USEF POSITION PAPER

FLEXIBILITY VALUE CHAIN

Version : 1.1
Date : October 2015

Authors : Rob van Gerwen, Hans de Heer

A solid foundation for smart energy futures

Table of Content

1. Introduction

Developing a smart energy system that supports a higher volume of renewables and shift to electrification is dictating a need for demand-side flexibility. Putting prosumers at the heart of the system, enabling them to play an active role, and rewarding decisions they take that improve efficiency, or reduce system stress, are essential to delivering this. There are currently several barriers to achieving it. Current markets are not designed for the active participation required or for grid optimisation at distribution level. There is also no standardisation of the products, services and processes which will ultimately all need to be compatible, interconnected and communicating as part of a smart energy system.

USEF was founded to address these challenges. A non-commercial partnership of seven organisations, all active in the smart energy space, the USEF Foundation has developed a framework which delivers one common standard to accelerate an integrated smart energy future. Its aim is to unlock the value of flexibility for all stakeholders in the energy system. This is achieved by delivering a market structure for trading of flexible energy use, and the tools and rules to make it work effectively.

This paper discusses USEF's flexibility value model which specifies each stakeholder's role in the system, how they interact and how they can benefit by doing so. Crucial to this is the role of the Aggregator. Situated centrally, it is functionally responsible for buying and collating enough prosumer flexibility to offer as services to other parties. The prosumer therefore benefits financially from the sale of flexibility and can also save money by optimising his/her usage based on financial incentivisation and, where also producing energy, by self-balancing.

Aggregated flexibility offers significant value to other stakeholders in the system, specific to challenges they each face.
The Distribution System Operator, can use it to more effectively manage the distribution grid, for example, to avoid congestion, improve power quality and avoid investment in upgrades. The Balance Responsible Party (BRP) can use it to avoid buying wholesale electricity when prices are high, better balance its portfolio and avoid imbalance charges. With a focus on system stability and capacity management, the Transmission System Operator (TSO) also indirectly benefits through the BRP, since its optimised portfolio will allow it to offer better balancing capacity to the TSO.
Unlocking flexibility across the value chain this way could revolutionise the energy landscape, with all stakeholders incentivised to work together in a scalable system that is greener, more secure and more cost-effective.

This paper is focused specifically on the Flexibility Value Chain as a key consideration for USEF. For broader information about USEF, its benefits and the USEF Foundation, please visit our website. The whole framework is also available there as a free download www.usef.energy

2. USEF's proposed flexibility value model

To meet the system-wide need for demand-side flexibility, USEF accords the Aggregator a central position in the flexibility value chain. The Aggregator is responsible for acquiring flexibility from Prosumers, aggregating it into a portfolio, creating services that draw on the accumulated flexibility, and offering these flexibility services to different markets, serving different market players.

We distinguish four potential customers for the Aggregator's flexibility services:

1. The Prosumer
2. The Distribution System Operator (DSO)
3. The Balance Responsible Party (BRP)
4. The Transmission System Operator (TSO), which is indirectly served by the Aggregator through a BRP[1]

A complete overview of the flexibility value model is depicted below. Whether these services represent viable business models, will vary from country to country, and is strongly depending on national regulations, market conditions and Prosumers' willingness to participate. The value model does not differentiate between customer segments (commercial and industrial (C&I) or residential), the actual value, however, may differ for each segment and each service.

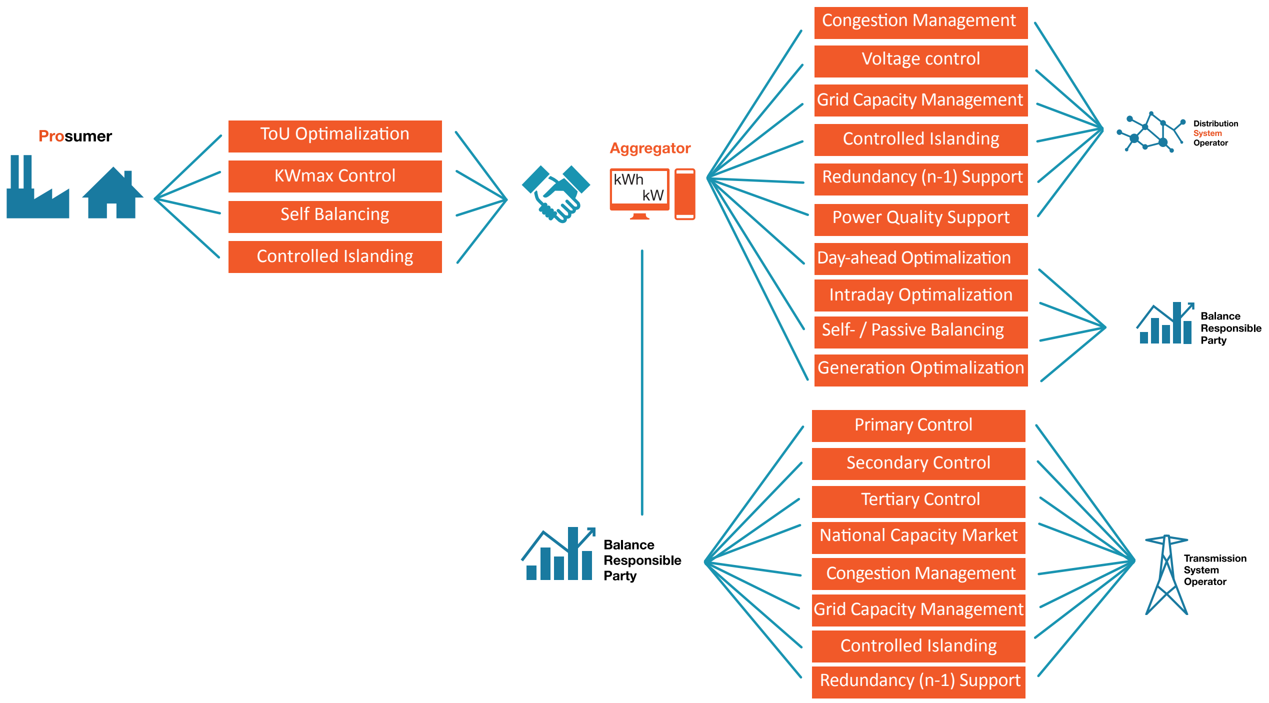

Figure 1: Complete flexibility value model.

The next section elaborates on the services available in each path through the value chain.

1 The position paper The Independent Aggregator describes the rationale for positioning the BRP between the Aggregator and the TSO

3. Paths through the flexibility value chain

The Aggregator is the pivotal partner in acquiring, aggregating, and selling Prosumer load flexibility. In section 2, we identified four potential customers for the Aggregator's flexibility services, giving rise to four different paths through the flexibility value chain. The first path, services for the Prosumer, represents the existing approach; the other three represent new options that will enable stakeholders to extract maximum value from demand-side flexibility and increase the energy system's security of supply, sustainability, and efficiency.

3.1. In-home optimalization services for the Prosumer

Before flexibility is offered to other customers in the energy market, a Prosumer can use its own flexibility for in-home2 optimization. Since no aggregation is required, we consider the Energy Service Company (ESCo) the logical role to provide these services. Note that an ESCo who decides to bring the remaining flexibility to market along one of the other three paths through the value chain takes on the role of Aggregator.

This approach is already in use, and is based on tariff structures to incentivize the desired behavior. This model for using Prosumer flexibility will very likely lead to sub-optimization. Tariff schemes are rigid structures that do not reflect the actual requirement for flexibility, and different tariffs for grid use and electricity consumption do not allow for a common optimization objective. We nonetheless include these services in the flexibility value chain model for the following reasons:

- Even after flexibility markets have been created, in-home flexibility consumption is still a viable option within certain Aggregators' value propositions and should not be neglected (e.g., kWmax control for charging of electric vehicles behind a residential or C&I connection).
- Their inclusion lets us see how, over time, the flexibility that is currently locally applied may be transferred to other markets to create greater value.

The graph below summarizes the services the ESCo can provide and their value to the Prosumer.

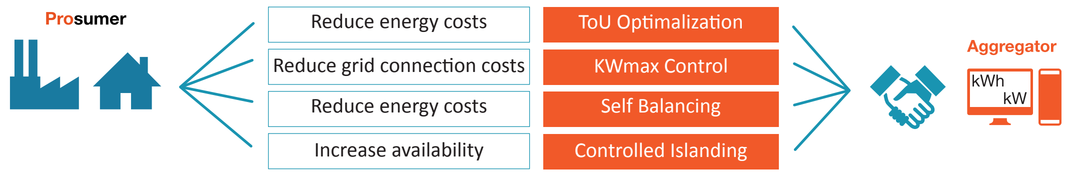

Figure 2: Flexibility services for the Prosumer, representing the current approach toward using Prosumer load flexibility.

Time-of-use (ToU) optimization is based on load shifting from high-price intervals to low-price intervals or even complete load shedding during periods with high prices. This optimization requires that tariff schedules are known in advance (e.g., day-ahead) and will lower the Prosumer's energy bill. ToU is a specific form of implicit demand response (price-based), performed by the Supplier. In this paper we focus on the value of explicit demand response (incentive-based), performed by the Aggregator. Both forms may co-exist.

Control of the maximum load is based on reducing the maximum load (peak shaving) that the Prosumer consumes within a predefined duration (e.g., month, year), either through load shifting or shedding. Current tariff schemes, especially for C&I customers, often include a tariff component that is based on the Prosumer's maximum load (kWmax). By reducing this maximum load, the Prosumer can save on tariff costs. For the DSO, this kWmax component is a rudimentary form of demand-side management.

2 In this paper, "in-home" means "behind the meter" and includes commercial and industrial units in addition to residential ones.

Self-balancing is typical for Prosumers who also generate electricity (for example, through solar PV or CHP systems). Value is created through the difference in the prices of buying, generating, and selling electricity (including taxation if applicable). Note that solar PV self-balancing is not meaningful where national regulations allow for administrative balancing of net load and net generation.

An additional service is **controlled islanding** during grid outages. Whether this is of sufficient value to the Prosumer depends mainly on the grid's reliability and the potential damage from a grid outage, which in turn depends on the type of Prosumer (e.g., residential home, office building, hospital). Islanding may require additional investments, such as storage and synchronization systems.

3.2. Aggregation services for the Distribution System Operator

The USEF framework identifies six different Aggregator flexibility services for the DSO client, summarized in the graph below. These flexibility services provide value by helping the DSO increase its performance and efficiency in managing the distribution grid.

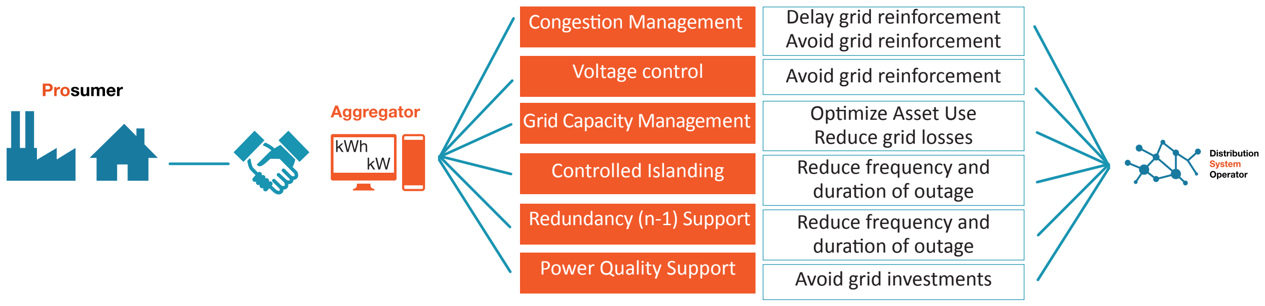

Figure 3: Flexibility services for the DSO.

Congestion management[3] refers to avoiding the thermal overload of system components by reducing peak loads. In contrast with grid capacity management, this is a situation where failure due to overloading may occur. It is a short-term problem (with respect to the duration of a grid reinforcement project) for the DSO that requires a relatively swift response. The conventional solution is grid reinforcement (e.g., cables, transformers). The alternative (load flexibility) may defer or even avoid the necessity of grid investments.

Voltage problems typically occur when solar PV systems generate significant amounts of electricity. This will "push up" the voltage level in the grid. Using load flexibility by increasing the load or decreasing the generation is an option to avoid exceeding the voltage limits. This mechanism can reduce the need for grid investments (such as automatic tap changers) or mandatory generation curtailment.

Grid capacity management aims to use load flexibility primarily to optimize operational performance and asset dispatch by reducing peak loads, extending component lifetimes, distributing loads evenly, and so forth. An added benefit may be the reduction of grid losses.

Controlled islanding aims to prevent supply interruption in a given grid section when a fault occurs in a section of the grid feeding into it.

Redundancy (n-1) support refers to actions that help reduce the frequency and duration of outages. An example is supplying emergency power (or shedding loads) in the event of a severe power shortage, or supplying backup power during grid maintenance activities.

Another potential DSO service is **power quality support**. Power quality issues are rapid phenomena that occur in the sub-minute to milliseconds range (e.g., harmonics, flicker, dips). Power quality support requires fast devices and local control loops. Some equipment on Prosumer premises (especially inverter-based equipment) might be technically capable of improving the grid's local power quality. An Aggregator might provide the equipment to the Prosumers and the service to the DSO.

3 The current version of the USEF specifications uses the term grid capacity management. In this paper we prefer the term congestion management, to distinguish from (long term) capacity management and voltage control.

3.3. Aggregation services for the Balance Responsible Party

The Balance Responsible Party (BRP) naturally aims to reduce its sourcing cost (purchase of electricity) and follow its electricity program (submitted to the TSO) as closely as possible to avoid imbalance charges. Demand-side flexibility from Prosumers within the BRP's client base can be used to optimize its portfolio. We discern four potential energy-based services, summarized in the graph below.

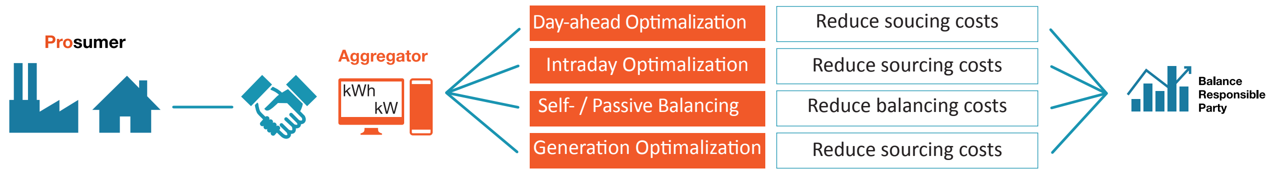

Figure 4: Flexibility services for the BRP.

Day-ahead portfolio optimization aims to shift loads from a high-price time interval to a low-price time interval on a day-ahead basis or longer. It enables the BRP to reduce its overall electricity purchase costs. Clearly, this cost advantage will have to be shared with the Prosumer as an incentive to shift his load.

Intraday portfolio optimization closely resembles day-ahead optimization, but the time frame is constrained to the day of the electricity program. Depending on national regulations, the electricity program can be changed one to a few hours before the actual time period it refers to. This enables intraday trading and load flexibility can be used to create value on this market, equivalent to the day-ahead and long-term markets.

Self-balancing is the reduction of imbalance by the BRP within its portfolio and within one imbalance settlement period to avoid imbalance charges. From a TSO's point of view, this is a suboptimal strategy; **passive balancing** offers greater benefits. In passive balancing, a BRP helps reduce the imbalance for the whole control area by deviating from its own electricity program. If this contributes to reducing the total imbalance, the BRP may receive remuneration for its passive contribution, depending on market design.[4] The BRP does not actively bid on the imbalance market using its load flexibility (see section 3.4), but uses it within its own portfolio. There are risks involved in this strategy, related to the predictability of the total imbalance. Generally, an online signal for the total imbalance is required, provided by the TSO or other means.

Generation optimization refers to optimizing the behavior of central production units as they prepare for their next hourly planned production volume. Because the control speed of conventional power units is limited, they start ramping up or ramping down minutes before the hour. To avoid imbalance, some overshoot or undershoot in output is necessary, which may reduce these units' lifetime and increase their fuel consumption. This over- or undershoot can be avoided by using demand-side flexibility. The trade-off between the cost of flexibility and increased generator cost determines the feasibility of this service.

4 E.g., the Dutch imbalance market supports passive balancing, but the German market does not.

3.4. Aggregation services for the Transmission System Operator

The TSO is responsible for system stability and capacity management. This combined responsibility is reflected by the number of services that an Aggregator can offer, through a BRP. These are summarized in the graph below.

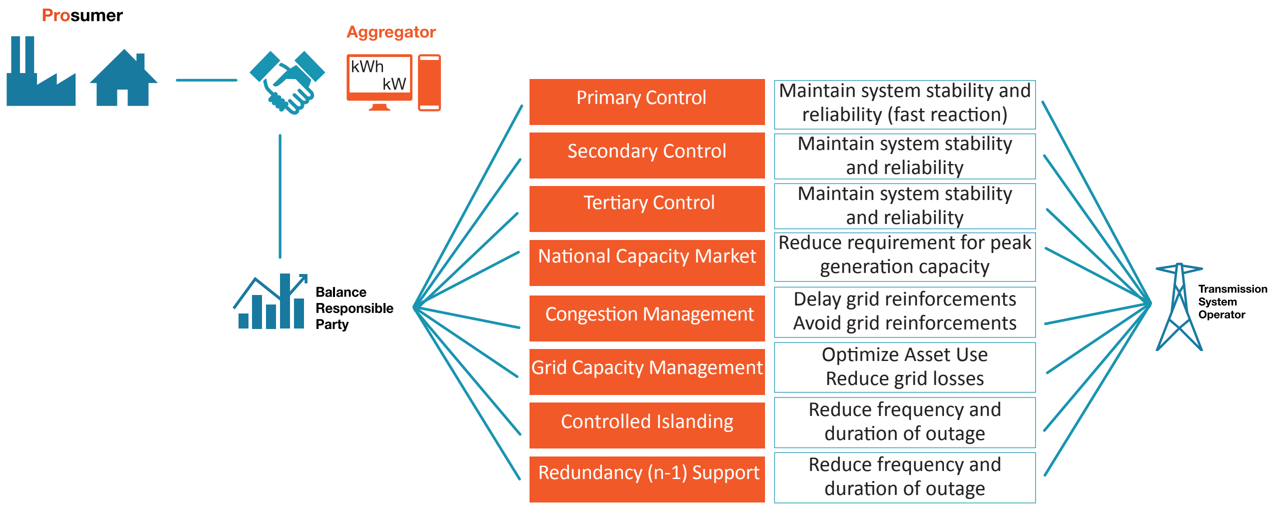

Figure 5: Flexibility services for the TSO.

The timescales of the potential services provided to the TSO vary from seconds to years. **Primary control** or frequency containment reserves are the first line of defense against frequency deviations in the grid caused by, for instance, the unexpected tripping of a large generation unit. Primary reserves respond rapidly (within seconds). They aim to maintain the grid frequency at 50 Hz (in Europe). Equipment on the Prosumer's premises that is able to support the grid frequency can provide this service. For instance, in Germany and the Netherlands primary control is auctioned by the TSO on a weekly basis. Traditionally, only rotating equipment has supplied primary control, but several types of Prosumer loads can supply this service as well.

Secondary control or frequency restoration reserves are used to relieve the primary control from its duty and allow it to return to a normal operational state. Secondary control aims to reduce imbalance within one imbalance settlement period. Secondary control is generally supplied to the TSO based on public bidding (on the imbalance market) and dispatched based on a merit order. Depending on national regulations, aggregated loads can also bid in to provide secondary control.

Tertiary control resembles secondary control, but it responds more slowly and can be sustained for a longer time period (several ISPs). It relieves the secondary control from its duty. As with secondary control, aggregated loads can also supply this service, based on national regulations.

National capacity markets (including strategic reserves) aim to increase the security of supply by organizing sufficient long-term peak and non-peak capacity. Typically, an increase in solar and wind generation requires greater supporting capacity to compensate for daily and seasonal fluctuations and during prolonged periods of solar and wind absence. An alternative is load shifting or shedding. Depending on national regulations, load flexibility can be aggregated and supplied to capacity markets. Although some national capacity markets (and strategic reserves) are already active in the EU, it is not yet clear how many capacity markets will be created in the long term and whether the TSO will manage this market.

Congestion management and **grid capacity management** in the transmission grid are basically the same as congestion management and grid capacity management in the distribution grid (see section 3.2), though the size of the congestion and the applicable regulations will differ. Aggregated load flexibility is a feasible service for both.

Controlled Islanding in the transmission grid is essentially the same as in the distribution grid (see section 3.2), though the size of the region that operates in island mode and the applicable regulations will differ.

Redundancy (n-1) support refers to the supply of emergency power and black-start capability. Depending on national regulations, these services are contracted out or provided by the TSO itself. Emergency power in particular is a viable market for (aggregated) load shedding.

Not mentioned in the list of viable TSO services are voltage control and power quality support. Voltage control on the transmission-grid level is based primarily on reactive power control. Transmission grids need significant amounts of reactive power to function properly. This reactive power is supplied by (large) generators, capacitors and inverters of large wind farms. As reactive power cannot be transported over long distances (> 100 km), aggregation services for reactive power supply to the transmission grid are not deemed feasible. Notwithstanding this, there is value in supplying reactive power to the transmission grid and TSOs do contract reactive power from for instance large generators.
Power quality is not an issue in the high-voltage grid, so that services related to power quality are not required.

4. The USEF roadmap

4.1. Introduction

Given the wide variety of potential flexibility services, the USEF organization needs to prioritize the order in which the framework will support these services. Section 4.2 describes which services are supported in the current version of the framework; section 4.3 describes the prioritization for future releases of the framework and its implementations.

4.2. Mapping USEF 2014:I.II onto the flexibility value model

The USEF 2014:I.II release describes a selection of services for the BRP and DSO. No TSO and Prosumer services have been elaborated.

1. Only one DSO service is described: congestion management.
2. All four BRP services are described, where the focus is on self-balancing and passive balancing.

The rationale for this prioritization is as follows:

- The focus on the Aggregator's relationship with the DSO is driven by the fact that this market is not yet defined in the EU member states.
- The Aggregator's relationship with the BRP is of interest because BRPs that already perform portfolio optimization may wish to split off the Aggregator role as a separate identity, creating the opportunity to also serve other customers (DSOs, TSOs, or other BRPs).
- Services for the TSO have not yet been explored because USEF places the TSO behind the BRP, whereby there is no direct relationship between the Aggregator and TSO. However, as different services may require different process and information flows throughout the value chain, these services are relevant to explore as well.
- Prosumer services have not been described because USEF proposes a market model to exploit demand-side flexibility. However, some of the Prosumer services listed in section 3.1 may be an excellent fit for Aggregators' Prosumer value propositions.

4.3. Roadmap

Table 1 displays the proposed roadmap in terms of the following elements:

- **USEF scope**
  Some services are considered outside the scope of USEF, as these are not aligned with the USEF market concept.
- **Relevant phases**
  The USEF framework is based on the concept of flexibility markets, ensuring that demand-side flexibility is deployed where it creates the highest value. USEF distinguishes between long-term markets and contracts, where options on future flexibility are traded (ensuring its availability at required times or places), and day-ahead and intraday markets, where this flexibility is actually acquired.[5]
  The concept of day-ahead and intraday markets is limited for two reasons:
  - certain services require fast responses that do not allow for complex interactions between market parties; for example, primary control requires an immediate reaction to frequency deviations.
  - certain services require the guaranteed availability of flexibility.
    USEF distinguishes between services for which only the Contract and Settle phases are described (long-term markets only) and services for which all phases are described.

Figure 6: The USEF phases

5 See also the USEF position paper "Long-Term Flexibility Contracts".

- **2014:I.II coverage**
  For each service, the roadmap indicates whether it is described in the 2014:I.II release and included in the reference implementation.
- **Priority**
  Services not covered in the 2014:I.II release are prioritized based on:
  a. the current need for these services in the EU markets
  b. their expected market value
  c. the presence, addition, or removal of regulatory barriers

Customer	Service	USEF Scope	Relevant phases	2014:I.II coverage	Priority
DSO	Congestion Management	Y	C-P-V-O-S	Y	n/a
	Voltage Control	Y	C-P-V-O-S	N	Medium
	Grid Capacity Management	Y	C-P-V-O-S	N	High
	Controlled Islanding	Y	C-S	N	Low
	Redundancy (n-1) Support	Y	C-S	N	Low
	Power Quality Support	N	-	-	-
BRP	Day–Ahead Optimization	Y	C-P-V-O-S	Y	n/a
	Intraday Optimization	Y	C-P-V-O-S	Y	n/a
	Self / Passive Balancing	Y	C-P-V-O-S	Y	n/a
	Generation Optimization	Y	C-P-V-O-S	Y	n/a
TSO	Primary Control	Y	C-S	N	Low
	Secondary Control	Y	C-P-V-O-S	N	High
	Tertiary Control	Y	C-P-V-O-S	N	High
	National Capacity Market	Y	C-P-V-O-S	N	High
	Congestion Management	Y	C-P-V-O-S	N	Medium
	Grid Capacity Management	Y	C-P-V-O-S	N	Low
	Controlled Islanding	Y	C-S	N	Low
	Redundancy (n-1) Support	Y	C-S	N	Low
Prosumer	ToU Optimization	N	-	-	-
	KWmax Control	N	-	-	-
	Self-Balancing	N	-	-	-
	Controlled Islanding	N	-	-	-

Table 1: The USEF roadmap for incorporating flexibility services. The relevant phases refer to Contract, Plan, Validate, Operate, and Settle. High priority implies that the service will be supported by the 2015:I version of the framework. Medium priority implies that the service will be supported by the next version after 2015:I

4.4. Justification for the roadmap

The main arguments for the prioritization shown in table 1 are as follows:

1. The limited amount of demand-side flexibility that is currently exploited in the EU is mostly used for portfolio optimization, secondary control, tertiary control, and redundancy support. BRP portfolio optimization is already described by USEF; the other (TSO) services are of interest since there is apparently already a business case for bringing demand-side flexibility to these markets. Although these services are provided by a BRP, we expect that the interaction between the Aggregator and the BRP, as currently described by USEF, will need to be adapted to meet the TSO's (and BRP's) specific requirements.
2. National capacity markets and strategic reserves are interesting for two reasons. First, demand-side flexibility has high potential, as it only needs to be activated a few times per year, keeping operational costs low. Second, these are potentially high-value markets, which can be a strong driver to unleash the value of dormant flexibility.
3. Renewables are currently causing voltage problems in specific parts of the distribution grid in the EU. This is expected to further increase, especially as the penetration of solar PV systems rises. Demand-side flexibility may offer a welcome short-term alternative to grid reinforcements or generation curtailment in certain cases.
4. Congestion management on the TSO level is already in place in several countries, though primarily served by generation units. The processes for congestion management on the TSO level can be similar to those on the DSO level, which are already described by USEF. Including this service may therefore be straightforward and expand the opportunities for exploiting demand-side flexibility.