TradeRES

TradeRES
New Markets Design & Models for 100% Renewable Power Systems

D3.2 – Characterization of new flexible players

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1.0	30.06.2021	Public	Report with detailed technical and economic characterization of the behaviour and capabilities of actors in the electricity market.

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Executive Summary

The subject matter of this report is the analysis of the electricity markets' actors' scene, through the identification of actor classes and the characterisation of actors from a behavioural and an operational perspective. The technoeconomic characterization of market participants aims to support the upcoming model enhancements by aligning the agent-based model improvements with the modern market design challenges and the contemporary characteristics of players. This work has been conducted in the context of task T3.2, which focuses on the factorization of the distinctive operational and behavioural characteristics of players in market structures. Traditional parties have been considered together with new and emerging roles, while special focus has been given on new actors related to flexible technologies and demand-side response. Among the main objectives have been the characterization of individual behaviours, objectives and requirements of different electricity market players, considering both the traditional entities and the new distributed ones, and the detailed representation of the new actors.

An overview of roles and actors of electricity markets is presented through an exhaustive review of existing and developing representation and modelling approaches. The Harmonised Electricity Market Role Model (HEMRM) of ENTSO-E, ebIX and EFET, a commonly accepted role model is explored, while other frameworks such as the Universal Smart Energy Framework (USEF) and the Smart Grid Architecture Model (SGAM), and ontologies like the Open Energy Ontology (OEO) and the Smart Energy Aware Systems (SEAS) ontology are examined regarding the scope of the players and their roles. The HEMRM offers a harmonized and complete role representation, ensuring at the same time some degrees of freedom with respect to market design. The USEF focuses on the realization potential of flexibility with storage and demand response being at the center of its market organization proposal. The SGAM develops a technically robust approach around smart grid architecture while it inherits roles from HEMRM, and the ontologies provide the insight on the vocabulary required in representing the electricity market in models. Although these approaches originate from different starting points and follow their own evolvement path, they contain systematic ways under which actors have been identified and relationships have been examined on an effort of representing the electricity markets through the incorporation of actors in models. Therefore, the review of all those initiatives has provided a useful insight on how the issue of identification, analysis and representation of actors has been tackled before and enabled the development of definitions and structures around actors.

The relation between the technological progress and the actor scene is an extra aspect considered as the groups of actors and interactions that exist are influenced by the emergence of new technologies, while at the same time new technologies are the outcome of R&D efforts of stakeholders. Definitions in the context of TradeRES of the actors and their roles are provided, while actor classes are identified. The main classes of actors considered are the Prosumer, the Producer, the Supplier, the Aggregator, the Trader, the ESCo, the Operator and the Regulator. The classes have been allocated into the four layers considered, namely the social, the physical, the aggregation and the market layer, while they have been used to provide a structure to the technoeconomic analysis that follows in two dimensions, namely the operational and the behavioural one. The actor classes are also consid-

ered under two broad categories, one focussing on the pre-existing and very common parties and another one where the emerging entities are concerned. Apart from the distinction between traditional and new actors' categories, the influence of technology on the assets' operation and consequently on actors' behaviour is considered. The technologies that actors can exploit for achieving their goals affect their positioning in the environment and the way of interaction. Therefore, part of the analysis has been also the mapping of actor classes and technologies relationships. Those relationships of actors and technologies have been considered from the scope of current and envisaged versions of agent-based models as well as from the overall vision of TradeRES project and depict the outcomes of the actor-related survey that was conducted inside the consortium. Similarly, the relationships of the actor classes with operational and behavioural aspects have been examined with respect to their intensity, completing that way the qualitative characterization of actors.

From the operational dimension point of view, we find that prosumers are strongly related to inflexible demand as well as demand side response attributes, with demand profiles being among the important ones. Load shedding and demand shifting are also found to be of high relevance in that class of actors, while energy saving appears to influence the operation. Storage and electric vehicle attributes exhibit strong relationships with prosumers, while industrial prosumers and energy communities seem to be connected with both controllable and non-controllable operational aspects. Energy communities are considered also in the role of a local network operator as they have been related, although mildly, to network parameters. Large generation is strongly affected by capacity and power limits, while the capacity factor and the generation profile seem to be among the most important aspects. Regarding distributed generation, emphasis is given to non-controllable generation and specifically to the generation profile. For the storage, either large-scale or distributed, attributes such as the energy limit, the charging/discharging limit and charging/discharging efficiency appear to matter. The aggregator is also among the class of actors that are affected by demand response attributes, renewable generation and storage characteristics since flexibility aggregation makes use of these technologies. The operators of the transmission and distribution systems have non-negligible connections to network operational attributes as they are affected by the topology, the line characteristics and the technical limits. From the behavioural perspective, prosumers seem to be driven mainly by utility maximization and cost minimization, producers incorporating the firm and investor aspects of microeconomics and along other business entities being more focused on profit maximization. While market operators mainly minimize costs, regulators focus on maximizing welfare including environmental, social and sustainability concerns by setting the legislation standards that affect several actors.

Both dimensions have been exploited for the proper characterization of actors that enable the incorporation of contemporary trends to the agent-based model formulation phase, where the objectives of players and the constraints will be enhanced. The Actor-ID cards that have been deployed are four-block tables that summarize the description, the main technologies, the operational attributes and the behavioural aspects for each actor class. The key findings of the analysis are presented through the cards and the main characteristics of the actors are pointed out.

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1. Introduction

1.1 Scope of the deliverable

This deliverable focuses on electricity markets' actors and, by considering their participation from a behavioural and an operational point of view, aims to perform their technoeconomic characterization that is to be used for the proper alignment of players' modelling. The exhaustive analysis of the spectrum of stakeholders can be considered an important step as it enables the identification of the behavioural objectives and operational requirements of the different parties involved in the markets and allows the better understanding of the interactions' dynamics that need to be incorporated in the modelling part of TradeRES project. This work has been conducted in the context of task T3.2, which precisely consists of the factorization of the distinctive operational and behavioural characteristics of players in market structures, with special focus on new actors related to flexible technologies and demand-side response. Among the main objectives of the task are the analysis of (i) individual behaviours, (ii) objectives and (iii) requirements of different electricity market players, considering both the traditional entities and the new distributed ones, as well as the detailed representation of those new actors. For covering those needs, a two-step methodology has been adopted, where first the identification and then the characterization of players take place. The identification part that has been supported by a review of the regulation, the institutions and the organizations in EU, a widely accepted market role model, an energy system framework and a smart grid architecture model connected to market models and ontologies that cover electricity markets. On the other hand, the characterization follows the findings of an actor-related survey that focused, from a qualitative point of view, to the relationships between the actors and (i) the technologies, (ii) the operational attributes and (iii) the behavioural aspects. For the survey development, key elements of other deliverables and important aspects found in the literature related to electricity market modelling and individuals/collectives' behavioural analysis, have been used. The survey supports the identification of relationships from the scope of current and envisaged agent-based models as well as from the TradeRES project vision and therefore pave the way for the more model oriented analysis that follows on WP4 related activities.

1.2 Structure of the deliverable

The deliverable initially provides an overview of the roles and the actors found in electricity markets by reviewing existing and developing approaches. This part is covered in Section 2, where after a short introduction of the current electricity market framework, the Harmonised Electricity Market Role Model (HEMRM), other frameworks such as the Universal Smart Energy Framework (USEF) and the Smart Grid Architecture Model (SGAM), and ontologies like the Open Energy Ontology (OEO) and the Smart Energy Aware Systems (SEAS) ontology are examined regarding the players and their roles. The relation between the technological progress and the actors' scene is an extra topic considered since the groups of actors that exist may be influenced by the emergence of new technologies, while at the same time new technologies are the outcome of R&D efforts of stakeholders.

The identification of the actors and their roles in electricity markets is performed in Section 3, along with their classification that aims to provide a structure to the subsequent technoeconomic analysis. After providing the definitions that have been adopted for some key terms, the process of actors' identification that is held via the consideration of two broad categories, one with the pre-existing and very common parties and another one with the emerging entities, the traditional and the new actors' categories, namely, begins. Then the presentation of the main classes of actors, such as the Prosumer, the Producer, the Supplier, the Aggregator, the Trader, the Energy Service Company (ESCo), the Operator and the Regulator is given. The section concludes with the influence of technology on the actors, and specifically on their emergence and further specification with respect to their operation, behaviour and overall interaction with the rest of the system.

In Section 4, the technoeconomic analysis is performed. The analysis takes place with respect to two dimensions, the operational and the behavioural one. Both have been identified as the main dimensions required for a properly structured characterization of the players, since they cover the core parts needed in the modelling phase for the formation of the objective function and the constraints. To summarize the key findings of the analysis and point out the main characteristics of the classes of actors, a novel approach inspired by the demo identification cards used in BRIDGE initiative, has been adopted. Aiming to serve as a quick reference point, the so-called TradeRES Actor-ID cards that are presented in Section 5, include the most important information related to each of the actors and serve as a facilitator for further integration of players' characteristics in upcoming phases of the project. Finally, the deliverable concludes in Section 6 with some key remarks of the current version.

1.3 Relationship with other deliverables and tasks

This deliverable uses several other preceding deliverables and tasks for gathering inputs and identifying key aspects in a wide range of related subtopics, varying from existing models and their coupling to market design principles.

The concepts tackled here are also closely relevant to other tasks of WP3, in the sense that systems, products, services and markets are designed and developed with actors being the underlying driving force. Therefore, either from the system's performance point of view or by considering products and markets for core and ancillary services, stakeholders' behaviour, which arises from needs, is directed by incentives, is restricted by rules and is finally formed through repeated interaction of potentially strategic nature, is on the centre of the undertaken analysis.

Particularly, this deliverable heavily relies on information of other WP3 deliverables, such as D3.1 and D3.5, while simultaneously receives inputs from task of WP2 and WP4, related to either the centralised or decentralized -agent based- modelling approaches adopted in TradeRES project (see D2.1 and D4.6). Finally, it needs to be mentioned that the work conducted in T3.2, which is summarised in D3.2, paves the way for the representation of actor types and behaviour through novel modelling techniques that will be the subject matter of subtask T4.2.1 and of the corresponding deliverable D4.4 that will follow in two versions.

2. Overview of roles and actors in electricity markets

2.1 Policy trends, electricity markets and organizations

In accordance with the Paris Agreement and its objective to keep the global temperature increase to well below 2°C and pursue efforts to keep it to 1.5°C, the European Green Deal is an ambitious policy package with a wide range of actions and measures for the containment of climate change [1]. Among the most highlighted proposals is the emissions' reduction target which has been set to at least 55% below 1990 levels by 2030 and the long-term goal for climate-neutrality by 2050, which can be achieved through the transition to a sustainable and circular economy with net-zero greenhouse gas emissions.

With the energy system being at the centre of the undergoing transformation, the Clean Energy for all Europeans Package includes ambitious rules and puts forward the legislative parameters to reconsider for responding to contemporary challenges and maintaining the lead in the global energy transition for the coming years [2]. Its main goals are the prioritization of energy efficiency, the intensification of renewable energy sources (RES) take-up, the provision of a stable private investment enabling framework, the strengthening of rights and possibilities for consumers, and the establishment of a smart and efficient market able to guaranty high security of supply standards.

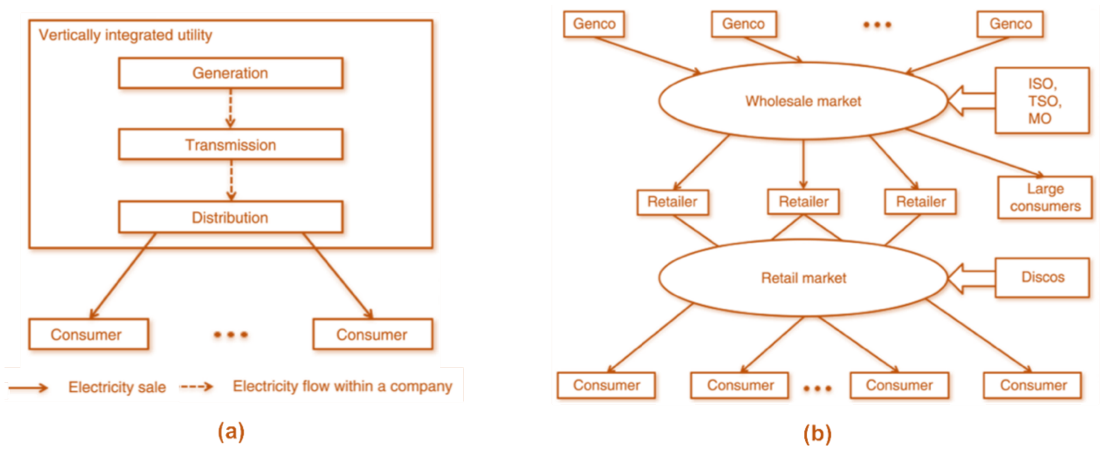

Figure 1: Traditional electricity supply model (a) and market with retail competition (b) [3].

Given the three legislative packages that the EU has adopted in 1996, 2003 and 2009, respectively, the originally vertically integrated electricity systems, where a national monopoly owned and operated generation units and networks turned to competitive and integrated electricity market structures, with the core differences becoming even clearer through the schematics of Figure 1[1]. Consequent directives set common rules for the internal electricity market, allowed new suppliers to enter Member States' markets, and also customers to

[1] In Figure 1b, "Genco" stands for generation companies and "Discos" for distribution companies.

choose their electricity supplier, while liberalized markets through the unbundling of supply, generation and networks sides and allowed third parties to access markets of increased transparency.

Essential have also been the reforms introduced in the Third Package for the integration of the market and the establishment of the legislative framework, parts of which provide the legal basis for the electricity market of today. Transmission and distribution networks have been also an aspect tackled further during that phase, with the roles of the operators becoming more specific. Noteworthy have been the efforts for cooperation between EU member states' authorities with an early tendency for harmonization. The creation of two entities, the Agency for Cooperation of Energy Regulators (ACER) [4] and the European Network of Transmission System Operators for Electricity (ENTSO-E), namely, has facilitated the design and promotion of policy frameworks, guidelines and network codes. The priority dispatch for renewables, the definition of shorter-term market models for electricity and an overall framework enhancing transparency in price signals for fair participation of different technologies have been among the concepts that promoted RES further. With rules for unbundling generation and supply from transmission networks being already in place, with the retail side being competitive and consumers more protected than before, with the national regulatory authorities being independent and the cross-border infrastructure enhanced, the new legislative proposals that European Commission (EC) introduced, focused on the further exploitation of the RES potential, on strengthening the security of supply, on enhancing energy efficiency in all sectors and on developing contemporary market designs.

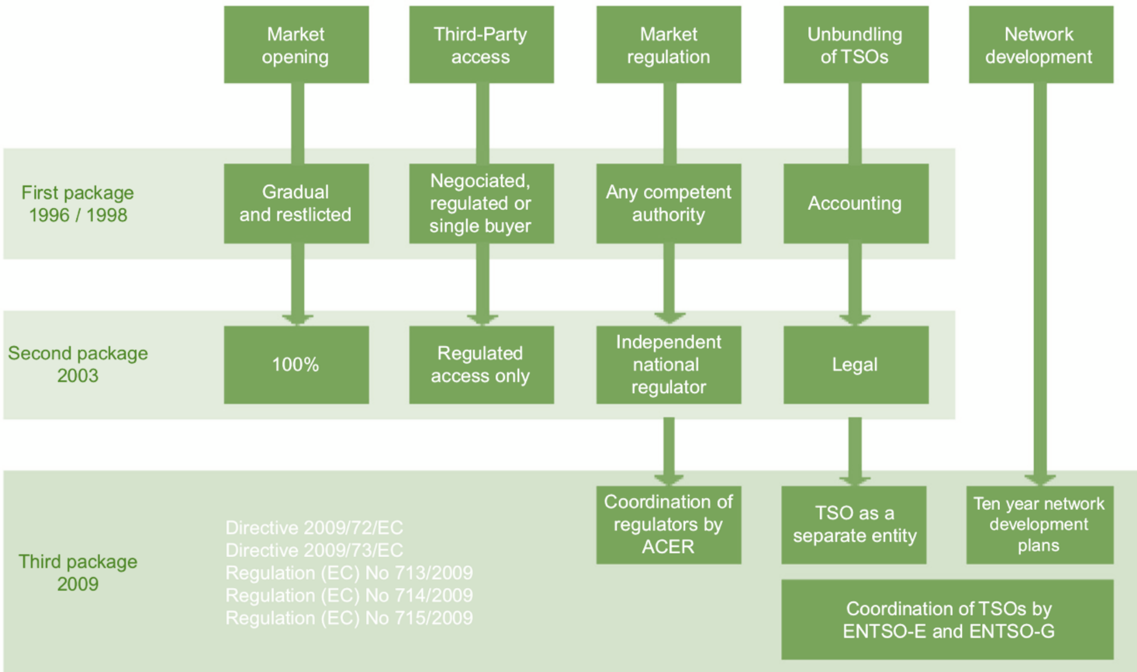

Figure 2: The three Energy Packages formed the basis of electricity market legislation [5].

The recent Directives and Regulations (2019) of EU add the market signalling objective to increase the system's flexibility, enhancing decarbonizing technologies and promoting innovation. Non-discriminatory market access is guaranteed for all resource providers and end consumers, with market-based remuneration being supported even for RES and demand side response (DSR), which is positioned at the centre of energy efficient demand [6]. The notion of aggregation on either the demand or supply side has been introduced for enabling consumers, small and medium-sized enterprises (SMEs) and citizen energy communities (CECs) to participate in the market. The aggregators can perform multiple functions such as assist balance responsible parties through their portfolio optimization allowing minimizing imbalances. Certain goal of the rules set has been the further incentivization of investments in the fields of low carbon generation, energy efficiency, distributed storage and DSR, with clear remuneration processes and equal opportunities.

From a market perspective, the integrated day-ahead and intraday markets are managed jointly by the Transmission System Operator (TSO) and a Nominated Electricity Market Operator (NEMO), while trading should be as close as possible to real time. Decisions ranging from bidding zones' definitions to transmission capacity allocation and congestion management should aim to maximize the economic efficiency, facilitate the cross-border trading and maintain high security of supply standards. All market participants, who should have access to the balancing markets, are set responsible for the imbalances they cause [7], while they can also delegate that responsibility. Beyond certain exceptions, the market-based dispatch includes the RES as well, with priority being restricted only to small previously benefited projects. Long term actions of the TSO and Distribution System Operator (DSO) should target the minimisation of low-carbon generation's curtailment or redispatching, both representing processes governed by non-discriminatory, transparent and objective criteria.

In this legislative framework, design principles for effective, although temporary, capacity mechanisms have also been included, to address the resource adequacy problem in the medium and long run by ensuring that adequate generation resources exist for meeting electricity demand, given the reliability standard that indicates the security of supply level needed [8]. In addition to ENTSO-E's existing tasks and responsibilities, regional coordination centres[2] with clearly defined mission, geographic scope and tasks have been introduced to ensure that the operation of interconnected transmission systems is even more reliable and efficient. A new entity for enhancing the cooperation of DSOs at the EU level, the EU DSO entity[3] has been described along with its rules, procedures and tasks targeting to the completion of the internal market through the promotion of optimal network management and coordinated operation of distribution and transmission systems.

The presented EU regulations together with the more technical regulatory documents, the network codes (NCs), constitute the framework that governs stakeholders' operation and participation in electricity markets. Beyond the differentiation of markets with respect to

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[2] Often called regional operation centres (ROCs).

[3] https://www.eudsoentity.eu/

the geographical scope, ranging from local markets to transnational wholesale markets, another core classification aspect is the timeframe at stake. Based on the market or contract type, transactions may refer to many years in advance (long-term contracts, derivative products in future and forward markets), to the following day (day-ahead market), to a specified short time period (intra-day market) and to real-time balancing (balancing market) [9]. The different timeframes along with the main objective served by each type of market and the key regulative documents are presented in Table 1.

Table 1: Different timeframes, market types and objectives [11].

Managing Risk	Managing Energy		Managing the System
Forward Market	**Day-Ahead Market**	**Intraday Market**	**Balancing Market**
• Market players managing price risks • Forwards, futures and transmission rights	• Market players balancing their physical positions • Operational planning, capacity allocation, congestion management		• TSO balancing the system in real time • Re-dispatching, frequency control and incidents management
Years ahead to 24 h prior hour of operation	12-36 h prior hour of operation	> 5 min[4] - 1 h prior hour of operation	Hour of operation
Forward capacity allocation	**Capacity allocation and congestion management**		**Electricity balancing guidelines**
Regulation (EU) 2016/1719 [12]	Regulation (EU) 2015/1222 [13]		Regulation (EU) 2017/2195 [7]

Electricity markets are constantly monitored, with the Energy market observation system (EMOS), a system maintained and operated by the Market Observatory for Energy, being the tool that facilitates data feeding and analysis of the Directorate-General for Energy. The ENTSO-E Transparency Platform provides also open and continuous access to pan-European electricity market data for all users, covering for categories such as the demanded load, the generation capacities and dispatches, the transmission and balancing details, the outages and congestion management reports [10]. The European Commission publishes reports on European electricity markets on both a short (quarterly) and long run basis, focusing on the evolution of prices, volumes and countries' interactions and analysing the underlying factors. There is also the EurObserv'ER[5], with its RES barometers and RES policy reports that monitors and analyses the development of renewable energy sectors in the EU, while at the same time evaluates the progression made given the objective set by

[4] Updated. Shorter gate closure times (even zero minutes) exist and are an important step in development of the real-time continuous markets, allowing participants to adjust their balances as close as possible to delivery.

[5] https://www.eurobserv-er.org/

the European commission. Market reports and outlooks are issued also by intergovernmental organisations and agencies like the International Energy Agency (IEA) and the International Renewable Energy Agency (IRENA). Although the IEA[6] was initially established in response of Organisation for Economic Co-operation and Development (OECD) to the oil crisis, nowadays it has a more energy policy advising role with energy security, economic development, environmental protection and climate change mitigation orientation. IRENA[7], which has been more recently founded, aims on facilitating cooperation, advancing knowledge, promoting RES adoption and enhancing sustainable energy initiatives.

There is also a number of institutions and observatories with subject closely related to the energy sector and electricity markets. One such example is the Energy Watch Group[8] (EWG), an independent non-profit global network of scientists and parliamentarians, which aim to influence political actions towards 100% renewable energy and climate protection. Another one is the International Energy Forum[9] (IEF), an organization consisting of energy ministers from several countries, some of which are EU member states, with a broad mandate covering for many energy issues, such as oil and gas, clean and renewable energy, sustainability, energy transitions and new technologies. The World Energy Council[10], an accredited by the United Nations non-governmental (NGO) and non-commercial organization with a long history, as an impartial global network of many national Member Committees that connects energy leaders, industries, governments, innovators and experts across the world, constitutes another example. Many other regional and local energy and greenhouse gases (GHG) observatories exist (Table 2) and play an important role in the implementation of efficient strategies at the local level, with an indicative and not exhaustive list covering for the informal European network of ENERGee Watch project[11] (H2020 funded).

Other notable associations are the European Federation of Energy Traders (EFET), the Union of the Electricity Industry (Eurelectric), the European Federation of Local Energy Companies (CEDEC), the European forum for energy business information exchange (ebIX). EFET[12] is the association of European energy traders in wholesale electricity and gas markets, while beyond its general purpose of promoting and facilitation energy trading in open, transparent and liquid wholesale markets, as a standard setting body, aims to provide standard solutions to common aspects of wholesale energy transactions. Eurelectric[13] is the sector association that represents the common interests of the electricity industry at

[6] https://www.iea.org/about

[7] https://www.irena.org/aboutirena

[8] https://energywatchgroup.org/about-us

[9] https://www.ief.org/about

[10] https://www.worldenergy.org/about-us

[11] https://energee-watch.eu/

[12] https://efet.org/about-us/

[13] https://www.eurelectric.org/about-us/about-eurelectric/

pan-European level by covering for issues ranging from generation and distribution networks to markets and customer issues. CEDEC[14] represents the interests of medium-sized local and regional energy companies, active in electricity and heat generation, supply, distribution and metering operations, while GEODE[15] focuses particularly on energy distribution. Finally, ebIX[16] is a non-profit European organisation aiming to advance, develop and standardise the electronic information exchange in the European energy industry, by providing harmonised processes for the liberalised downstream electricity, compatible with European and national rules.

Table 2: List of regional and local energy and GHG emissions observatories

Regional Energy and GHG Emissions Observatories
Technical Chamber of Greece Energy Observatory [GR]
OREGES – Centre-Val de Loire Regional Energy and GHG Observatory [FR]
Nord-Pas-de-Calais Climate Observatory [FR]
Zlin Region Energy Monitoring Centre [CZ]
SiReNa20 – Energy and Environmental Observatory of Lombardia Region [IT]
Liguria Region Energy and Environment Observatory [IT]
Energy and Environmental Observatory of Kent [UK]
Energy Observatory of the Metropolitan City of Torino [IT]
Local Sustainability Observatory of the Basque Country [ES]
North Sweden “Energiluppen” [SE]
Energyhub.ie, Carlow Kilkenny Regional Energy Observatory [IE]
ROECC – Regional Observatory for Energy, Environment and Climate [BG]
ANERGO – Alba eNERGy Observatory [RO]
OREGES Poitou-Charentes, Regional observatory for Energy and GHG emissions [FR]
ROSE – Regional Observatory for Energy and GHG Emissions [FR]
ORECA Region Sud [FR]
Inventory of GHG of the Basque Autonomous Community [ES]
OREGES Rhone-Alpes Regional Observatory for Energy and Greenhouse Gases emissions [FR]
Hallbarometer, Norrbottens County [SE]
OPTEER – Regional observatory for energy climate and air [FR]

[14] http://www.cedec.com/en/about-us

[15] https://www.geode-eu.org/

[16] https://www.ebix.org/

Examples of organizations with a more special focus are the REScoop.eu, the European federation of citizen energy cooperatives that aims to represent citizens and energy cooperatives in the European energy debate, the WindEurope, a non-profit organization that represents the wind industry and actively promotes wind energy, the SolarPower Europe, a member-led association that aims to promote solar as the core of a smart, secure and sustainable energy system, the European Association for Renewable Energy EUROSOLAR[17], an independent non-profit association supporting the transition to a sustainable environment-friendly economy based on 100% renewable energy, the World Council for Renewable Energy[18] (WCRE), an independent global network of NGOs, companies and scientific institutes acting in the fields of renewable energy, environmental protection and development aid and European Green Vehicles Initiative[19] (EGVI), a contractual Public Private Partnership dedicated to promoting and facilitating pre-competitive research on road transport vehicles within the European Research Area and focused on delivering green vehicles and mobility system solutions which match the major societal, environmental and economic challenges.

Based on this short overview of trends and policies related to the energy sector and the structures and associations involved, it can be said that there is a significant number of several stakeholders behind this multibillion industry, with each one of them playing their role and serving their interests.

[17] https://www.eurosolar.de/en/index.php/eurosolar/head-office-eurosolar-bonn

[18] https://www.wcre.org/index.php/about-us

[19] https://egvi.eu/who-we-are

2.2 The Harmonized Electricity Market Role Model (HEMRM)

The Harmonized Electricity Market Role Model has been a continuous effort of ENTSO-E and the associated organizations EFET and ebIX to develop a Role Model capable of representing several domains within the electricity market. The main aim of the initiative that started several years ago, with the first version being launched almost ten years ago, has been the facilitation of the dialogue between market participants with a particular focus on the development of ICT solutions under a common terminology. Although such a model mainly focuses on the information interchange in the electricity market rather than the market structure itself, it has been a structured and organized way to identify roles and interactions.

This way of harmonization has evolved in parallel to the extension of the common information model (CIM) of International Electrotechnical Commission (IEC) into the context of European markets (IEC 62325). That extension set the ground for developing and integrating software applications related to the deregulated energy market's data exchanges. On the other hand, the CIM has been an abstract model of representing all the major objects in an electric utility enterprise typically needed for modelling operational aspects and considers energy, generation and distribution management systems by defining a common vocabulary and creating a basic ontology. The CIM vision of IEC 61970 includes the core with the operational limits and the topology on top of which all other notions (wires, generation, protection, outage, control area, load model, etc.) are developed. Similar to the CIM, which is maintained as a Unified Modelling Language (UML) model, the class diagramming technique has been used to represent the HEMRM. Two of the UML symbols are mostly used, the "actor" symbol that is used for representing a role and shouldn't be confused to the actors of the market, and the "class" symbol is used to define a domain.

Beyond the two structural elements of the Role Model, the role and the domain, there is also the conceptual component of the actor. Based on the description of the model, the roles represent the behaviors deployed by different parties, as perceived from the system's point of view, and may include the external business interactions with other parties. Identified delimited areas, where the consumption, production and/or trade of energy take place, are represented by the domains. Actors, finally, cover for the parties that are active in the market and participate in business transactions. Based on the regularity and legislative framework that has formed the environment, actors undertake one or more roles during their operation. For keeping the Role Model free from any given market instance and independent of business processes specifics, actors do not appear directly in the model so that the electricity market is decomposed into a set of autonomous roles and domains. Although HEMRM does not provide a direct description of the parties, the structured overview of their roles that it provides can be found useful in identifying and categorizing actors. Table 3 presents the roles of HEMRM 2020-01 and interrelates them with three very broad labels that aim to characterize the role's reference. The "Connected Party" label refers to parties that have physical subsistence, the "Market Party" label covers for parties that are involved in market operations and transactions, while the "Operators" label which is analyzed further to "Market Facilitation", "Grid Operation" and "Meter Operation", covers for activities related to the system operation.

Table 3: HEMRM 2020-01 roles

ENTSO-E, EFET and ebIX HEMRM 2020-01		Connected Party	Market Party	Operators		
Number	**Role Name**			**Market Facilitation**	**Grid Operation**	**Meter Operation**
1	Balance Responsible Party		X			
2	Balancing Service Provider	X	X			
3	Billing Agent	X	X	X	X	X
4	Capacity Trader		X			
5	Consumer	X				
6	Consumption Responsible Party		X			
7	Consent Administrator			X		
8	Coordinated Capacity Calculator				X	
9	Coordination Centre Operator			X	X	
10	Data Provider		X	X	X	X
11	Energy Service Company (ESCo)		X			
12	Energy Supplier		X			
13	Energy Trader		X			
14	Grid Access Provider			X		
15	Imbalance Settlement Responsible		X	X		
16	Interconnection Trade Responsible			X		
17	LFC Operator				X	
18	Market Information Aggregator			X		
19	Market Operator			X		
20	Merit Order List Responsible		X	X		
21	Meter Administrator		X			X
22	Meter Operator		X			X
23	Meter Data Administrator		X			X
24	Metered Data Aggregator		X			X
25	Metered Data Collector		X			X
26	Metered Data Responsible		X			X
27	Metering Point Administrator		X			X
28	Nominated Electricity Market Operator			X		
29	Nomination Validator				X	
30	Party Administrator			X	X	X
31	Party Connected to the Grid	X				
32	Producer	X				
33	Production Responsible Party		X			
34	Reconciliation Accountable		X			
35	Reconciliation Responsible		X			
36	Reserve Allocator			X		
37	Resource Aggregator		X			
38	Resource Provider	X				
39	Scheduling Agent		X			
40	Scheduling Area Responsible		X			
41	System Operator				X	
42	Trade Responsible Party		X			
43	Transmission Capacity Allocator			X		

Beyond the actor, role and domain notions, the HEMRM 2020-01 version introduces the resource, the account and the CIM Object. The (harmonized) resource represents grid assets, either on the production or consumption side, that are used in certain processes of the electricity markets. Moreover, the (harmonized) accounts stand for the business functioning objects that are necessary for aggregated reporting and finally the CIM Objects that incorporate to the role model objects from the IEC/CIM standards. Figure 3 presents the most recent version (2020-01) of HEMRM, slightly adjusted and with the highlighted parts containing the roles presented below.

Related to the physical infrastructure at the Accounting Point level (red marked area), the Party Connected to the Grid is the party that contracts for the right to consume or produce electricity by being a Consumer and/or a Producer respectively. An Energy Service Company (ESCo), a party offering energy-related services (insight services, energy management services) but not being directly active in the energy value chain or in the physical infrastructure itself, may be contracted by the Party Connected to the Grid. The Grid Access Provider is responsible for providing access to the grid through an Accounting Point for energy consumption or production, while it is also responsible for creating and terminating Accounting Points. The Energy Supplier with which the Party Connected to the Grid has a balance delivery contract, either supplies electricity to or takes electricity from it at an Accounting Point. Closely connected to the accounting point are two other roles (purple marked), the Resource Aggregator that aggregates resources for usage by a service provider for energy market services, and the Energy Trader that is selling or buying energy, respectively.

With balancing responsibility on one or more Accounting Points (blue marked area), a Balance Responsible Party (BRP) is a market participant or its chosen representative that is responsible for its imbalances, i.e. the energy volume representing the difference between the allocated volume attributed to that party and its final position. It can be a Consumption Responsible Party and/or a Production Responsible Party, with a direct contractual connection to an Energy Supplier. Alternatively, it can be an Interconnection Trade Responsible which is a party recognised for the nomination of already allocated capacity or a Trade Responsible Party who can be brought to rights, legally and financially, for any imbalance between energy nominated and consumed for all associated Accounting Points. Scheduling information can be exchanged with a Scheduling Agent, an entity with the task of providing schedules.

Regarding the balancing service provision (orange marked area), the LFC Operator is responsible for the load frequency control (LFC) for its LFC Area or LFC Block, while the Coordination Centre Operator is the party responsible for coordinating activities within a zone (Coordination Centre Zone) related to scheduling, load frequency control, time deviation and compensation of unintentional deviation. By acquiring capacity from Reserve Resources, a Balancing Service Provider provides balancing services to one or more LFC Operators after biding for balancing to a Reserve Allocator who is responsible for specifying the reserve requirements, receiving the bids in compliance with the prequalification criteria, and determining which bids meet the requirements. Finally, it should be noted that the reserve-providing units or reserve-providing groups are considered as resources that are managed by Resource Providers, who provide production/consumption schedules for them.

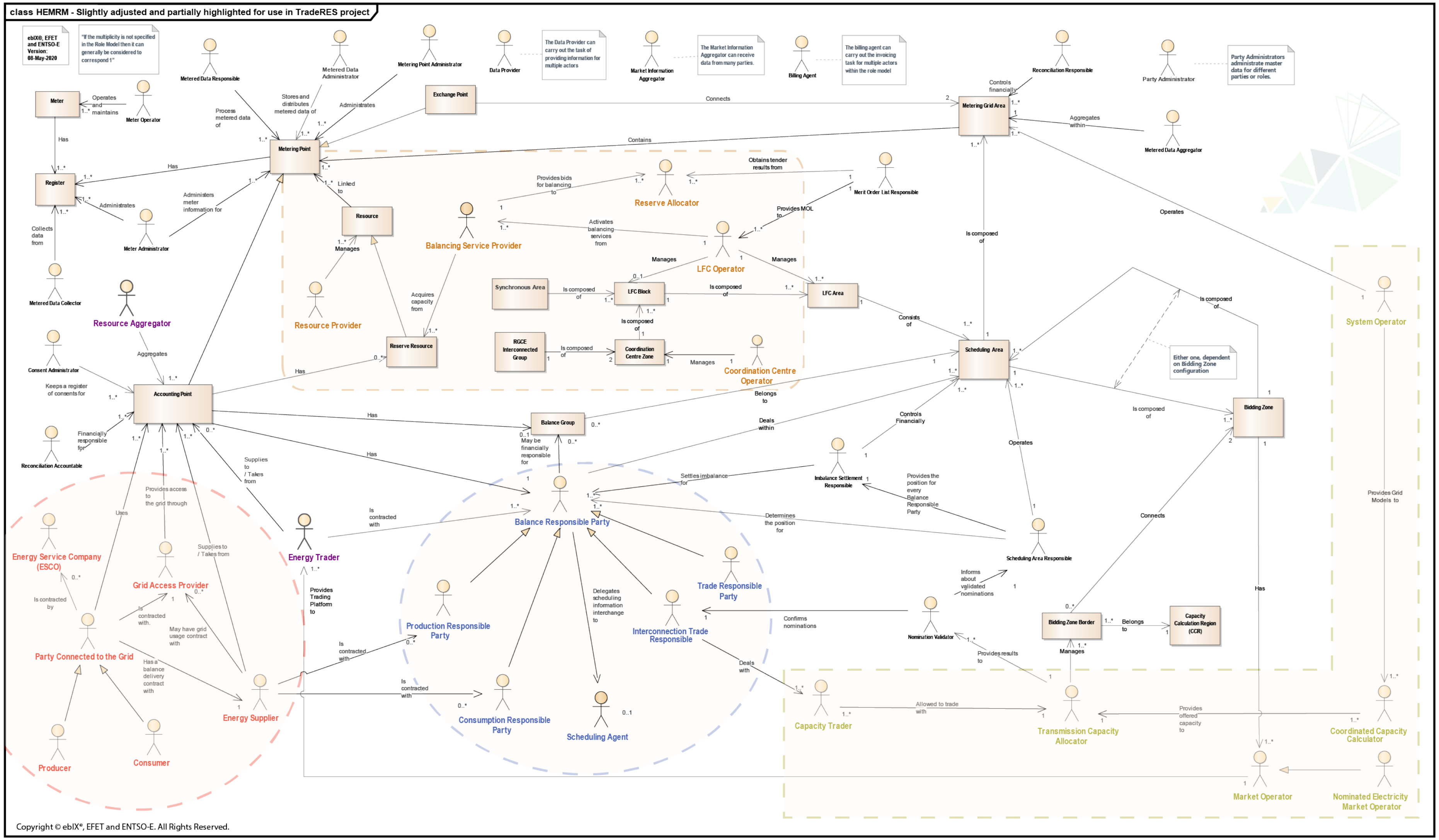

Figure 3: The Harmonized European Electricity Market Role Model (Adjusted/highlighted for demonstration purposes of TradeRES project).

Finally, on the system, market and capacity allocation side (green marked area), Capacity Traders participate in the transmission capacity market, while the Coordinated Capacity Calculator is responsible for calculating transmission capacity, at regional level or above. The Transmission Capacity Allocator manages the allocation of available transmission capacity for a Bidding Zone Border, by offering the available transmission capacity to the market and allocating the available transmission capacity to individual traders. These roles act on behalf of the System Operators, which represent the parties responsible for operating and ensuring the maintenance and development of corresponding systems in given areas. Moreover, System Operators are responsible for establishing the interconnections with other systems and for ensuring the long-term ability of the systems to meet reasonable demands for the distribution or transmission of electricity. On the market side, Market Operators provide the service to match the offers to sell electricity with bids to buy electricity and Nominated Electricity Market Operators (NEMO) are entities designated by the competent authority to organize cross-zonal trade of electricity, i.e. perform tasks related to the single day-ahead or single intraday coupling. Following the developments of the BRIDGE General Assembly 2020 [17], a subgroup of ENTSO-E's Regulation Data Management Working Group was created and worked towards a differential analysis with respect to the ENTSO-E – ebIX – EFET model. The related report [18] focused on flexibility roles and emphasised on the clarification of the Operator role to DSO and TSO, while currently is under discussion with the responsible bodies.

2.3 Roles and actors in other frameworks

In the following paragraphs, other contemporary frameworks that have been widely adopted in several applications related to the electricity sector transformation are presented from the roles/actor perspective, aiming to provide a more comprehensive outline for the actor scene and set the ground for further analysis.

2.3.1. The USEF

The Universal Smart Energy Framework (USEF), although focusing on Europe, describes the market for flexibility and aims to become an international standard for smart energy systems. It has been developed by USEF Foundation that consists of seven key players from the industry and offers to all stakeholders, from energy companies to consumers, the needed Framework description, with specifications, designs and implementation guidelines, for accelerating the establishment of an integrated smart energy system. The concept behind the framework involves end-use consumers accessing the electricity market and being able to sell flexibility, which is offered to Operators and Balance Responsible Parties after its accumulation by the Aggregators. Among the key aims of USEF is the specification of the parts that enable the trading of flexible energy use through the market and the crystallization of the new and existing roles along with their interactions. Among the stakeholders interested in the transformation of the energy system to its smart version with high penetration of RES, USEF considers the following groups [19]:

- the Suppliers, the BRPs and the Producers,
  - Suppliers, BRPs and Producers are foreseen to use prediction models and dispatching algorithms for efficient management of generation assets
  - Suppliers, BRPs and Producers are expected to optimize their client portfolios aiming to adapt the consumption profiles to available RES generation
- the DSOs and the TSOs,
  - DSOs introduce smart meters enabling dynamic tariffs, reduced settlement costs and better insight to end users' load profiles as well as grid load up to the low voltage level
  - DSOs face the challenge of increasing grid capacity demand, which alternatively to grid reinforcements can be tackled by exploitation of flexibility and active network management
  - TSOs are foreseen to play a more active role in the power system since load flow patterns across the transmission grid are continuously changing due to VREs, ensuring that the transmission capacity and the system balance are properly managed
  - TSOs will rely more on smaller generation units and DSR devices that will manage to access markets and through the strengthening of interconnections (as according to the EU Roadmap 2050) shortages and surpluses of power should be balanced out across Europe.
- the Prosumers,
  - Prosumers are envisaged to surpass the position of the passive consumers and participate actively in the energy market
  - Prosumers may participate in a variety of innovative organizations, such as the energy communities that may include wide range of collective energy actions that involve citizens' participation in the energy system.
  - Prosumers have fundamentally different needs than classical end users who are targeted by the incumbent market players and no interest in the limitations of the existing market model
- the Aggregators and the ESCos,
  - Aggregators accumulate flexibility mainly from DSR resources of end users and offer reliable products to various stakeholders, preserving resource owners from exposure to market participation risks
  - ESCos are considered to provide a very broad range of services to end users, included but not limited to information, maintenance and operation of equipment services, without being directly involved in the energy and flexibility supply chain.

When it comes to the market organization, instead of proposing exact business models, USEF adopts a role model approach, by aligning the roles and their names with those of HEMRM. To the extent possible, the USEF role model is in accordance with terminology of pre-existing business models, widely adopted in Europe, and leaves sufficient degrees of freedom in describing the interaction between the market participants and conceptualization of businesses independently to the actors. With the standardization of the flexibility market being at the heart of the USEF role model, the roles defined [19] are the following:

- Prosumer: the end user that not only consumes but also produces energy, with no further distinction on the type i.e. residential, SME, industrial.
- Active Demand & Supply (ADS): demand or supply systems that are actively controlled
- Aggregator: the party that accumulates flexibility and sells it to BRP, DSO and TSO with main goal being its profitability that is achieved through the maximization of flexibility's value and by undertaking the deliverability risks.
- Supplier: the business entity responsible for sourcing/supplying and invoicing its customers, in certain cases including the flexibility's invoicing in cooperation with the Aggregator.
- BRP: the party that is responsible for balancing the supply and demand of its portfolio, which may contain Producers, Aggregators, and Prosumers and can be contracted on the basis of undertaking the imbalance risk of the parties connected to the grid and other business entities.
- DSO: the operator that manages actively and cost-effectively the distribution grid that transports energy on the regional and local level by ensuring system operation and grid maintenance
- TSO: the operator of the transmission system that transports energy transregionally and transnationally from centralized Producers to industrial Prosumers and DSOs and is responsible for short-term system adequacy and balance.
- Producer: the party that feeds energy into the grid through investing in and efficiently operating its assets and thereby providing the required energy security of supply being ensured.
- ESCo: the party that offers energy-related facilitating and enabling services that can offer value to Prosumers, e.g. better insights into prosumer's consumption and production, improved operation and remote maintenance of their assets.
- Common Reference Operator (CRO): the operator that is responsible for the Common Reference information system, which includes details about connections and congestion points of the network.
- Meter Data Company (MDC): the entity that acquires and validates metered data and is involved in the settlement processes of the flexibility and wholesale markets.
- Allocation Responsible Party (ARP): the party responsible for establishing and communicating realized volumes either on consumer or aggregation level that are used on the settlement processes.

USEF positions the Aggregator in the centre of the value chain, mediating between the Prosumer and the three potential customers of flexibility services, namely the BRP, the DSO and the TSO. The analysis of the value proposition of specific services, reveals aims and objectives in the context of the TradeRES project through the values offered to the aforementioned actors. More details can be seen in the schematic of Figure 4, where USEF's value chain with the related elaboration on the proposed services is presented. For the Prosumer, USEF identifies the reduction of costs related to energy procurement and grid use, and for the BRP reduction of sourcing and balancing costs is the main interest. The DSO aims to delay or avoid grid reinforcing investments, to optimise the operation of assets while trying to minimize losses and to reduce the frequency and the duration of load shedding actions. Finally, among the TSO's objectives, are the maintenance of the stability and reliability of the system, the reduction of capacity requirements for the system adequacy, the differing of capital-intensive network reinforcements and the improvement of security of supply measures with the reduction of outages' frequency and duration.

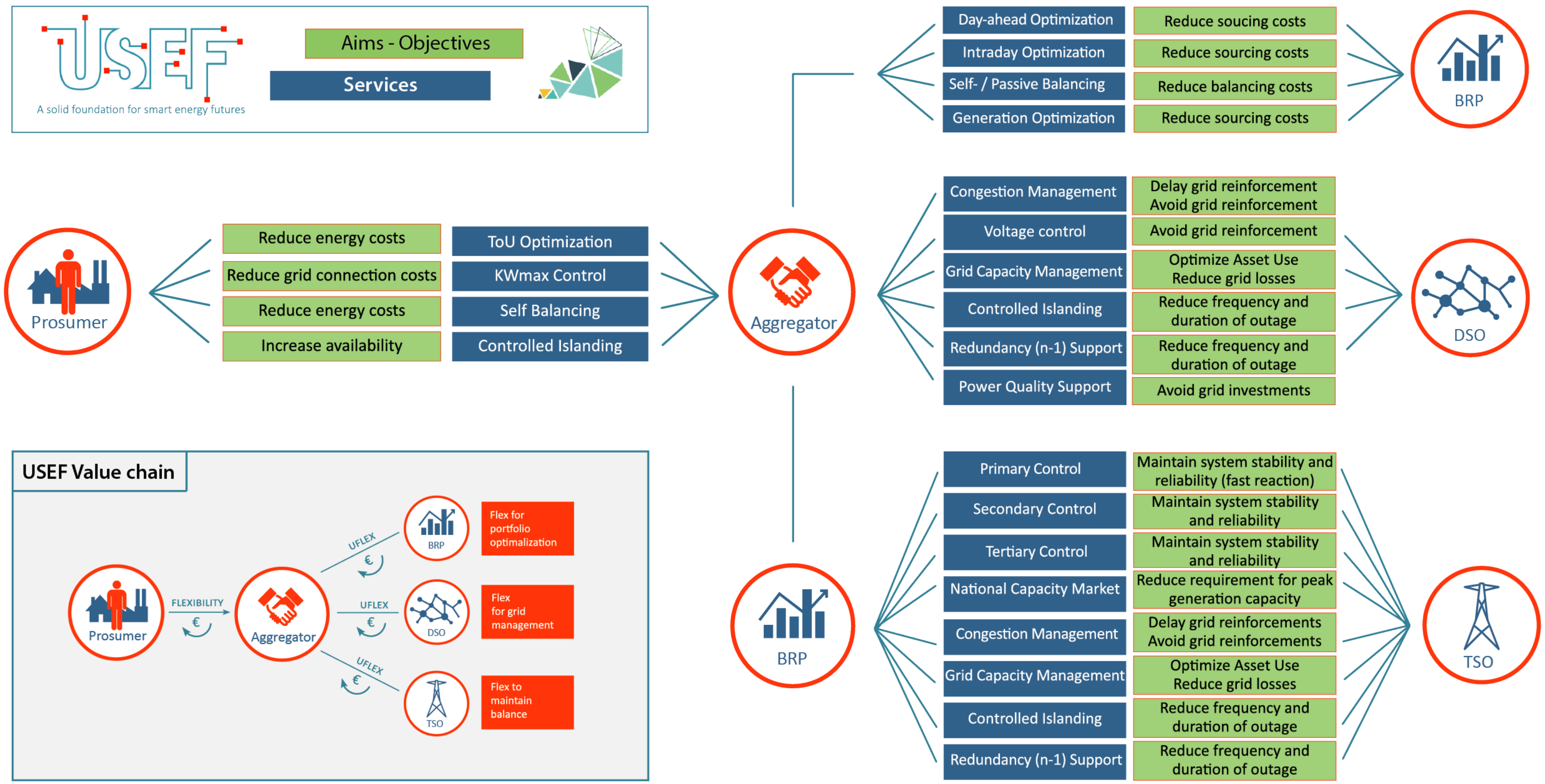

Figure 4: USEF Value chain along with services and values that represent aims and objectives.

2.3.2. The SGAM

The Smart Grid Architecture Model (SGAM) is a reference model that has been developed by three European Standardization Organizations responsible for developing and agreeing on standards so that a wide range of products and services can meet certain safety and quality requirements. These are the European Committee for Standardization (CEN), the European Committee for Electrotechnical Standardization (CENELEC) and the European Telecommunications Standards Institute (ETSI). The model aims to provide a systematic approach for tackling complex interdisciplinary systems, such as the smart grids, by offering a universal, consistent, flexible, interoperable and technology neutral framework.

The framework itself builds on pre-existing material such as the NIST Conceptual Model [20], the European Conceptual Model [21] and architecture standards for creating a comprehensive model capable to support the design of smart grids by representing several viewpoints. The five interoperability layers of SGAM that stand for Business, Function, Information, Communication and Component, span the perpendicular to the Smart Grid Plane dimension. The Smart Grid Plane is formed by setting up the hierarchically ordered levels of power system management against the electrical energy conversion chain. This first dimension stands for the Zones and includes the Process, Field, Station, Operation, Enterprise and Market, while the latter is for the Domains and contains the Bulk Generation, Transmission, Distribution, DER and Customers Premises components. The three dimensions of the SGAM framework are presented in Figure 5 [18].

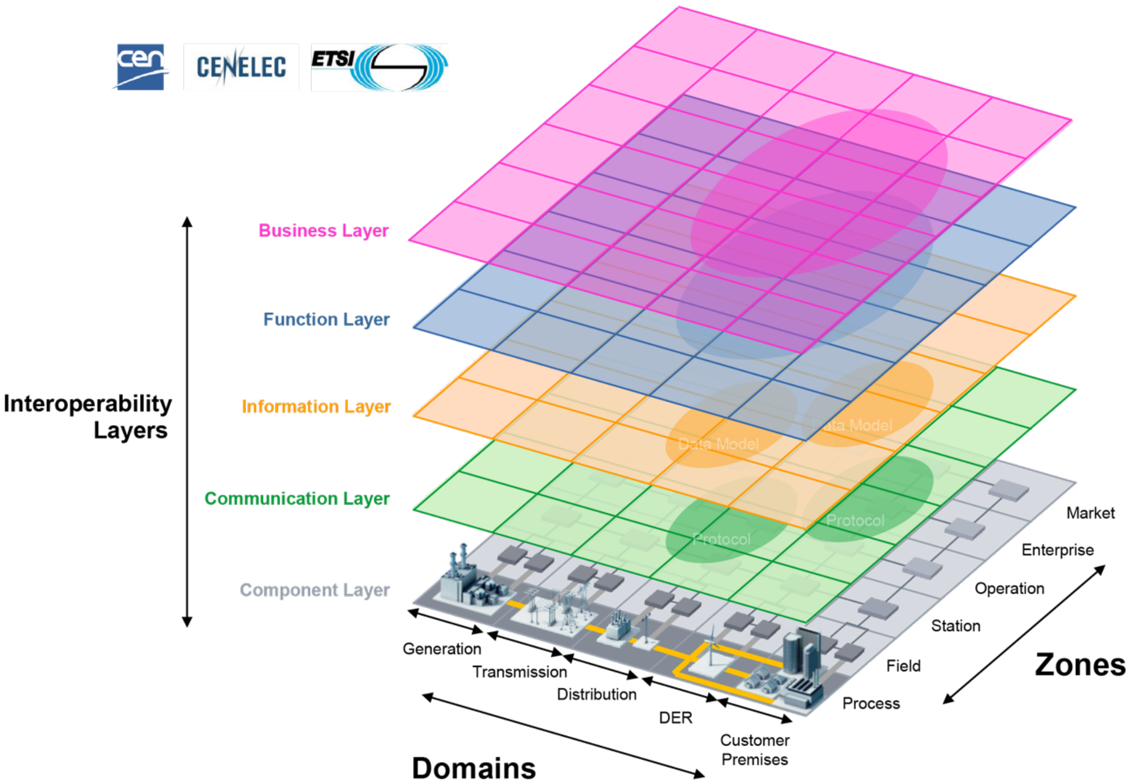

Figure 5: The three dimensions of the SGAM framework

The SGAM Interoperability Layers are based on categories identified with respect to three drivers, a technical, an informational and an organizational one. Starting from bottom to top, the basic connectivity, that is related to the Component Layer, belongs to the technical driver and consists of all the mechanisms required for establishing physical and logical connections between systems. The network interoperability includes the mechanisms for messages exchanging between systems and across networks, together with the syntactic interoperability that is about the interpretation of data structures of messages for the Communication Layer. On the informational driver side, the concepts contained in the data structures are understood and combined with the business knowledge related to specific interactions, so that the Information Layer is formed by the combination of the semantic understanding and the business context. The business procedures are the part of the organizational driver mapped to the Functional Layer and this is the level where the alignment of the operational business processes and procedures takes place, independently of systems, components and actors. Finally, the Business Layer covers the strategic and tactical objectives shared between businesses and the political and economic objectives that are embodied in regulation and policies.

The business layer is the one that includes the market model and consequently this is where the actors are defined. The relations between markets, products and processes belong on this top layer of the framework, and although the exact market and business models are not in the scope of the analysis, the business services together with the linking interfaces form the business architecture. As it is mentioned in [18], SGAM through this layer can be used to map regulatory and economic (market) structures and policies, business models, business portfolios (products & services) of market parties involved. With the representation of business capabilities and processes enabled, the decision making related to (new) business models and specific business projects (business case) can be supported and new market models can be defined by regulators.

Focusing on the roles and actors from the business perspective, SGAM exploits the roles defined by HEMRM in terms of responsibility and considers their allocation to market parties, i.e. the legal entities that can perform one or more roles, a process strongly interrelated to regulation and legislation. The roles describe the external intended behaviours of parties, under a certain goal, when getting involved in business transactions and interacting with other parties. Since the generic representation of actors that SGAM promotes, enables the actor context to cover for people, systems, databases, organizations and devices, there is a distinction between system and business actors. While the system actors cover for the functions or devices foreseen in the Interface Reference Model (IEC 61968-1), the business actors are considered to play a role and thus there is a one-to-one correspondence with the roles defined in HEMRM. Given the progress of unbundling in the European electricity sector, some activities are still regulated while others are left to the commercial market and therefore some “smart grid parties” such as DSOs and TSOs are contrasted to “smart market parties” such as suppliers, ESCos, traders, customers etc. Finally, as the transition to the future energy system proceeds, SGAM foresees the update of the list of actors in the model, with new business models being introduced and market models being updated and harmonised across the difference EU market states.

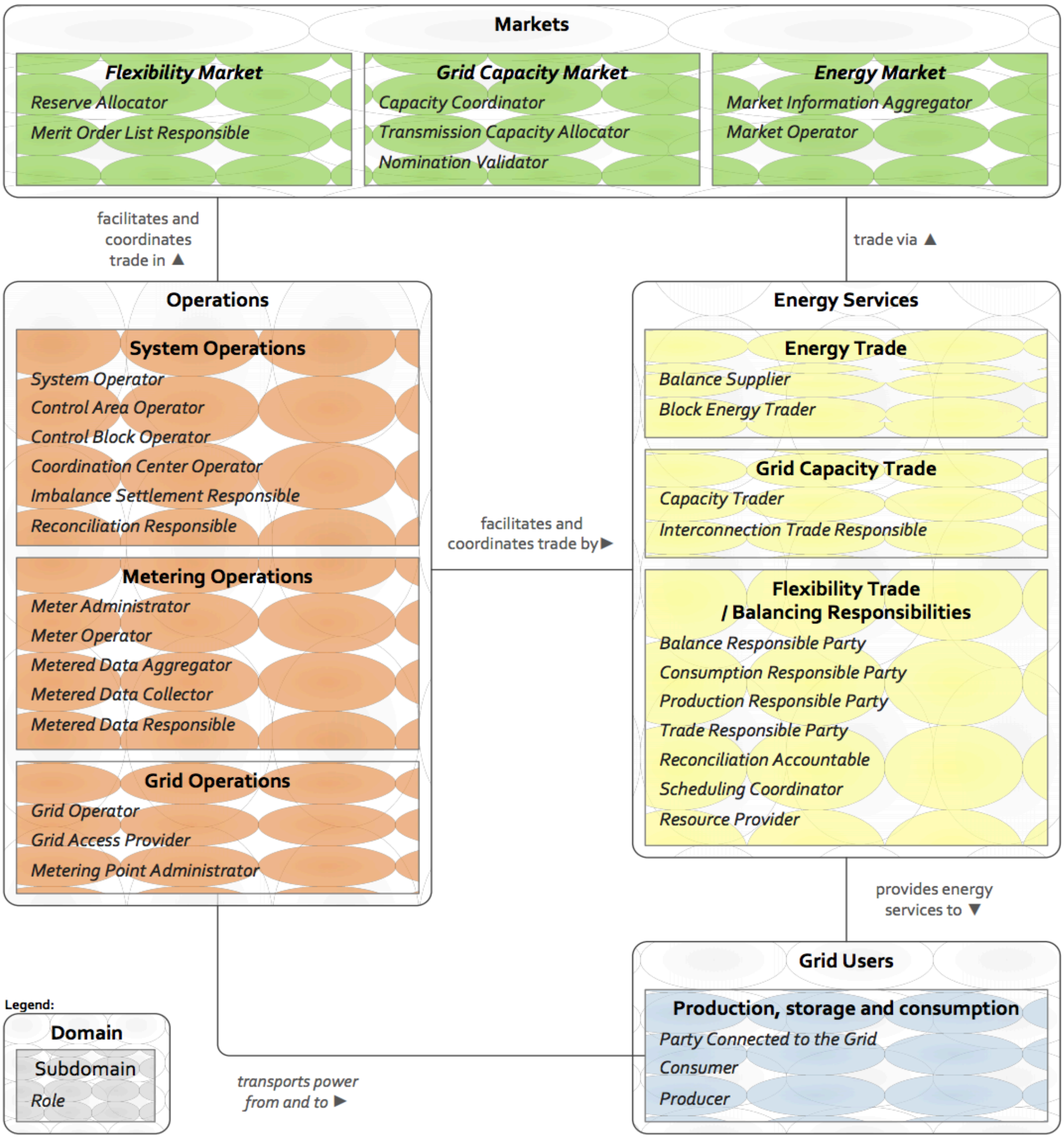

Figure 6: The HEMRM roles included in the European Conceptual Model for the Smart Grid.

The last part related to SGAM that is worth mentioning, is the relationship between the domains of the European Smart Grid Conceptual Model, which are actually a grouping of roles and actors, and the European HEMRM. There have been four main domains in the European conceptual model of Smart Grids, the Operations, the Grid Users, the Markets, and the Energy Services respectively. In Figure 6, roles are presented along with main domains and subdomains for providing an aligned overview between the models. Specifically about the flexibility trade that is explicitly mentioned together with the balancing responsibilities, the BRP is envisaged to act as the flexibility operator while in the case of direct control of the demand and/or supply the Resource Operator is expected to undertake that role, with the Party Connected to the Grid being the “Smart Customer”.

2.3.3. The SEAS Ontology

Ontologies, as part of a semantic web, are collections of terms and relations between terms that aim to provide a clear understanding of a domain. Primarily, ontologies can serve as the vocabulary for a specific domain and can be used as standardized terminology, while they provide the framework in data related activities such as capturing, annotation, integration and mining. They make data and metadata interoperable and ready to share and reuse in an efficient way by both people and machines. This last property is mainly the reason behind the consideration of ontologies in the project, as in WP2 and WP4 the need for an agreement-based knowledge representation through a vocabulary was already identified.

For the specific domain of interest, there are some ontologies available that offer a wide coverage, such as the Open Energy Ontology [18] and the Smart Energy Aware System (SEAS) Ontology [19], while others have been focusing more on markets, such as Electricity Market Ontology (ELMO) [20], Electricity Markets Ontology (EMO) and certain instances that have been used in European electricity markets (MIBEL, EPEX and Nord Pool) [21], [22]. An overview of the application of ontologies in the energy domain is provided in [23], with respect to agents, the design methodologies and the architectures of multi-agent systems.

The SEAS knowledge model consists of a set of ontology modules, which are in the form of OWL2 DL ontologies. Among the vertical modules for the Smart Grid and Micro Grid domains there is the "Player Ontology" module, presented in Figure 7, that defines business players who can offer services and perform actions that are related to payments. The parties considered are the Aggregator, the Authority, the Balance Responsible Party (BRP), the Balance Service Provider (BSP), the Charge Service Provider, the Charging Station Operator, the Clearing House, the Consumer, the Curtailment Service Provider, the Data Broker, the Data Management System, the Distributed Energy Resources Information Provider, the Distribution System Operator (DSO), the Electricity Trader, the Energy End Customer, the Energy Producer Operator, the Energy Provider, the Energy Retailer, the Forecast Provider, the Generation Equipment, the Home and Building Management System, the Market Operator, the Operator, the Smart Charging Provider and the Transmission System Operator (TSO). Among the Electricity Market classes included in SEAS ontology there is the Day Ahead Electricity Market, the Electricity Capacity Market, the Intraday Electricity Market, the Long-term Electricity Market and the Wholesale Electricity Market.

Some of the Player classes have a one-to-one correspondence with roles from HEMRM while others are focused more on specific and complementary services. Below, following the description of the players, some of the most characteristic classes foreseen in the SEAS knowledge model and have not been introduced already are presented in more detail.

- **Charge Service Provider:** This is the party responsible for provision of e-mobility services to Electric Vehicle users (may include charging, search & find, routing and other services). It operates as a contract party for the EV user, taking care of the authentication and billing process. It provides an access card available for many EVs whose Charging Station Operator has an agreement with the Charge Service Provider and may have some roaming agreement with other Charge Service Provider registered by a clearing house.

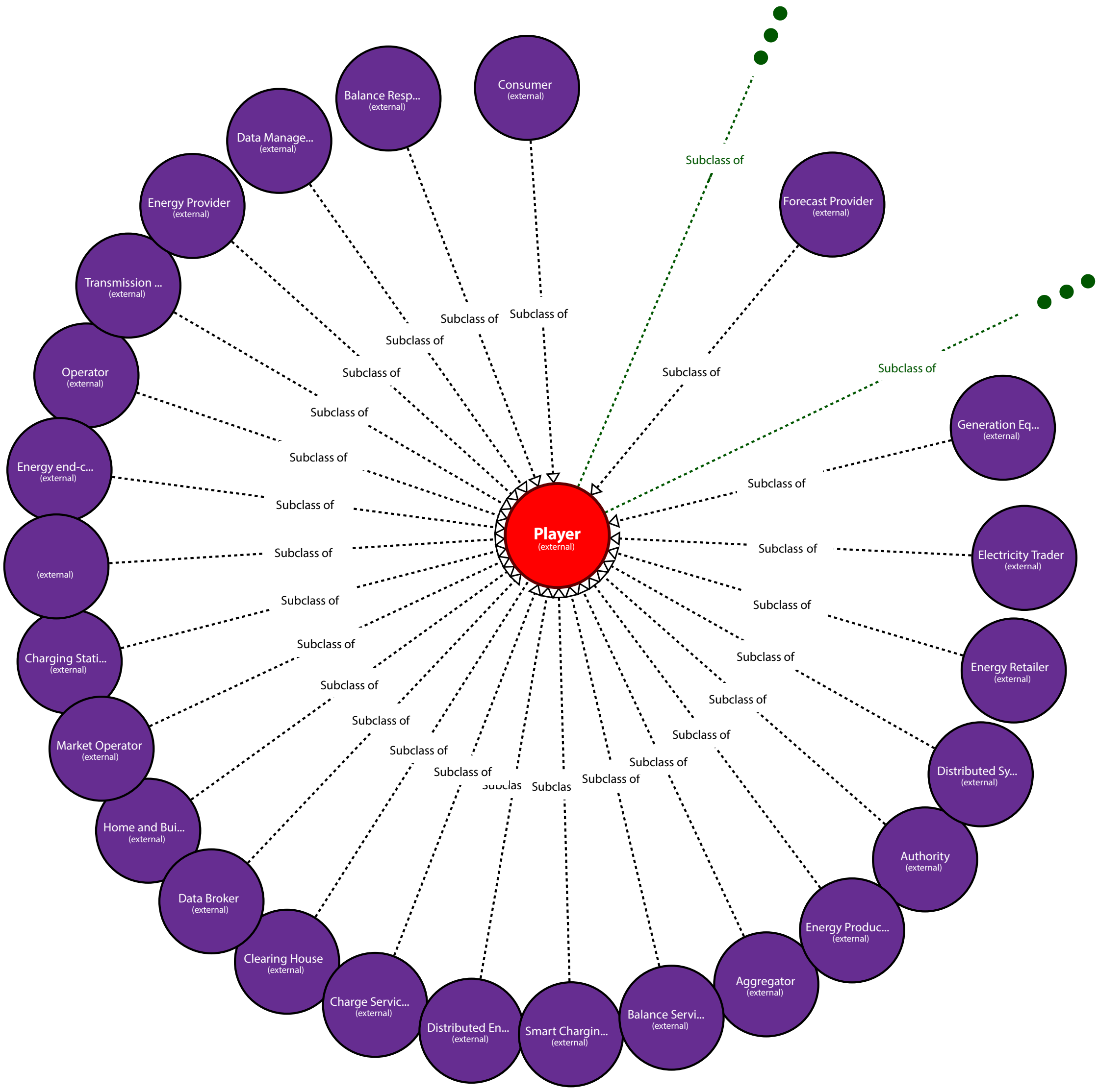

Figure 7: The Player ontology module of SEAS knowledge model.

- **Charging Station Operator:** This is the party that delivers and manages physical equipment to supply the charging procedure of EVs. It can be generally an investor, owner and operator of the EVs and the private electricity network to which they are connected, which is defined as the charging station.
- **Clearing House:** The Clearing House records all the roaming agreements between the Charge Service Provider and Charging Station Operator (EV service roaming). It facilitates data exchange between roaming partners: authentication, validation of contracts, charge retail records (duration, energy, load…)
- **Curtailment Service Provider:** This party serves as an intermediary between utilities and customers, pooling together groups of customers who participate in demand response programs to reduce energy usage during periods of peak demand. It aggregates load profiles of small and medium consumers to have a better support for the participation in DR events.

- **Data Broker:** This entity is responsible for collecting data from a variety of sources, including the internet, the online sources as well as databases, and other resources such as print documentation and surveys, and selling data packages and information as a product or service to other entities. It can include personal consumer data or business data to serve information needs of private sector and governmental agencies.
- **Distributed Energy Resources Information Provider:** This party provides information of power system variables such as loads and production from renewables, forecasts, information on electric vehicles, etc. It can act as a trusted third party responsible for dispatching information about the consumption between many energy suppliers and sharing a registry for metering data.
- **Energy Retailer:** The party that sells or buy energy to the Energy End Customer and purchases it on the electricity market. It charges the customer based on the flexibility, duration and power. It communicates to the customer the energy metering values, in accordance with the DSO or TSO metering.
- **Forecast Provider:** The entity that provides forecasts of the value of power system variables such as loads and production from renewables or performs and updates the forecasted values about the weather, the prices, the consumption and the generation, which are transmitted to the network operator.

Finally, the Player ontology module is related to other modules of SEAS, such as the System and the Procedure Executor, by being a subclass of those ontologies as it is depicted in Figure 8.

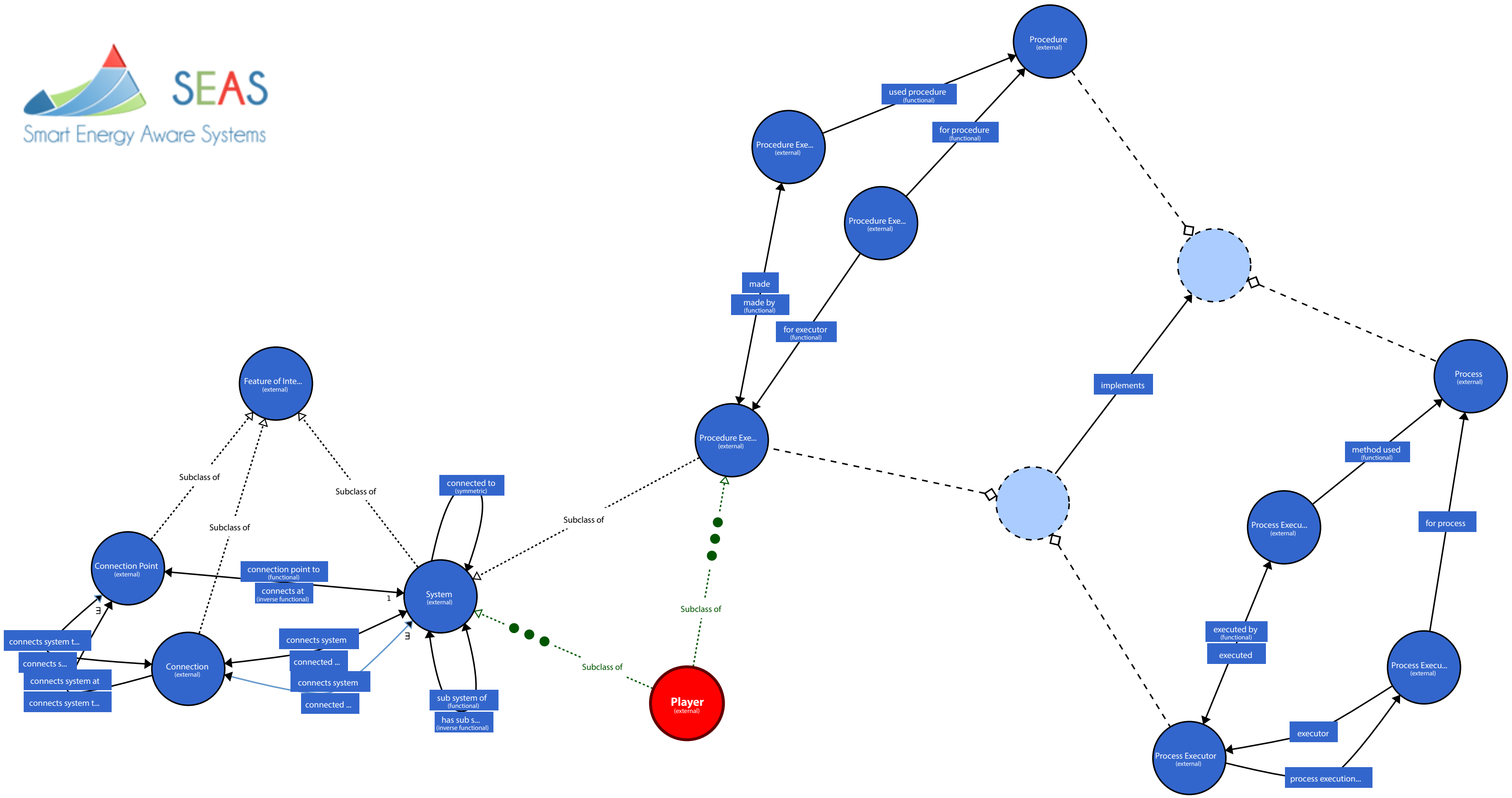

Figure 8: Relation of Player ontology module to other modules of SEAS.

3. Identification and classification of actors

3.1 Definitions of roles and actors

In the previous section, an overview of the parties interested and involved in the energy sector, have been provided from a wide perspective and with special focus on the electricity sector side. Initially, following the policy trends and the regulatory initiatives, the policy making and advising bodies have been described together with the associations and organizations responsible for representing different sectoral interests, indicating the variety of stakeholders. Next, the HEMRM, a commonly accepted role model, provided the context for roles, indicated those on the electricity market domain and covered their evolution during the last decade, through its sequential versions. Other frameworks, such as the USEF, the SGAM and the SEAS model have been examined with respect to the stakeholders, actors, roles and players that each one of them defines and incorporates.

Although this review has offered a good coverage on the multitude of entities currently considered and required for the analysis and implementation of a wide range of contemporary and future use cases and applications, it also pointed out the lack of clear and universal definition of the related terms. Therefore, the need for defining primarily the “role” and “actor” terms for their further use in TradeRES project has emerged, while for clarity reasons definitions of the terms “stakeholder”, “player” and “agent” are provided beforehand.

Stakeholder:

From a management theory perspective, given an organization and the specific environment that surrounds it, which consists of parties (other organizations, groups, individual persons) with whom the organization interacts, the stakeholder is a member of that environment and is affected by the organization’s performance and can influence it directly or not [24]. Around a firm, the Stakeholder Model [25] identifies the governments, the investors, the political groups, the suppliers, customers, the trade associations, the employees and the communities while the Stakeholder Theory also considers competitors and distinguishes between primary (internal) and secondary (external) stakeholders. Considering the wider environment that results from the union of the specific environments of the interacting organizations within a sector, the set of stakeholders becomes even larger and can include the society at large and the future generations.

A stakeholder is a person, group or organization that has an interest in a system since it is a member of its environment, influences it and is affected by it in a direct or indirect way.

Player:

In game theory, a strategic game captures the interaction of decision makers. In that context, the interacting individuals are considered to be the players of the game, the rules of which define the actions allowed to them to take and their effects [26]. The goals of the players are specified by their objectives, they have preferences over the set of action profiles and what they know before decision making is following the information structure of the game. Based on the game considered the player can represent different type of entities such as individuals, groups, firms, countries, etc.

A player is an individual decision maker that accepts the rules and constraints of the game(s) that participates in and behaves strategically given the information available, his preferences and his objectives.

Agent:

In microeconomics, the basic unit of analysis is the individual economic agent that represents the decision maker and following the classical distinction of activities in consumption and production, typical examples are the consumers and the firms [27]. In microfounded macroeconomics the agents of the economy are the households, the firms and the central banks, while in certain modelling instances of special focus consumers, workers, voters of commercial banks may appear [33]. In a generalized form of microscale modelling, such as the Agent-Based Models (ABM), the agents may be individual or collective entities such as groups and organization that undertake actions and interact with each other.

An agent is a persistent individual or collective entity with physical, social or economic substance that interacts with other entities in a dynamic system framework and his functionality is considered in the context of an ABM.

The conceptual relation between the terms defined is presented in Figure 9 (a), where the environment with stakeholders forms the broad space and the intersecting sets of players and agents are relatively positioned.

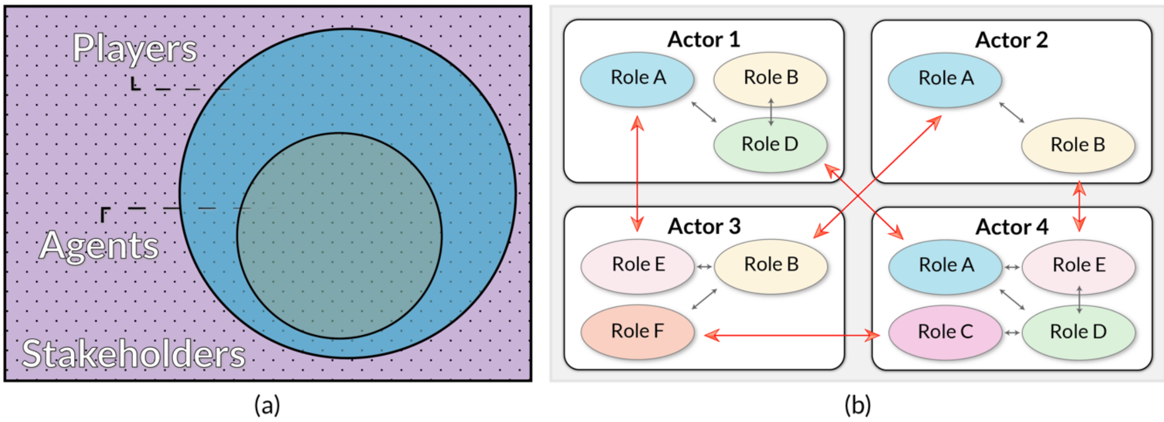

Figure 9: (a) Relative positioning of the "Players" and "Agents" in the "Stakeholders" environment, and (b) interactions between "Roles" and "Actors" on the role model landscape.

About the roles and the actors, following the principles followed in HEMRM for both terms and differentiating from the one-to-one correspondence between roles and business actors in SGAM, the terms are interpreted as follows.

Role:

A role (i) performs specific activities, (ii) has a strict set of functionalities, (iii) operates under certain responsibilities, (iv) has control of specific resources and (v) communicates with other roles.

A role represents the intended behaviour of an entity and is related to specific business-oriented activities that govern its external interactions.

Actor:

An actor can be an individual (user) or collective entity (group, organization) and has ownership of resources, has and develops relations and undertakes one or several roles.

An actor is an entity that has the ability to undertake one or more specific roles for participating in business-oriented transactions and through these roles can interact with other actors.

Finally, the perception behind the definitions provided above is depicted in the schematic of Figure 9 (b), where the internal relations between the roles that the actors incorporate, the relations of actors and the interactions at a role level are presented.

3.2 Traditional and new actors

In the heart of the massive transformation of the energy sector under the low carbon agenda, there is the shift from the supply-driven approach to the contemporary active and bidirectional demand-side participation paradigm, conceptualised by the smart grid and the system of systems approaches. Integral part of any envisaged future instance are the traditional parties that play their significant and structural role on even the new energy architecture along with the new entities that emerge in response to the new set of mechanisms, participating actively in the new market framework and supporting the fulfilment of the policy goals. Exactly those points are analysed in this section, where the enhanced and more active role of traditional entities like the TSOs, the DSOs, the Producers and the Suppliers is presented, and the core involvement of emerging concepts like the Prosumers, the Aggregators and the ESCos is also considered.

3.2.1. Traditional actors (TSOs, DSOs, Producers, Suppliers)

TSOs are entities responsible for the bulk transmission of electric power on high voltage electric network level [3]. The system is operated independently from other electricity market players, in a way that does not favour or penalize one market participant over another. TSOs provide grid access to other parties according to non-discriminatory and transparent rules or codes established in the context of a competitive electricity market environment. The maintenance of the stability and operational reliability of the power system through balancing the load at high voltage level is the primary responsibility of TSOs. Beyond the safe operation of the system, its maintenance and development are also priorities for ensuring the security of supply. Although the exact role of this actor is to be refined in the coming years and decades, the decentralised generation trend along with the weather dependence of production of a greater share of resources are among the challenges faced. Digitization is expected to support the security of supply helping to keep the system balanced and facilitated the better adjustment of the fluctuations in power load. On top of that, the enhanced cross-border cooperation between TSOs and the clarification of responsibilities between TSOs and DSOs will enable the improved and efficient coordination within and across countries making a fully integrated network a reality.

DSOs own and operate or are granted concession contracts to operate the distribution networks, with security of supply and quality of service being among their core responsibilities. The continuously increasing share of RES connected to the distribution level makes the DSOs mission more challenging. Together with the classic role of network operation and development, DSOs have to evolve and become active network managers. Electrification adds to the changing nature of the energy landscape new forms of bidirectional flows (e.g. EVs). Key-enabling technologies such as smart meters, ICT and power electronics, distributed resources and energy storing assets are expected to offer a wider toolbox in contrast to the limited options of extending and/or reinforcing the physical infrastructure that traditionally were available. Beyond arranging a grid connection, providing relevant data while ensuring data privacy, informing customers of disturbances, maintenance works or outages, DSOs have to move towards enhancing system's observability and controllability, focus on smart grid planning and smart asset management, invest on local flexibility mechanisms and customer inclusion, ensure transparency in data access and sharing and manage the system in an active and efficient way exploiting any flexibility potential by acting as neutral market facilitators [28]. As foreseen in the Clean Energy Package and highlighted by E.DSO [29], DSOs and TSOs shall cooperate with each other in planning and operating their networks, by exchanging information and sharing data about the operational aspects of distributed assets and their networks and the long-term investment plans they have. Cooperation is also envisaged for accessing resources such as distributed generation, energy storage or demand response with the main goal being to support the needs of both the distribution and the transmission systems.

Traditionally, the network has been used for merging the generation with the consumption side in a downstream way, with the active parties being the producers and the retailers. Producers, in their typical version are the generating companies that have resulted by the unbundling of utilities process, own generating plants and sell electrical energy. They may also sell services such as regulation, voltage control and reserve that the TSO needs for maintaining the quality and operational reliability of the electricity supply. Producers can own a wide range of number of plants starting from a single plant to a portfolio of plants of different technologies, with the main conventional ones being hard coal, lignite, gas and nuclear generation. Retailers on the other side, buy the electrical energy on the wholesale market and resell it to consumers who may be connected to the grid through different DSOs and do not wish or are not allowed to have more direct access to the wholesale market. Although they do not need to own any power generation unit, retailers can enter into bilateral contracts like the power purchase agreements (PPA) with producers, while in some cases they are subsidiaries of generation companies. Switching from one supplier to another in very short time is promoted by legislation, while DSOs play an important role in handling that process [30].

3.2.2. New Actors (Prosumers, Aggregators, ESCos)

A core part of the decentralization process is the shifting the passive role of the energy consumer to the more proactive behaviour of the prosumer. Small consumers used to buy electrical energy from a retailer, who were able to choose, and lease a connection to the power system from the local DSO. In contrast, prosumers of energy, although initially emerged as the individuals that had also the ability to produce energy locally in a sustainable way, they have turned to the smart and active individual and collective parties that can self-generate energy, participate in peer-to-peer transactions, interact with national energy market actors and exploit the full potential of energy storage, energy conservation, and demand response. In the Clean Energy for all Europeans package end-users have the right to consume self-generated renewable electricity and are empowered to trade the surplus they produce and sell electricity services, other than electricity supply, independently from their supply contract. Moreover, the concept of collective prosuming where active energy citizens act together in collectives such as energy communities is explicitly recognized with the right of prosumers to group and function in the market collectively being granted, although details such as applicable network tariffs have yet to be defined nationally. Provision of additional information is considered a key driver for empowering prosumers and energy communities, with access to dynamic prices through the smart meter infrastructure being considered an important prerequisite. Finally, in the current regulatory framework [6] customers are defined as the wholesale or final customers of electricity, with the latter being distinguished between household and non-household customers given the reference (household, commercial, professional) of their consumption. Active customers are considered the final customers or the groups they create and get involved in a not primarily commercial/professional way of consumption, storage, generation activities and/or participate in flexibility or energy efficiency schemes. On the collective side, citizen energy communities are defined as the legal entities that have as primary goal to provide communal benefits, instead of profits, by providing services related to generation, distribution, supply, consumption, aggregation, energy storage and energy efficiency.

From the regulatory point of view [6], aggregation has been considered as the function of combining load or generated electricity for sale, purchase and auctioning purposes performed by natural or legal persons. At the same time, emphasis is given in the fostered participation of demand response through aggregation and the operation of storage facilities, while the intermediary role that the aggregator can play between customer groups and markets is highlighted. The entity of the “independent aggregator” is defined as the market participant that is engaged in aggregation and is not affiliated to the customer’s supplier, with the exact implementation model not being strictly imposed but rather left in the discrepancy of the Member States. Such a model, combined of course with suitable products in all markets, is expected to provide fair and transparent rules that allow aggregators play their intermediatory role in a way that benefits final customers as well.

Aggregators, when considered under the flexibility scope, are the entities that get in contractual agreements with a number of end-users that own directly connected to the distribution level resources, for providing services to the grid and overcoming participation restrictions of other monetization routes. Such resources can be distributed generation assets, controllable loads and energy storage assets that can offer both supply-side and demand-side flexibility services [31]. By aggregating disperse DERs (with or without storage units) in a virtual power plant (VPP) configuration, the aggregated flexible resources can behave as (close as possible to) a conventional power plant with standard attributes, with the combination being sufficiently large for enabling their participation in electricity or ancillary services markets [32].

On the other hand, when it comes to the demand-response resources or energy storage units there is a time-coupling property that can be used for the grid benefit. Since the aggregator can be a grouping of other actors of the system, its exact type and capabilities when represented as a single entity in structured markets or in bilateral agreements with operators are found to depend strongly on the nature of aggregating assets.

For facilitating the transformation of the sector and enabling the aforementioned changes, there is a need for efficiency in a series of activities such as financing, implementation and management, leaving much space for provision of comprehensive energy services to final energy users. ESCos are expected to play an important role in that regard, through a wide range of activities around energy analysis and audits, energy management, project design and implementation, maintenance and operation, monitoring and evaluation of savings, property/facility management, energy and/or equipment supply, provision of services such as space heating and lighting [33]. With all those activities tied to the improved efficiency, the remuneration of the ESCos is proportional to the savings achieved, which are shared between the client and the company. This can be described as performance contracting and the share is related to the level of involvement of the ESCo, which can vary by even including financing and full risk undertaking [34]. Energy services are also offered to final users, by Energy Service Provider Companies (ESPCs) that can be directly linked or affiliated with consultants specialised in energy efficiency, equipment manufacturers or suppliers. The difference with the ESCo, lays mainly on the fact that there are not strong incentives in reducing consumption or achieving certain efficiency levels, since the cost of the services is recovered by the fixed fee or the added value with which the service is offered.

3.3 Classes of actors

In this subsection the classes of actors considered in TradeRES are presented. In Figure 10 the actors' scene is analysed in four layers, namely the social, the physical, the aggregation and the market one. The social layer contains the individuals, the social coalitions and the legal entities that are to different extents involved in the energy sector. In their physical interpretation that is interrelated with the assets they possess, the social individuals and entities turn to the actors that own and operate resources such as distributed generation, energy storage, controllable load, etc. and infrastructure like the network. On top of the physical layer is the layer where business entities are involved in aggregating activities, varying for demand to generation and including suppliers, aggregators and VPPs. Finally there is the market layer where all the financial transactions take place under market structures and actors interact. Three out of the four layers are mapped against the zones of SGAM, with this being depicted in Figure 11.

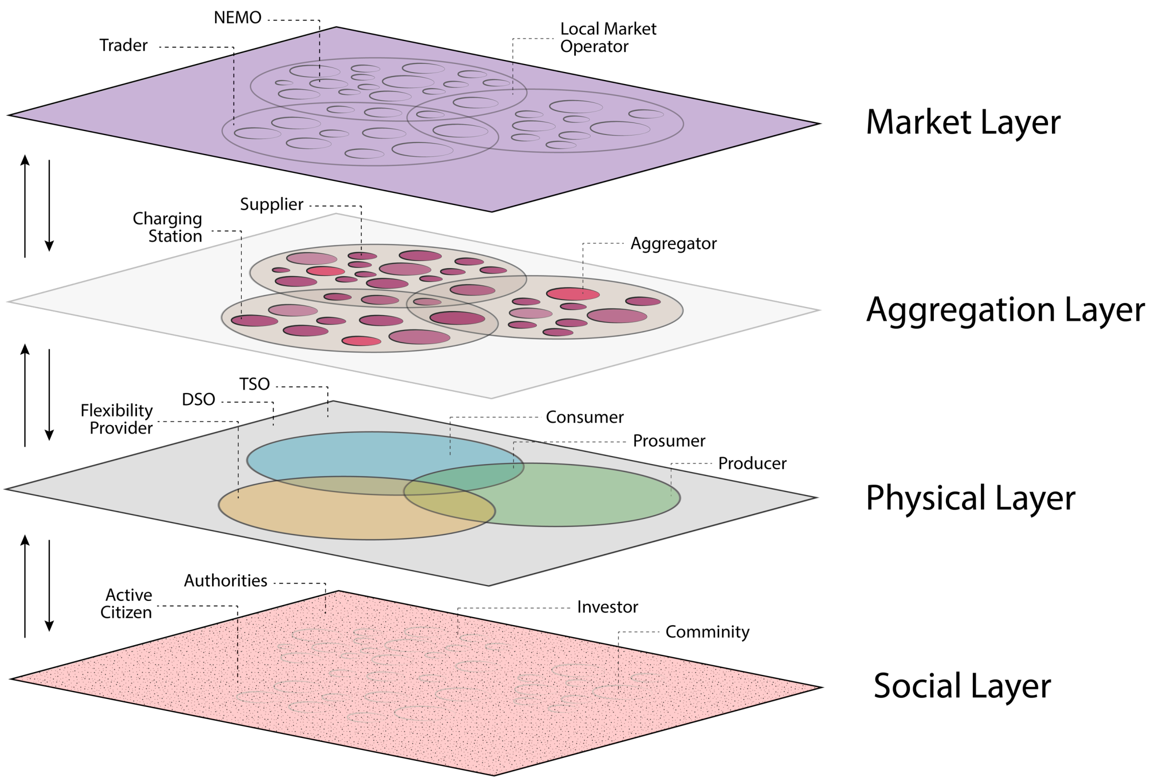

Figure 10: The actors' scene in TradeRES separated in 4 layers.

3.3.1. Prosumer

It is the final user or group of users who consumes, stores, self-generates, participates in flexibility or energy efficiency schemes, in a not primary commercial or professional way. Prosumers are distinguished based on their type to residential, enterprise, industrial prosumers, while the group instance is expressed through the community prosumer. The traditional consumers fall under this category.

3.3.2. Producer

It is the legal entity that owns and operates for commercial purposes, from a single to a portfolio of different and hybrid technologies supply providing assets, such as generation plants, pumped storage facilities, distributed generation and storage assets. Producers are distinguished according to the size of their assets to those who primarily own large generation/ storage assets and to those who own distributed generation and storage assets.

3.3.3. Supplier

It is the entity that buys electricity from the wholesale market or directly from the producers and sells it to the end users. Margins in the supply segment are considered relatively low due to high competition intensity and thus branding, marketing and product differentiation play a role [35].

3.3.4. Aggregator

It is the entity that aggregates a number of end-users and entities that own directly connected to the distribution level resources, like prosumers, producers or any mix of them, for overcoming technical barriers and limitations through the effects resulting by their combination and internalization of operational aspects.

3.3.5. Trader

It is the entity that can represent large energy volumes into the wholesale markets and achieve better positioning and reduced non-energy costs. Monitors all markets, manages the risk of fluctuating energy prices by offering minute-by-minute decisions offers capitalization of advantageous price movements and exploitation of arbitrage opportunities.

3.3.6. ESCo

It is the entity that can act as a facilitator in investments, operations and decision making by internalizing activities that encounter risks and/or can be further improved. Typically offers services through performance contracts through which they obtain a share of achieved improvement.

3.3.7. Operators

It is the entity responsible for the operation of its system, which can have either a physical or an economic interpretation. The TSO is responsible for the trans-national and trans-regional transportation of electricity and for balancing the system, the DSO manages actively the local networks and the grid connections, the wholesale market operator is responsible for collecting the bids and clearing the market at certain time frames, and the local/community market operator is responsible for coordinating the trading at the local level.

3.3.8. Regulators

It is the entity that is legally entitled to supervise the energy industry and is concerned about its sustainability, while maximizing welfare through principles related to cost-efficiency, security of supply and social acceptance. Although it expresses the policy makers' concerns, it aims to balance the interests of all stakeholders, with special focus on the more vital participants of power system, i.e. the generators, suppliers and customers.

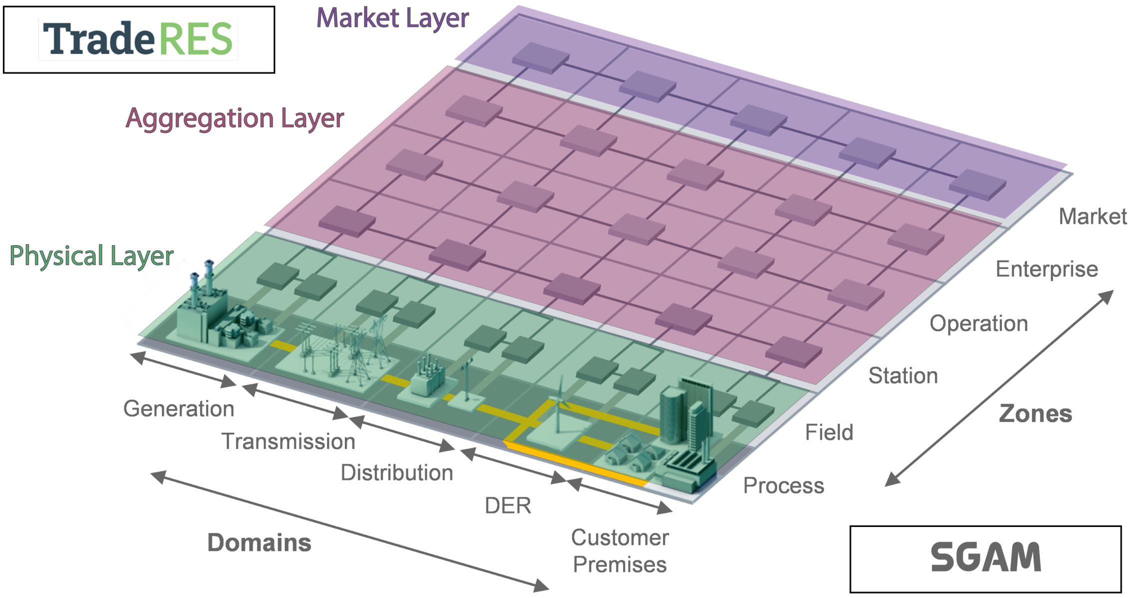

Figure 11: The three layers of the actor scene mapped to the SGAM zones.

3.4 Technology's influence on the actors' scene

The physical layer, as introduced in Subsection 3.3, consists of systems with physical interpretation and forms the basis of any further intellectual development. This cross-domain layer, that incorporates the Process and the Field zones of SGAM, combines assets that span across the electricity supply chain, involving technologies related to generation, transmission, distribution and consumption.

On the one hand, technologies act as enablers and as they go through the lifecycle stages, they drive the emergence of new actors and roles. The four phases of the technology lifecycle are (i) the research and development phase, (ii) the ascent phase, (iii) the maturity phase and (iv) the decay phase. All along the technology evolution there is the adoption lifecycle as well, where the individuals are distinguished with respect to the diffusion of the innovation into the following five groups. There are the innovators, the early adopters, the early majority, the late majority and the laggards. To that extend new or evolving technologies pave the way for new actors, innovators and early adopters that become entrants from the market perspective. On the other hand, technologies influence directly the operation side of assets as they set boundaries due to technical limitation and dictate the interaction of components. The business models, which describe the value proposition, the cost structure and the revenue streams are strongly affected by characteristics and parameters of operation. At the same time the business models set the key activities, the key resources and key partners, with the interactions being related to technological aspects. Therefore, it can be said that there is a bidirectional relation between technologies and actors, with the technologies being promoted by actors and the actors emerging due to the technological evolvements.

Following the developments around the common database of the project that have been reported in D2.1, several technologies have been identified and data related to their cost, their energy potential and their operational parameters have been gathered. On the electricity production side, onshore and offshore wind, photovoltaics of different scales, hydropower facilities, concentrated solar power plants, wave energy installations, open and closed cycle gas turbines fuelled by both fossil and "green" gases, such as green hydrogen, and nuclear power plants are among the technologies considered. Regarding heating and cooling, heat pumps differentiated with respect to their scale, the conversion medium and the temperatures are examined along with electric or gas heaters and boilers, geothermal installations, solar district heating and cooling infrastructure and combined heat and power setups based either on closed cycle gas turbines or biomass or nuclear power. About storage, technologies related to lithium-ion batteries, pumped hydroelectric energy storage, hot water tanks and hydrogen storage are among the reported ones. Carbon capture and storage, polymer electrolyte membrane electrolysis and methanation are some of the technologies mentioned for the utilization of carbon dioxide, the production of hydrogen for being used as an energy carrier and the production of synthetic natural gas from carbon oxides.

All the technologies mentioned above are in different stages of their lifecycle, with some being in the mature phase. Improved and more efficient versions emerge, while undergoing research may lead to new developments of innovative technologies in all the related fields, i.e. generation, storage, demand response and interoperability of systems and sectors. A better insight on the current R&D directions at the European level can be obtained by considering the technologies tackled in research projects of related fellow calls. The BRIDGE initiative, that includes several Horizon 2020 projects on several energy-related disciplines, provides a complete overview. The subjects covered by projects are related to local small-scale storage and next generation energy storage technologies, large scale energy storage technologies, distribution grids and retail markets, transmission grids and wholesale markets, technologies for the deployment of meshed off-shore grids, next generation technologies of renewable electricity and heating/cooling systems, system integration aspects with smart transmission grid and storage technologies under increasing share of renewables, etc. As per the BRIDGE projects brochure [42], the technologies tackled by projects are divided to five main categories, these are (i) technologies for consumers, (ii) grid technologies, (iii) large-scale storage technologies at the transmission level, (iv) small-scale storage technologies connected at distribution level and (v) generation technologies. As far as technologies for consumers are considered, the focus is on demand response, while smart metering and smart appliances follow. In terms of grid technologies, many projects deal with network management, monitoring and control tools as well as microgrids. Regarding storage technologies there is interest in hydro storage, compressed air energy storage and power to gas solutions as well as batteries, EVs and thermal energy storage when it come to the distributed form. About generation photovoltaics along with wind turbines are the technologies considered by the majority of projects, followed by micro-generation, solar thermal, biogas and tidal energy.

It is also interesting to see the wide range of stakeholders participating in the projects and consequently in the BRIDGE initiative. Following the categorization of the BRIDGE projects brochure, there are the consumers including residential, professional and industrial consumers, the regulated operators including the TSOs and DSOs and the regulators as the national regulatory authorities. Moreover, there are the local energy communities including associations, cooperatives, non-profit organisation or other legal entities involved in distributed generation and in performing activities of either a distribution system operator or a supplier or an aggregator at a local level. There are also the electricity markets players, in the category of which broad notions of the energy suppliers, the aggregators and the market operators belong. Generators, retailers and ESCos are considered in the context of the energy supplier, aggregators are foreseen to combine multiple customer loads or generated electricity, while market operators seem to cover for power exchanges, brokers and traders.

The technologies that have been considered to influence the actors, either by driving their behaviour or by dictating their operation, cover for the consumption, the storage, the generation, the network and digitalization part. More precisely, the inflexible demand, the demand side response and the flexible heating cooling are the categories that belong solely to the consumption side. Electric vehicles combine the consumption aspect with the storage one, while battery energy storage systems, heat storage, pumped storage hydropower and power to gas are the energy storage categories involved. A wide range of generating technologies, such as photovoltaics, wind turbines, biomass and biogas, concentrated solar power, geothermal power, other RES, combined heat and power, hydroelectric power, nuclear power, gas carbon capture and storage, open and closed cycle turbines and other non-RES generation alternatives are considered. Finally, distribution and transmission network technologies together with advanced information and communication technologies complete the wide range of identified technologies.

In Table 4 the intensity of relationships between classes of actors of Subsection 3.3 and identified technologies are presented. That association has been made primarily in the context of TradeRES for the needs of the current and further actor-related analysis. On the practical side, the project partners have filled out a table-based survey where they marked the relations with respect to the project's aims and goals. All partners that participated in the survey, through their selections indicated the existence of the relations and captured their importance, while partners that contribute an agent-based model had also the chance to indicate which of the relations are already incorporated in current versions of their models.

The relational table that follows, as well as two similar ones that are on Section 4, have been created through the aggregation of the table-based survey responses. As it was mentioned before, the survey participants, were asked to use two flags, one for indicating a general relationship that is considered of interest in the context of TradeRES and one for marking a relationship already incorporated in the models. Given that this type of indication had a qualitative ground, for the aggregation needs the flags were mapped to real numbers. Due to the higher relative significance assumed for the already modelled relationships a greater number was assumed over the number assigned to the general relationship flag. Thus, with the numerical interpretation available, the aggregation through summation has been made possible and for visualization purposes a green tint scale has been adopted, with the significance following the colour intensity.

As it can be seen in Table 4, prosumers as they incorporate solely consumption, they are related with the demand side categories, while they are connected to distributed generation and storage as well as to electric vehicles. Producers on the other hand, when considered at the large scale are related to wind, photovoltaics and biomass from the generation aspect and to pumped storage hydropower and battery energy storage systems from the storage perspective. Given the intense involvement of distributed assets to the prosumer side, the distributed generation and storage seem to be of less significance when considered independently of the consumption, with photovoltaics and battery energy storage systems being the most noteworthy technologies respectively. Aggregators seem to be another class of actors with intense interest focusing greatly to demand and storage technologies on the one hand and to variable renewables and biomass on the other. The intrinsic feature of this new actor may contribute to increase the market efficiency by helping to unlock a range of flexibility solutions at the generation and consumer level. Finally, the wholesale market operator seems to be strongly related to variable renewables, which are considered to participate at a very high share.

It is worth mentioning that the relationships identified and the highlighted intensity should be mainly considered in the context of the TradeRES project, given its aims and objectives. In other words, the high or low significance of a relation should not necessarily be interpreted in a universal way, since it aims to provide an insight of design directions and the priorities that should be followed within the project. Therefore, actor classes that are not strongly related to technologies, it does not mean necessarily that are not influenced by them (e.g. the DSO), but that they should not be considered and internalised in the project's developments.

Table 4: Relational table between actors and technologies.

BESS: Battery Energy Storage System
CCGT: Combined Cycle Gas Turbine
CCS: Carbon Capture and Storage
CHP: Combined Heat and Power
CSP: Concentrated solar power
DSR: Demand Side Response
EVs: Electric Vehicles
OCGT: Open Cycle Gas Turbine
P2G: Power-to-Gas
PSH: Pumped Storage Hydropower
ICT: Information and Communication Technology

Intensity: High – Low

		Inflexible Demand	DSR	Flexible H&C	EVs	BESS	Heat Storage	PSH	P2G	PV	Wind	Biomass	Biogas	CSP	Geothermal	Other RES	CHP	Hydro	Nuclear	Gas CCS	OCGT	CCGT	Other non-RES	Distribution Network	Transmission Network	ICT
1. Prosumer	**Residential**																									
	Enterprise																									
	Industry																									
	Community																									
2. Producer	**Large Generation / Storage**																									
	Distributed Generation / Storage																									
3. Supplier	**Supplier**																									
4. Aggregator	**Flexibility Aggregator / VPP**																									
5. Trader	**Wholesale Trader**																									
6. ESCo	**ESCo**																									
7. Operator	**TSO**																									
	DSO																									
	Wholesale Market																									
	Local / Community Market																									
8. Regulator	**Regulator**																									

4. Technoeconomic analysis of actors

Given the eight actor classes that have been presented in Subsection 3.3 and the technologies considered in Subsection 3.4, a technoeconomic analysis of actors is performed. This analysis is based on two dimensions that have been identified, one related with the actors' operational elements, which are closely related to their technical limitations, and one focusing solely on the behavioural aspects that drive the decision making of actors and influence their interactions. As a result, each of the dimensions is represented in maximal granularity. Particularly several operational attributes related to the groups of technologies have been included based on an exhaustive review of power system modelling literature, such that each one of them covers a different type of properties that is usually included in modelling. Similarly, our elaboration on the behavioural dimension is based on classical textbooks and the contemporary literature of traditional microeconomic theory, game theory and behavioural economics, representing those fields that study the behaviour of individuals, groups and firms.

In the following two subsections the two dimensions are discussed further, with the attributes and aspects presented and explained. This broad approach becomes more concrete and focused through a similar technic as the one described in Subsection 3.4 for the development of the heatmap-style table. Once again, it should be stated that those tables highlight the interest and the focus of the project and although they provide a pretty straight forward indication of existing relationships, they have to be interpreted in the context of TradeRES project.

4.1 Operational dimension

The operational dimension of the technoeconomic analysis aims to shed light on the technical side. In several cases the actors are bound to a single technology or a set of technologies in the sense that a part of their role is the operation of assets and to some extent interactions may take place over a network with some physical infrastructure. Of course, this is accordance with the layered structure that was adopted in Section 3.4, with this technology related part being represented at the physical layer. The physical instance actually has a twofold effect, initially at the very basic level where it sets the nature of the role by providing the main characteristics and later on where it imposes operational constraints. The operational attributes described below aim to provide a wide coverage to the groups of technologies considered, these are the flexible and inflexible demand, the controllable and non-controllable generation, the storage and the EVs, and the networks.

Among the most common parameters when the physical infrastructure is at stake, are the capacity and power limit of the installations (e.g. power plants and network elements), along with the power factors of operation of the metering points. If the demand side is considered, and more precisely the part of the demand that doesn't offer any flexibility, there are two main parameters, the inflexible demand profile that is provided in a time series format and the load curtailment at the specific metering point. Regarding the demand side response, there are mainly two possible cases considered, the first one that refers to cycles of fixed power profiles that can be shifted [36] and the second one where the time when the energy is acquired is flexible and leads to continuously adjusted power. There is also the power demand that is not realized, where energy is saved either because of long run actions that result in reduced demand or voluntary load curtailment that results in a short run reduction.

The generation can be distinguished by the classes of non-controllable generation, including variable renewables, and to that of controllable generation where the rest of the renewables and the conventional means are included. For the non-controllable generation, the capacity factor of the unit that is used to describe the utilization of the installed capacity by considering the ratio of the actual power produced over the maximum possible output is one of the important attributes. It is followed by the generation profile, which can either refer to a forecast or actual realization and the allowance for curtailment, which can either provide continuous power curtailment or curtailment at the metering point in an on/off basis. Regarding controllable generation, the minimum stable generation limit, the ramp-down and the ramp-up limits of the units, the startup and shutdown time requirements, and the minimum time for changing state of operation are among the characteristics considered [37].

Other important operational aspects have to do with the storage assets and the electric vehicles, which are closely related to the time coupling property imposed by those technologies. Given that energy storage is the subject matter, the minimum and maximum energy limits of the assets certainly play a role, while the charging and discharging capabilities together with the efficiency of those operation, are critical parameters [38]. Concerning the network, independently if transmission or distribution is at stake, the network topology is the most critical element, combined of course with the characteristics of lines and nodes. For describing the lines and the nodes, the most common characteristics have been the line length, the conductance and the susceptance, along with the thermal capacity limits and the voltage range for operation in normal conditions.

By observing Table 5, it can be seen that prosumers, independently of their type, are related strongly to inflexible demand and demand side response attributes, with demand profiles being the trivial one. Load shedding and demand shift follow next on high intensity levels, while the energy saving appears more mild but again universal. Storage and electric vehicle attributes present strong relationships with prosumers, while industrial prosumers and energy communities seem to be connected with both controllable and non-controllable operational aspects. Energy communities have been related, although mildly, to network parameters, which may be an indication of their potential involvement in local network operation. Large generation is strongly affected by capacity and power limits, while capacity factor and the generation profile seem to be among the most important aspects. Of course, these are followed by all other generation attributes but when it comes to distributed generation emphasis is given in non-controllable generation and specifically in generation profile. Regarding storage, either large or distributed, attributes like the energy limit, the charging/discharging limit and charging/discharging efficiency appear to matter. The aggregator is also among the classes of actors that are interrelated to demand response attributes and storage characteristics, since from the flexibility aggregation point of view, such technologies are relevant. Finally, the transmission system operator and the distribution system operator have not negligible connections with network operational attributes as their operation is affected by the network topology, the line characteristics and the technical limits.

Table 5: Relational table between actors and operational attributes.

- General
- Inflexible Demand
- Demand Response
- Non-controllable generation
- Controllable generation
- Stortage/EV
- Network

Intensity: Low – High

		Capacity/ power limit	Power factor	Demand profile	Load curtailment	Shiftable fixed cycles	Continuously adjustable power	Energy saving	Capacity factor	Generation profile	Curtailment action	Minimum stable generation	Ramp-down/up limit	Startup/ shutdown time	Minimum up/down time	Minimum/Maximum energy limit	Charging/ discharging power	Charging/ discharging efficiency	Network topology	Voltage limits	Thermal Capacity	Line/node characteristics
1. Prosumer	Residential																					
	Enterprise																					
	Industry																					
	Community																					
2. Producer	Large Generation / Storage																					
	Distributed Generation / Storage																					
3. Supplier	Supplier																					
4. Aggregator	Flexibility Aggregator / VPP																					
5. Trader	Wholesale Trader																					
6. ESCo	ESCo																					
7. Operator	TSO																					
	DSO																					
	Wholesale Market																					
	Local / Community Market																					
8. Regulator	Regulator																					

4.2 Behavioural dimension

The behaviour of actors constitutes an important aspect that affects the interactions that occur in the physical and in the market layer as both have been defined in Subsection 3.3. It is certainly affected by the environment and affects the behaviour of other actors as well, along with the outcome of the system. Behaviour in certain cases coincides with decision making, which may occur with or without the involvement of the decision maker's consciousness. From psychology to classical economics and from behavioural economics to multicriteria decision aiding, tools have been developed to allow the analysis and studies of the behaviour of individuals in a structured manner, enabling its further understanding, explanation and incorporation in models. Given the interdisciplinarity of that dimension, this section aims to present and analyse relevant concepts before introducing the behavioural aspects considered.

Considering the decision-making process, there are four common problematics that actors usually face individually or in sequence of two or more, or in a mixed form [39]. The "choice problematic" refers to the identification of a subset of actions, as small as possible, that contains either the best or the satisfactory actions in terms of optimal or satisficing solutions respectively. Another problematic is the "shorting problematic" in which the actor aims to place actions into predefined categories that are formed beforehand in terms of certain norms that deal with the eventual fate of actions that are assigned to them. The "ranking problematic" refers to the case where the goal is to determine an order over the subset of actions so that they are assigned to equivalence classes that completely of partially ordered. There is also the "descriptive problematic" under which the aim is to make the information related to actions and their consequences explicit so that there can be a systematic and formal description that leads to the qualitative and quantitative descriptions that enable the cognitive procedure of decision making [46].

As the basis of the study of actors' behaviour, classical decision theory sets two basic situations, that of indifference and that of strict preference. The indifference between two alternatives corresponds to the existence of clear reasoning that justifies the equivalence between those actions. Respectively, in the case of strict preference there are positive reasons that can justify clear and significant preference in favour of one of the two alternatives. The situations can be extended further for making the representation of the actor's preferences more realistic by incorporating the weak preference and the incomparability situations. In the former situation there are insufficient reasons for deducing either strict preference or indifference although there is some reasoning in favour of one of the alternatives, while in the latter reasons that could justify any of the other possible relations is absent [46]. There are two major axioms that are related to preferences and these are the axiom of transitivity and the axiom of completeness [40]. Transitivity, which is the fundamental principle, says that if an actor prefers the A over the B and the B over the C, then prefers A over C. Similarly, in the case of indifference if an actor is indifferent between alternatives A and B, and between alternatives B and C, then is indifferent also between A and C. The axiom of completeness, in the classical assumption of the two basic situations, states that the actor that is aiming to make a choice between two alternatives may be indifferent between the two or have a strict preference of the one over the other, or the vice versa. There are also other axioms that assign extra characteristics to the preference and impose convenient properties that enable and facilitate their mathematical representation. Such axioms are about the continuity, the homogeneity and the convexity of the preferences sets. Although the axiom of continuity is of special importance when the mathematical modelling of preferences is considered, the transitivity and the completeness of preferences are the two assumptions that enable an internally consistent ranking of the set of actions. Those two axioms give rise another important concept, that of rationality [48].

More from the social sciences perspective, there are four different types of rationality, the "instrumental rationality", the "belief-oriented" rationality, the "affectual rationality" and the "conventional rationality". The first type refers mainly to the expectation about the behaviour of other actors, the second one is following the ethical, aesthetic and cultural drivers, the third one is concentrating on the effects of feelings and emotions while the fourth one is based on habits. Although it is clear that in reality it would be rare these types to be found individually and combination of types could explain better the behaviour of actors, from an economics perspective rationality is considered in a more restricted setup. Given the required set of assumptions regarding preferences, predictability of actions that attempt to maximise beliefs of actors is limited and therefore rational choice seems closer to the normative than the descriptive approach. Although both approaches provide specific definitions for rationality, the normative theory considers rationality as the mean for achieving the actors' goals through the best arrangements, while the descriptive approach focuses on the pattern of choices and assumes that choices and outcomes can be predicted with sufficient information about the rules and the set of alternatives [41]. A detailed overview and discussion of rational choice theory considerations and limitations can be found in [42] while also other concepts such as the bounded rationality, i.e. the limited ability of the actor to remember and process information, are considered relevant [51].

Rationality also gives rise to the notion of "homo economicus" which refers from an economics point of view to the actor that is considered consistently rational, self-interested and pursues its subjective goals optimally. To that extent the well-being of the actor can be defined by a utility function, which seeks to optimize the following available opportunities. The utility measure, which is not unique and differs between individuals, is the ranking of actions, from the least to the most desirable ones, that is possible due to the axioms discussed earlier. Given the multifactorial sensitivity of utility, there is the "ceteris paribus" assumption that is common when trying to identify the effect of a specific parameter to the satisfaction level finds use when the indifference curves and the marginal rate of substitution of actors are considered. For extending to a more multicriteria framework [46], there is the fuzzy notion of the consequence cloud that incorporates any effect or attribute of interacting with objectives, strategies and value streams actions. Given the consequences, dimensions are required for reflecting the preferences of actors along with scales. The preferences scales can be considered as a more relaxed ranking way that follows a complete preorder of actions. Some typical scales that allow definitions of dimensions for various elementary consequences are (i) the monetary scale, (ii) the discomfort scale, (iii) the complexity scale, (iv) the risk scale and (v) the functional breakdown scale. It is important to mention that through the identification of consequences and the development of the cloud, the decision maker is enabled to specify the criteria with respect to which will take the decisions.

Turning to the several behavioural aspects that have been considered in our analysis, four categories have been defined, namely the self-interest drivers, the non self-interest drivers, the influencing standards and the other characteristics that have more behavioural economics grounds. The self-interest drivers cover for the common goals of actors as perceived in classical economics and include the utility maximization, the cost minimization, the profit maximization and the return on investments. Considering the aforementioned analysis, there is a need for well-defined functions or metrics that enable a consistent measure for the utility, the cost and the profit, respectively. In consumer theory, it is common for utility maximization to take place given a fixed level of spending with the individual buying those quantities of goods that exhaust the total income and for which the trade-off of marginal utilities between the goods is equal to the rate at which the goods are traded in the marketplace [47]. Such concept can be slightly differentiated in a dynamic setup for incorporating time as a characteristic and having a boundary based on consumption instead of budget to meet the needs of the specific good. On the other hand the cost minimization, which is not limited to consumer modelling but is usually found as a social planner objective, sets certain requirements and the aim is their achievement in the least possible cost. Profit maximisation is commonly found in production theory, with firms choosing both their inputs and outputs with the goal of maximizing of their economic profits, resulting as the difference between the total revenues and the total economic costs. Return of investments is most usually considered as the internal rate of return (IRR) and considered in contrast to the weighted average cost of capital (WACC). It is a metric pointing in the same direction as the profit although it is more focused on the timing of the cash flows and approaches the business operation from the investor's side.

From the sustainability perspective there are all those drivers that don't focus on the individuals' well-being directly but see the greater good through individuals' actions. It is common to find such phenomena modelled as externalities, while there are models focusing on the effect of prosocial behaviour that causes actors to experience positive feelings, i.e. the "warm-glow" in which an individual's personal donation to public good makes a positive impact on his utility, independently of how this action influences the social allocation [52]. The environmental aspects possible to include but not limited to the emission of greenhouse gases, to the land use and the pollution of air, water and soil. Societal challenges are more related to the common welfare, to labour issues and to quality-of-life aspects, while the overall perception/acceptance of undergoing developments by local communities is also quite relevant. Sustainability concerns are also of great importance, becoming of high priority in modern societies and developed countries, since they enclose a balanced approach combining economic, societal and environmental aspects. From the economic aspect, these can be related to growth, profit, research and development, from the societal aspect these are related to the standard of living, the education, the labour and the access in equal opportunities, while from the environmental one the use of natural resources, the prevention of pollution and the protection of bio-diversity are the key points. Of course, in between those pillars there are aspects such as the business ethics, the fair trade, the energy efficiency, the green technologies and the renewables that are strongly related with the sustainable development, a top priority in the agenda of decision makers either individuals or organisations.

Moreover, there are the influencing standards that focus on financial, comfort, safety, technical and legislator aspects. The standards refer mainly to the achievement of a corresponding level for satisfying some minimal requirements and are mostly seen as loose behavioural drivers. Finally, there are attributes like the satisficing behaviour, the attitude to risk, the reputation and conscience, the herd behaviour, the framing effect, the loss aversion and several types of bias that have their grounds in behavioural economics and can complement the traditional disciplines. Satisficing behaviour is a decision-making strategy that can be considered as an alternative objective to the utility or profit maximisation [43]. Given the framework deployed before, by considering an agent either the utility or profit are treated more as constraints rather than as ultimate goals, with a certain threshold being set and its achievement leading to satisfaction. Semi-optimality is also an aspect closely related, as under the satisficing behaviour there can be the paradigm where actors can either find optimal solutions through simplified models that end up being satisfactory solutions to the more realistic world. This is closely relevant to the bounded rationality idea, and as it was mentioned earlier limitations including the availability of information, the difficulty of the problem requiring a decision, the cognitive capability of the mind, and the time available to make the decision lead decision makers to act as satisfiers, seeking a satisfactory solution, rather than an optimal one.

Another important subject has to do with how actors deal with risk in an uncertain environment. Extending the utility concept to the expected utility version, attitude towards the risk is combined with preferences. Under the expected utility theory, individuals may be risk-averse [44], i.e. actors would not undertake a fair gamble, which implies that the utility function is concave on wealth. There is also the risk neutrality where the function gets linear and the convex version where actors seek risk. In modern portfolio theory risk aversion is measured as the marginal expected reward that the investor requires for accepting additional risk. There is a trade-off between the expected return and the exposure to risk with the optimal portfolio lying on the efficient frontier, with the capital allocation line being tangent to this point. This later line is the market-based relation between the risk and the returns, in an idealized financial market framework, where decisions are based on risk-return assessments, there is perfect competition and investors are price-takers, there are no transactions costs and borrowing/lending takes place at riskless rates. Loss aversion that captures the tendency to prefer avoiding losses to acquiring equivalent gains is also relevant, with the difference being on the fact that the utility of payoffs depends on previous experiences.

The reputation and conscience are also parameters that drive actors' behaviour, with the importance of the former being also revealed through game-theoretic contexts where in repeated interaction better off equilibria can be sustained by good reputation of players. The herd behaviour has also grounds on the mimic tendency of actors, with groups acting collectively without centralised coordination and the framing effect captures the influence that may have in the decision the presentation of the alternatives [45]. There are several types of bias that may be relevant to the decision-making processes, with the status-quo/activity bias capturing the tenancy of actors to leave things as they are and, on the contrary, to take actions mostly for keeping things in motion. There is also the recency bias, which is also known as gambler's fallacy, where actors' expectations are affected more by the more recent outcomes [46].

In Table 6, prosumers seem to be driven mainly by the utility maximization and the cost minimization, producers incorporating the firm and investor aspects and other business entities being more focused on profit maximization. Market operations mainly minimize costs, regulators focus on environmental, social and sustainability concerns while influence the legislation standards that affect several actors.

Table 6: Relational table between actors and behavioral aspects.

- Self-interest drivers
- Non Self-interest drivers
- Influencing standards
- Other characteristics

Intensity: High – Low

		Utility Maximization	Cost Minimization	Profit Maximization	Return of Investment	Environmental Concerns	Social Concerns	Sustainability Concerns	Financial Standards	Comfort Standards	Safety Standards	Technical Standards	Legislation Standards	Satisficing Behaviour	Attitude to Risk	Reputation and Conscience	Herd Behavior	Framin Effect	Loss Aversion	Status-quo / Activity Bias	Recency Bias
1. Prosumer	**Residential**																				
	Enterprise																				
	Industry																				
	Community																				
2. Producer	**Large Generation / Storage**																				
	Distributed Generation / Storage																				
3. Supplier	**Supplier**																				
4. Aggregator	**Flexibility Aggregator / VPP**																				
5. Trader	**Wholesale Trader**																				
6. ESCo	**ESCo**																				
7. Operator	**TSO**																				
	DSO																				
	Wholesale Market																				
	Local / Community Market																				
8. Regulator	**Regulator**																				

5. TradeRES Actor-ID cards

Following the concepts analysed so far and the respective developments, this section aims to summarize and highlight the key findings. The creation of identity cards for the traditional and new actors that have been identified as participants in the electricity system and markets, provides a complete high-level overview indicating the main technologies, along with the operational and behavioural characteristics of the actors.

Each of the Actor-ID cards consists of four blocks, one with a short description of the actor, with the types being noted where relevant, another with the key technologies and other two where the operational attributes and the behavioural aspects are distinguished to primary and secondary ones. This classification follows the intensity of the relation as this has been found in Table 5 and Table 6. It needs to be mentioned once again that the relations identified along with their intensity refer the mapping of the actor scene for the purposes of TradeRES project and aim to pave the ground for the enrichment of the agent-based models that follows in WP4.

The Actor-ID Cards 1-8 that follow are one for each of the actor classed that have been identified in Subsection 3.3. These have been the Prosumer, which was distinguished based on its type to residential, enterprise, industrial and community, the Producer including generation and storage, which was distinguishes based on its size to large and distributed, the Supplier, the Aggregator, the Trader, the ESCo, the Operator and the Regulator.

Prosumer

Description	Technologies
The final user or group of users who consumes, stores, self-generates, participates in flexibility or energy efficiency schemes, not primary professional. Types: Residential, Enterprise, Industrial, Community	Inflexible Demand, DSR, EVs, Flexible H&C, BESS PV, Wind, CHP Biomass, Heat Storage, CSP, Distribution network, ICT
Operational Characteristics	**Behavioural Characteristics**
Primary: Demand profile, load curtailment, shiftable fixed cycles Secondary: Continuously adjustable power, Min/Max energy limit, Charging/Discharging power	Primary: Cost minimization, Utility maximization Secondary: Comfort standards, Attitude to risk, Environmental and Social Concerns

Actor-ID Card 1: The prosumer

The technological influence on the actors' operation and behavior is twofold as it has been elaborated in Subsection 3.4. Technologies act as enablers and cause the emergence of new actors and roles, while they influence directly the operational side of assets by positioning the actor into the system and due to the technical limitations they impose, as well as by giving structure to the business model which frames actors' behaviour.

Producer

Description	Technologies
The legal entity that owns and operates for commercial purposes, from a single to a portfolio of different technologies generation/storage assets. Types: Large, Distributed	Wind, PV, BESS, PSH, Biomass, Hydro, Nuclear, CCGT Geothermal, CHP, CSP P2G, Heat Storage, EVs
Operational Characteristics	**Behavioural Characteristics**
Primary: Capacity/ power limit, Capacity factor, Generation profile Secondary: Curtailment action, Min stable generation, Ramp limit, Up/Down time, Energy limit, Charging power, Charging efficiency	Primary: Profit maximization, Attitude to risk Secondary: Return of investment, Legislation standards, Technical standards

Actor-ID Card 2: The producer

Supplier

Description	Technologies
The entity that buys electricity from the wholesale market or directly from the producers and sells it to the end users.	Inflexible Demand, DSR, Flexible H&C, EVs, PV, Wind, Biomass, CHP, Nuclear,
Operational Characteristics	**Behavioural Characteristics**
Primary: Demand profile, load curtailment, shiftable fixed cycles Secondary: Continuously adjustable power, Min/Max energy limit, Charging/Discharging power, Efficiency	Primary: Profit maximization Secondary: Return of investment, Attitude to risk, Environmental concerns

Actor-ID Card 3: The supplier

Extensive discussion on the two dimensions considered in the technoeconomic analysis of the actors has been presented in Section 4, where more details on the operational attributes and the behavioural aspects are given.

Aggregator

Description	Technologies
The entity that aggregates a number of end-users that own resources, like prosumers, producers or a mix of them. Types: Aggregator, VPP	Inflexible Demand, DSR, Flexible H&C, BESS, EVs Wind, PV, Biomass, ICT
Operational Characteristics	**Behavioural Characteristics**
Primary: Shiftable fixed cycles, Continuously adjusted power, Min/Max energy limit, Charging power Secondary: Capacity/power limit, Capacity factor, Generation profile, Curtailment action, Ramp limit, Up/down time	Primary: Profit maximization Secondary: Attitude to risk, Legislation standards, Environmental concerns

Actor-ID Card 4: The aggregator

Trader

Description	Technologies
The entity that can represent large energy volumes into the wholesale markets and achieve better positioning and reduced non-energy costs.	Biomass, Biogas, PV, Wind, OCGT, CCGT, Nuclear, Hydro, Other non-RES, PSH, P2G, BESS
Operational Characteristics	**Behavioural Characteristics**
Primary: Capacity factor, Generation profile, Curtailment action Secondary: -	Primary: Profit maximization Secondary: Legislation standards, Attitude to risk

Actor-ID Card 5: The trader

Finally, it is worth mentioning that some classes of actors present more interest than others, since the importance of their role has been highlighted and several operational and behavioural characteristics have been pointed out. Given the analysis that took place, these actors are eligible for improving their representation in agent-based models, with this prioritization being part of the T4.2.1 work. Further details on the actor modelling priorities along with the outcomes of the work related to actors that continues in the project and focuses especially on their representation in models, is expected in D4.4 and its consequent versions.

ESCo

Description	Technologies
The entity that can act as a facilitator in investments, operations and decision making by internalizing activities that encounter risks and/or can be further improved	ICT
Operational Characteristics	**Behavioural Characteristics**
Primary: - Secondary: -	Primary: Profit maximization Secondary: -

Actor-ID Card 6: The ESCo

Operator

Description	Technologies
The entity responsible for the operation of its system, which can have either a physical or an economic interpretation. Types: TSO, DSO, Wholesale market, Local/community market	Wind, PV, Biomass, Inflexible demand, DSR, BESS, PSH, P2G, Hydro, Nuclear, OCGT, CCGT, Other non-RES, ICT
Operational Characteristics	**Behavioural Characteristics**
Primary: Network topology, Line/node characteristics, Thermal capacity Secondary: Demand profile, Generation profile, Curtailment action	Primary: Cost minimization, Legislation standards Secondary: Safety standards, Technical standards, Environmental concerns

Actor-ID Card 7: The operator

Regulator

Description	Technologies
The entity that is legally entitled to supervise the energy industry and is concerned about its sustainability	Inflexible demand, DSR, BESS, PV, Wind, OCGT, CCGT
Operational Characteristics	**Behavioural Characteristics**
Primary: - Secondary: -	Primary: Environmental concerns, Legislation standards, Sustainability concerns Secondary: Cost minimization, Social concerns

Actor-ID Card 8: The regulator

6. Final remarks

This first version of the deliverable on “Characterization of new flexible players”, is the report that summarizes the work conducted in T3.2 and is about the technical and economic characterization of the behavior and capabilities of actors in the electricity market. For that purpose, the analysis has been performed in two dimensions, the operational and the behavioral one, namely, while special focus has been given in the mapping of actors and technologies.

After a short summary of the regulatory framework from the stakeholders’ perspective and an overview of the institutions and organizations that represent different interests in the industry, the widely accepted role model of the electricity market, developed and maintained for several years by ENTSO-E, EFET and ebIX, along with other frameworks, architectures and ontologies have been reviewed. Both the role model (HEMRM) and the other initiatives considered, focus on the actors and their roles in the power system generally and specifically on the electricity market, while each initiative approaches the topic from a different perspective. The HEMRM offers a harmonized and complete role representation, with degrees of freedom with respect to market design. The USEF focuses on the realization potential of flexibility with storage and demand response being at the center. The SGAM develops a technically robust approach around smart grid architecture while inherits roles from HEMRM, while the ontologies provide the insight on the vocabulary required in representing the electricity market in models. The review of all those systematic approaches on the identification of actors and their relationships provided an insight on how the issue of analysis and representation has been tackled, which enabled the development of definitions and structure around actors, adopted in TradeRES project.

Definitions of the stakeholder, player and agent terms have been provided, while the meaning of the role and actor terms has been clarified. Several, traditional and new, classes of actors have been identified, each one of them covering for parties that play a role in the market formation and operation as well as on the system development and management. These classes have been the Prosumer, the Producer, the Supplier, the Aggregator, the Trader, the ESCo, the Operator and the Regulator. The classes have been allocated into the four layers considered, namely the social, the physical, the aggregation and the market layer. Moreover, part of the analysis has been the mapping of actor classes and technologies relationship, since the technologies to which an actor is exposed to and can exploit for achieving its goals affect their positioning in the actors’ environment and the way they interact. The relationships of actors and technologies have been considered from the scope of current and envisaged agent-based models as well as from the TradeRES project vision and depict the outcomes of the related survey. Similarly, the relationships of the actor classes with operational and behavioural aspects have been examined with respect to their intensity, completing that way the qualitative characterization of actors. The results of this technoeconomic analysis are summarised through the Actor-ID cards, which aim to serve as a quick reference source for the key findings of the actor characterization work that is expected to feed the work towards the improved representation of the behavioural and operational aspect into the agent-based models.

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