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Report on description of market actors' activities and roles

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Research report

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Report on description of market actors' activities and roles

This work was carried out in the research program Flexible Energy Systems (FLEXe) and supported by Tekes – the Finnish Funding Agency for Innovation. The aim of FLEXe is to create novel technological and business concepts enhancing the radical transition from the current energy systems towards sustainable systems. FLEXe consortium consists of 17 industrial partners and 10 research organisations. The programme is coordinated by CLIC Innovation Ltd. www.clicinnovation.fi

CONTENTS

1. Objectives

The goal of this report is to describe the main market actors' activities and roles in the future flexible energy systems.

1. The traditional operating environment is briefly described, the main triggers are listed that create the need for transition to the sustainable flexible energy system.
2. The main challenges in the new operating environment with highly intermittent generation resources are described.
3. The new activities are analysed that are required to maintain the emerging new operating environment. There activities are then allocated to the already existing market players. In other words, how does the changing environment form/shape the activities of the players?

The flow of the report is illustrated in Figure 1.

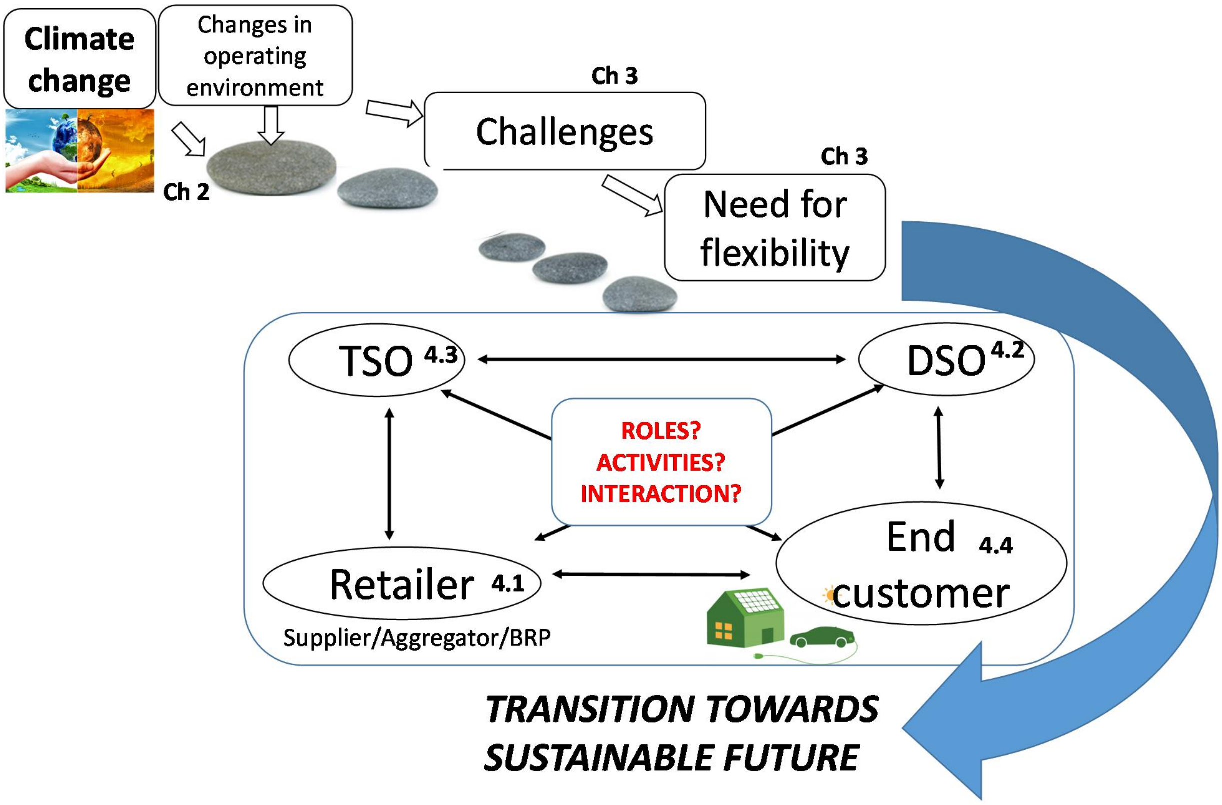

Figure 1. Contents of the report.

2. Background

Traditionally the generation levels have followed the consumption levels and the power has been generated from the large centralized power plants. In the future power systems this will change because of the ever increasing proportion of highly intermittent energy resources such as wind and solar energy in all levels of the grid, starting from large wind farms and solar parks in the high voltage level grids and going down to small scale solar PV panels on the residential rooftops. The need to change the system from the fossil fuel based one to the renewable based one is due to the following aspects:

1. Emissions, environmental problems, health problems
2. Finite fossil fuel resources
3. Increasing costs of procurement of the conventional resource due to its scarcity
4. Growing electricity demand
5. Energy injustice: renewables, in particular, solar and wind, are available evenly all over the world unlike conventional energy resources, which are mainly concentrated in certain parts of the world
6. Low efficiency and high costs due to system complexity: fossil fuel resources require many more energy conversion steps until it can be used as electricity.

The above mentioned factors give a strong incentive to shift the present fossil fuel based energy system to the renewable based system. The main challenge in the emerging renewable-based environment is a lack of flexibility because renewables are intermittent sources of energy.

The central question is how the penetration of renewables will change the activities and roles of the market actors. The market actors are the ones who will provide flexibility and create an intelligent environment, which is able to accommodate highly intermittent sources of energy.

The role of electricity markets become very important in incentivizing flexibility in all levels of electricity networks, such as low-, medium- and high-voltage grids.

The results of the report will demonstrate the key activities of the flexible energy system actors and the conflicts of interests they cause (Figure 2). Another outcome is what kind of trade-offs are made to solve the conflicts between the actors and how their activities and roles constitute the flexible energy system of the future.

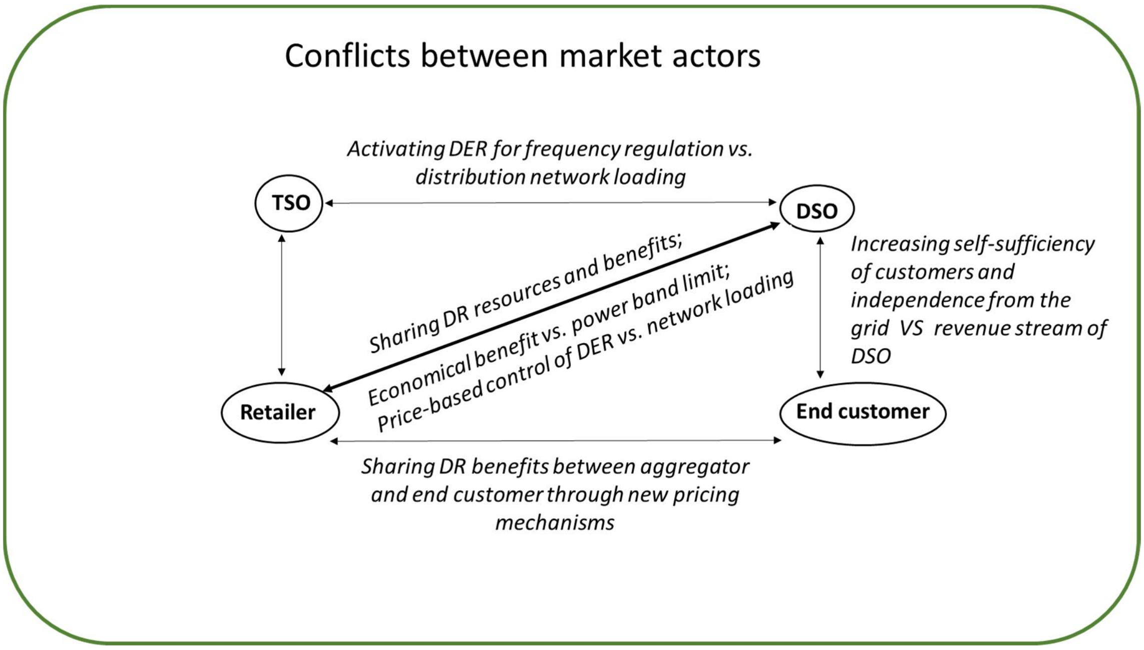

Figure 2. Conflict of interests between different market actors in future flexible electricity networks

The market actors considered in this study are a single end-customer, primarily a residential one, a distribution system operator (DSO), an electricity retailer and a transmission system operator (TSO). A balancing responsible party and an aggregator may be considered as separate actors. However, in this report the activities of these actors are not described separately but included in the retailer's activities and roles.

3. Major challenges in the future energy systems and the new activities

The changes in the market actors' activities and roles are related to the high penetration rate of variable renewable generation sources in the future electricity systems as well as their decentralized nature.

The global final aim of the electricity power system and market players is to facilitate a sustainable and resilient smart grid environment with a high proportion of intermittent renewable energy resources at the least-cost solution for every involved party (Spiliotis, Ramos Gutierrez & Belmans 2016). The main challenge of the transition from traditional to a smart grid environment is the ever-increasing need for flexibility resources to back up the intermittent energy resources (Eid et al. 2016), (Ela et al. 2016),(Alizadeh et al. 2016), (Papaefthymiou, Dragoon 2016).

In addition to the increasing need of flexibility in the future energy system, the other major challenges are:

- clarify the needs and requirements of flexibility users and flexibility providers (Figure 3), and formulating their activities and roles in the future flexible energy system

- create the right incentive regulatory framework to the flexibility users and providers in order to attract the most cost-effective and sustainable flexible energy resources (M. Sandoval, S. Grijalva 2015). This includes electricity market rules, requirements for the flexibility users and taking advantage of the already available flexibility in the grid. In other words, establishing a new electricity market design (CEDEC 2015), (European Energy Regulation 2014), (Rious, Perez & Roques 2015) to attract sustainable flexible resources and accommodate high proportions of variable RES is a relevant research question nowadays.

- to improve coordination and cooperation between multiple markets players, grid operators and balancing areas to take full advantage of the available flexibility in the grid (ENTSO-E 2015),(Zegers A. 2014), (THEMA Consulting Group 2015).

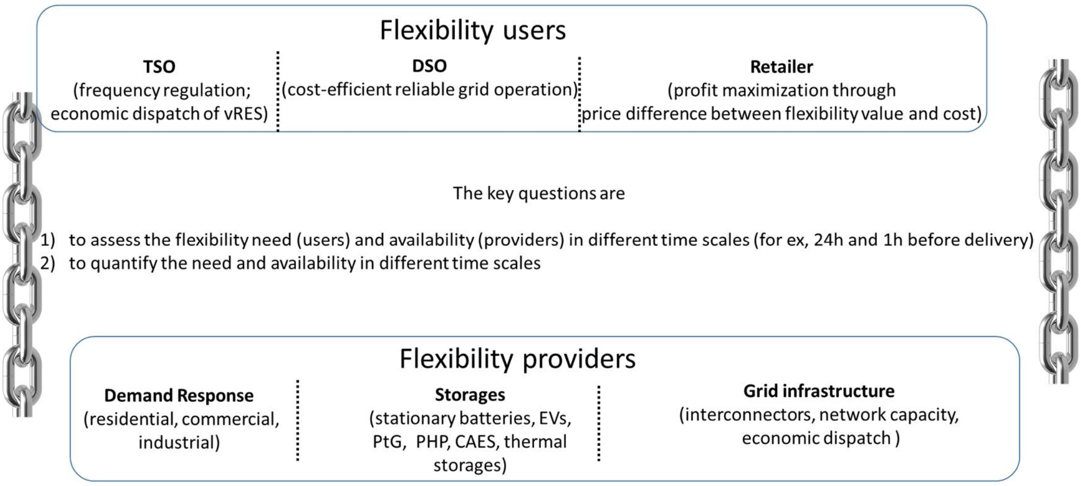

Figure 3. Clarifying the needs and requirements of flexibility users and providers

Because of the new challenges emerging in the operating environment, there is a need for new roles and maybe also new market players in the future. A question of whether there will be new market actors in the future flexible energy system is out of scope of the report. There will be definitely a place for the flexibility operator in the future environment. Will this role be taken by one of the existing market actors such as a retailor/aggregator, or will it be distributed among several market actors and be part of the DSO and TSO as well? The flexibility operator's role will most probably be assigned to different market players and grid operators depending in which area the flexibility is coordinated: LV-, MV-, HV-grid or in the form of asset for energy arbitrage on the electricity markets.

The new activities and roles can be assigned to the already existing market players discussed in the previous sections. The new activities in the emerging smart grid environment are:

1. Providing flexibility to the electricity grid to manage (emerging role of end-users)

   a) congestion (overloading, peak powers)
   b) frequency
   c) lack of generation

2. Giving incentives to end-users to provide their flexibility resources (role of DSOs, retailers through tariff structures, services, etc; TSOs through frequency regulation contracts)
3. Aggregating flexibility resources into a Virtual Power Plant / optimal operation of a virtual power plant from economical (retailers)and technical (DSOs) perspectives
4. Improving energy efficiency at the end-users' premises by raising awareness and offering incentives (DSOs as Energy Service Companies)

To enable a flexibility in the future sustainable flexible grid, the roles and responsibilities of the market players and grid operators must be clear, especially when recognizing that one party can fulfil more than one role. There needs to be an appropriate balance between incentivising consumers to participate in demand response and incentivizing TSOs, DSOs and suppliers to use it. Proper pricing signals for flexibility will ensure that balancing can be undertaken in the most efficient way and should strive to ensure that the consumer receives the real market value for participation, so that benefits are properly shared amongst all network users. Figure 4 shows possible relations between the market actors' roles.

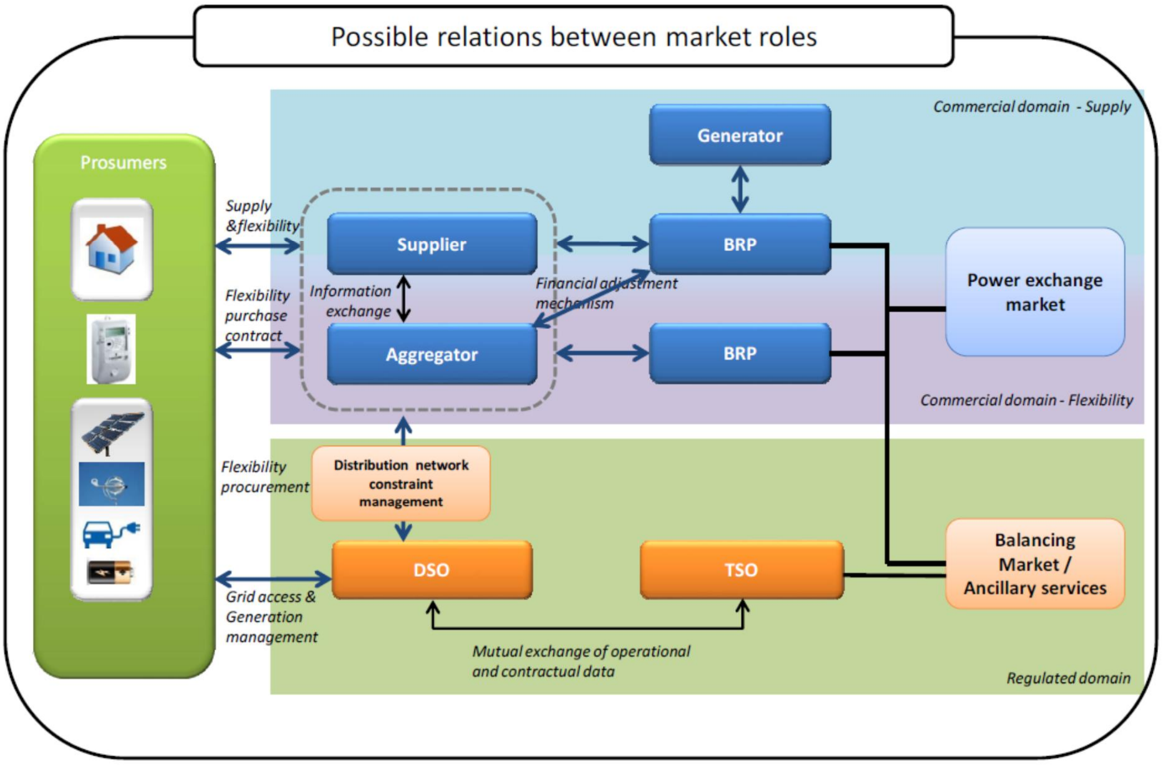

Figure 4. Possible relations between market players’ roles (EG3 of the Smart Grid Task Force 2015)

This report describes the activities and roles of both electricity market players (retailers, consumers) and grid operators (TSOs, DSOs), because the grid operators act as market facilitators and thereby constitute a necessary part in the analyses. The TSO and the DSO act as neutral market facilitators between different market actors such as aggregators, balance responsible parties and retailers, providing the communication and settlement services.

4. Market actors’ roles and activities in future flexible energy systems

The market players’ activities and roles are described in the following order:

1. First, the ***retailer***’s role and activities are described.
2. Second, the challenges in the distribution network because of the changes in the customer’s premises and new activities of the electricity retailers are analysed. The corresponding activities and roles of ***DSO****s* are drawn.
3. Third, the new activities and roles of ***TSOs*** are listed as a result of the needs in the transmission system and the flexibility potential in the medium- and low-voltage grid.

4. Finally, the newcomer in the electricity markets will be presented. Namely, the changes on the ***end-customer*** premises will be analysed which allow us to draw conclusions on the potential and role of a single end customer in the future flexible operating environment.

4.1. Supplier's activities and roles

An electricity supplier's main role is to offer energy supply to the customers. The supplier can also fulfill the task of aggregator and forward flexibility offers of small customers to the wholesale market.

The role of the aggregator in the future energy system changes dynamically depending on regulatory framework and technological development. The value of aggregation may thereby be fundamental, transitory or opportunistic (see Figure 5).

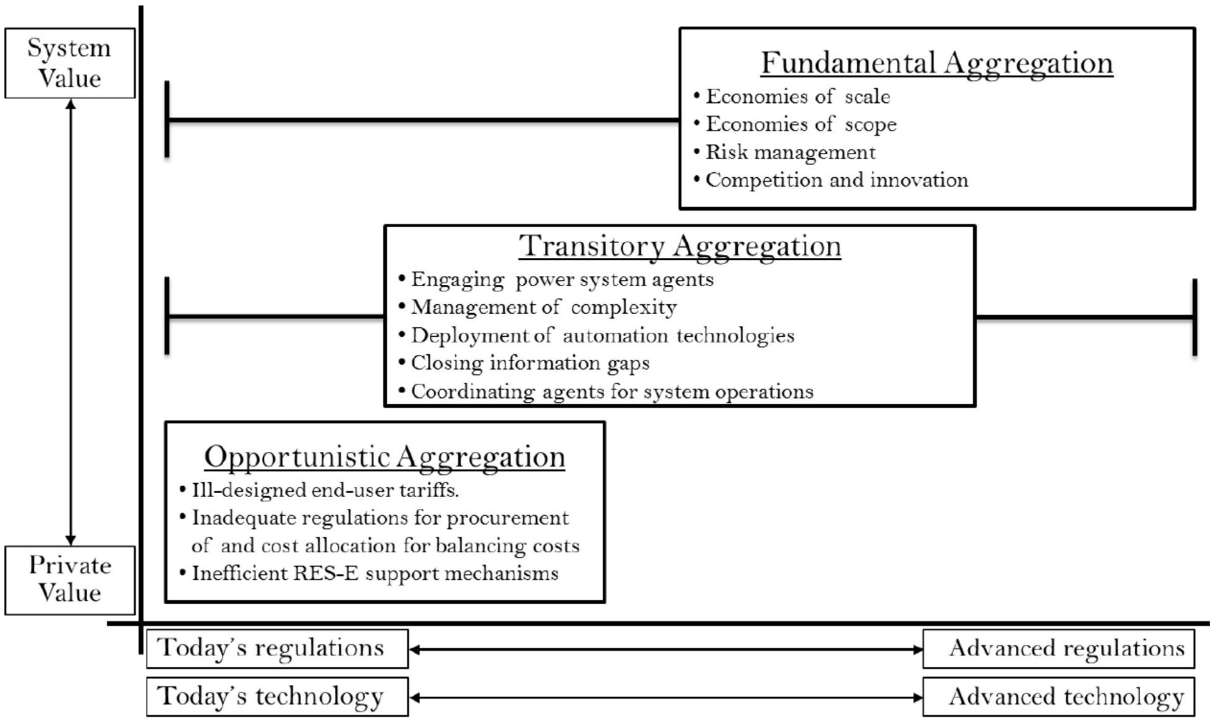

Figure 5. Value of aggregators based on technology and regulatory contexts (Burger et al. 2016)

Figure 5 shows that the aggregation creates fundamental value for the power system as a whole, through capitalizing on economies of scale and scope and by mitigating uncertainties.

Here, the main question is what level of aggregation is optimal and whether there should be one single aggregator or multiple competing aggregators. The transitory value of aggregation supports the transition of the energy system from the present to the future superior system. However, this value may diminish as technical, organization and regulatory conditions improve. The opportunistic value is created as a reaction to regulatory or market design "flaws" that are inherent to any regulatory system.

While the fundamental and transitory values of aggregation are encouraged by the regulators or policy makers because these values benefit the whole power system, the opportunistic aggregation, which delivers value to private agents, sometimes even at the expense of system-wide economic efficiency, should be minimized by modifying the regulation system.

Besides the role of aggregator, the electricity supplier can offer dynamic pricing, feedback and home automation program options for all consumers, including commercial and domestic consumers. Therefore, they also play a crucial role in empowering the full range of consumer flexibility.

As the demand side becomes more flexible and the major part of the end customers are getting equipped with AMR devices, one of the major activities and goals of the supplier is to maximize its portfolio in short-term by using the distributed energy resources (DER). This topic was extensively analysed in (Valtonen 2015).

The main principle in the supplier's portfolio optimization activities is energy or price arbitrage, in other words, gaining profit or reducing costs on the price difference in the wholesale day-ahead and real-time markets. However, in the future flexible energy system, where the cost of energy will be minor in comparison to the cost of power (marginal costs of RES are close to zero), the potential of energy arbitrage might diminish either. However, there will be more trading activities on the intra-day and real-time markets where the cost of flexibility will more likely become power-based than energy-based.

The role of supplier as a balance responsible party will become more significant in the future energy system.

4.2. DSO's activities and roles: enabler of penetration of distributed energy resources into the distribution grid

According to (CEER 2014) the activities of DSOs can be divided in core activities and "Grey areas" activities, which can be either allowed under conditions or not allowed. The core activities include planning, developing, operating and maintaining the electricity distribution network.

Besides that, load and distributed generation shedding to maintain system security, technical data management (e.g. aggregated consumption, energy flows in the grid, voltage profiles, interruptions) including TSO-DSO communication and DSO-DSO information exchange, and electricity grid losses management belong to the core activities of DSOs (activities I in Figure 6). All these activities are monopolistic.

Next, the activities can be divided into traditional (old) competitive activities that are not allowed for DSOs such as energy generation and supply (Activities V), and new activities, which can be either competitive or not (Activities II, III and IV).

The major new activities and roles in the emerging flexible energy system, in which DSO are allowed to participate are:

- Commercial data management (collection, processing, storing and forwarding of individual consumption profiles) to coordinate the needs of different market players.
- Dispatching of local distributed energy resources that will require a stronger cooperation with TSOs
- Grid-oriented services of energy storage operation. This activity should be reconsidered once a market for local grid-related services is properly designed
- Development of EV charging infrastructure
- Improve energy efficiency of the network (incentivize efficiency in consumption end-points rather than providing energy efficiency services)
- Accommodate flexible demand and microgeneration of residential customers within the distribution network.
- Cooperate with aggregators, balance responsible parties and other service providers to take advantage of demand response in order to ease local network congestion, thus facilitating the integration of distributed energy resources

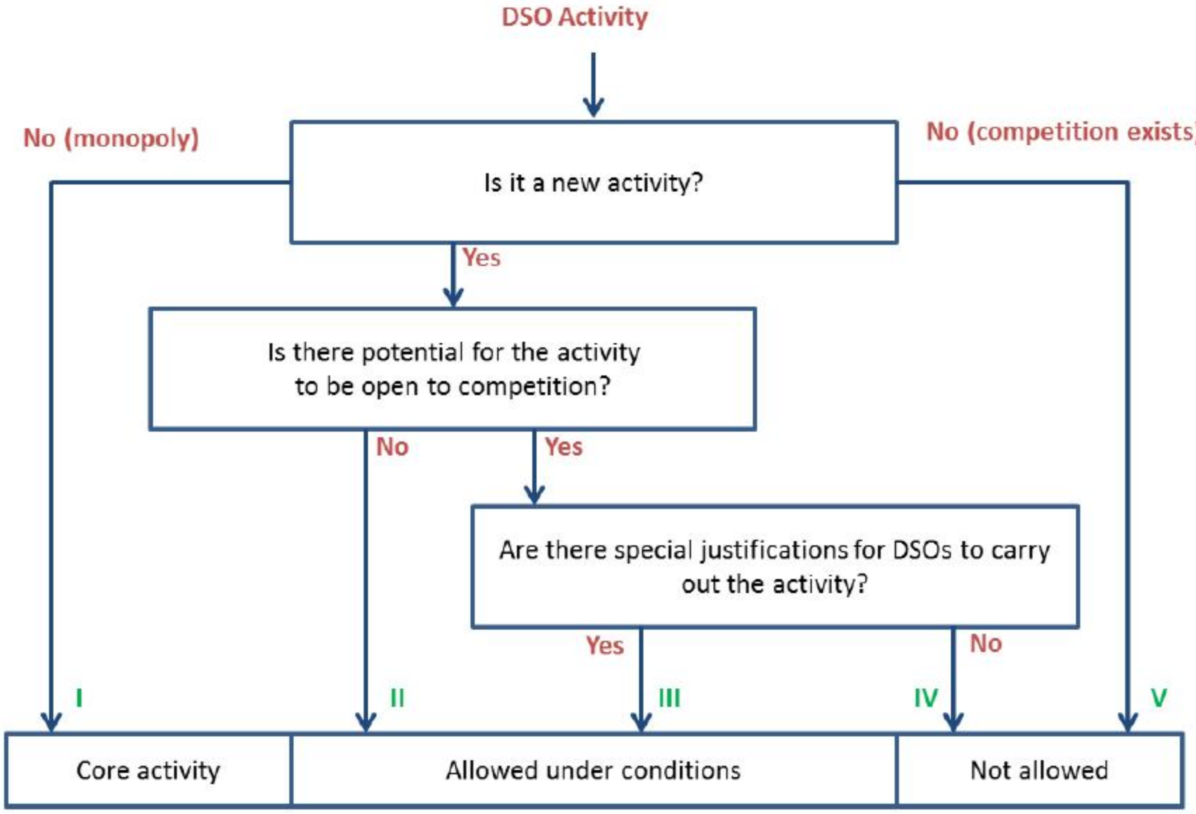

Figure 6. Logical framework for DSO activities.

Other activities are:

- Enabling operation of virtual power plants by providing information on network state in real-time
- Operator of an active distribution network (ADN): a) voltage regulation b) feeder and line congestion management
- integration of a technical VPP (see FENIX project http://www.fenix-project.org/)
- optimal use of DER to enable reliable and cost-effective operation of the distribution grid

Major challenges for the DSO in the future flexible energy system are:

- Distribution grid operational and maintenance cost recovery is jeopardized due to energy-based tariff structure and customers consuming less energy from the grid (grid-defection phenomenon) because of the emerging low-carbon technologies and stand-alone solutions on the end-customer's premises such as solar PV and battery

solutions, energy efficient appliances (energy consumption decreases while power levels increase).
- Distribution grid voltage and power quality as well as congestion management issues become more relevant than in the traditional operating environment due to high proportion of intermittent generation sources, reverse power flows, LV and MV flexible resource control by other market players such as supplier, aggregator, TSO.

In this regard, the corresponding features are becoming more relevant in the DSO business:

- introduction of power-based tariff structure for small customers to guarantee cost recovery in the DSO business
- increased cooperation and coordination between DSO and TSO regarding the use of flexibility resources
- improved distribution grid automation and ICT communication network
- transparency and fairness in all transactions

4.3. TSO's activities and roles

The traditional core activities of the TSO have been ensuring the overall system security and maintain the frequency of the electricity power system. In the future flexible energy system, the TSOs are getting a very important role in facilitating and incentivizing the development of demand side flexibility. Because the TSOs decide (in most of the European countries) the requirements within the balancing and ancillary service markets, this stakeholder will have a big impact on which flexibility resources and when are used in the markets. To be more specific, such parameters as requirements for the minimum size and response time of the resource, presence or absence of reward component for response time of the resources build a remuneration framework in the ancillary service markets for attracting the flexible resources.

There exist numerous flexibility options in all voltage levels of the grid (LV, MV, HV) such as flexible generation plants (mostly expensive fossil fuel-based ones), energy storages (large-scale in MV and HV, and small-scale in LV), flexible demand (industrial, commercial and residential), interconnectors and grid infrastructure (Figure 7). The key challenge and the main goal is to create financial incentives in the electricity markets such that the sustainable and cost-effective flexible options are dominating in the flexible energy system.

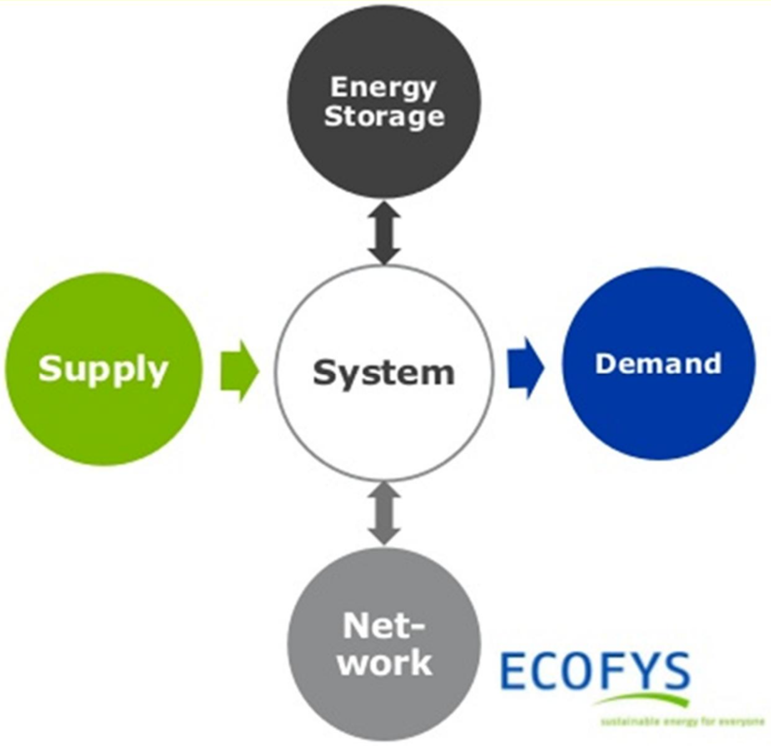

Figure 7. Five categories of flexibility options (Ecofys 2015)

In the recent years, European energy regulators and policy makers have been working towards creating a single electricity market framework for flexibility resources (EG3 of the Smart Grid Task Force 2015) with the aim of establishing an equal access not only for producers but also for all consumers to the electricity market platform. In the coming years, there will be a transformational change in how electricity markets and power system operation function (European Energy Regulation 2014), (CEDEC 2015). Some of these changes are:

1. increased cooperation between TSO and DSO regarding the use of flexibility options, establishing a TSO-DSO interface , (Zegers A. 2014),(CEER 2014),(ENTSO-E 2015)

The conflict of interests between the market parties and grid owners arises when the flexibility resource is activated by one party and it causes an undesirable effect on another party. For example, the flexible resources of a single customer are used by a TSO as an ancillary service product in hour h1 because it is the most economical solution for TSO in that moment compared to other flexibility options. This, in turn, will cause overloading and/or voltage problems in the distribution network. On this basis, the conflict of interests arises between TSO and DSO on using the flexibility resource. In this case, the choice should be made for the party who will get most value out of using the resource. The network problems on the distribution level should be compensated by TSO.

A solution to DSO-TSO conflict of interests could be creating a common framework for demand-side flexibility by TSOs and DSOs (Smart Energy Demand Coalition April 2016) which will improve the coordination between the two parties and make the transactions transparent for both parties.

As the balancing markets develop it will be increasingly important that TSOs and DSOs communicate and coordinate their actions and exchange relevant operational data with each other. This facilitates the cost-effective use of flexibility resources. Provided DSOs are not closely linked with a BRP, TSOs will need to report to the DSOs about the existing flexibility contracts and activations in the corresponding distribution grid area.

DSO constraint management will also affect the TSO grid and balancing of the system, therefore, constraint management procedures need to be in place. And like the DSO, the TSO must have access to all technical relevant data needed to perform their activities both at prequalification stage and in or close to real time.
Modifications of relevant activation of flexibility by DSOs or TSOs shall be exchanged with each other in advance, before the selection of the flexibility to be activated. Regulated revenues should integrate the recovery of these costs in a way that does not distort the optimal economical arbitrage for the system between distribution and transmission system grid reinforcement/development versus costs of managing grid congestions without this grid extension.

2. A centralized exchange platform, Datahub (THEMA Consulting Group 2015) .

Such platform will facilitate demand response services and activate customers to participate in electricity markets providing them equal access to all market places. Data exchange hub works as an information exchange platform between electricity market actors such as TSO, DSO, supplier, customers, generators and other third parties. Single centralized market platform means that each market player, i.e. retailer, DSO and TSO, can use the same flexibility resources to meet their interests, but in different time. If they use the same resources to satisfy their needs, it means that there has to be a transparent regulatory framework that unambiguously states the rules of using the flexibility options and the corresponding sanctions and penalties in case of violating the rules or when inflicting a damage or putting another party in a jeopardized state. The centralized exchange platform will facilitate this requirement.

In Denmark, the data exchange hub has been already implemented starting from 2014. In Finland, the Fingrid DataHub Oy company has been established in 02/2016 in order to build the centralized data exchange platform which is now under construction.

3. Interaction between electricity and gas TSOs and DSOs in order to harness the flexibility from decentralized biomethane injections into the electricity grid (European Energy Regulation 2014)

This issue is relevant in the nearest future when the transport and heating sectors are gradually becoming electrified. The unification of heat and transport sectors into the electricity sector increases the flexibility potential of the whole energy system as well as requires better coordination and cooperation network of the electricity, heat and transport sectors' stakeholders.

4.4. End-customer as a flexibility provider

The demand profile on the end customer side is changing due to stand-alone solutions such as solar PV and battery energy storage system (BESS), as well as low-carbon technologies (Barisa et al. 2015) such as heat pumps, electric vehicles, energy efficient appliances, home energy management systems (Elkhorchani, Grayaa 2016), (M. Erol-Kantarci, H. T. Mouftah 2011), (A. Mishra et al. 2013). This means that the residential electricity sector will provide much more flexibility than in the past decades.

A lot of efforts have been addressed towards assessing and quantifying the flexibility potential in the residential sector (D'hulst et al. 2015), (Sadeghianpourhamami et al. 2016), (Lopes et al. 2016),(A. van Stiphout et al. 2015), (M. Heleno et al. 2014).

The need for flexibility in the sustainable energy system at the least cost solution means that the already available energy resources in the electricity grid have to be utilized at their full capability. Single residential customers possess such promising flexibility resources.

The role of a single customer as a flexibility provider will be significant in the sustainable smart grid environment. The local flexible energy resources on the single customer's premises compete with the other flexibility options such as interconnectors, energy storage, commercial and industrial demand response, flexible generation and back-up generation. In addition to these options, also distribution network operation and electricity market rules have an impact on which flexibility options are activated and when.

The need for flexibility in the energy system urges the creation of new demand response (DR) marketplaces for a small end customer (see Figure 8). This is to say, the already available marketplaces for generation power plants, large industrial and commercial consumers should be made equally accessible also for the small residential customers in order to harness the residential flexibility. The proposed DR marketplaces are:

- day-ahead market
- intra-day, balancing power market
- frequency controlled reserve market
- peak load management
- greenhouse gas (GHG) emissions trading (to provide a consumer financial incentives to reduce his/her carbon footprint)

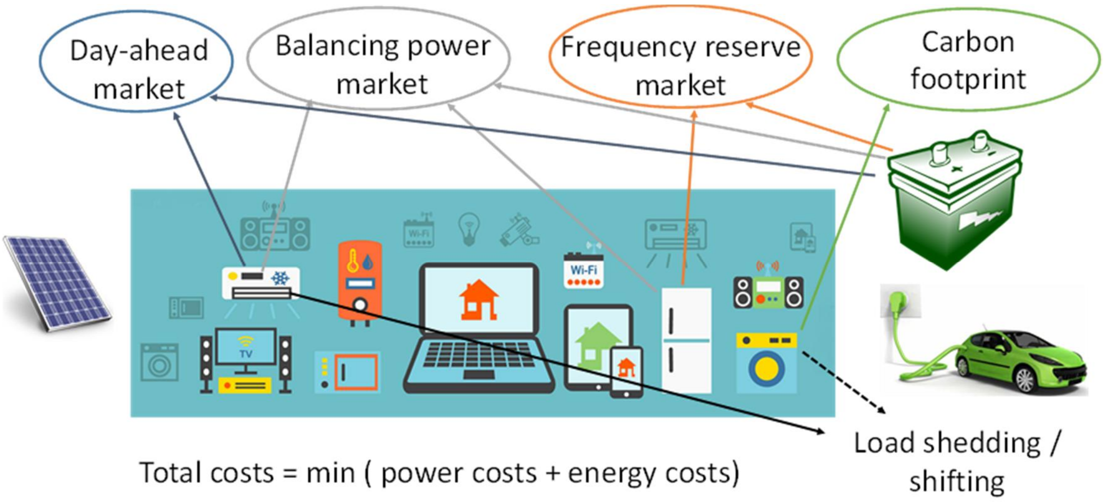

Figure 8. Proposed DR marketplaces for a single residential customer in the future energy system.

Each DR marketplace can be characterized by a quantitative characteristic, such as:

- day-ahead market - volatility and price level
- balancing power market – volatility and price level
- frequency regulation service – remuneration mechanism (power, response rate, droop function)
- power-based tariffs in the distribution system – cost of kW [€/kW]
- GHG emissions trading – carbon tax value [€/tCO_2]

These descriptive parameters may change in the future to the higher and the lower boundary. Depending on the value /characteristics in the DR marketplaces, the single customer behaviour will vary accordingly which eventually has an impact on defining the role of a single customer (Figure 9).

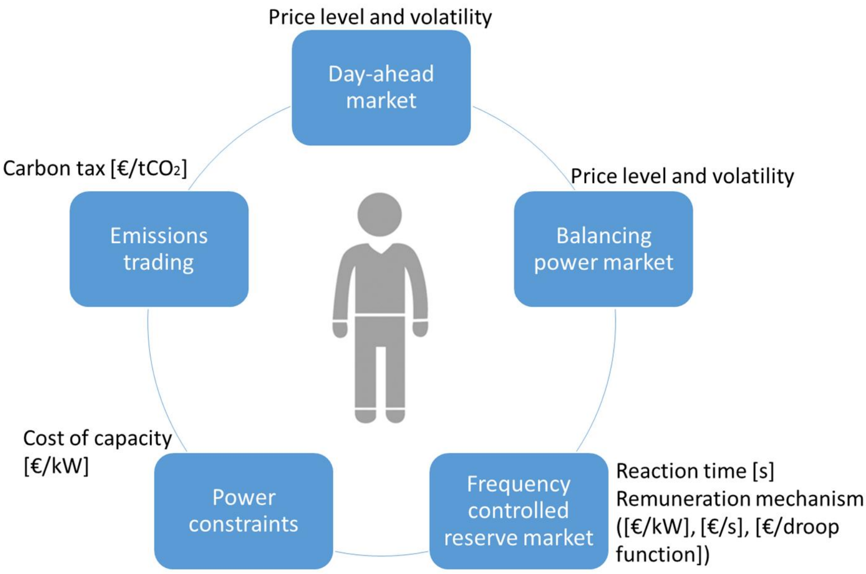

Figure 9. Attributes of DR marketplaces that affect customer behaviour.

These characteristic parameters depend on the future development of the whole energy system, which includes regulatory framework, development of electricity network infrastructure, design of electricity market, technological trends, proportion of RES and others.

For instance, a high price of kW for a single customer will create strong incentives for a customer to keep the consumption under predefined level. This, in turn, limits the earning potential on the other DR markets such as day-ahead, balancing and frequency reserve, and hence lower the participation rate of the customer in these applications. This means that the role of the single customer may become negligible there. However, if the prices on either of the markets are attractive for the customer and comparable with the cost of shifting to the higher power band level, then the chances of participation are more promising.

Integration of residential solar PV and PV-battery systems will have an impact on energy and power levels in the distribution grid. Customers become more self-sufficient and independent from the grid. The energy drawn from the grid decreases, while the peak power remains the same. Such grid-defection scenario creates incentives for the DSOs to introduce a power-based tariff in the residential sector. To be more specific, the motivation behind introducing the power-based tariff in the residential sector is justified by the following reasons:

1. To cover the cost of distribution network operation and maintenance when the energy consumption decreases and power consumption increases in the residential sector due to improved energy efficiency, increased amount of solar PV installations and other technological changes in the end-customer premises (Honkapuro et al. 2014), (Koliou et al. 2015).
2. To create a motivation for the end-customer to modify his/her consumption behavior in a beneficial way for the customer himself, distribution network, DSO business, retailer and other market and grid players in order to maximize the social welfare in the long-term run.
3. To solve the conflict of interests that a market-based demand response creates for a distribution network when the flexible energy resources are activated according to the electricity market-based incentives (day-ahead, balancing power, reserve markets).

5. Conclusions

The roles and activities of the market actors are being reconsidered in the changing operating environment. While the traditional core activities and roles continue to be in force for the corresponding parties, the new assignments are emerging due to the need for flexibility in the future energy system with the high proportion of intermittent generation sources and distributed energy resources.

The definition of the new roles and activities plays a significant role not only for the interests of the individual players but also for the energy system as a whole. The report has shown that the activities of all actors in the future energy system are much more interrelated than in the traditional operating environment. Moreover, the actions undertaken by some party may in some cases cause a conflict of interests or limit the activities of another party. This means that the unambiguous and transparent cooperation and coordination between the participants (both market actors and grid operators) of the energy system is of utmost importance in the future flexible systems. Such smoothly working relationship between the actors will not only incentivize the cost-effective sustainable flexibility options such as flexible residential demand (electric space heating, EVs, heat pumps, solar PV, BESS), transmission and distribution network capacity and interconnectors, flexibility coming from the transport and heat sector integration. It will also maximize the social welfare by diminishing the use of expensive and fossil fuel-based alternatives of the flexibility (fast ramping gas power plants, spinning reserves, expensive large-scale energy storage units, fossil-fuel based import electricity) and eventually, gradually getting rid of them completely.

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