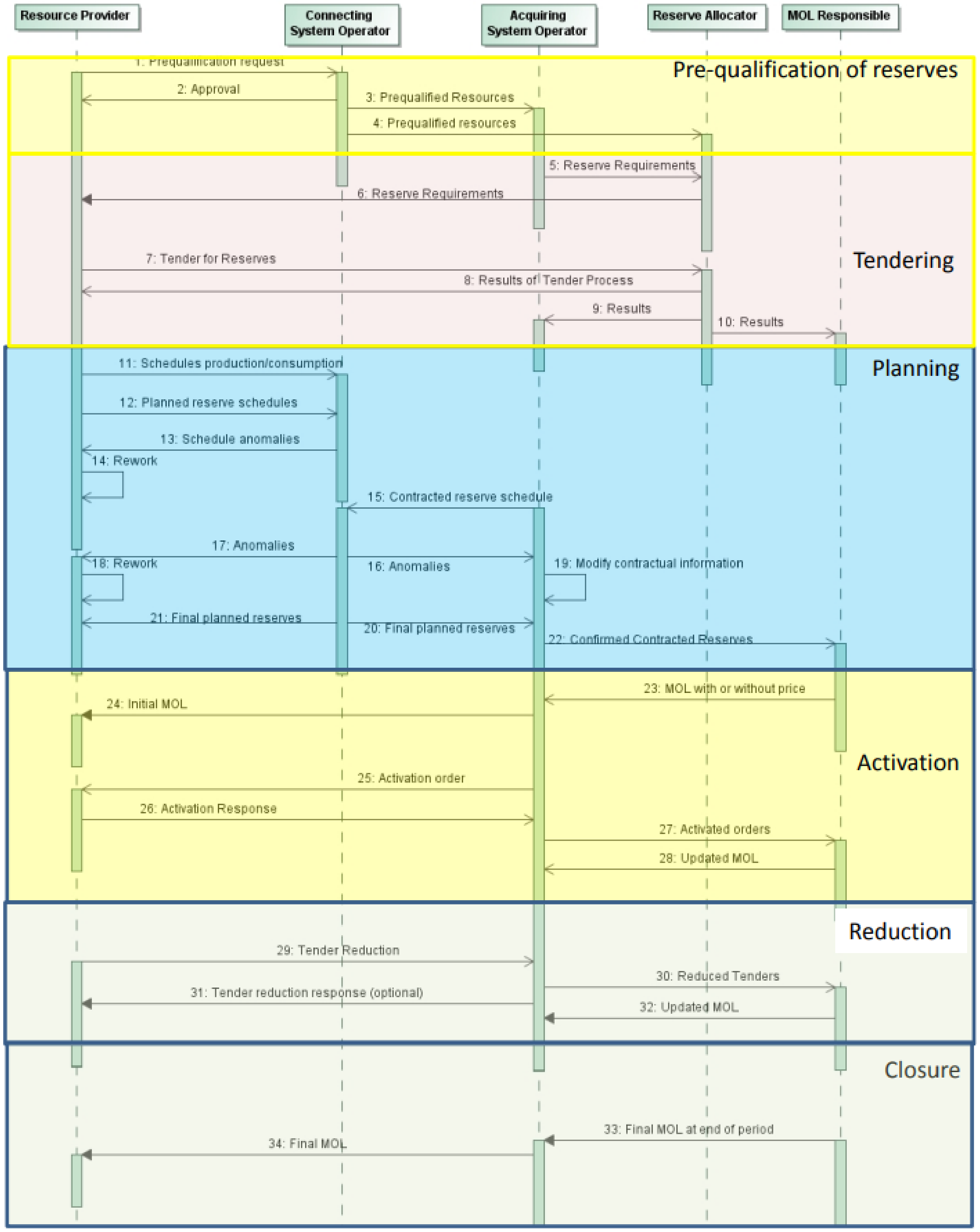


Figure 8: Reserve resource activation sequence [11]

In 2022, the Electricity Balancing Process will be implemented as communication standard for the platforms for procurement procedures of automatic Frequency Restoration Reserve (aFRR) (PICASSO project), manual Frequency Restoration Reserve (mFRR) (MARI project), and Replacement Reserves (RR) (TERRE project) by most European TSOs, and some TSOs will also extend the application to Frequency Containment Reserve (FCR) procurement. This fact makes it to the most relevant standard for ancillary services procurement in the European Union. The ENTSO-E has published several implementation guides to define the data exchanges with those European platforms for the exchange of balancing energy [12].

On the other hand, there are some market participants that criticize the Electricity Balancing Process for the following reasons:

- The Electricity Balancing Process causes high effort to implement which may be an entry barrier for smaller Balancing Service Provider (BSP).
- As for now, the application focuses on ancillary services procurement for TSOs but other use cases shown in Figure 8 like registration and prequalification. However, monitoring and settlement have not been applied in practice so far or are not even available at all.
- The standard represents the use cases of the TSOs, but DSO have not been involved in the standardization process.
- The utilization of XML formats creates much overhead and simpler format like JSON gain importance in internet communication.

As such, the Electricity Balancing Process alone cannot cover all use cases of ancillary services provision and needs to be combined with other CIM based standards to cover the entire workflow. If ENTSO-E maintains the pace of developing and implementing the Electricity Balancing Process, it is very likely that the standard will be further developed in the following years.

Implementation in PARMENIDES: This protocol is very focused on the balancing needs of the TSO, and includes a quite complex tendering process, that is not needed by Parmenides. This might therefore be too complex for the needs of Parmenides.

3.2.2 EQUIGY

The Electricity Balancing Process has developed towards the de-facto standard for balancing markets communications in the European Union. While the data model is applied consistently in different countries, the transport layers are not harmonized between the control zones and each European country can implement its own solution. Further critics are based on the use of XML formats, which may introduce too much communication overhead and limit the future development of applications for very fast services like real-time monitoring for aFRR.

EQUIGY [13] is a recent initiative driven by four European TSOs to combine the benefits of the data model of the Electricity Balancing Process with a widely applied state-of-the-art way for internet communication. The XML format is replaced by a JSON format, and the messages are exchanged by means of REST web services. It is intended to extend the application to the entire reserve resource process including registration on a “Crowd Balancing Platform”, trading like in the original Electricity Balancing Process, online monitoring and DSO flexibility markets. EQUIGY aims at providing a platform that can also integrate small flexibilities due to its rather lean protocol and simple implementation on the side of the Flexibility Service Provider.

EQUIGY is in the pilot stage, with ongoing pilots to develop and demonstrate Minimum Viable Product in five European countries. The initiative looks very promising, but because of its still early stage there is no publicly available information about the data model or protocol which limits the application independent from the key actors at the moment.

Implementation in Parmenides: The lack of information and open specifications around this protocol may prove challenging for the implementation within Parmenides. It is moreover very focused towards the needs of the TSO.

3.3.2 OpenADR

The Open Automated Demand Response (OpenADR) is an open-source smart grid communications standard used for demand response applications [14]. The protocol has been developed by the United Stated Department of Energy's Lawrence Berkeley National Laboratory in 2002. It is typically used in demand response scenarios when specific signals are sent to devices to be turned off during periods of higher demand. The OpenADR standard, currently at version 2.0b (with the recently released OpenADR 3.0 [15] add-on providing additional functionalities), prescribes the information exchange between utilities and energy management control systems.

OpenADR uses a service-oriented architecture in which all interactions occur between entities called virtual top nodes (VTNs) and virtual end nodes (VENs), as shown in Figure 9 below.

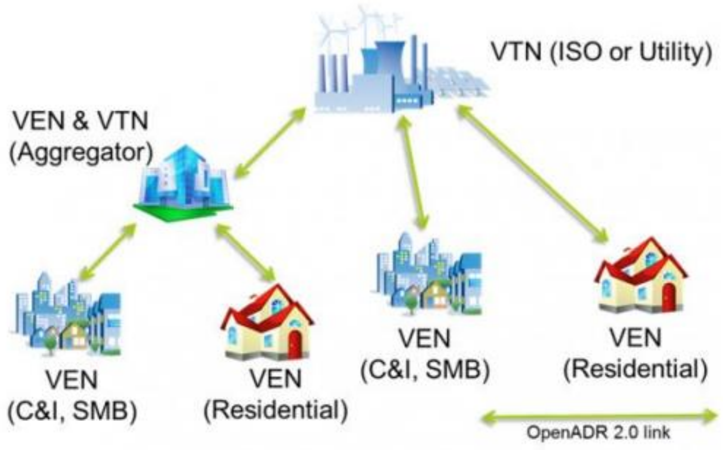


Figure 9: OpenADR service-oriented architecture [16]

In general, the VTNs send demand response signals to the VENs and there is a hierarchical relationship between VTNs and VENs, where in some cases a node can be a VEN and a VTN at the same time. This model therefore supports the notion of intermediaries such as aggregators, which are common within existing demand response implementations.

Up to now, two profiles of OpenADR 2.0 have been developed. Profile A is targeted towards low-end devices and is limited to a simple implementation of OpenADR enabling only the notification of the VEN of upcoming DR events and sending the demand response signals from the VTN to the VEN. Profile B is targeted toward fully functional control systems and devices and enables feedback and additional services. It includes the opt-out and opt-in of the VEN from DR events and the information reporting to the VTN. This information is typically used by the VTN to both predict and monitor the behaviour of the demand-side loads associated with the VEN.

The standard allows a response signal to the DR event to travel back from VENs to the VTNs, and, in addition, other information can also be exchanged related to DR events, such as event name and identification, event status, operating mode, various enumerations characterizing the event, reliability and emergency signals, renewable generation status, market participation data and test signals [17]. The implementation of the services is based on standard-based IP communications such as HTTP and XML Messaging and Presence Protocol (XMPP).

The demand-response signals are the means by which a VTN interacts with a VEN in order to influence or change the load profiles of the demand-side loads associated with the VEN. The OpenADR specification supports a wide range of different types of demand-response signals such as direct load control, or price incentives. From the launch of the OpenADR add-on (OpenADR 3.0) [18] additional functions are included, e.g, smart thermostats, gas signalling, EV charging stations, energy storage, control systems and grid code adjustments.

From the security perspective, OpenADR 2.0 aims to conform with the NIST Cyber Security requirements and follows the guidelines provided by the “Security Profile for OpenADR”. At the moment OpenADR 2.0 is limited to electrical DR. It would be important to consider the relation to other energy sources used e.g. for heating and cooling in a cross-carrier energy context to apply DR also to other energy sources.

Please note that in January 2019, the OpenADR Profile Specification was named as the IEC 62746-10-1 ED1 getting an international recognition as the standard for the implementation of automated demand response strategies. The IEC 62746 standard is fully named “Systems interface between customer energy management system and the power management system”.

In Europe, OpenADR has been implemented in several projects, such as the ELBE project, which goal is to install in Hamburg 7000+ intelligently controlled charging stations [19]. OpenADR is also used in the Intertrust Platform by E.ON, one of the largest utilities in Europe, for load balancing for efficient EV charging management in Germany and Western Europe [20].

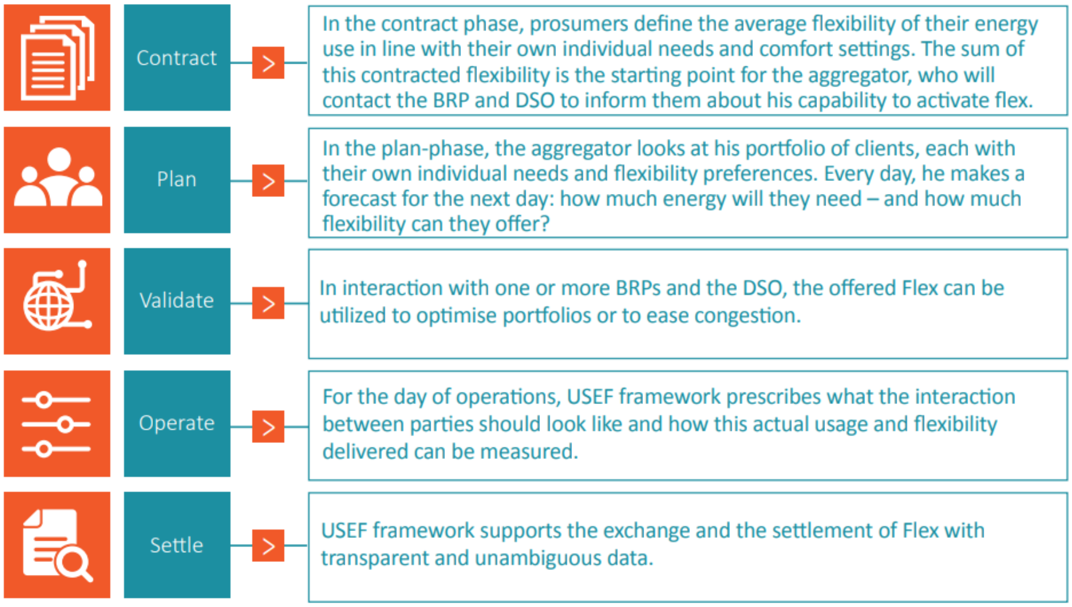
Implementation in PARMENIDES: OpenADR seems to be quite suited to the PARMENIDES project. The Open ADR and its hierarchical approach are convenient for the project requirements and could be translated from the DSO and the GCM as well as from the EMS4HESS and the HEMS.

3.4.2 USEF Flexibility Trading Protocol (UFTP)

USEF Flexibility Trading Protocol (UFTP) is a subset of the Universal Smart Energy Framework (USEF). Focused specifically on the exchange of flexibility between Aggregators and DSOs, it describes the corresponding market interactions between them. It can also be used as a stand-alone protocol for flexibility forecasting, offering, ordering and settlement processes. The USEF framework as well as the UFTP specifications (v1.01) are open and accessible to all in the USEF website (usef.energy).

USEF was founded in 2014 by seven key players, active across the smart energy industry: Alliander, Stedin, ICT Group, DNV GL, ABB, IBM and Essent. It grew out of the Smart Energy Collective, a Dutch multi-partner collaboration, developing smart energy technologies and services. The foundation aimed to contribute to the development of a common smart energy standard and shared EU framework to maximize the value of flexibility to all market stakeholders.

The framework describes some roles, responsibilities, and agreements, with very clear processes for effective interaction. The main processes of contracting, planning, validation, operation, and settlement are described in Figure 10 below.



In the contract phase, prosumers define the average flexibility of their energy use in line with their own individual needs and comfort settings. The sum of this contracted flexibility is the starting point for the aggregator, who will contact the BRP and DSO to inform them about his capability to activate flex.

In the plan-phase, the aggregator looks at his portfolio of clients, each with their own individual needs and flexibility preferences. Every day, he makes a forecast for the next day: how much energy will they need – and how much flexibility can they offer?

In interaction with one or more BRPs and the DSO, the offered Flex can be utilized to optimise portfolios or to ease congestion.

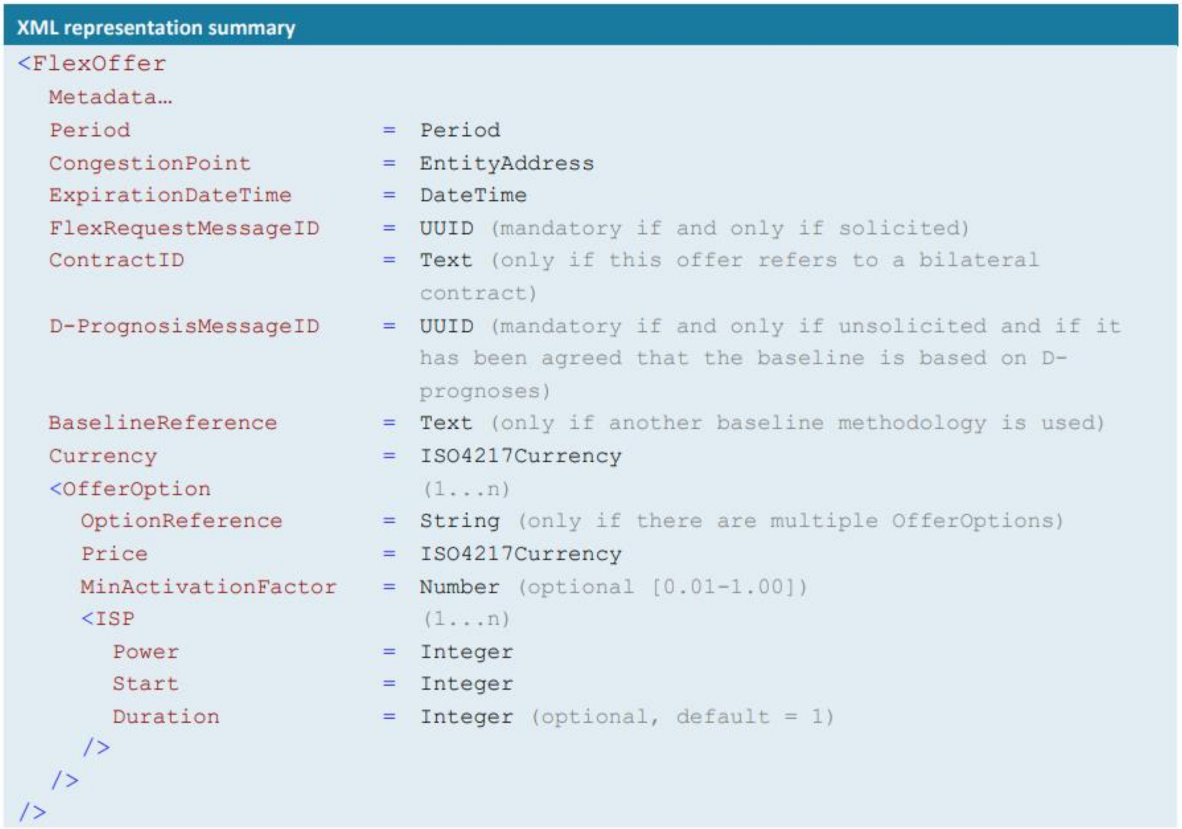
For the day of operations, USEF framework prescribes what the interaction between parties should look like and how this actual usage and flexibility delivered can be measured.

USEF framework supports the exchange and the settlement of Flex with transparent and unambiguous data.

Figure 10: Description of the main processes of the USEF framework [21]

Initially, the protocol has been developed to resolve grid constraints by applying congestion management or grid-capacity management. However, the protocol has been selected and extended for the use of some European projects (e.g., X-FLEX and MERLON) as described in [10].

All interactions between the Aggregator and the SO in the five different processes are described in the open specification [22], as well as the description of each XML message. As an example, the XML representation of the FlexOffer messages used by aggregators to make DSOs an offer for provision of flexibility is proposed in Figure 11.



XML representation summary

```
<FlexOffer
  Metadata…
  Period                  =  Period
  CongestionPoint         =  EntityAddress
  ExpirationDateTime      =  DateTime
  FlexRequestMessageID    =  UUID (mandatory if and only if solicited)
  ContractID              =  Text (only if this offer refers to a bilateral
                             contract)
  D-PrognosisMessageID    =  UUID (mandatory if and only if unsolicited and if it
                             has been agreed that the baseline is based on D-
                             prognoses)
  BaselineReference       =  Text (only if another baseline methodology is used)
  Currency                =  ISO4217Currency
  <OfferOption               (1...n)
    OptionReference       =  String (only if there are multiple OfferOptions)
    Price                 =  ISO4217Currency
    MinActivationFactor   =  Number (optional [0.01-1.00])
    <ISP                     (1...n)
      Power               =  Integer
      Start               =  Integer
      Duration            =  Integer (optional, default = 1)
    />
  />
/>
```

Figure 11: XML representation of the FlexOffer message [22]

Implementation in PARMENIDES: USEF focusses on the interactions between Aggregators and DSOs and lacks details in the Aggregator-EMSs interfaces, that are highly important for PARMENIDES.

3.5.2 FlexOffer

FlexOffer is an application-level communication protocol for flexibility trading between prosumers, aggregators, and DSOs. This protocol helps in defining and transmitting flexibility offers extracted from various assets (e.g., heat pumps, EVs and HVAC systems). In simple cases, it is an offer from a prosumer to an aggregator, but in more complex cases, a flexibility offer can represent a production, a mix between production and consumption (balancing, self-consumption) or a constraint on the electricity network. It thus offers a unified way of representing or modelling flexibilities and is relatively adaptable as it details the messages used and not the use cases. It also allows the aggregation of flexibility offers between different types of prosumers and different aggregators.

A visual representation of a (simple) flex-offer is shown Figure 12 below. Each bar in the graph corresponds to a time slice of energy consumption, with the lower part representing the minimum amount of energy that a flexible resource needs to provide its service, and the upper part an interval within which it can adjust its consumption, while still satisfying functional constraints (e.g., comfort temperature). This is called an (energy) amount flexibility. Another type of flexibility is time flexibility as shown in Figure 12.

Time flexibility is provided when an energy load can be shifted within a time interval, defined by an earliest start time at which the flexible resource can start its consumption, and a latest end time at which it should be done. When created, a flex-offer is assigned a baseline schedule that corresponds to the consumption pattern that the associated flexible resource prefers to follow. Updated schedules can be assigned to the flex-offers to modify the consumption behaviour of the flexible resource, utilizing its provided flexibility. More advanced forms of the flex-offer exist and are described in [23] and [24].

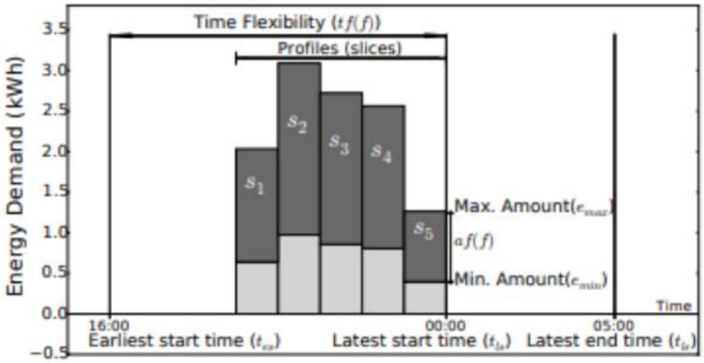


Figure 12: A visual representation of the simple flex-offer

FlexOffer has been used in several innovation projects (Mirabel, Totalflex, Arrowhead, DiCyps, Goflex, GIFT, Fever, and DomOS) since 2010. The compatibility of FlexOffer with the SAREF ontology was studied in the project domOS. More recently (2022), a FlexCommunity initiative has been created to gain a comprehensive understanding of the similarities and differences of the technical approaches developed in the projects, to strengthen cooperation in the development and implementation of advanced organisational structures and business models like energy communities and to align terminology and communication efforts. Additionally, a FlexOffer User Group, a technical community gathering implementers, adopters and promoters of the FlexOffer technology has been created. The FlexOffer specification were openly published in 2023 [25].

Implementation in PARMENIDES: FlexOffer seems well suited to the needs of PARMENIDES. The ontology could moreover build on the DomOS work.

3.6.2 IEEE 2030.5 / SEP 2.0

The SEP 2.0 protocol or IEEE 2030.5 standard formalizes the requirements for many aspects of the smart energy ecosystem including device communication, connectivity and information sharing requirements. It provides the guidelines on how devices should communicate with one another. The protocol is based on the IEC 61968 Common Information Model and the IEC 61850 information model for DER. It follows a RESTful architecture utilizing widely adopted protocols such as TCP/IP and HTTP. SEP 2.0 originates from the ZigBee Alliance [26] and is a successor to the Zigbee Smart Energy Protocol v1.

The protocol defines various device properties that can be manipulated. These properties (also known as “resources”) work together in logical groups to implement SEP 2.0 functionalities (called the “function sets”). A metering system, or pricing system, is an example of an application-specific function set. The protocol is quite broad and the function sets are defined in a generic way (client can be a thermostat, but also an EV) which means that it can be used in a wide range of areas.

Implementation in PARMENIDES: This protocol seems to be suited to the activities in PARMENIDES.

3.3. Decisions for PARMENIDES

In PARMENIDES, it has been decided to opt for OpenADR for the first part of the project, as some of the involved partners will be able to re-use some building blocks. However, if the timing and efforts enable it, it would be interesting to implement at least one other communication protocol, both to compare the results and to validate the coverage by the ontology.

It is however to be noted that the details of the implementation of this protocol remain to be specified. An instantiated specification of the protocol should therefore be defined in WP4 prior to its implementation by solution providers.

4. PARMENIDES generic architecture

4.1. SGAM

The SGAM is used as the main framework for the definition of the PARMENIDES architecture. The components and their interactions are described in the sections below. Each layer focusses on a specific aspect of the project.

ESCo is not part of the project and therefore not mentioned in the architecture graphics.

4.1.1 Component layer

The component layer shows the components used in PARMENIDES, as well as their interfaces. It is to be noted here that the two pilots use different gateways, that will be detailed in the pilot-specific architectures.

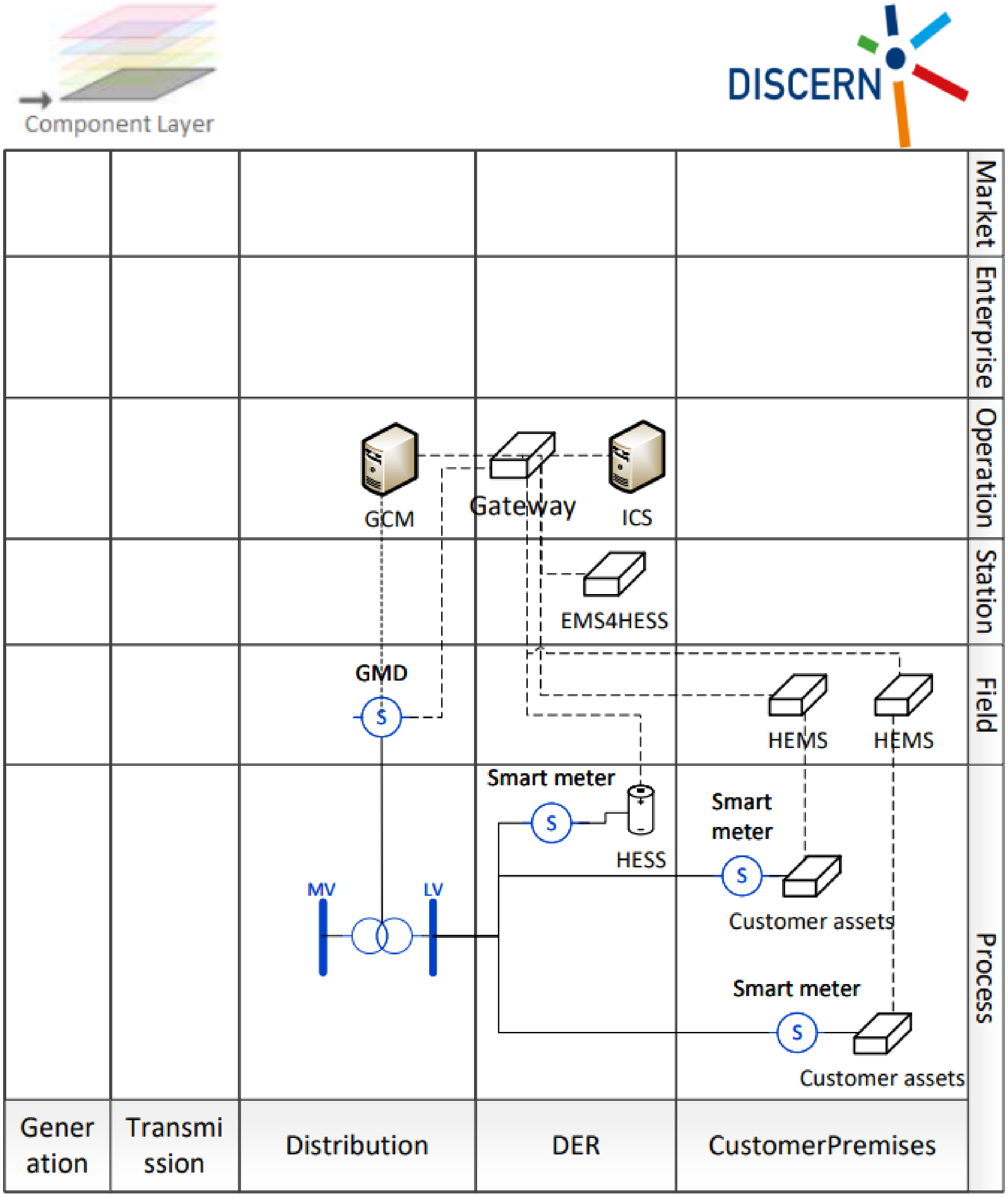


Figure 13: SGAM Component layer of the generic architecture

4.2.1 Communications layer

The communications layer shows the communication protocols used in PARMENIDES, in relation with the components.

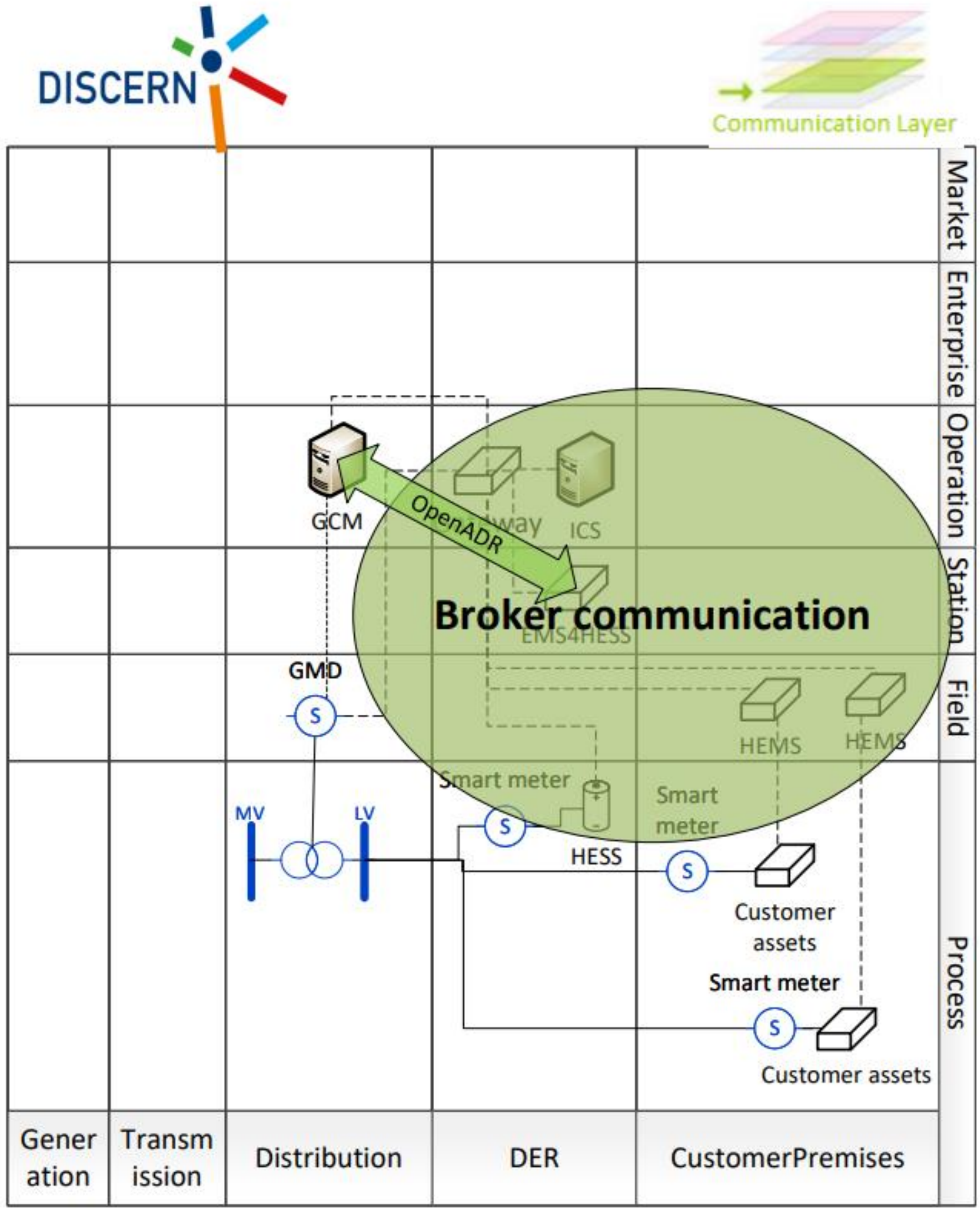


Figure 14: SGAM Communication layer of the generic architecture

4.3.1 Information layer – Information

The information layer (information) shows data exchanges, in relation with the components.

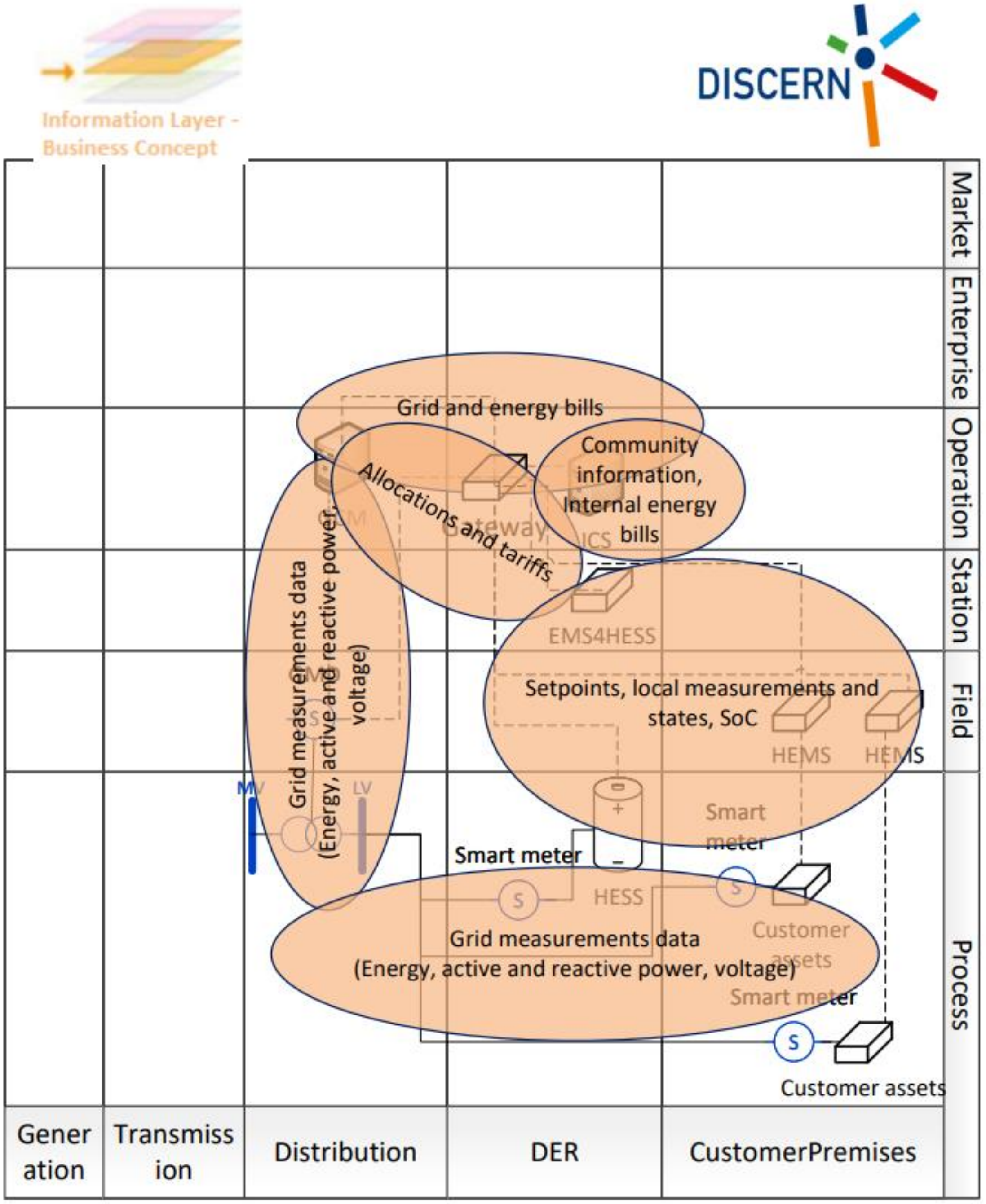


Figure 15: SGAM information layer of the generic architecture (information)

4.4.1 Information layer – Ontology

The information layer (ontology) shows the implementation of the ontology in PARMENIDES, in relation with the components. It uses the basic structure of the SIF framework.

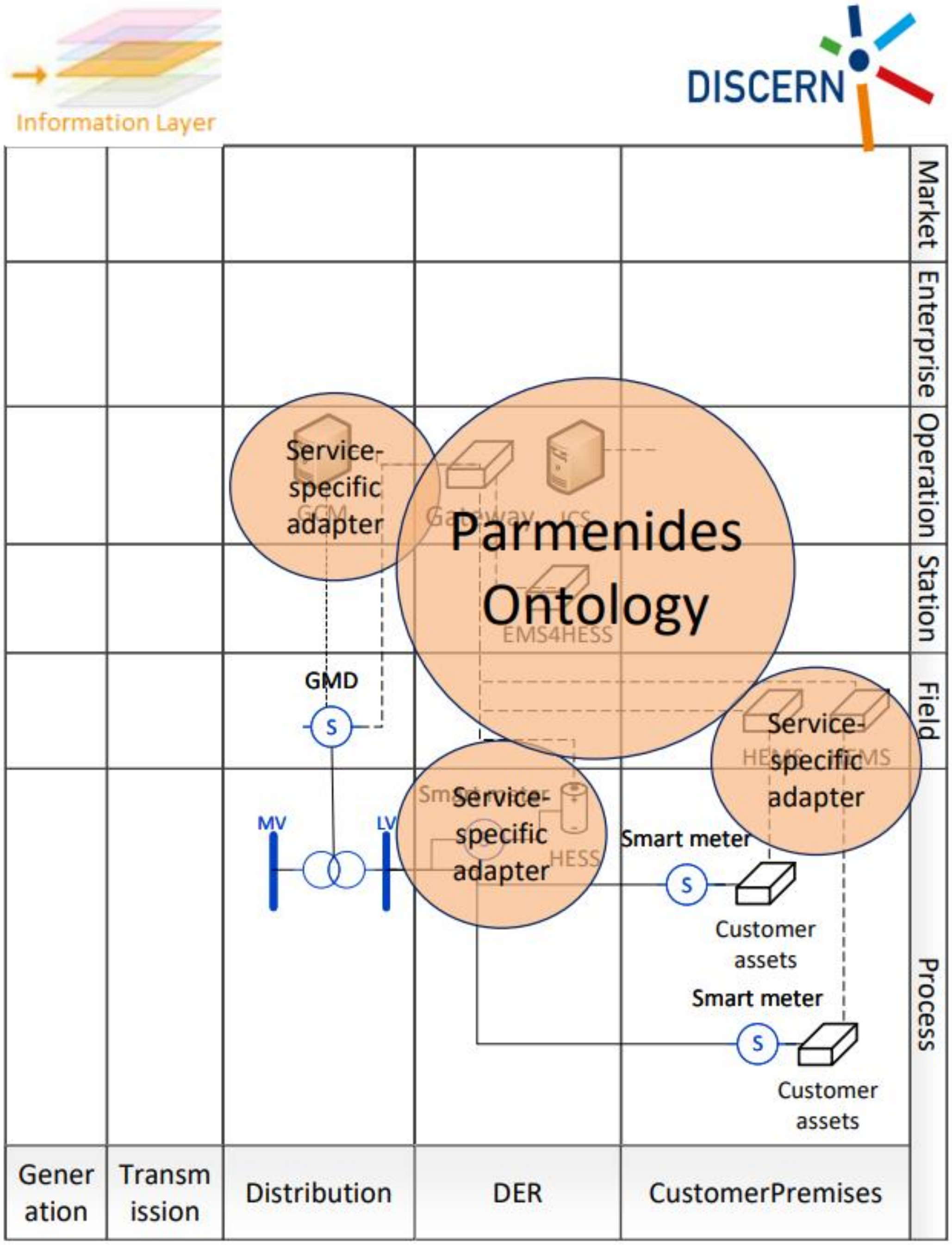


Figure 16: SGAM information layer of the generic architecture (ontology)

4.5.1 Functions layer

The Functions layer shows the functions performed by the architecture in relation with the components.

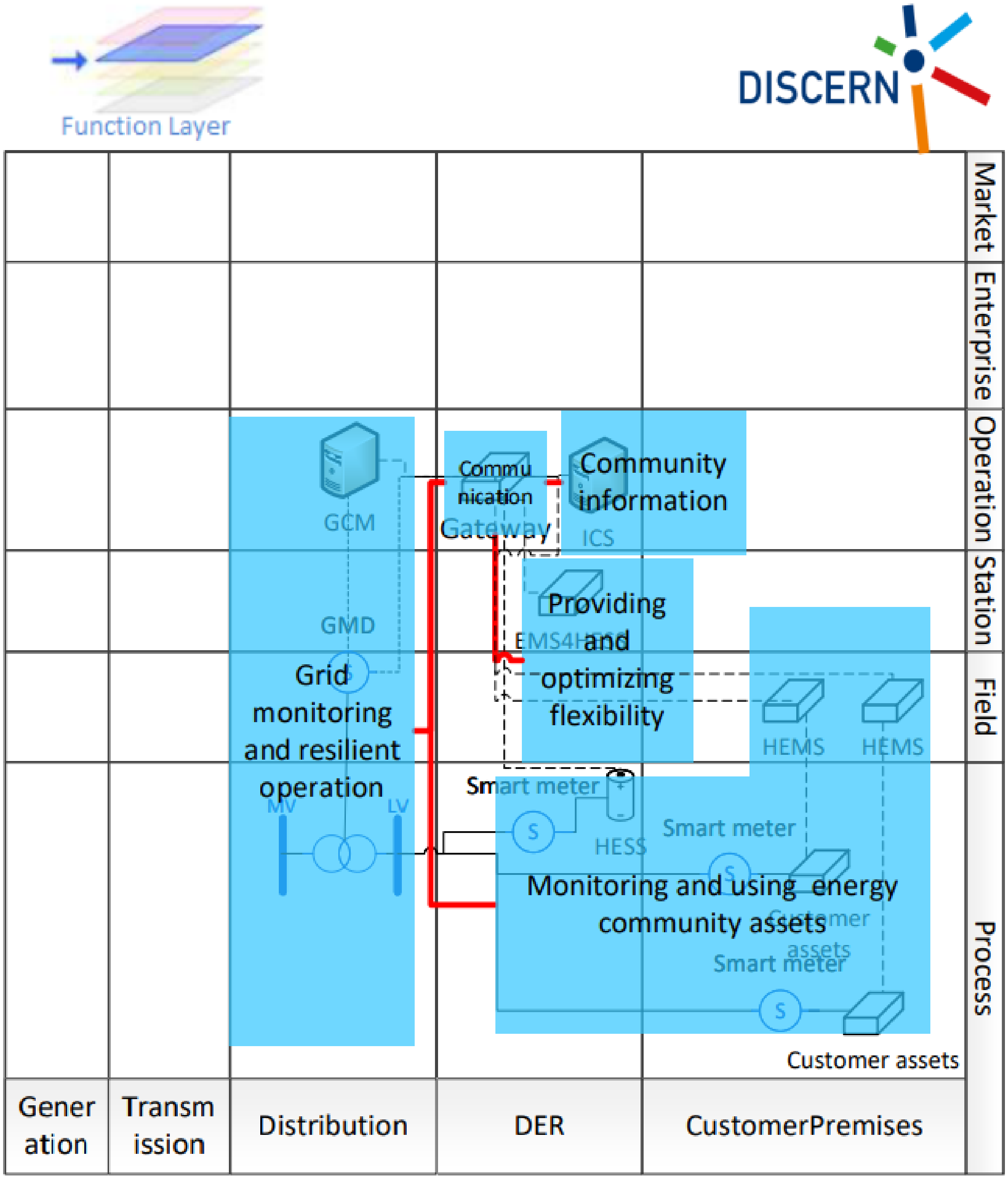


Figure 17: SGAM function layer of the generic architecture

4.6.1 Business layer

The business layer shows the business interactions of the project, in relation with the actors.

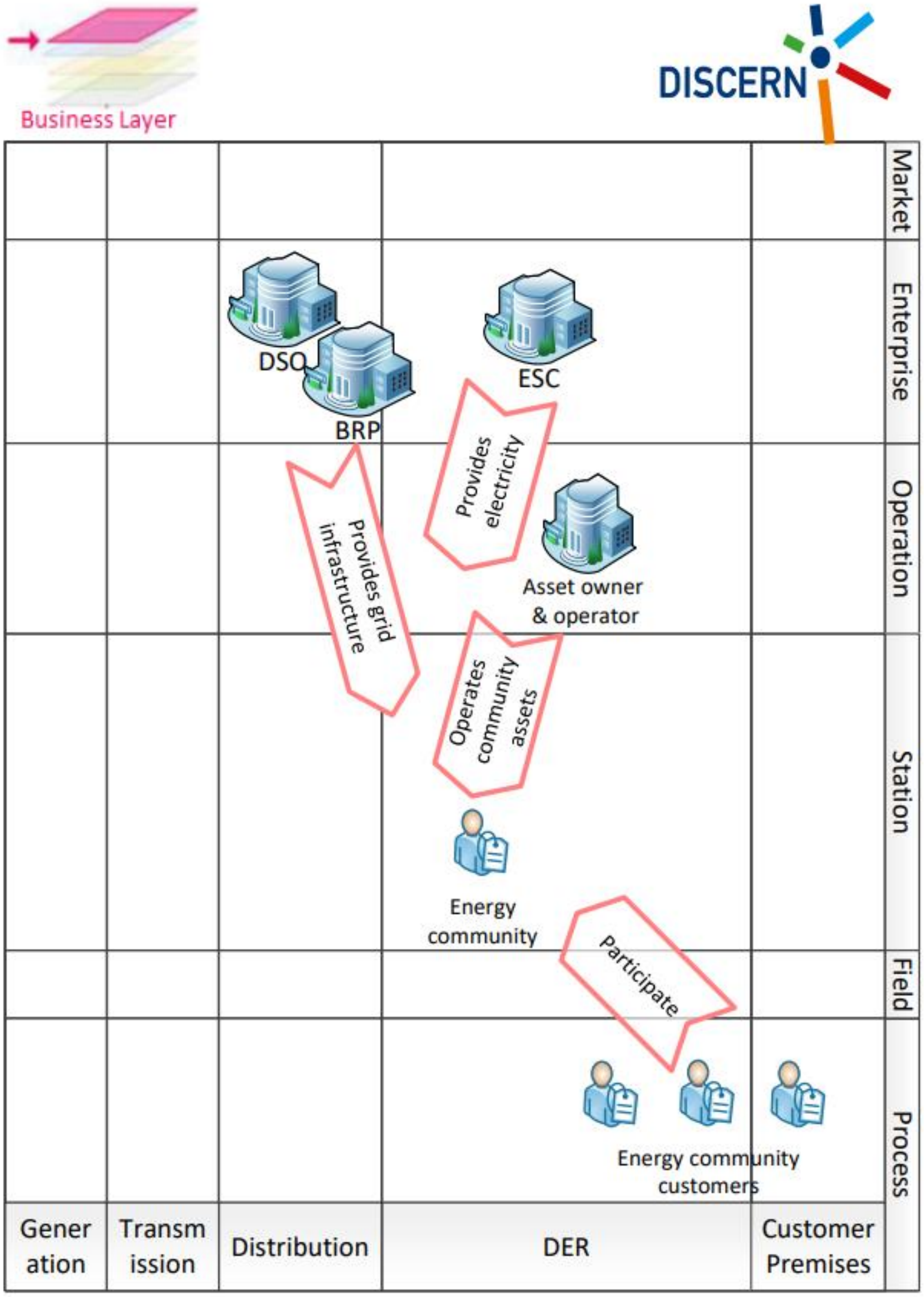


Figure 18: SGAM business layer of the generic architecture

4.2. DERA

In complement to the SGAM architecture description, we used the DERA to show which generic concepts are implemented in PARMENIDES. The DERA 3.0 architecture below shows the modules that are supported by PARMENIDES.

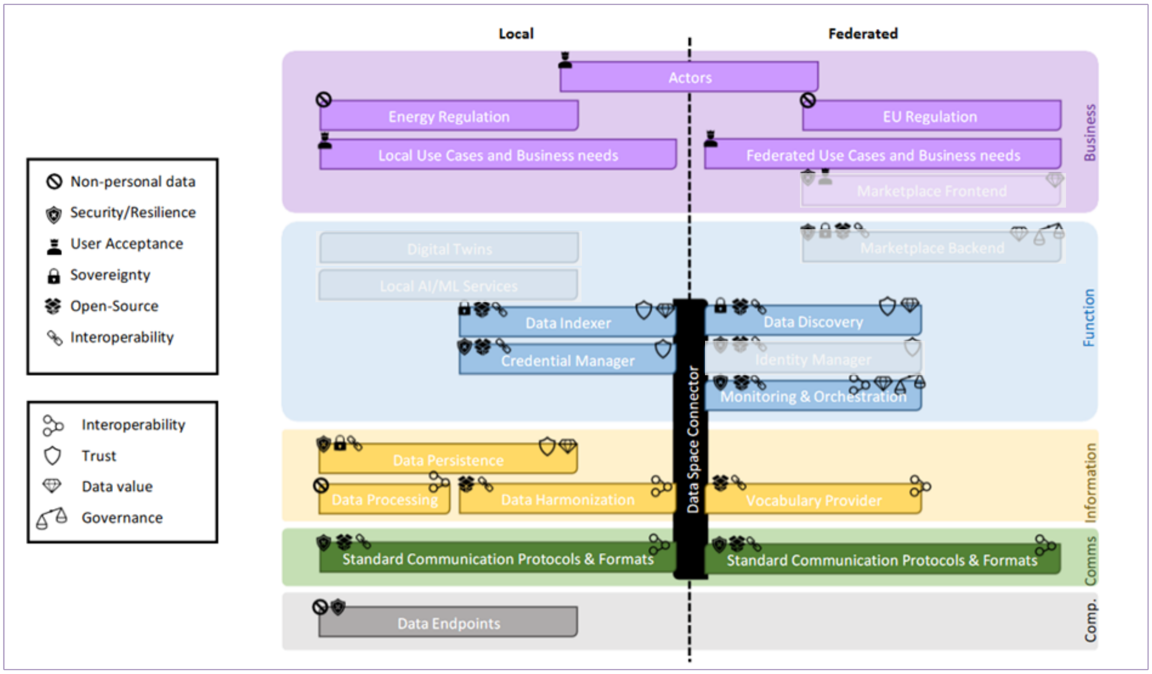


Figure 19: Application of the DERA architecture in PARMENIDES

The recommendations from the DERA 3.0 report are listed in Table 1, along with their relevance and implementation in PARMENIDES.

Table 1: Application of the DERA recommendations in PARMENIDES

Recommendation	Implementation in PARMENIDES
Leverage Smart Grid Architecture Model (SGAM) usage by completing it with data governance requirements, specifically from end-customer perspective, and map it to the reference architectures of other sectors (similar to the RAMI4.0 for industry – Reference Architecture Model Industry 4.0; and CREATE-IoT 3D RAM for health – Reference Architecture Model of CREATE-IoT project), incl. for basic interoperability vocabulary with non-energy sectors.	The reference architectures for other sectors mentioned are not relevant in the scope of PARMENIDES. However, the vocabulary of non-energy sectors will be included in the PARMENIDES Ontology where relevant.
Facilitate European strategy, regulation (harmonisation of national regulations) and practical tools for cross-sector exchange of any type of both private data and public data, e.g., through reference models for data space, common data governance and data interoperability implementing acts.	Cross-sector applications are not studied in PARMENIDES.

Ensure cooperation between appropriate associations, countries, and sector representatives to work on cross-sector and cross-border data management by establishing European data cooperation agency. This involves ongoing empowering/restructuring of the Data Management WG of the BRIDGE Initiative to engage other sectors and extend cooperation with projects that are not EU-funded and with European Standardisation Organisations (CEN-CENELEC-ETSI).	The PARMENIDES project is active in the BRIDGE initiative, as well as other cooperation actions as part of T6.2 and T6.3.
Harmonise the development, content, and accessibility of data exchange business use cases for cross-sector domain through BRIDGE use case repository. Track tools that identify common features on use cases, e.g., interfaces between sectors, and enable the alignment with any potential peer repositories for other domains. Also, the use case repository must rely on the HEMRM with additional roles created by some projects or roles coming from other associations (related to another sector than the electricity/energy sector).	The PARMENIDES use-cases will be included in the BRIDGE use-cases repository when the repository is available publicly.
Use BRIDGE use case repository for aligning the role selection. Harmonise data roles across electricity and other energy domains by developing HERM – Harmonised Energy Role Model and ensure access to model files. Look for consistency with other domains outside energy based on this HERM – cross-sectoral roles. Harmonised Energy Role Model shall have clear implications and connections with data (space) roles such as data provider/consumer, service provider etc.	Most of the roles defined in the PARMENIDES use-cases are compliant to the HERM, however many PARMENIDES roles are beyond the scope of the HERM.
Define and harmonise functional data processes for cross-sector domain, using common vocabulary, template and repository for respective use cases' descriptions. Harmonisation of functional data processes for cross-sector data ecosystems including Vocabulary provider, Federated catalogue, Data quality, Data accounting processes, Clearing process (audit, logging, etc.) and Data tracking and provenance.	This recommendation is not relevant for PARMENIDES, as little cross-sector data are used.
Define and maintain a common reference semantic data model and ensure access to its model files facilitating cross-sector data exchange, by leveraging existing data models like Common Information Model (CIM) of International Electrotechnical Commission (IEC) and ontologies like Smart Appliances Reference Ontology (SAREF).	The PARMENIDES ontology will be based on SAREF.

Develop cross-sector data models and profiles, with specific focus on private data exchange. Enable open access to model files whenever possible.	The privacy and security aspects of PARMENIDES will be studied in tasks 3.3 and 5.2.
Ensure protocol agnostic approach to cross-sector data exchange by selecting standardised and open ones.	The selection of standardized standards is described in section 3.
Ensure data format agnostic approach to cross-sector data exchange. The work done by projects like TDX-ASSIST and EU-SysFlex (using IEC CIM), and PLATOON (using SAREF) must be shared and made known to consolidate the approach to reach semantic interoperability. Metadata must also be taken into account.	Little cross-sector data will be used in PARMENIDES, however the ones that are used will be included in the ontology.
Promote business process agnostic DEPs (Data Exchange Platforms) and make these interoperable by developing APIs (Application Programming Interfaces) which enable for data providers and data users easy connection to any European DEP but also create the possibility whereby connecting to one DEP ensures data exchange with any other stakeholder in Europe. DEPs shall explore the integration of data space connectors towards their connectivity with other DEPs including cross-sector ones.	No data exchange platform is used in PARMENIDES.
Develop universal data applications which can serve any domain. Develop open data driven services that promote also cross-sector integration collectively available in application repositories.	Cross-sector applications are not studied in PARMENIDES.

4.3. SHBIRA

The SHBIRA architecture has been implemented in PARMENIDES as a complement of the SGAM, providing more in-depth structure in the customer premises area. The Figure 20 shows the global picture of the architecture, while the Figure 21 focusses on the implementation of the ontology by the different components.

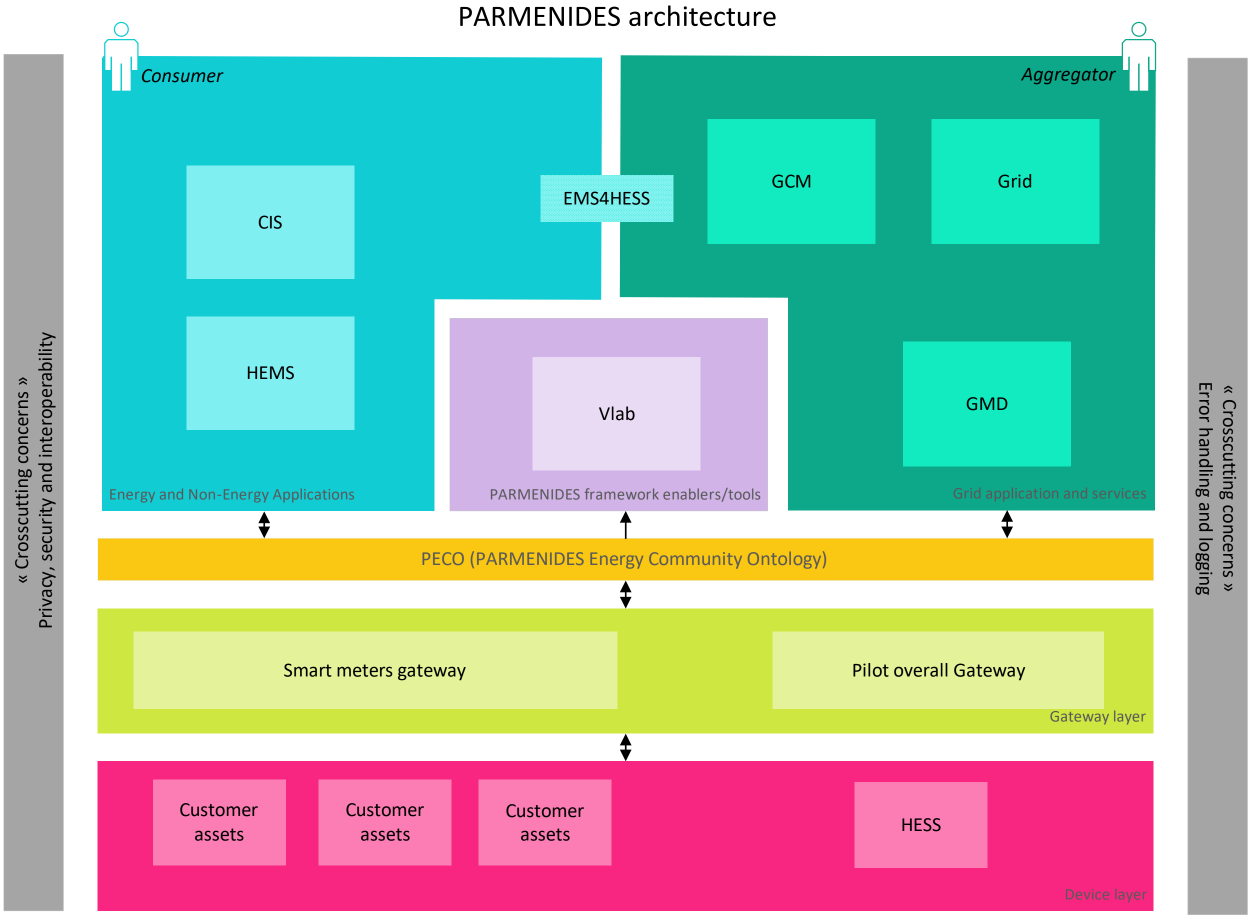


Figure 20: SHBIRA architecture of PARMENIDES

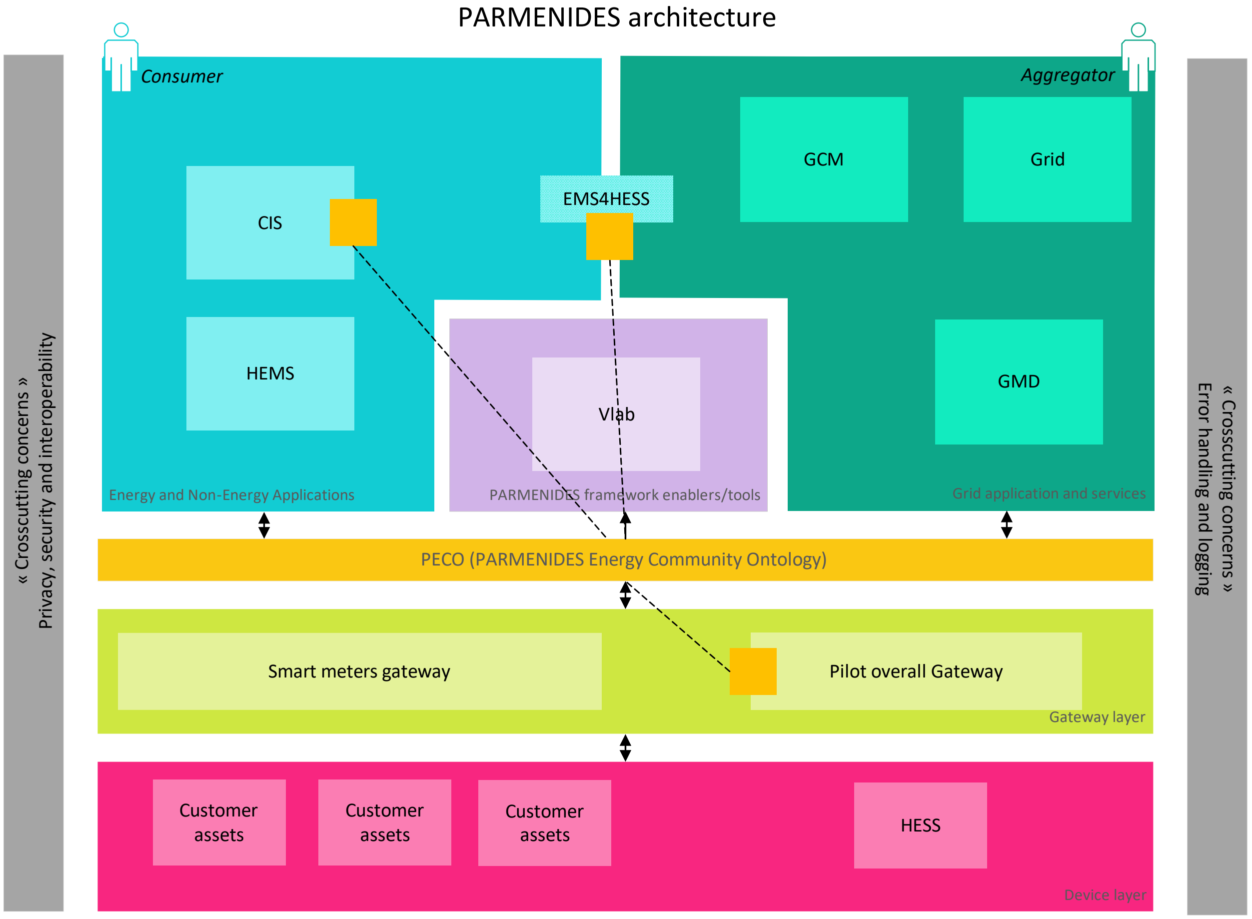


Figure 21: SHBIRA architecture of PARMENIDES, including the ontology implementation by the components (interfaces in yellow)

5. Use-cases specific architectures

The architecture was instantiated to show the different components and functions used in each of the use-cases defined in D2.1 [1]. The instantiated architectures are based on the SGAM generic architecture. In particular, the business layer is detailed to show the objectives and KPI of each use-case. ESCo is not part of the project and therefore not mentioned in the architecture graphics.

5.1. Use-case 1

The first use-case focusses on the behaviour of passive consumers. The behaviours may only change in this use-case based on the billing.

5.1.1 Component layer

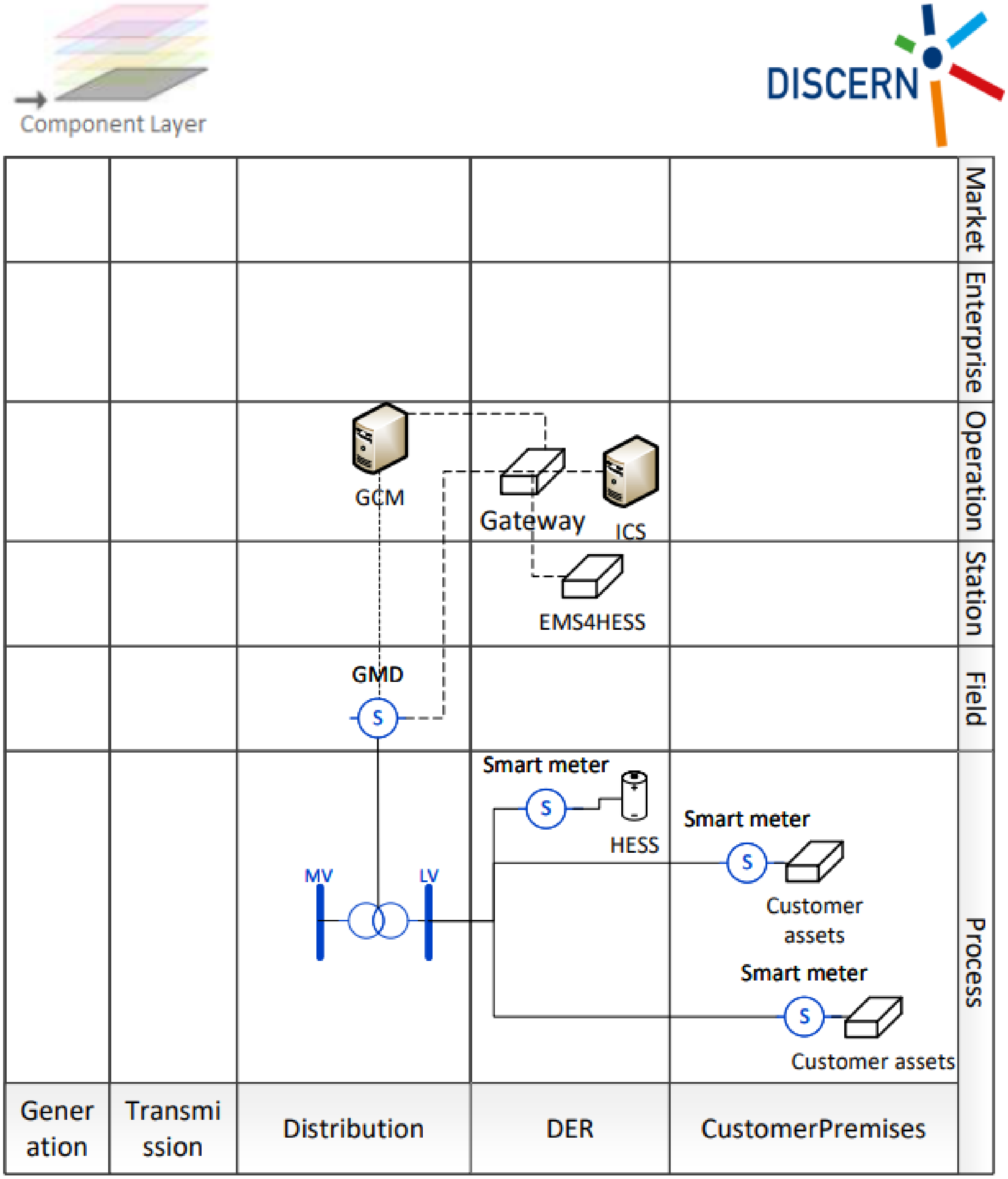


Figure 22: SGAM Component layer of the UC1 architecture

5.2.1 Communications layer

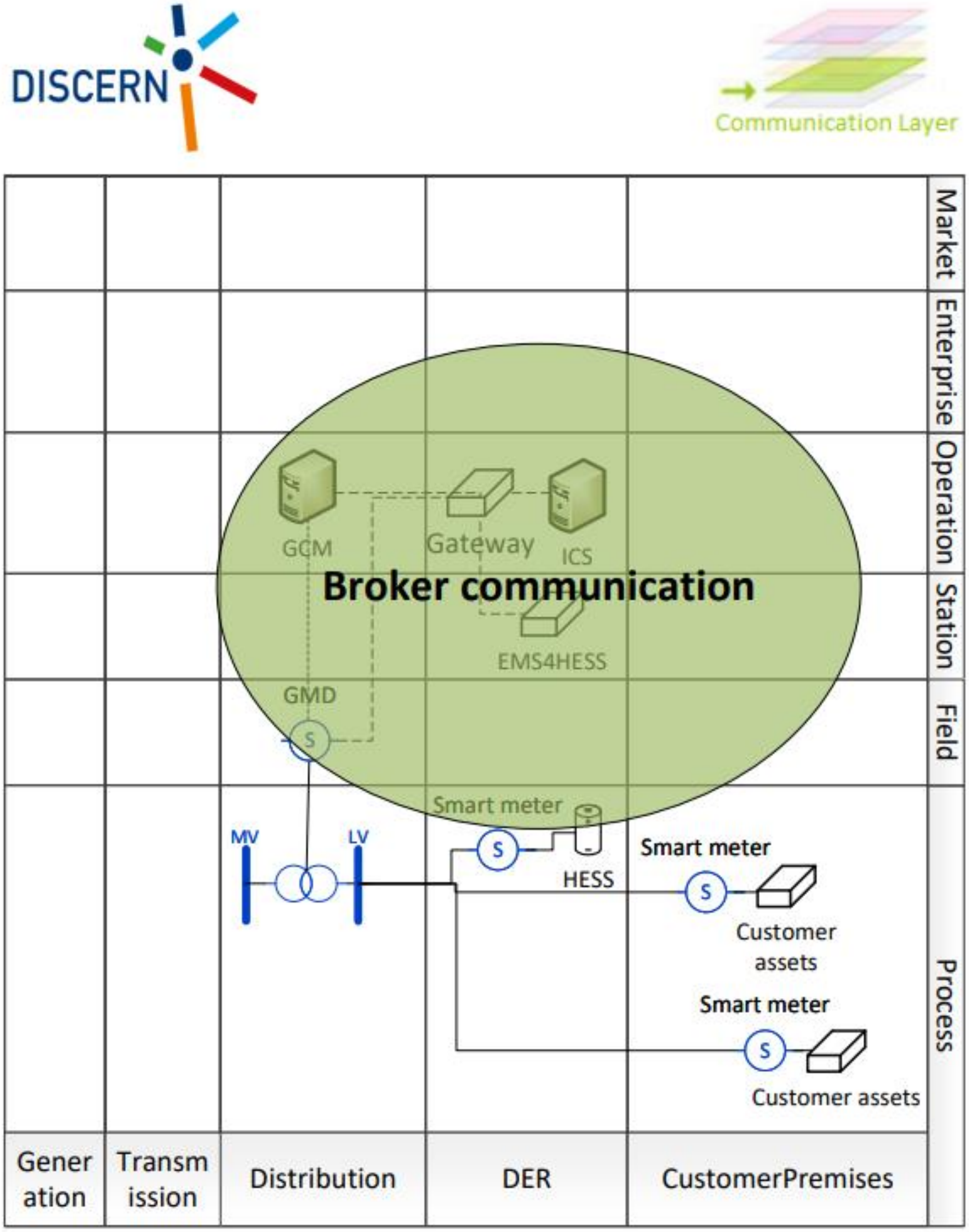


Figure 23: SGAM Communication layer of the UC1 architecture

5.3.1 Information layer – Information

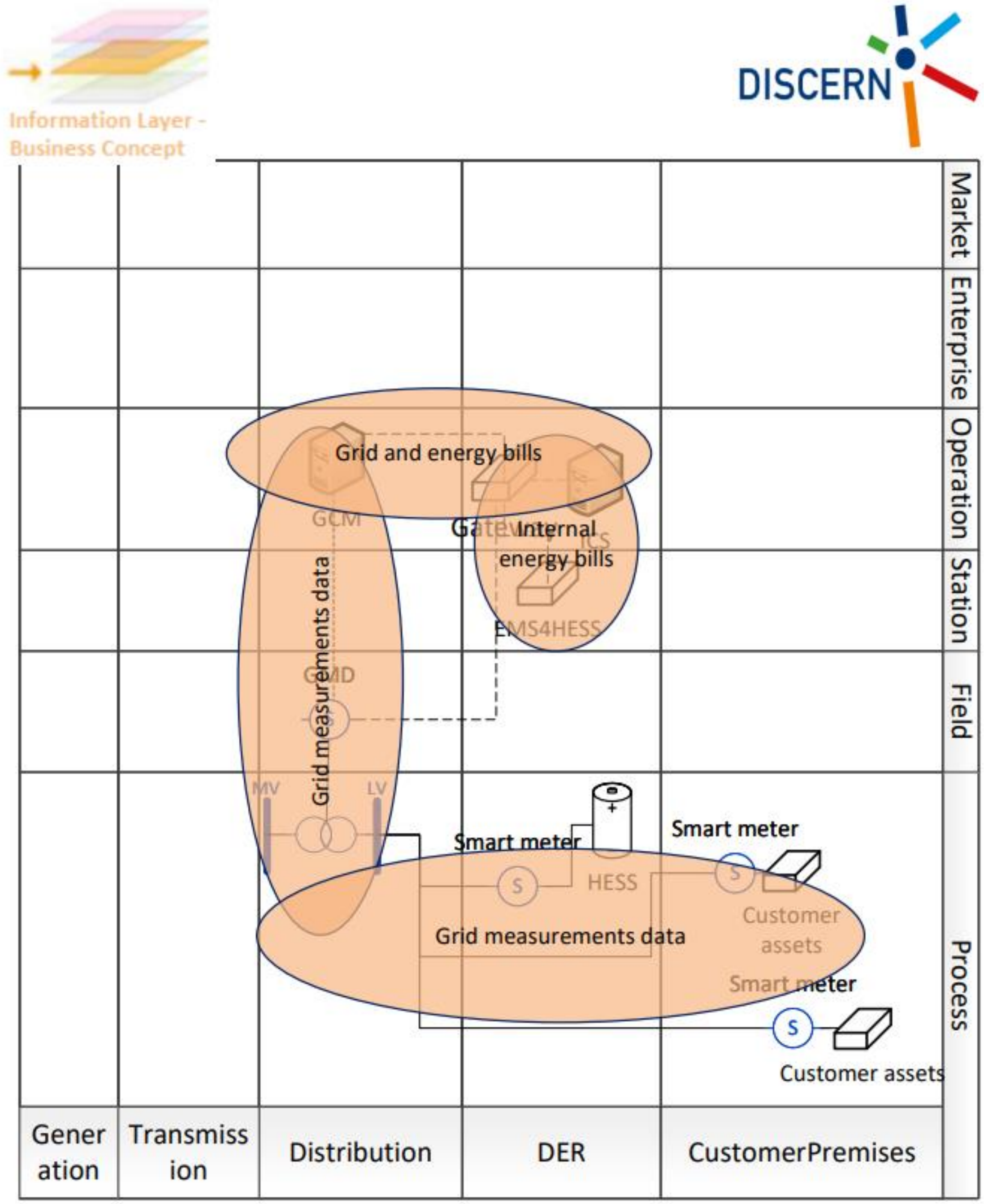


Figure 24: SGAM Information layer (data) of the UC1 architecture

5.4.1 Information layer – Ontology

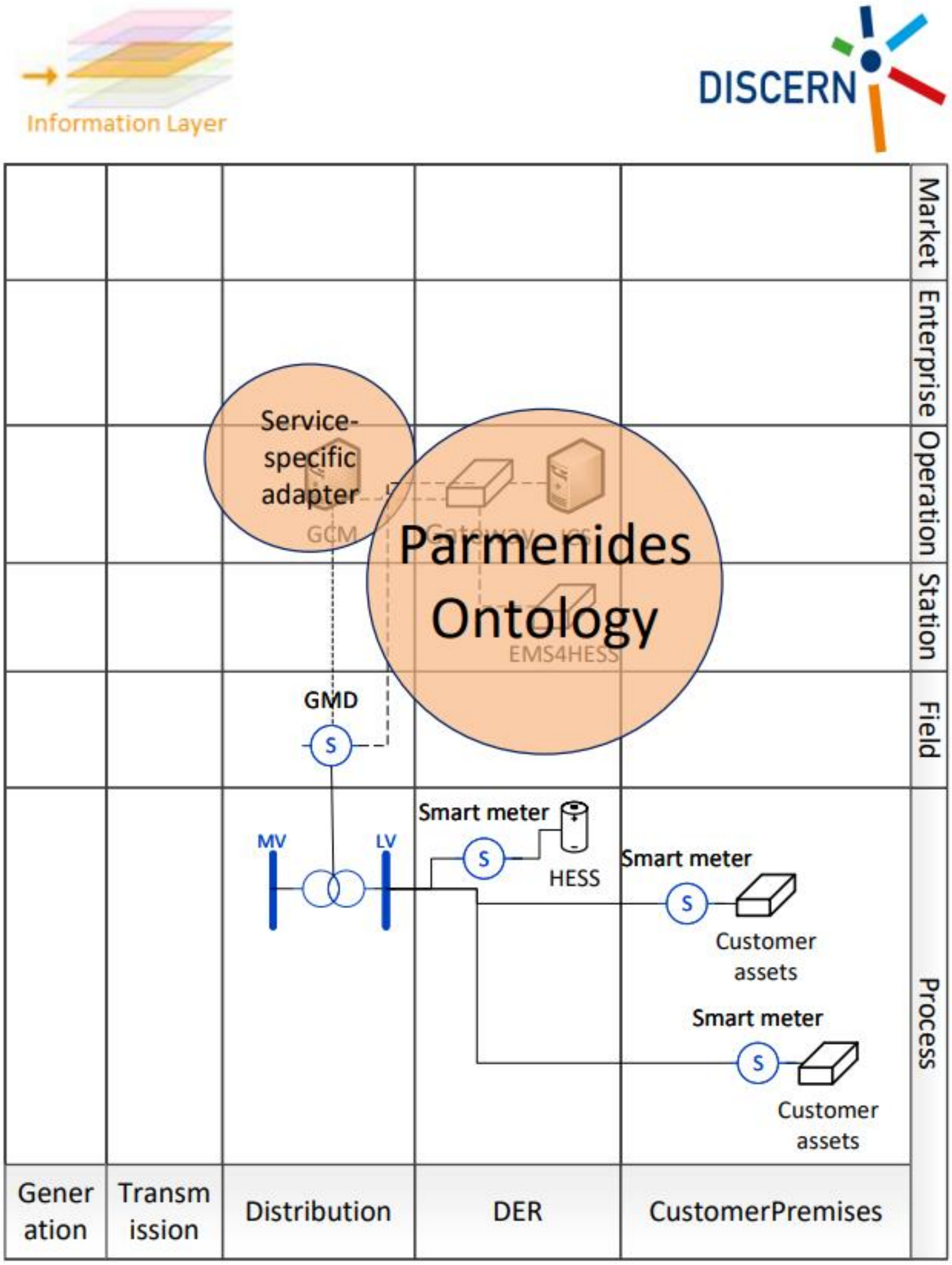


Figure 25: SGAM Information layer (ontology) of the UC1 architecture

5.5.1 Functions layer

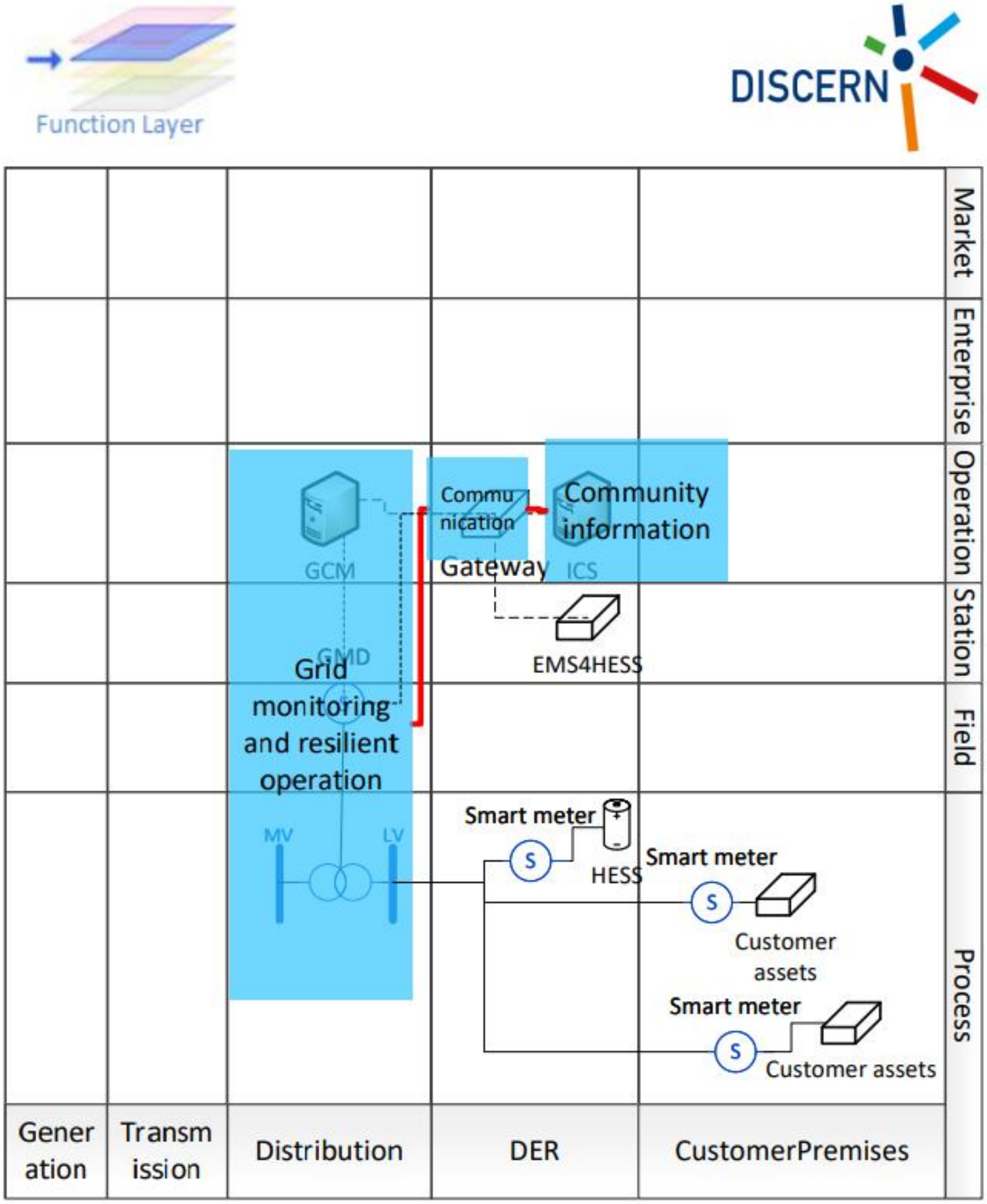


Figure 26: SGAM Function layer of the UC1 architecture

5.6.1 Business layer

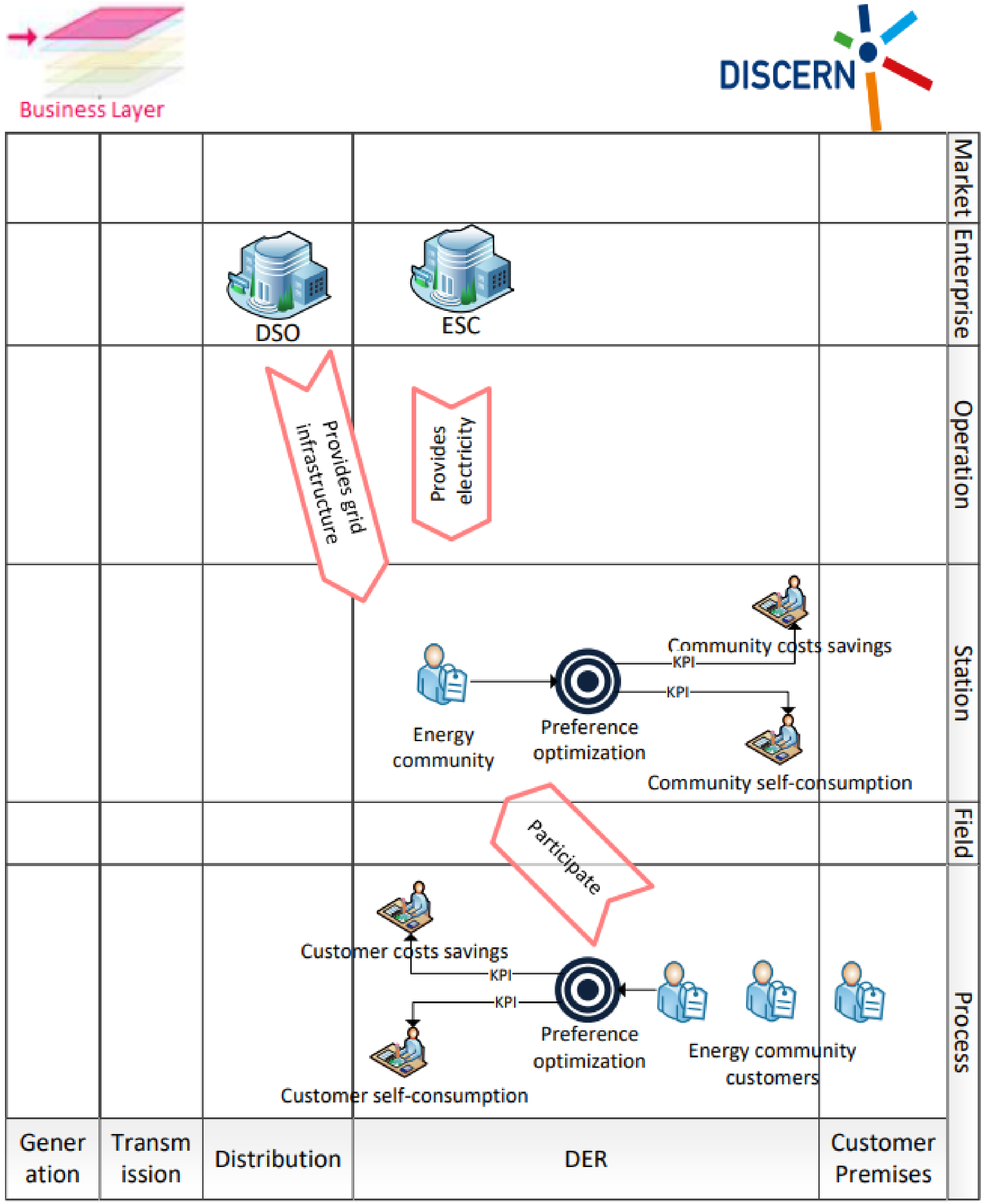


Figure 27: SGAM Business layer of the UC1 architecture

5.2. Use-case 2

The second use-case is based on the active consumers. In this use-case, active customers are incentivised to modify their behaviour based on insights from the EMS4HESS.

5.1.2 Component layer

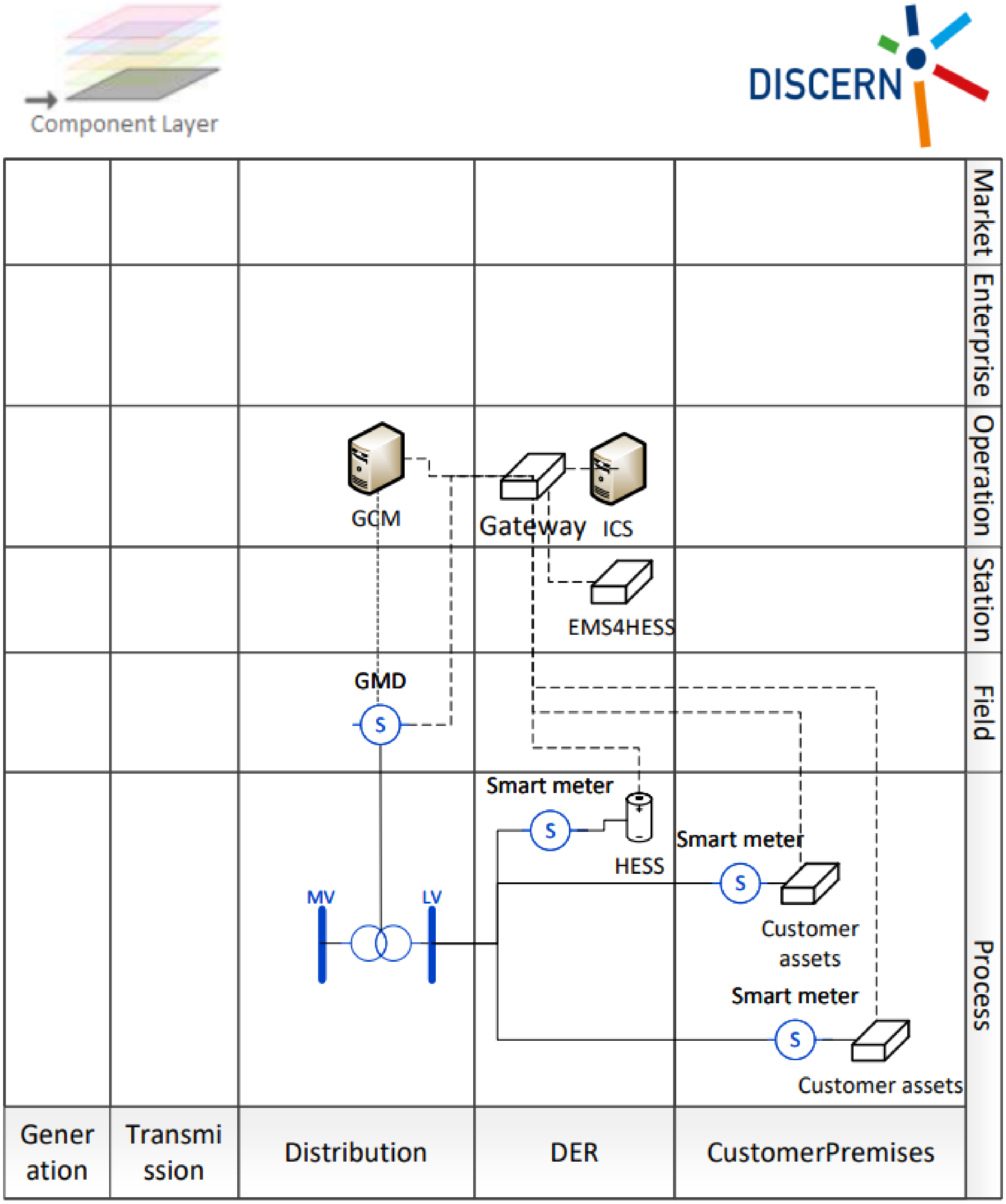


Figure 28: SGAM Component layer of the UC2 architecture

5.2.2 Communications layer

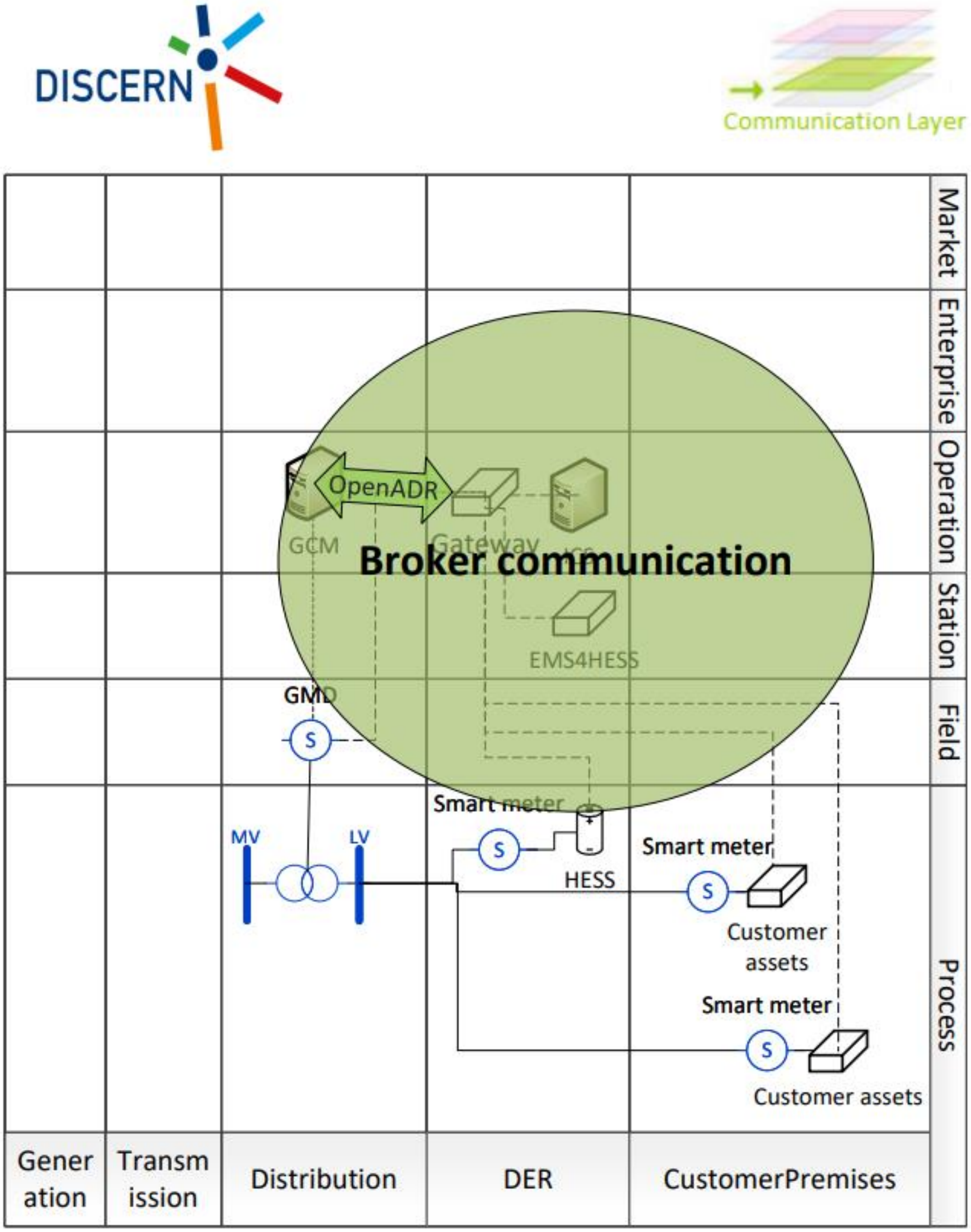


Figure 29: SGAM Communication layer of the UC2 architecture

5.3.2 Information layer – Information

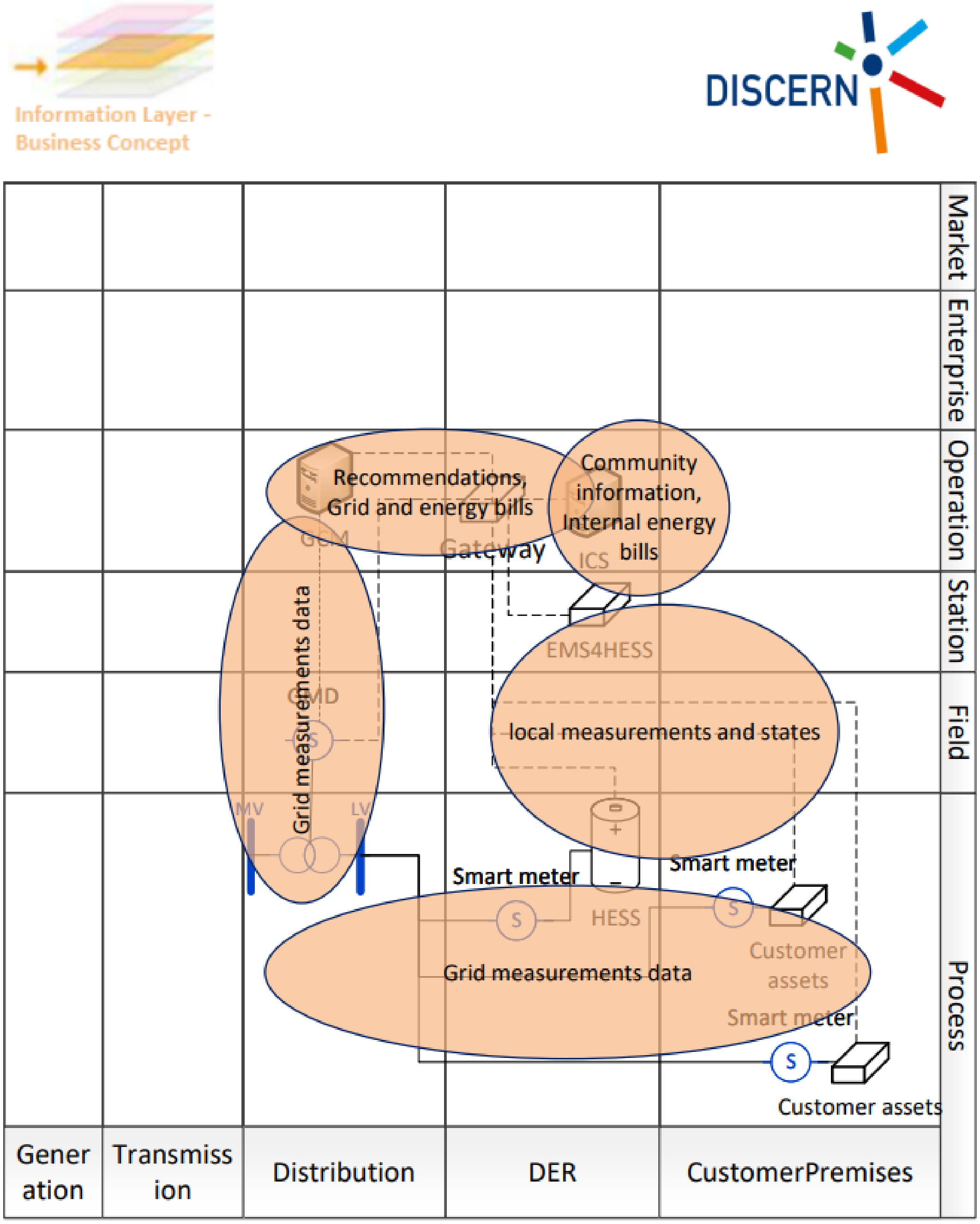


Figure 30: SGAM Information layer (data) of the UC2 architecture

5.4.2 Information layer – Ontology

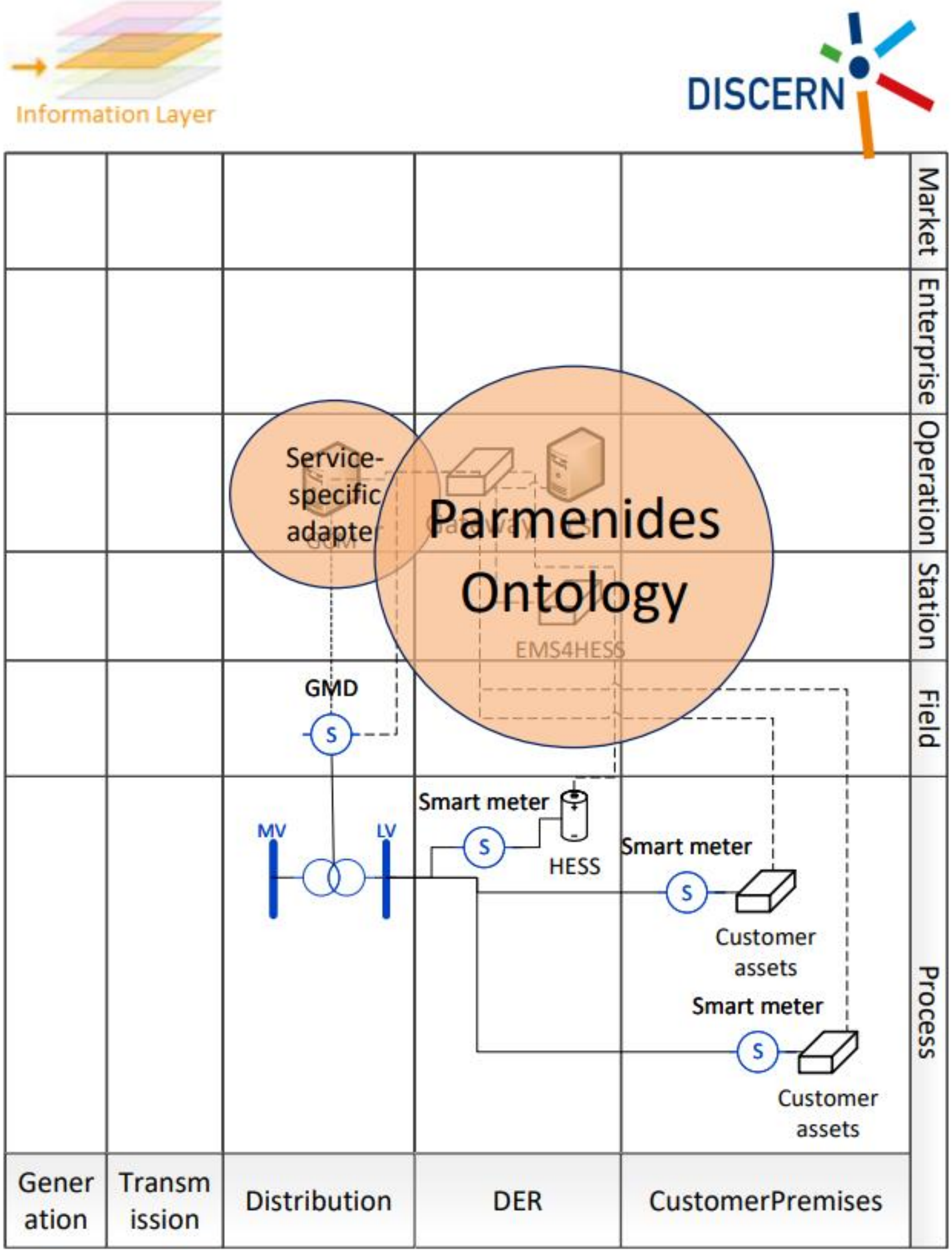


Figure 31: SGAM Information layer (Ontology) of the UC2 architecture

5.5.2 Functions layer

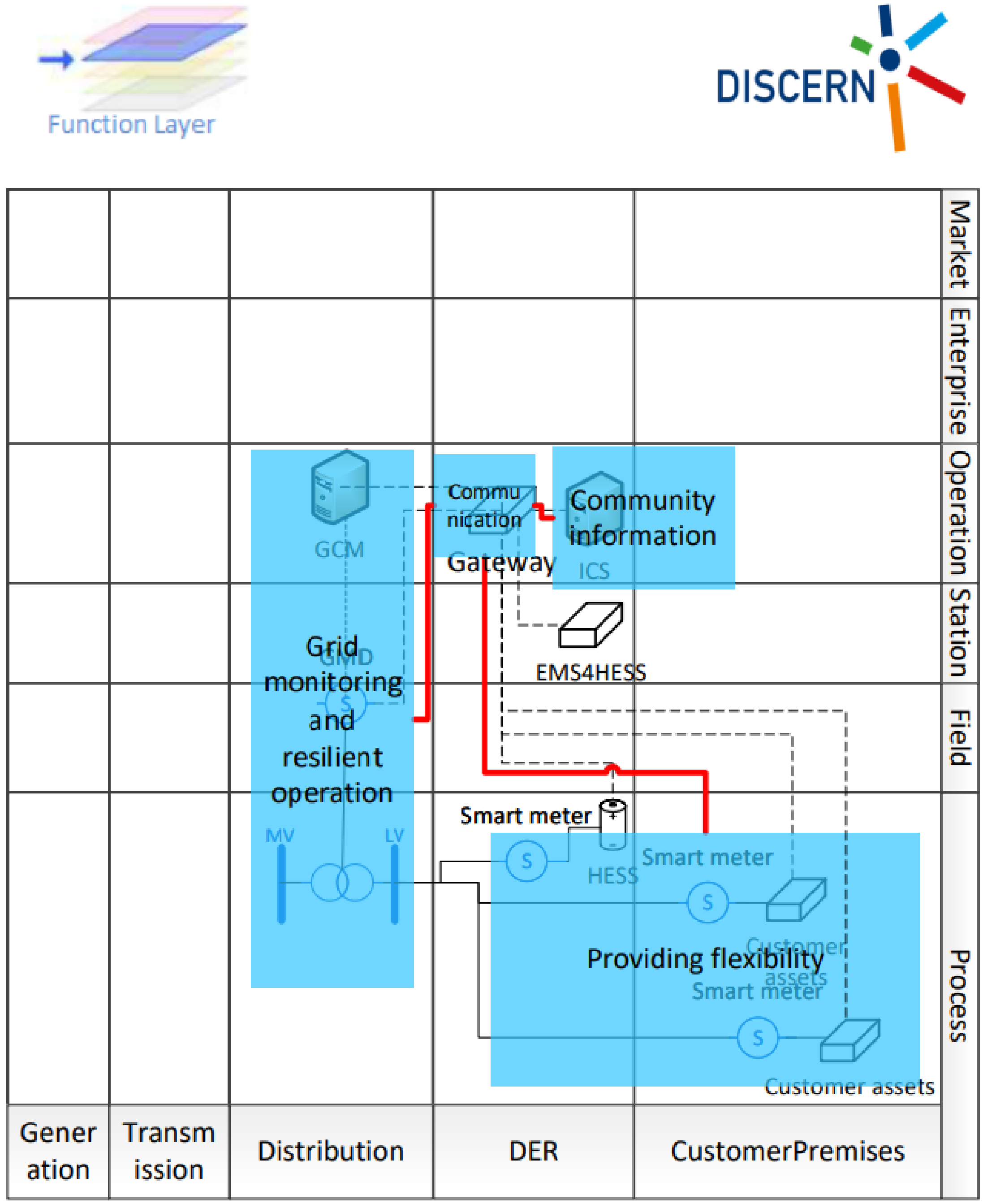


Figure 32: SGAM Function layer of the UC2 architecture

5.6.2 Business layer

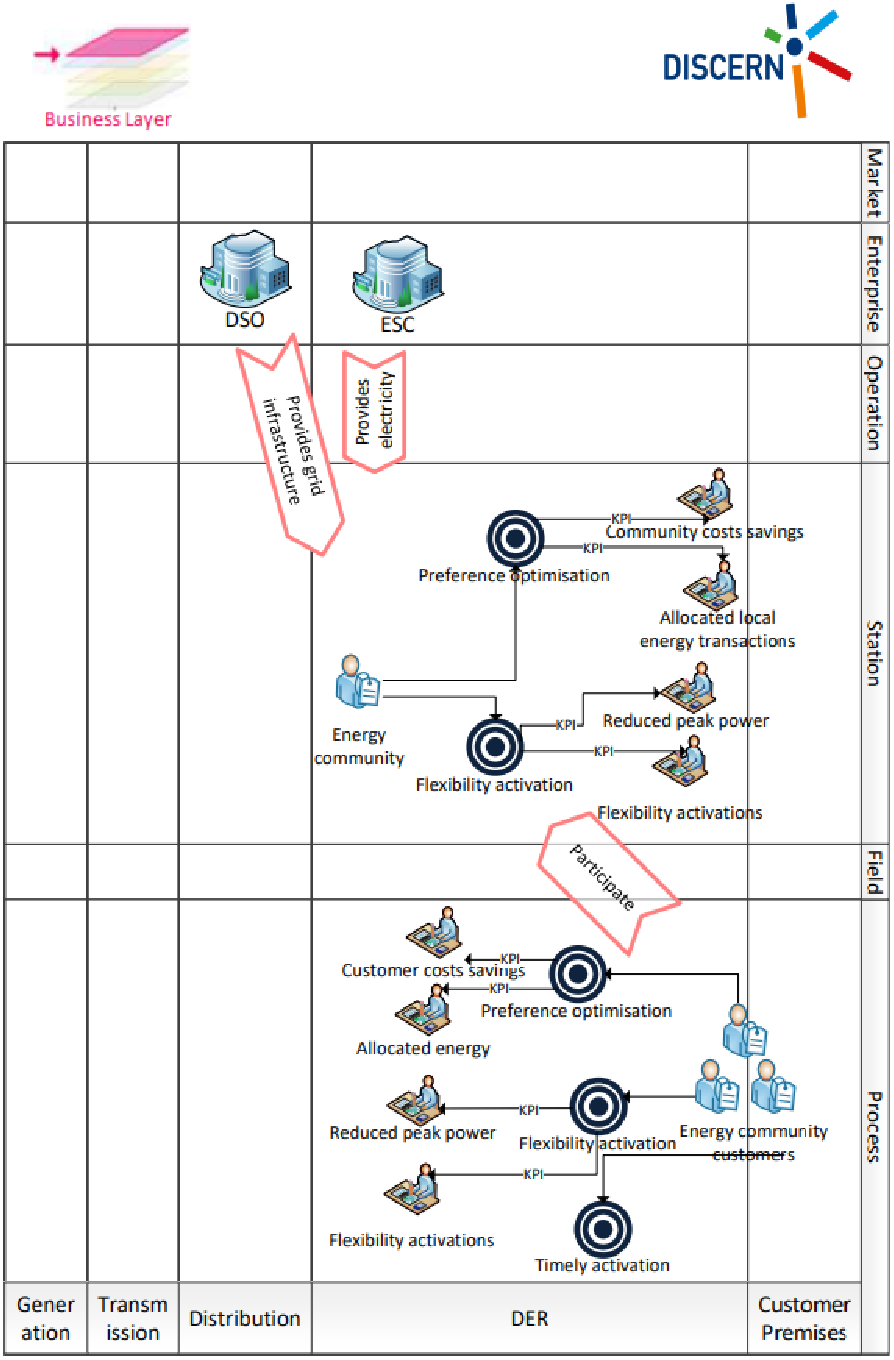


Figure 33: SGAM Business layer of the UC2 architecture

5.3. Use-case 3

The third use-case focusses on the automation of the flexibility process while still requiring some human inputs. Based on grid capacity, the EMS will produce recommendations or operate the assets within the limits set by the Energy community.

5.1.3 Component layer

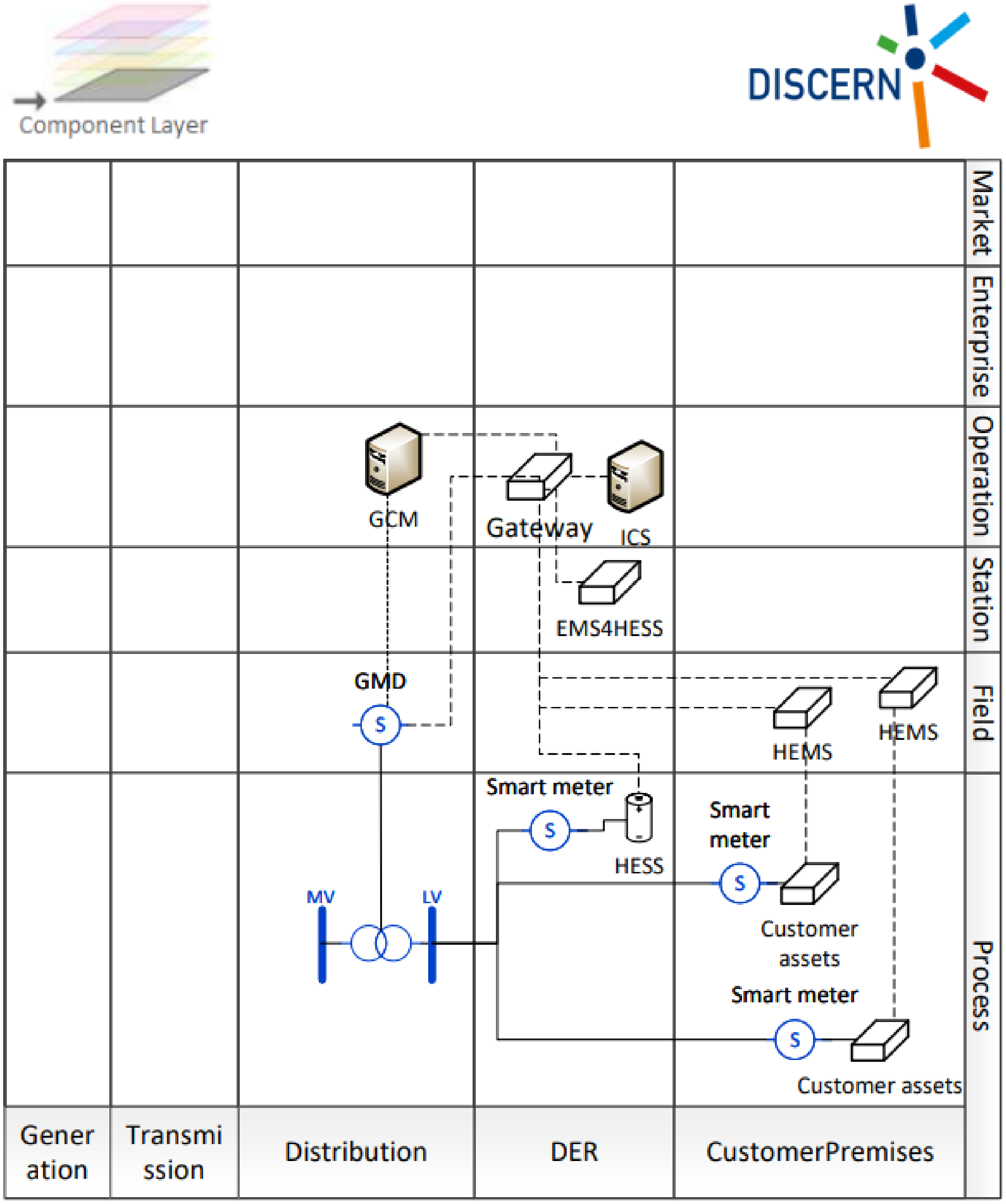


Figure 34: SGAM Component layer of the UC3 architecture

5.2.3 Communications layer

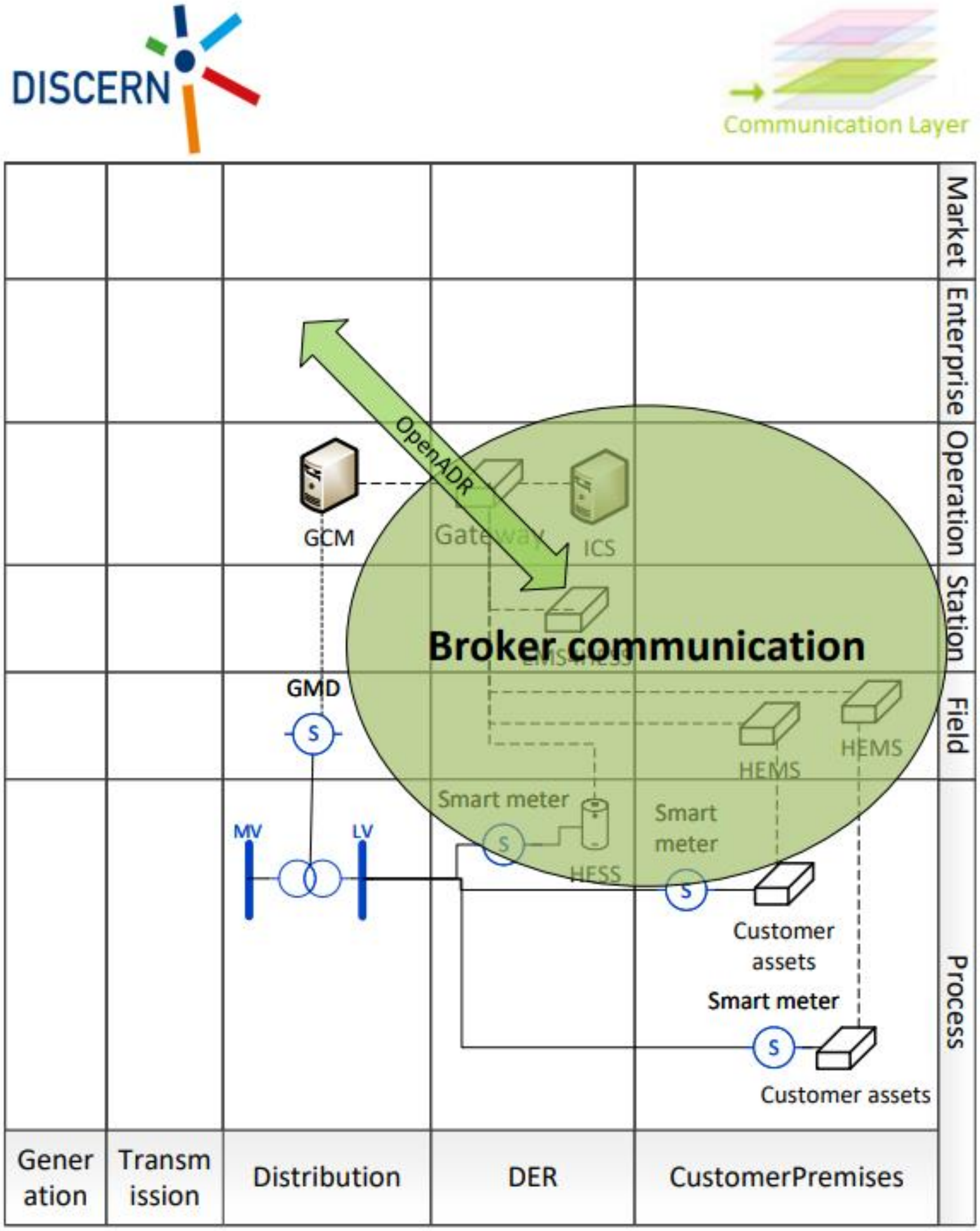


Figure 35: SGAM Communication layer of the UC3 architecture

5.3.3 Information layer – Information

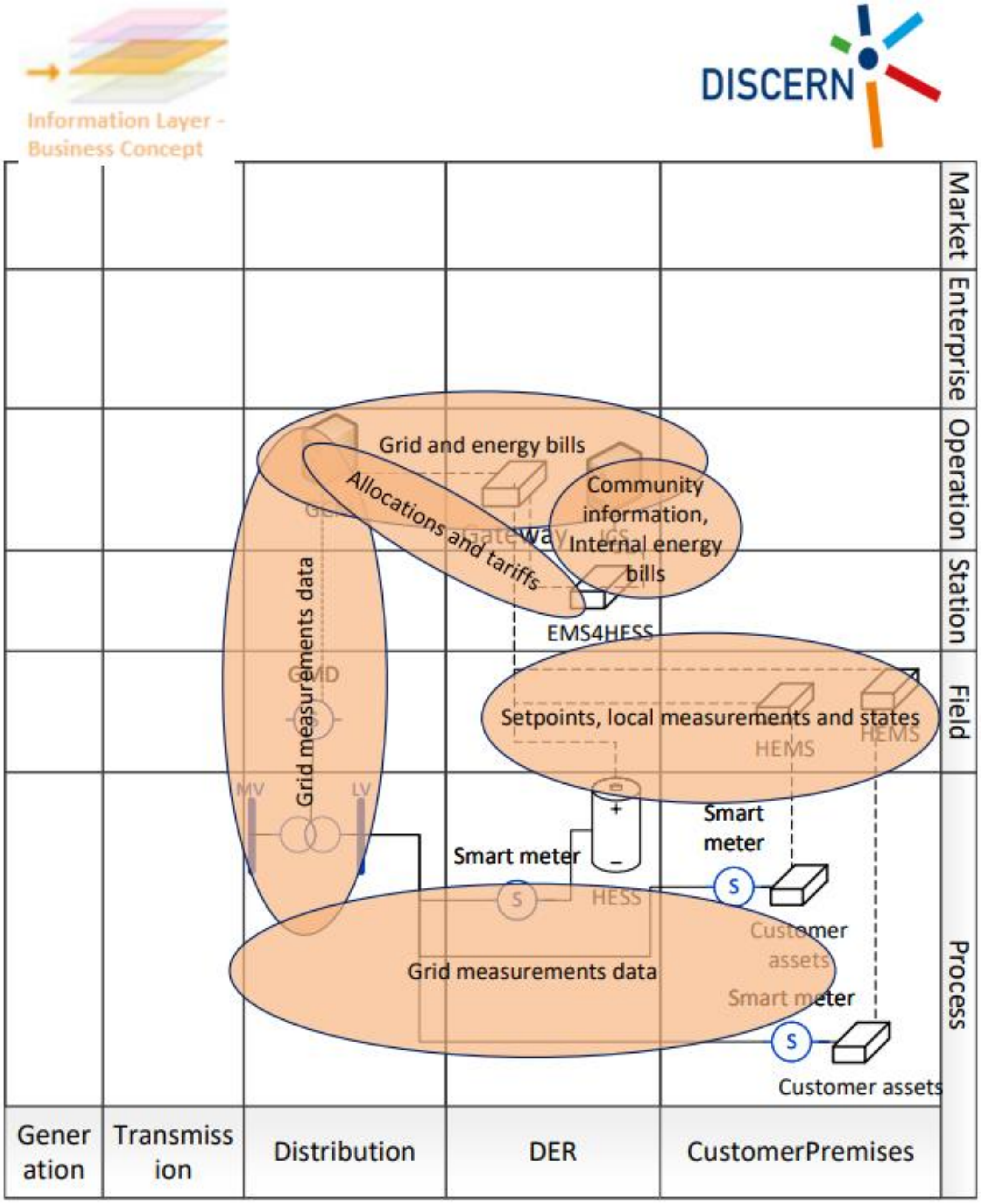


Figure 36: SGAM Information layer (data) of the UC3 architecture

5.4.3 Information layer – Ontology

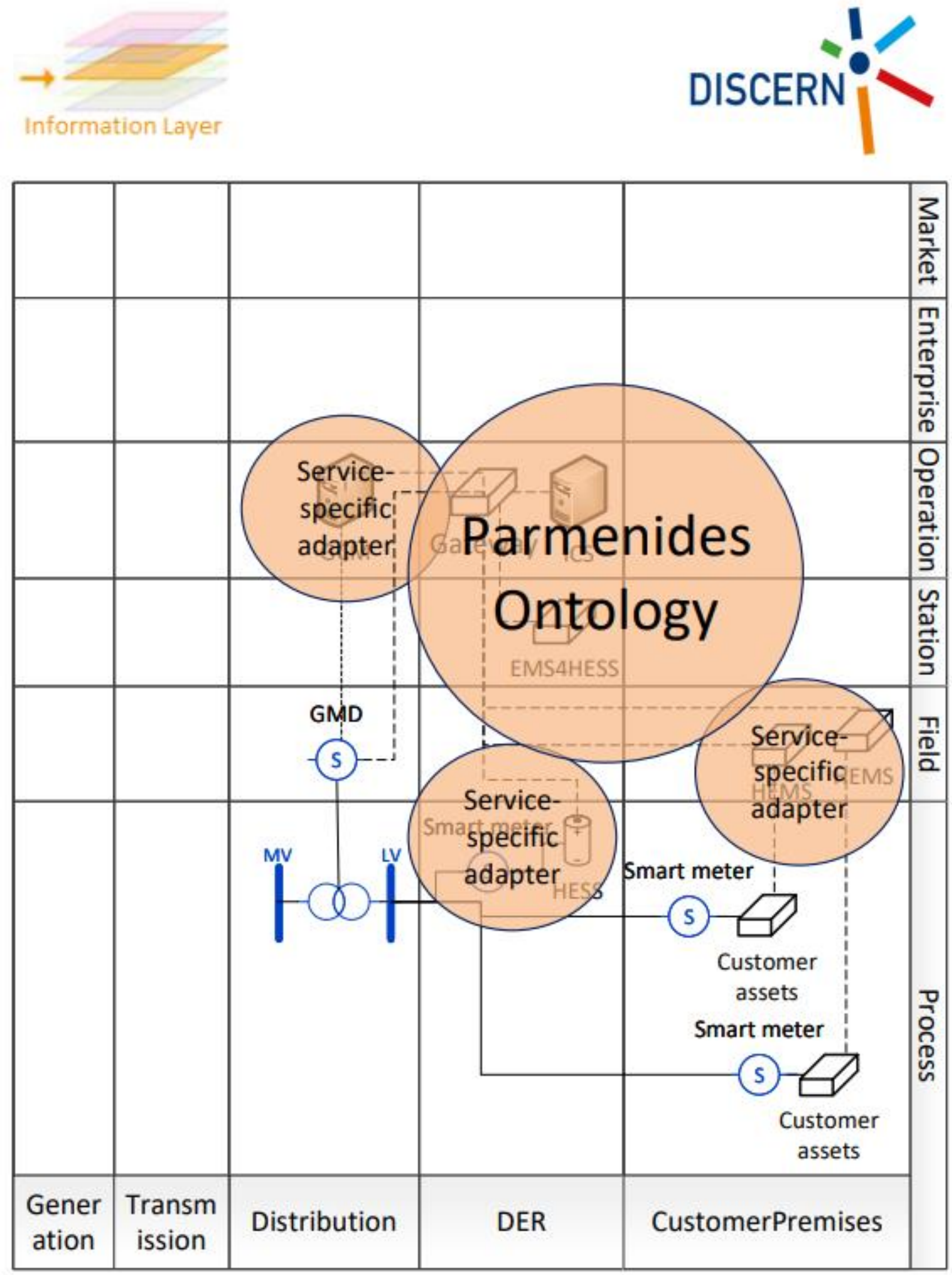


Figure 37: SGAM Information layer (Ontology) of the UC3 architecture

5.5.3 Functions layer

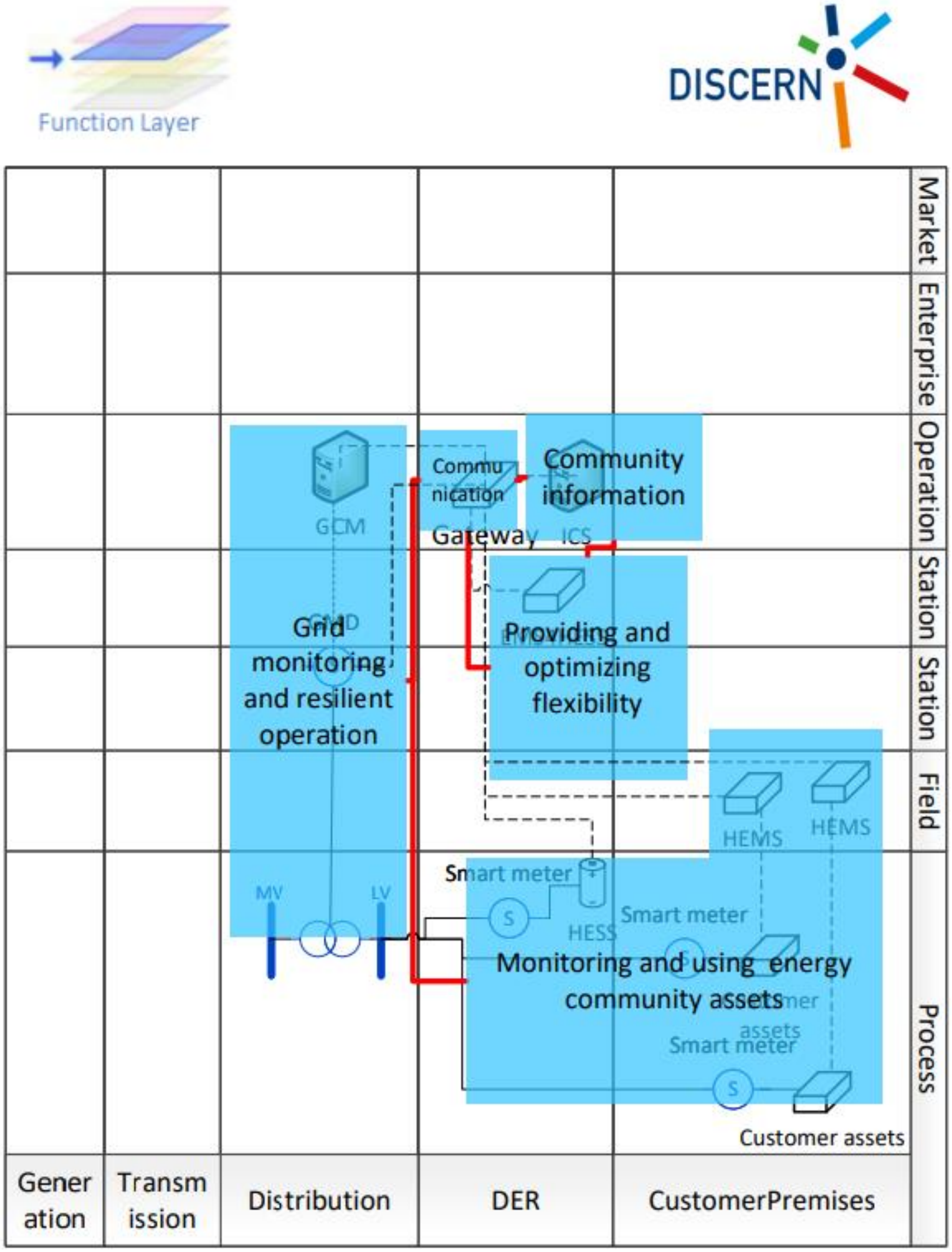


Figure 38: SGAM Function layer of the UC3 architecture

5.6.3 Business layer

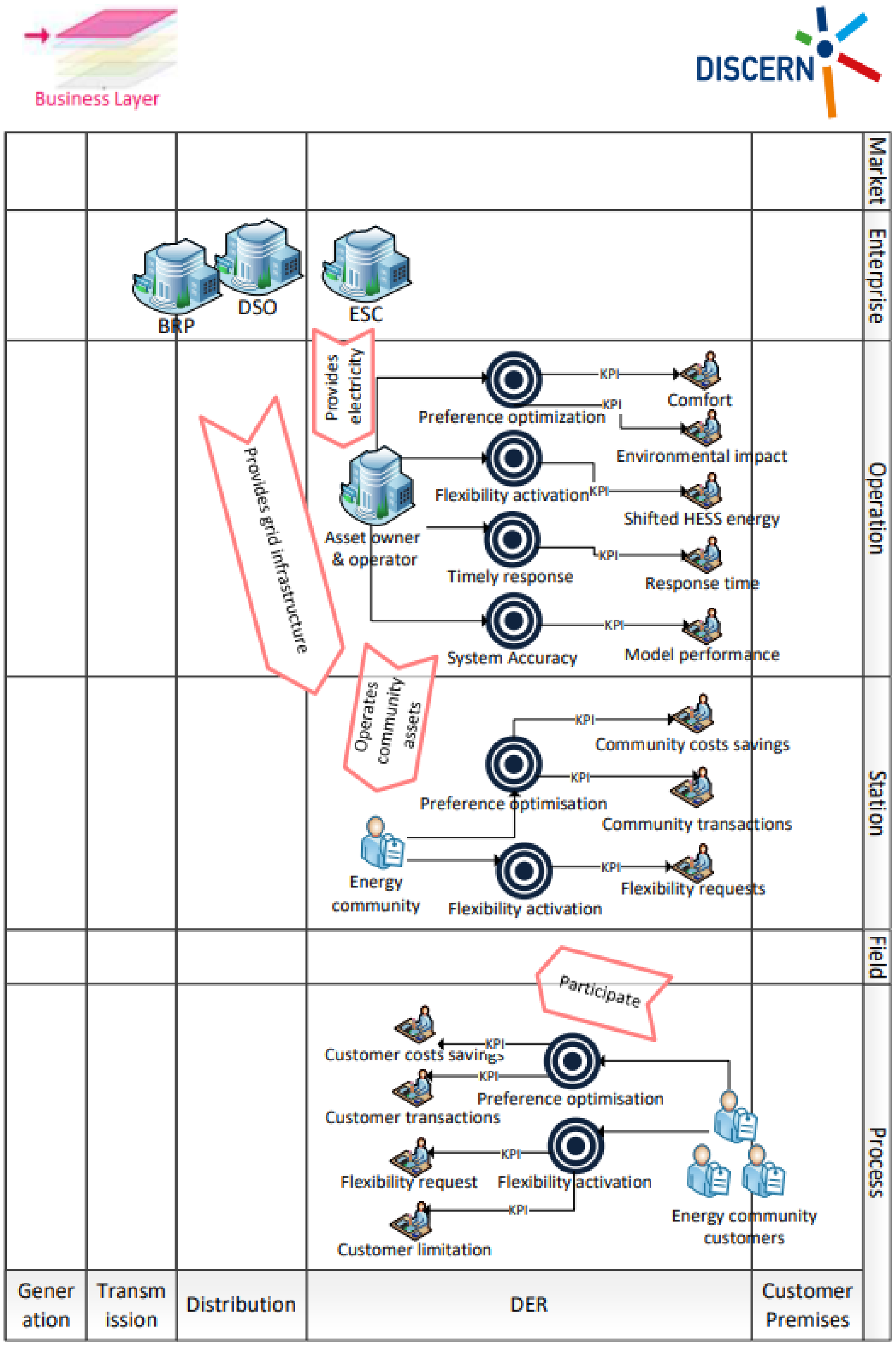


Figure 39: SGAM Business layer of the UC3 architecture

5.4. Use-case 4

The fourth use-case presents the process of a fully automated flexibility system. The EMS controls the Energy community assets based on the constraints from the grid, the predetermined constraints and preferences from the residential users.

5.1.4 Component layer

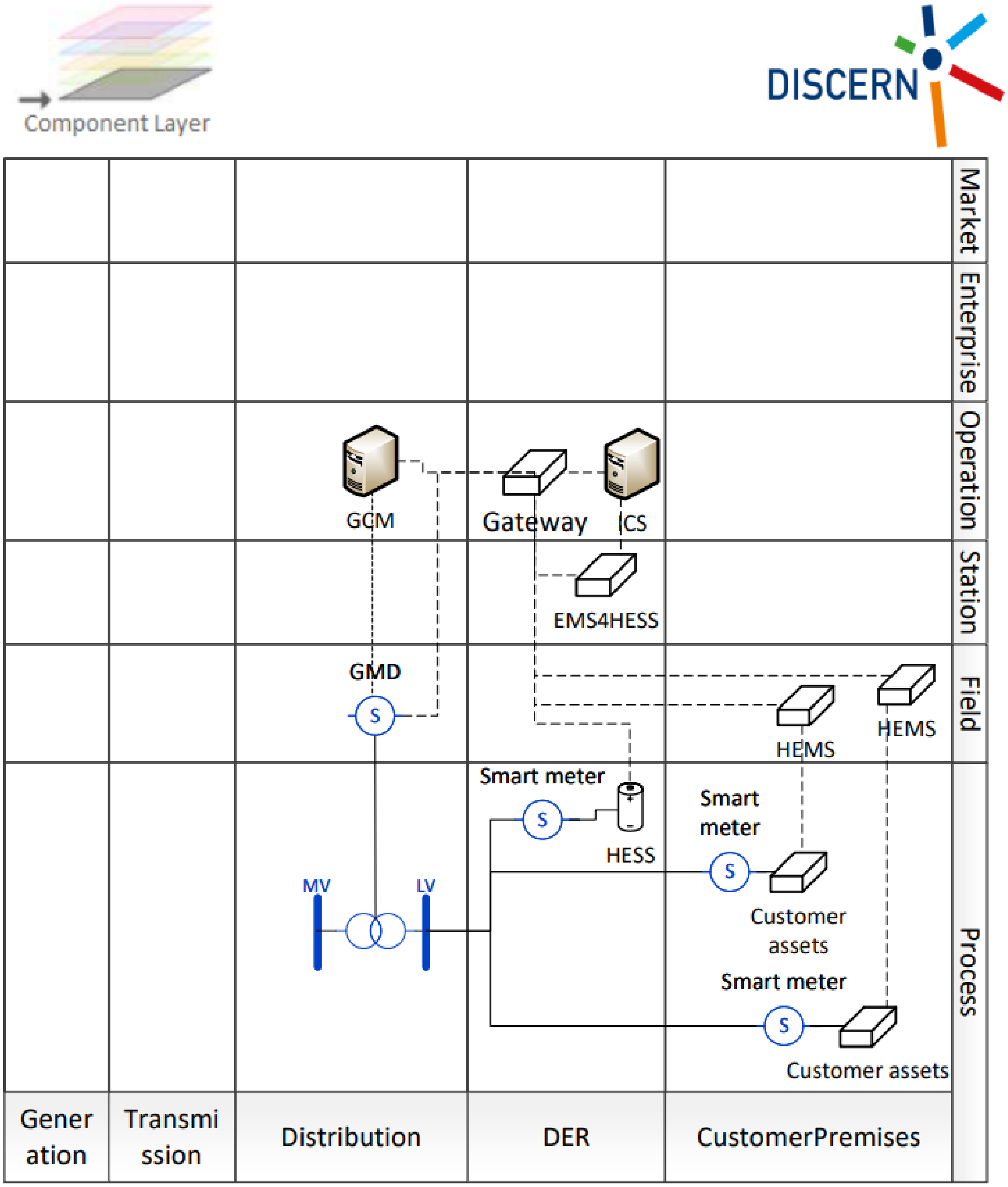


Figure 40: SGAM Component layer of the UC4 architecture

5.2.4 Communications layer

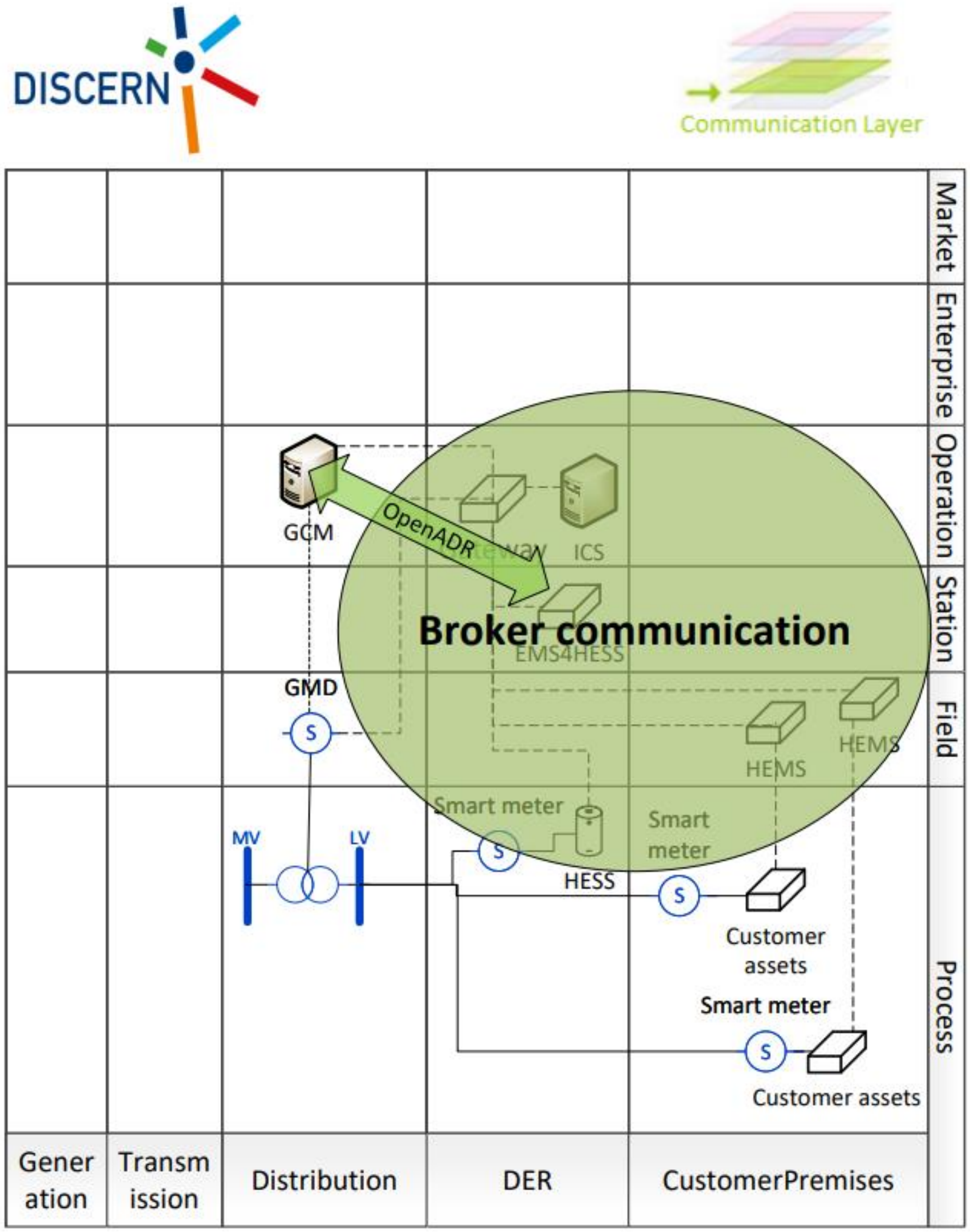


Figure 41: SGAM Communication the UC4 architecture

5.3.4 Information layer – Information

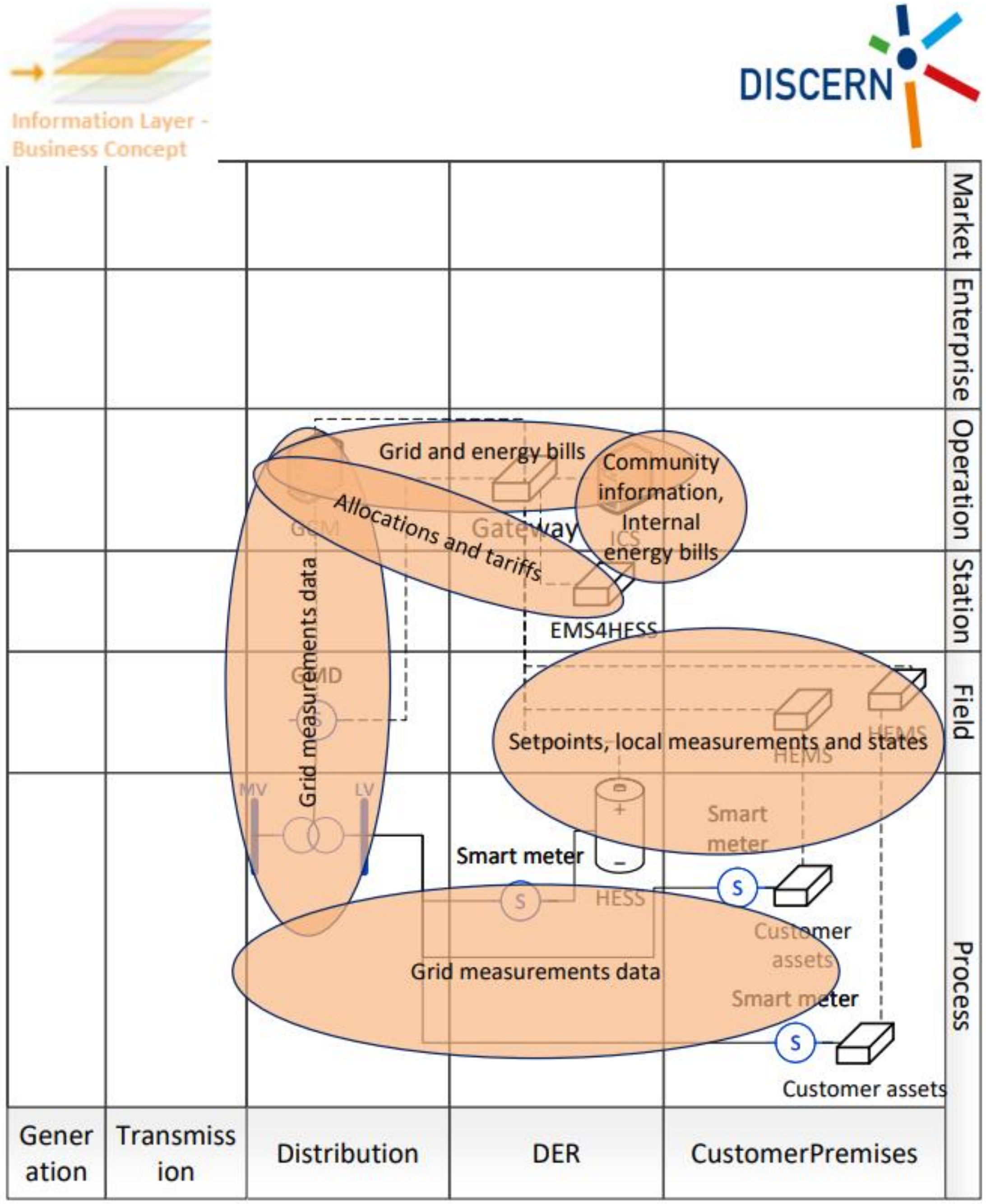


Figure 42: SGAM Information layer (data) of the UC4 architecture

5.4.4 Information layer – Ontology

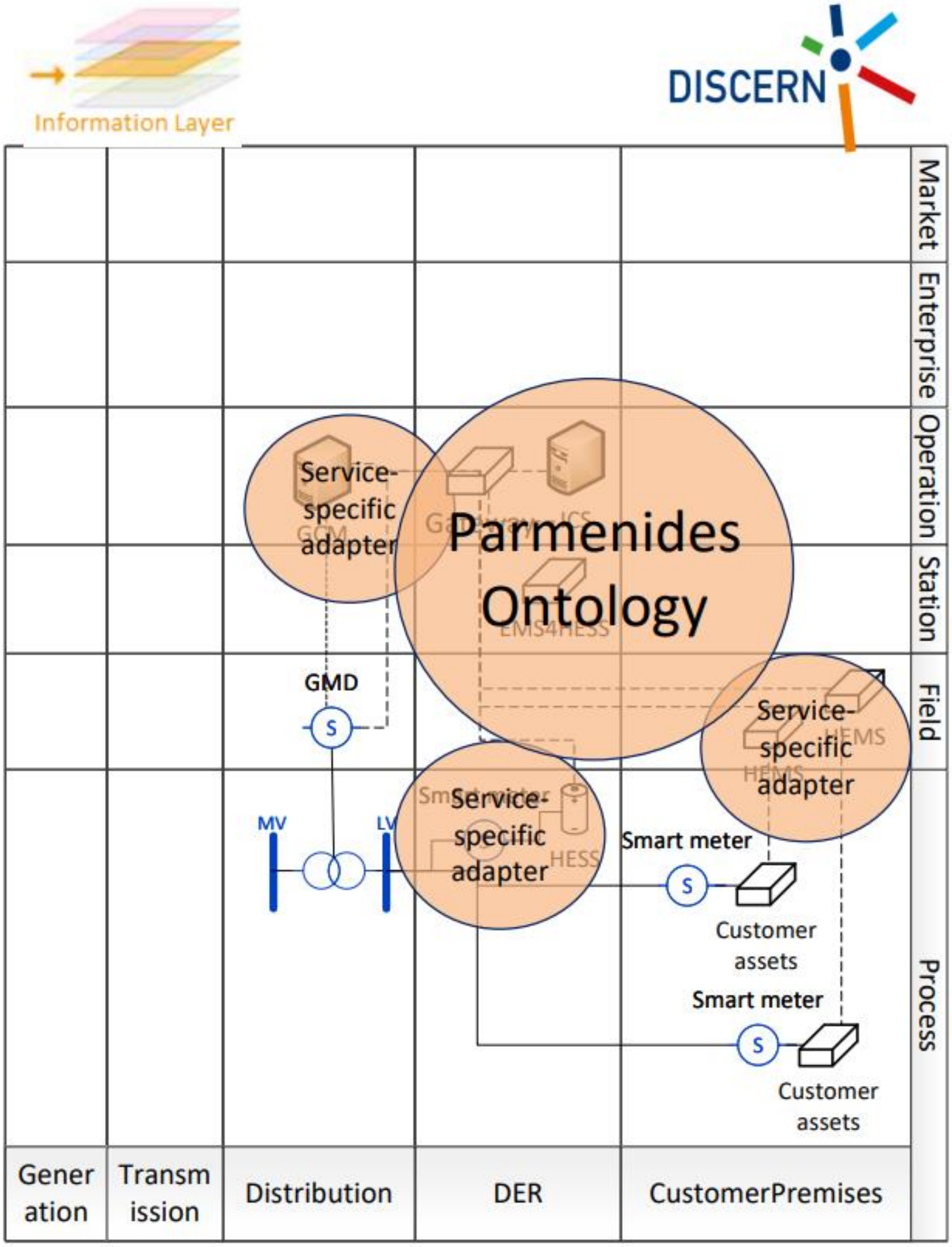


Figure 43: SGAM Information layer (ontology) of the UC4 architecture

5.5.4 Functions layer

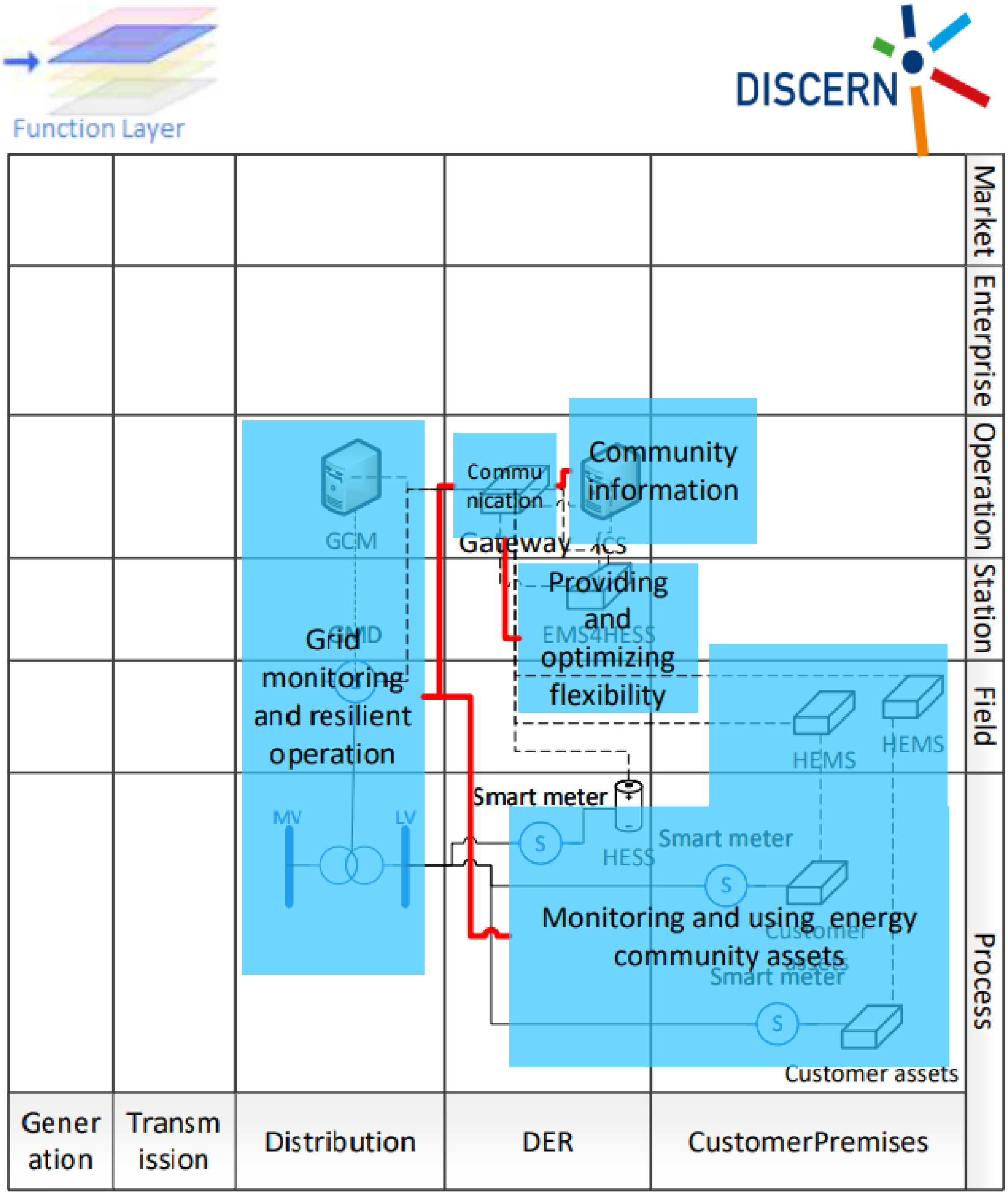


Figure 44: SGAM Function layer of the UC4 architecture

5.6.4 Business layer

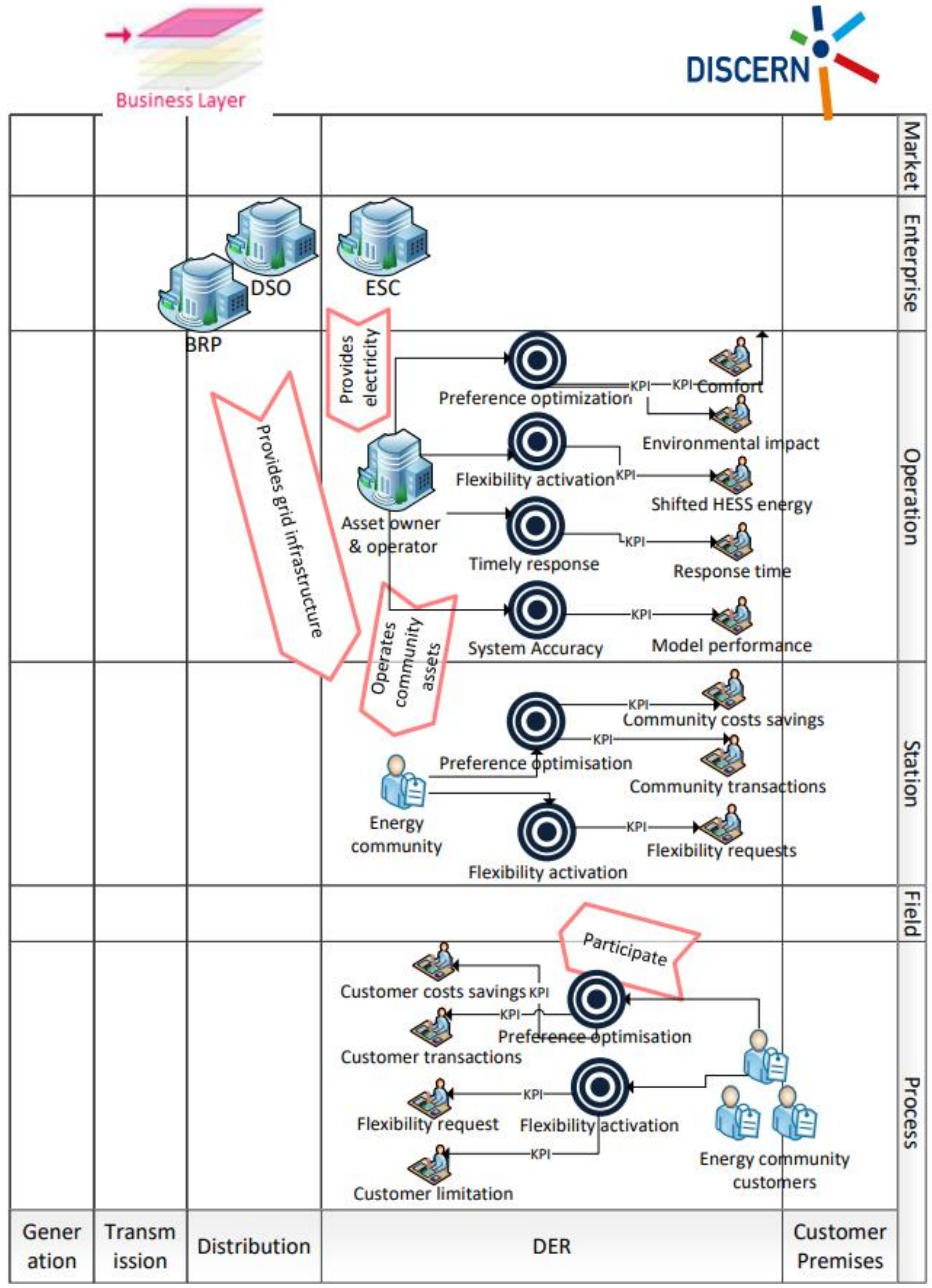


Figure 45: SGAM Business layer of the UC4 architecture

6. Pilot-specific architectures

Both pilots will implement a subset of the previously defined use-cases. However, their assets, as well as the communication protocols will differ depending on the local environment. The two architectures defined in this section show these specificities. They are based on the SGAM generic architecture. In particular, different gateways will be used for each pilot.

6.1. Austrian pilot

The Austrian pilot will use a gateway from Siemens[1] for most of its communications with the assets. It uses MQTT over SSL. The assets that will be controlled are not yet defined, however some potential communication protocols for the communications with the assets have been indicated.

---

[1] SIEMENS is a sub-contractor in PARMENIDES and provides parts of the measurement equipment as well as the ICT system. Therefore, existing components from other research projects could be re-used and adapted to the goals in PARMENIDES.

6.1.1 Component layer

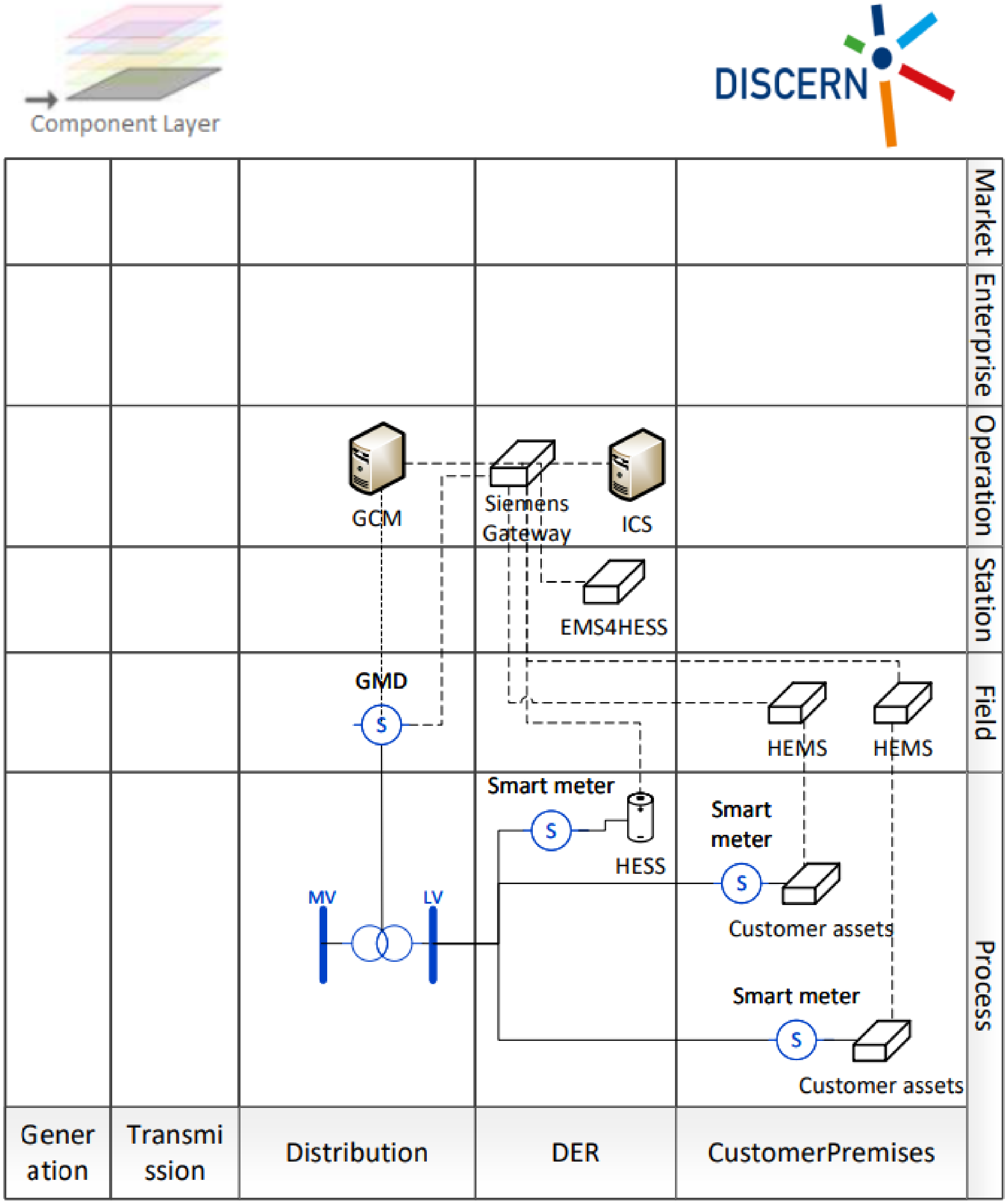


Figure 46: SGAM Component layer of the Austrian pilot architecture

6.2.1 Communications layer

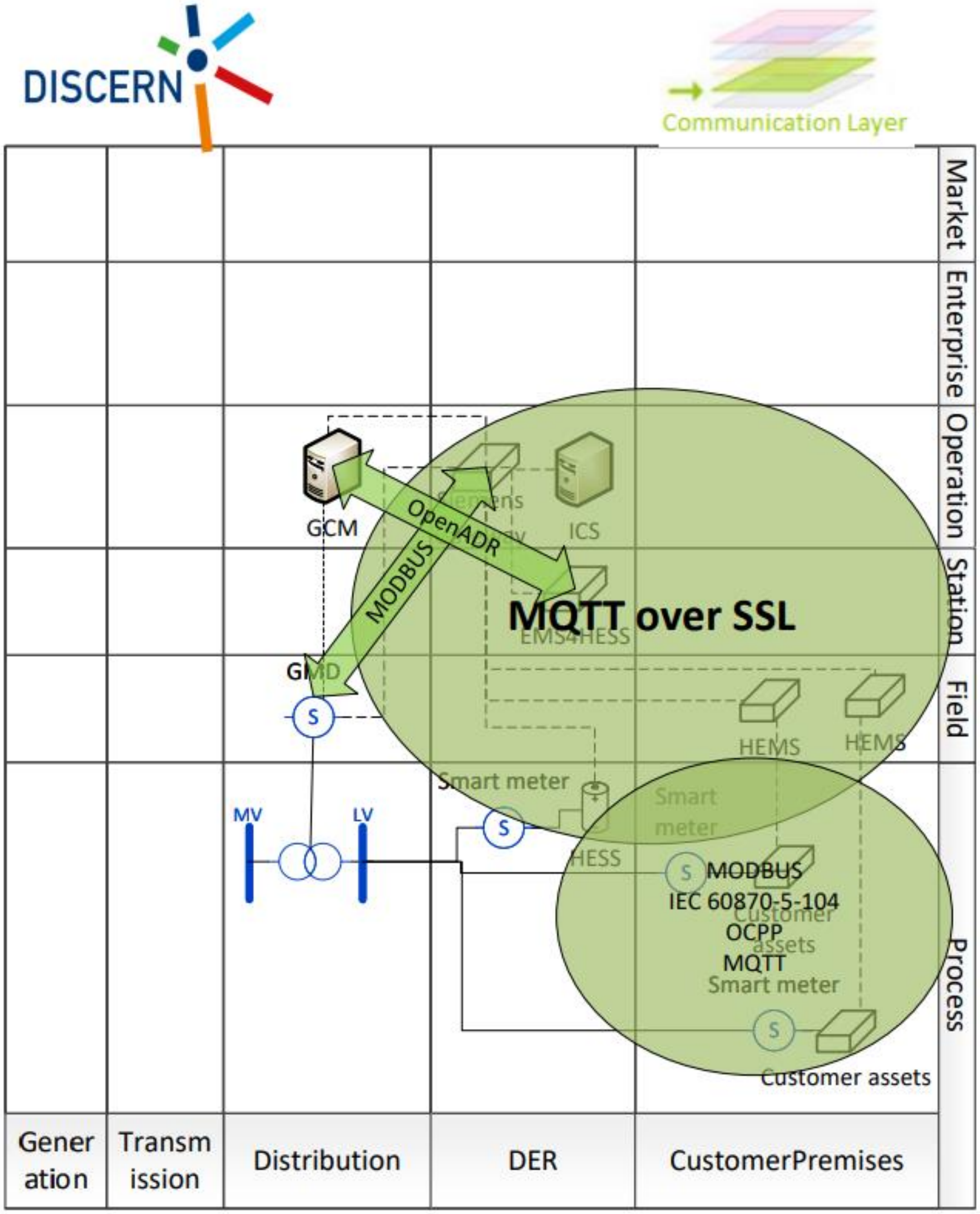


Figure 47: SGAM Communication layer of the Austrian pilot architecture

6.3.1 Information layer – Information

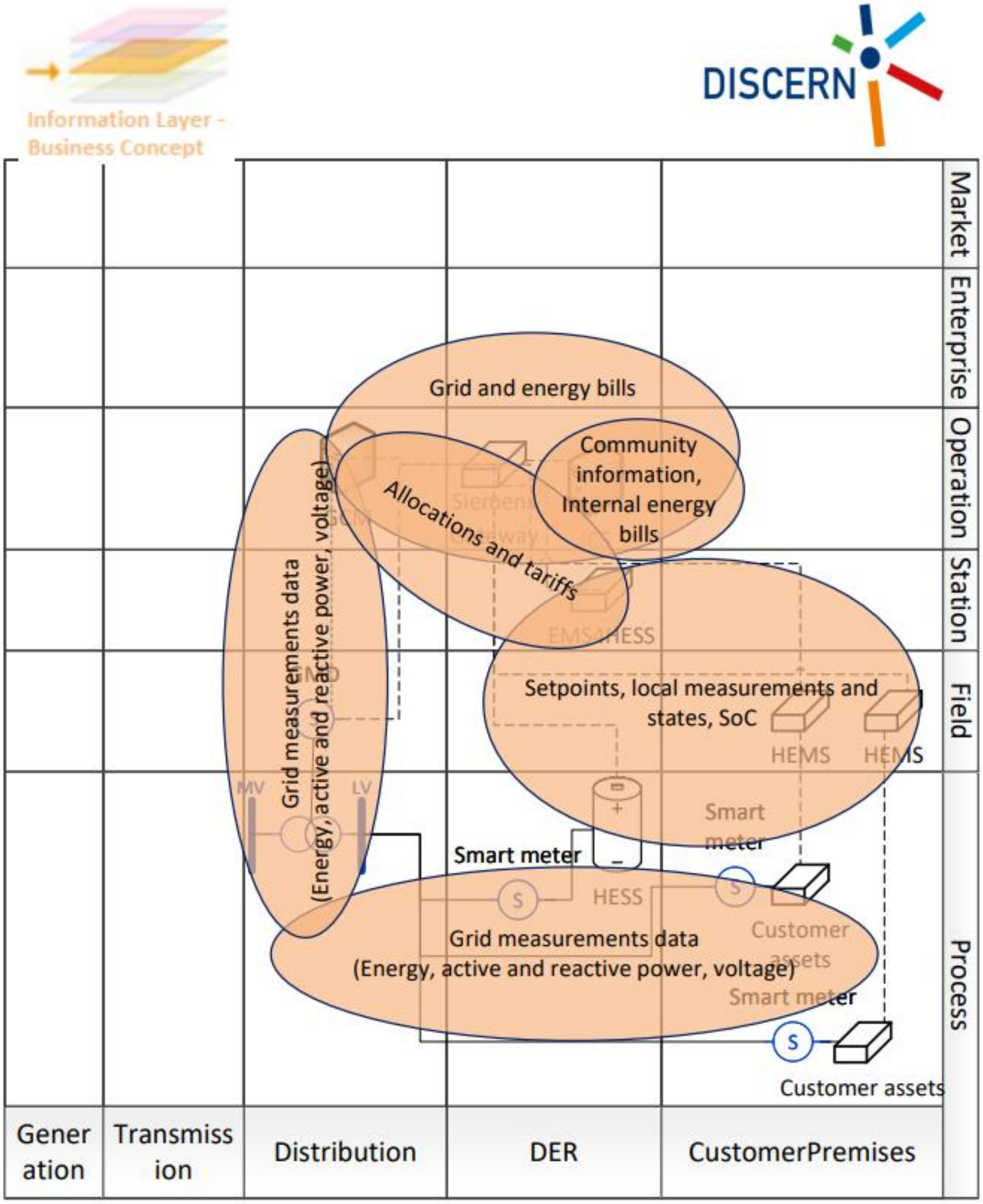


Figure 48: SGAM Information layer (data) of the Austrian pilot architecture

6.4.1 Information layer – Ontology

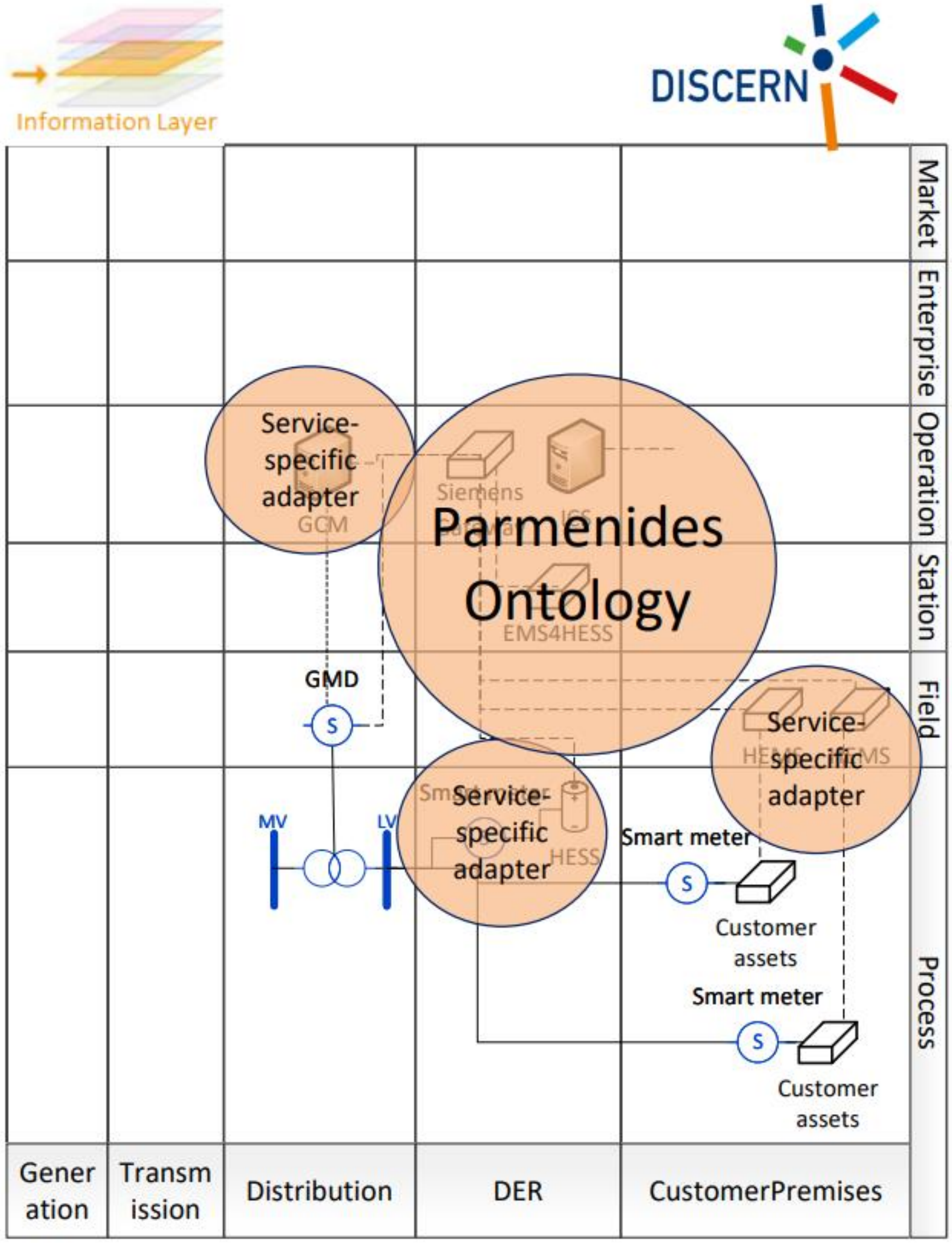


Figure 49: SGAM Information layer (ontology) of the Austrian pilot architecture

6.5.1 Functions layer

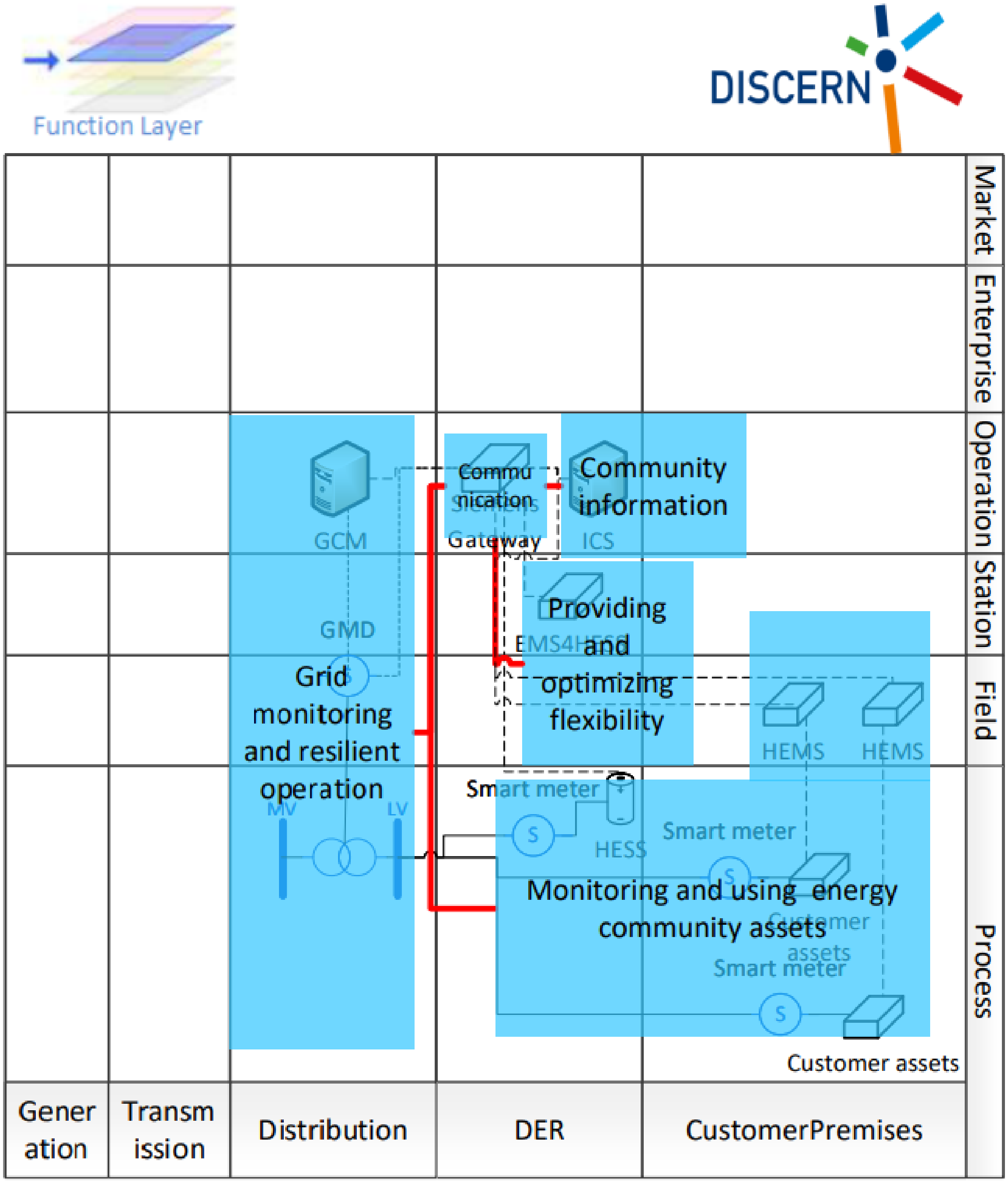


Figure 50: SGAM Function layer of the Austrian pilot architecture

6.6.1 Business layer

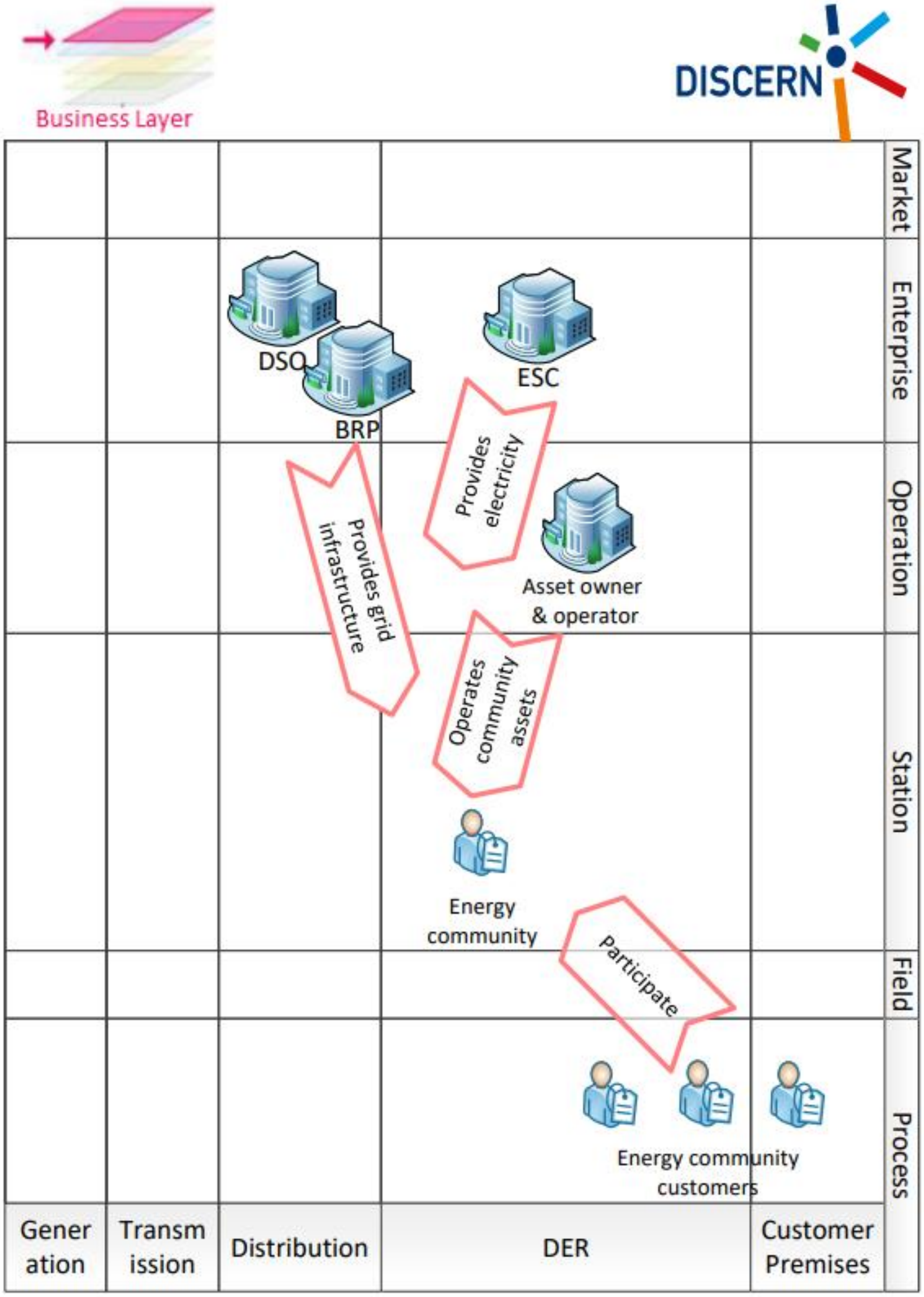


Figure 51: SGAM Business layer of the Austrian pilot architecture

6.2. Swedish pilot

The Swedish pilot will use a gateway from Schneider, that uses MQTT over REST API for its communications. The OpenADR protocol will not be used, as the DSO is not implicated in the pilot, and therefore the communications will not require setting up complex flexibility transactions. Instead, it is considered to use proprietary messages for controlling the local assets based on the optimizations computed by the EMS4HESS. On the other hand, the local assets of the pilot, and their respective communication protocols have been identified. They will include heat pumps, HVAC and lightings. The GCM is not part of the use case architecture elements.

6.1.2 Component layer

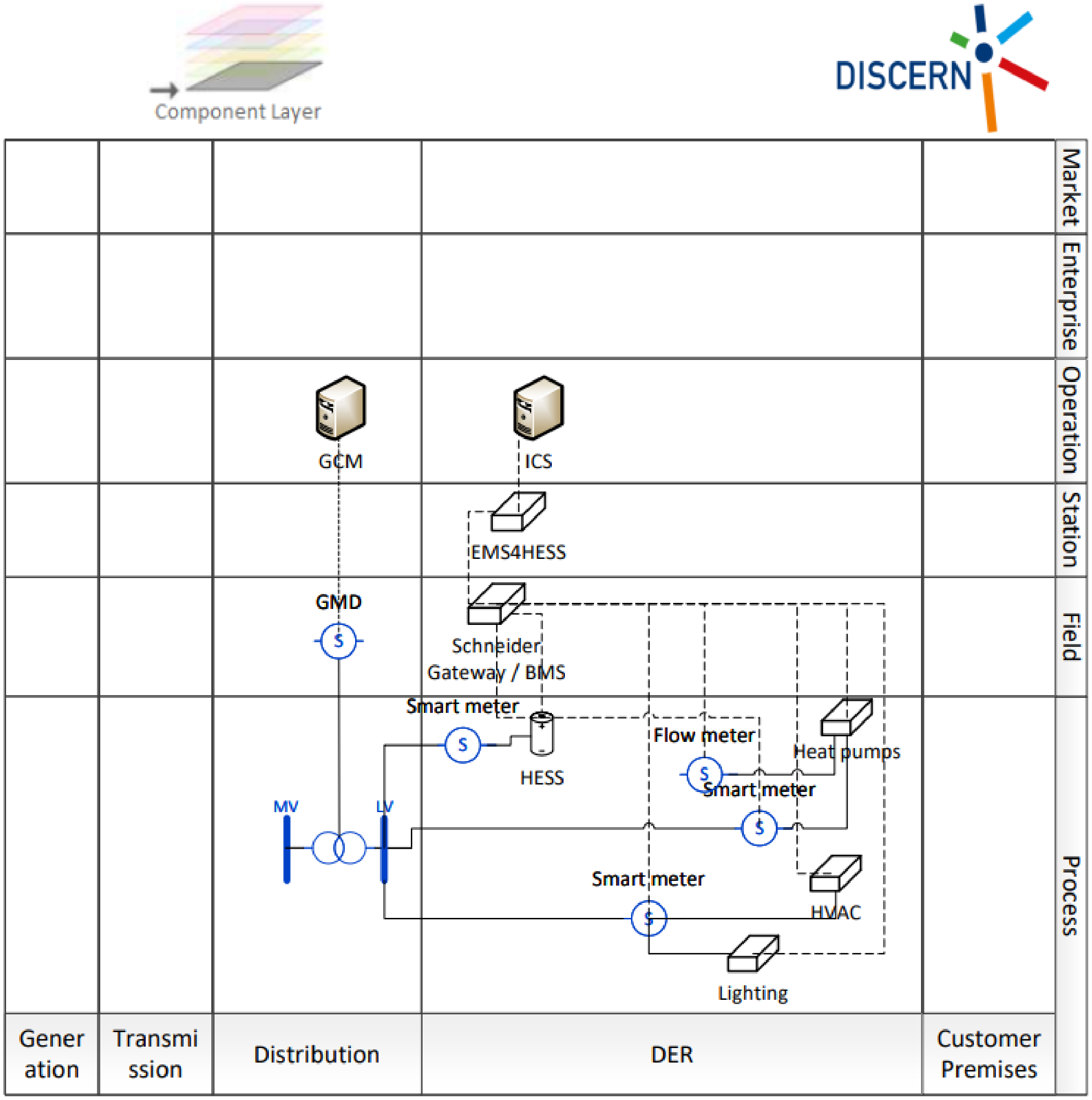


Figure 52: SGAM Component layer of the Swedish pilot architecture

6.2.2 Communications layer

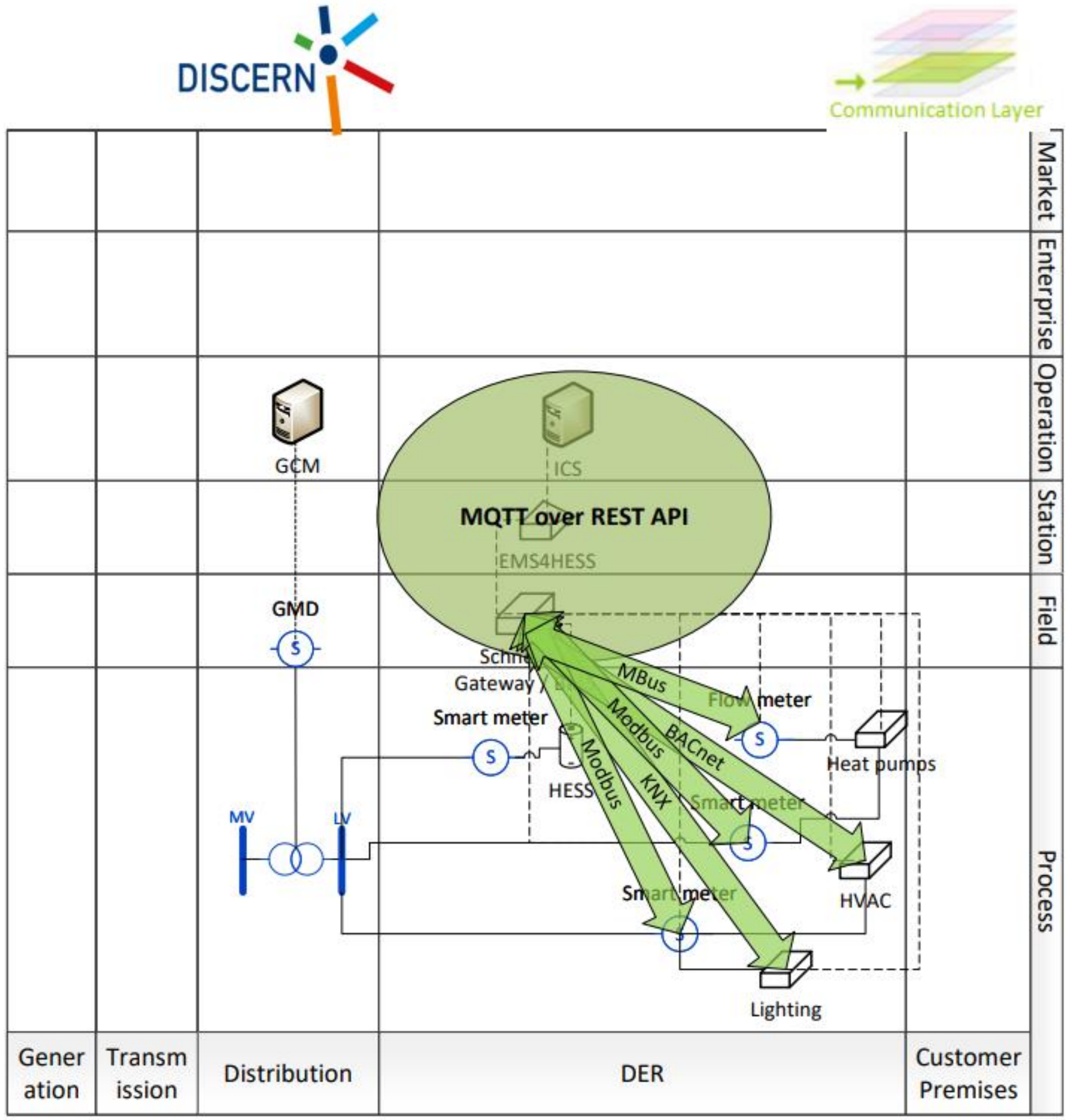


Figure 53: SGAM Communication layer of the Swedish pilot architecture

6.3.2 Information layer – Information

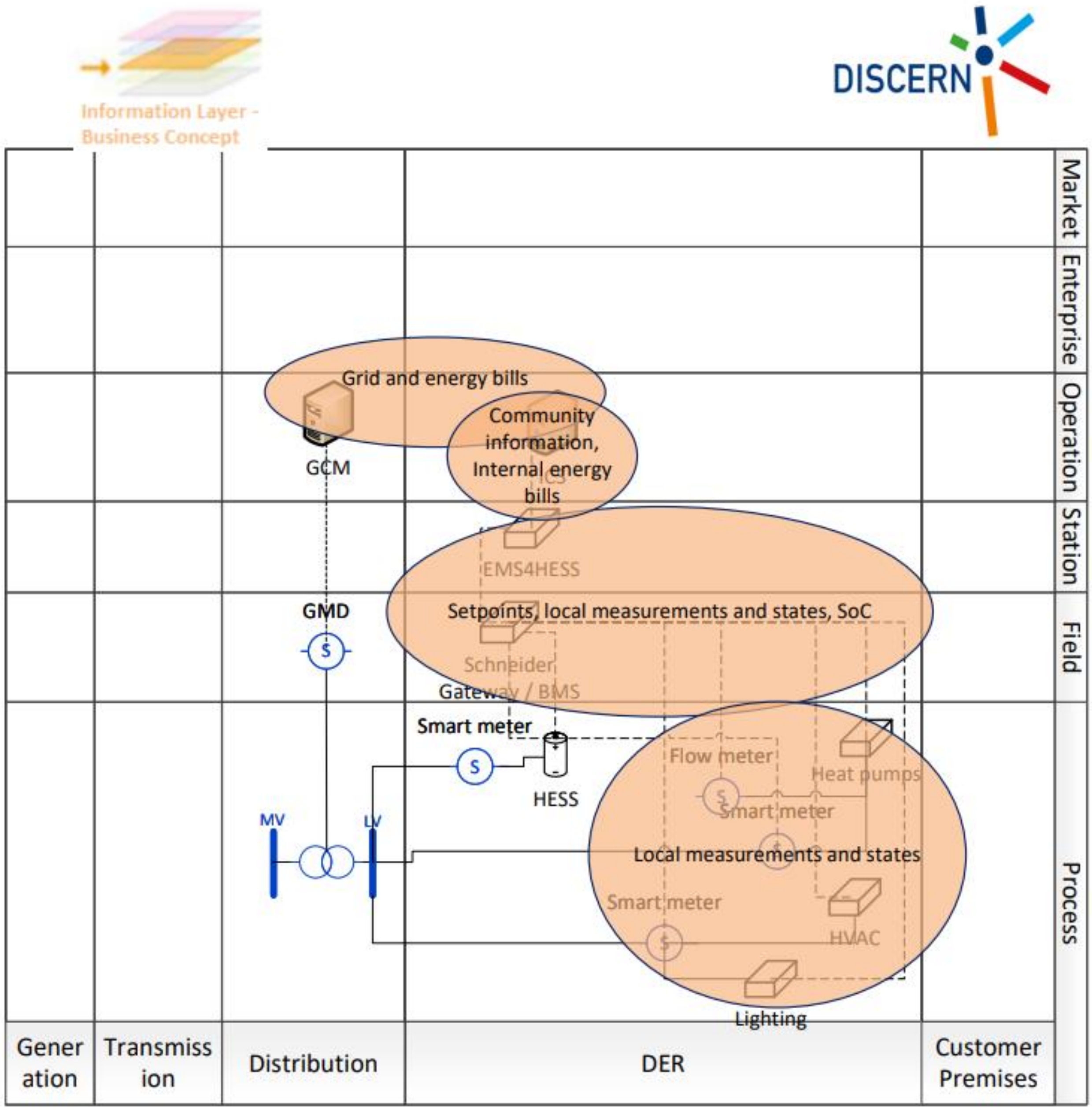


Figure 54: SGAM Information layer (data) of the Swedish pilot architecture

6.4.2 Information layer – Ontology

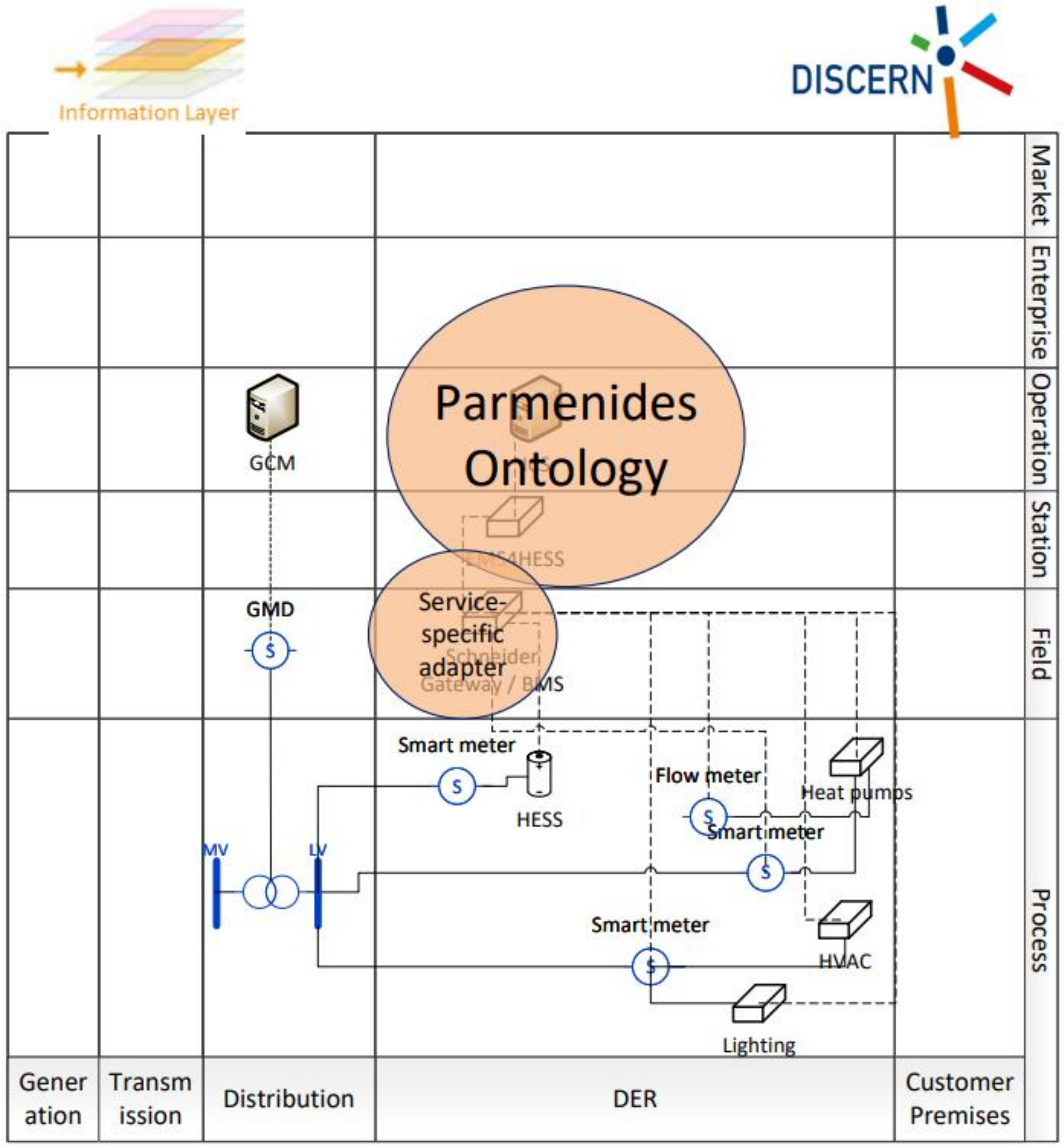


Figure 55: SGAM Information layer (ontology) of the Swedish pilot architecture

6.5.2 Functions layer

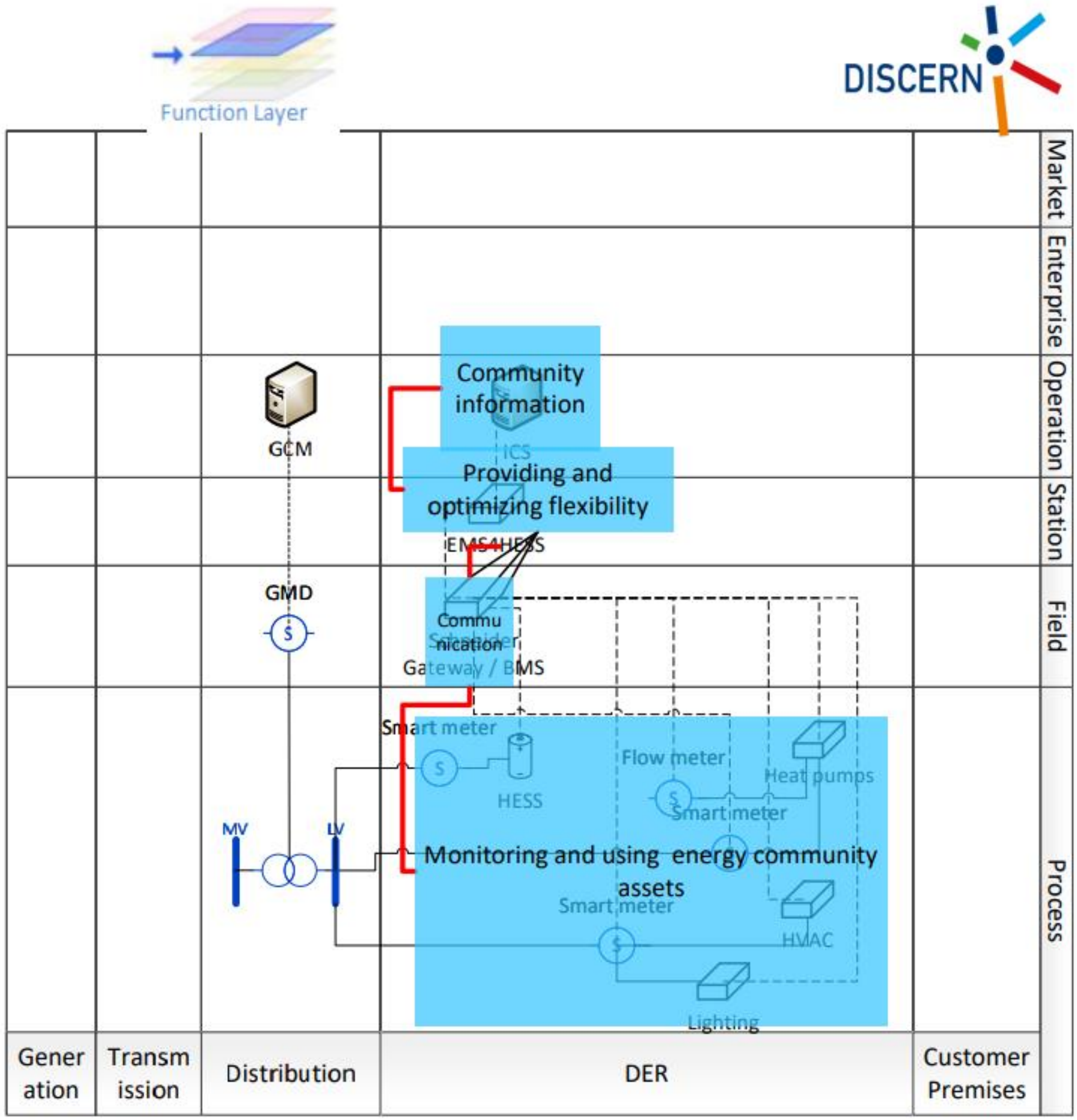


Figure 56: SGAM Function layer of the Swedish pilot architecture

6.6.2 Business layer

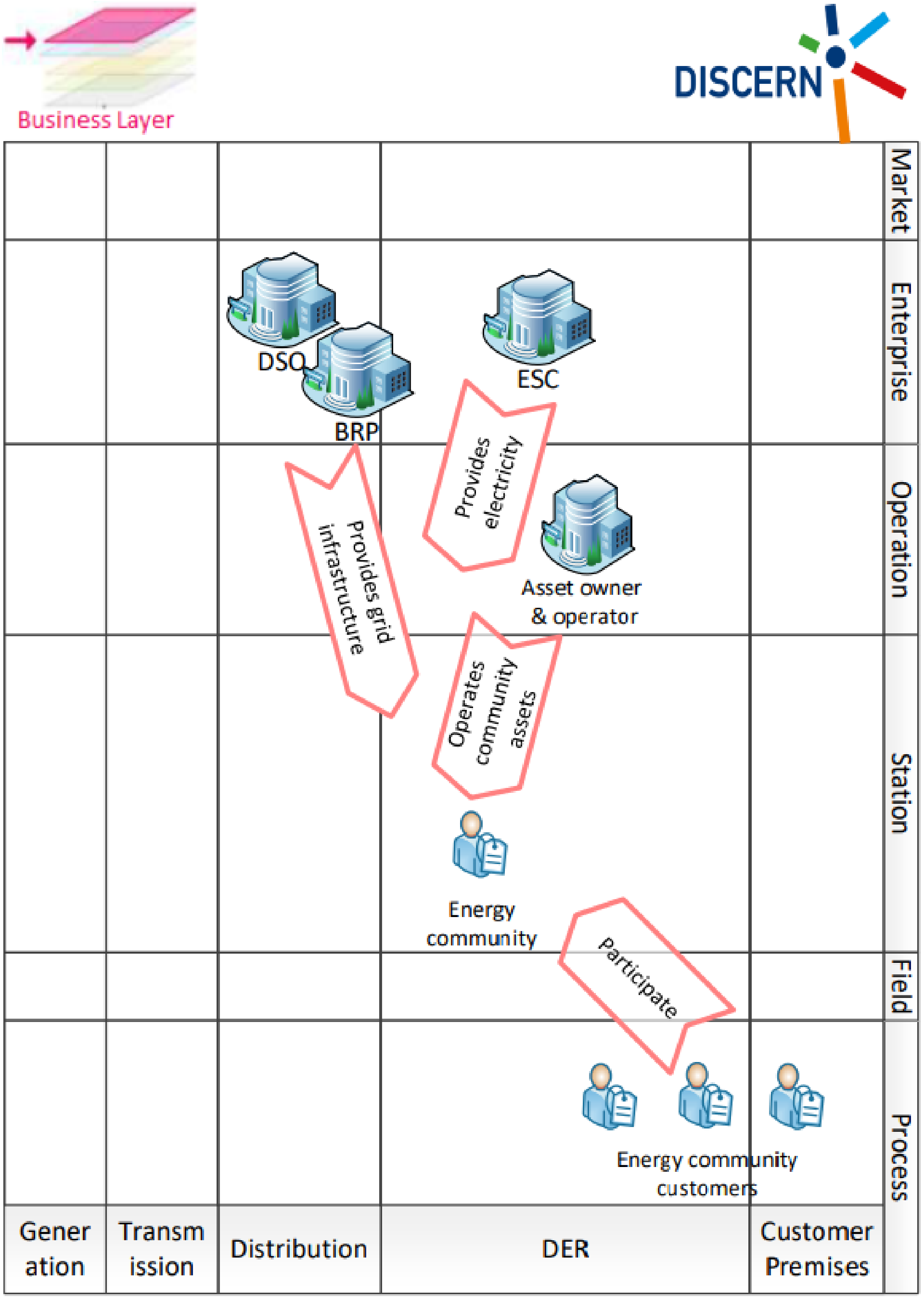


Figure 57: SGAM Business layer of the Swedish pilot architecture

7. Conclusion

The PARMENIDES architecture was defined through a methodology developed in previous innovation projects. A generic architecture was first developed, then specific architectures were instantiated based on it to show the details of the use-cases and pilots.

This process enabled to coordinate the actions of the solution providers and pilot leaders and ensure the coherence and interoperability of the developed system. It moreover led to identify gaps in the interoperability of the interfaces, in particular with regards to the flexibility protocols to be used and fill these gaps.

The architectures defined in this document should be used as a reference for the development and deployment of the PARMENIDES systems in WP4 and WP5.

8. Annex

8.1. List of Figures

8.2. List of Tables

8.3. References

[1] PARMENIDES european project, GA n°101096453, “D2.2 Use-case scenarios and requirements,” 2023.

[2] Bridge Data management working group, «European (energy) data exchange reference architecture 3.0.,» 07 2023. [En ligne]. Available: https://op.europa.eu/en/publication-detail/-/publication/dc073847-4d35-11ee-9220-01aa75ed71a1/language-en. [Accès le 24 11 2023].

[3] Interconnect European project Grant agreement No 857237, “Deliverable 2.1: Secure interoperable IoT smart home/building and smart energy system reference architecture,” 2020.

[4] Interconnect project, Grant agreement No 857237, “The Semantic Interoperability Framework,” in *Sustainable Places*, Brussels, 2022.

[5] CEN-CENELEC-ETSI Smart Grid Coordination Group, “Smart Grid Reference Architecture,” 11 2012. [Online]. Available: https://syc-se.iec.ch/wp-content/uploads/2019/10/Reference_Architecture_final.pdf. [Accessed 23 11 2023].

[6] European Commission, «EU action plan on Digitalising the energy system,» [En ligne]. Available: https://energy.ec.europa.eu/topics/energy-systems-integration/digitalisation-energy-system/key-actions-digitalising-energy_en.

[7] SENDER European project Grant agreement No. 957755., “D3.1: Interoperable architecture report,” 2021.

[8] The GridWise Architecture Council, “GridWise Interoperability Context-Setting Framework,” 2008.

[9] Data Management Working Group, “Main findings and recommendations,” 07 2019. [Online]. Available: https://bridge-smart-grid-storage-systems-digital-projects.ec.europa.eu/sites/default/files/documents/working-groups/BRIDGE-Data-Management-WG-Findings-and-Reco-July-2019.pdf. [Accessed 16 11 2023].

[10] Bridge Data Management Working Group, “Interoperability of flexibility assets,” 2022.

[11] ENTSO-E, «ENTSO-E Reserve Resource Process (ERRP) Implementation Guide,» 11 03 2022. [En ligne]. Available: https://www.entsoe.eu/publications/electronic-data-interchange-edi-library/.

[12] ENTSO-E, «Electronic Data Interchange (EDI) Library - Electricity Balancing Processes,» 2022. [En ligne]. Available: https://www.entsoe.eu/publications/electronic-data-interchange-edi-library/. [Accès le 08 04 2022].

[13] B.V., Equigy, “The Platform,” 2022. [Online]. Available: https://equigy.com/the-platform/. [Accessed 07 04 2022].

[14] C. McParland, «OpenADR Open Source Toolkit: Developing Open Source Software for the Smart Grid,» 2010.

[15] OpenADR Alliance, «OpenADR 3.0,» [En ligne]. Available: https://www.openadr.org/index.php?option=com_content&view=article&id=210:openadr-3-0&catid=20:general-site-content&Itemid=194.

[16] OpenADR Alliance, “Enabling the standard for automated Demand Response,” 04 2013. [Online]. Available: https://www.openadr.org/assets/docs/openadr%20plma%20seminar_final.pdf. [Accessed 13 04 2022].

[17] K. E. a. S. P. Samad, “Automated Demand Response for Smart Buildings and Microgrids: The State of the Practice and Research Challenges,” *in Proceedings of the IEEE,* vol. 104, no. 4, pp. 726-744, 2016.

[18] OpenADR Alliance, «Launch of the OpenADR add-on, OpenADR 3.0,» [En ligne]. Available: https://www.openadr.org/index.php?option=com_content&view=article&id=211:openadr-alliance-launches-openadr-3-0&catid=21:press-releases&Itemid=121.

[19] OpenADR Alliance, “OpenADR European case study – project ELBE,” 2020. [Online]. Available: https://www.openadr.org/assets/Enlit/OpenADR%20Case%20Study%20Stromnetz%20ChargePoint%20A4.pdf. [Accessed 04 04 2022].

[20] Intertrust, “Europe’s largest energy utility implements load balancing for efficient EV charging management,” 2020. [Online]. Available: https://www.intertrust.com/resources/europes-largest-energy-utility-implements-load-balancing-for-efficient-ev-charging-management/. [Accessed 04 04 2022].

[21] Universal Smart Energy Framework, “Unlocking the market for flexible energy use,” 2017. [Online]. Available: https://www.usef.energy/app/uploads/2016/12/USEF-A5-handout_2017.pdf. [Accessed 16 03 2022].

[22] USEF, “USEF Flexibility Trading Protocol Specifications,” 2020.

[23] GOFLEX, “An overview of the Flex-Offer concept,” 2018. [Online]. Available: https://www.daisy.aau.dk/wp-content/uploads/2019/05/FlexOfferOverview-v0.9.pdf. [Accessed 02 03 2022].

[24] L. Š. a. B. N. Torben Bach Pedersen, “Modeling and Managing Energy Flexibility Using FlexOffers,” in *SmartGridComm*, 2018.

[25] FlexOffer User group, “FlexOffer specification V1.0,” 26 07 2023. [Online]. Available: https://github.com/flexoffer/flexoffer-specifications/blob/main/FlexOffer%20specificationV1_with%20cover.pdf.

[26] CALLIA, «Deliverable 2.2,» 2017.

PARMENIDES

PARMENIDES

Plug&plAy eneRgy ManagEmeNt for hybrID Energy Storage