Deliverable 2.2

VITO/REstore

# Report on the state of the art of trading protocols

CALLIA – Open Inter-DSO Electricity Markets for RES Integration

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# Document Information

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## Summary

The aim of deliverable 2.2 is the presentation of the state of the art of flexibility trading protocols. Accordingly, four frameworks for use of local flexibility are described. Also a summarized description of the trading information, data models and communication is provided.

According to the task 2.3 description in the Callia proposal, the information and data models that will be provided by the RES/Load/Storage agents towards the Aggregator and Trading Platform agents to feed the Trading and Decision Support Algorithms will be clearly defined in task 2.3. Chapter 6 presents a brief introduction on the envisioned data models to be used in Callia.

# Contents

# 1. Introduction

The main focus of this deliverable is the description of current flexibility trading frameworks and protocols. Accordingly, four frameworks (Traffic light, FLECH, USEF & EcoGrid 2.0) that enable the use of flexibility from distributed energy resources (DERs) by the distribution system operator (DSO) are described and compared in section 2. The use of flexibility from DERs is typically organized in a local market, enabling the DSO to buy resources from third parties for operation and control of his distribution grid, in a liberated market setting.

Presented frameworks assume that the DSO has some infrastructure in place allowing him to have a better view on the state of the distribution grid and allow the DSO to perform more active control functions and the DSO to have a good short-term forecast of the state of the grid.

Discussed frameworks consider only *explicit (incentive-based) demand response*, where the consumers receive direct payments to change their consumption (or generation) patterns upon request, triggered by the buyer of the flexibility. This is in contrast to *implicit (price-based) demand response*, where the consumers are exposed to time-varying prices or grid-tariffs, which reflect the value and costs of electricity at different time periods. In this case however, the flexibility resources are not controlled directly by an external party as the consumer decides for himself if he wants to change his consumption pattern (could also be automated), and the impact of the demand response scheme can be less well defined. A clear definition of both forms of demand response can be found in [1].

The role of the aggregator is discussed in section 3 since he plays an essential role in the provision of flexibility. Transfer of energy is discussed in section 3.2 as this is an important issue in flexibility market design.

Market processes of the four frameworks are described in more detail in sections 4. The actual control of flexible DERs is briefly presented in section 5.

Section 6 briefly describes the data models and communication to be used in Callia.

A short conclusion can be found in section 7.

# 2. Frameworks for use of local flexibility

## 2.1. Smart Grid Traffic Light Concept

### *2.1.1. Description*

The Smart Grid Traffic Light model has been adopted by several European agencies and projects, such as the SMGS INTEGRA project in Austria [2] and BDEW in Germany [3]. The goal is the definition of a method that allows to reduce the need for expansion of the distribution network by using flexible resources provided by end customers through an aggregator or supplier. It allows for market participants and network operators to interact more than they do at present, while complying with unbundling regulations.

The main idea is that for a particular period of time and a particular network segment, the network status can be described using one of the colours "green", "amber" and "red", as depicted in Figure 1. Depending on the active colour, certain rules apply in the respective network segment. In traditional network control, the amber phase does not exist and the status of the distribution network goes immediately from green to red.

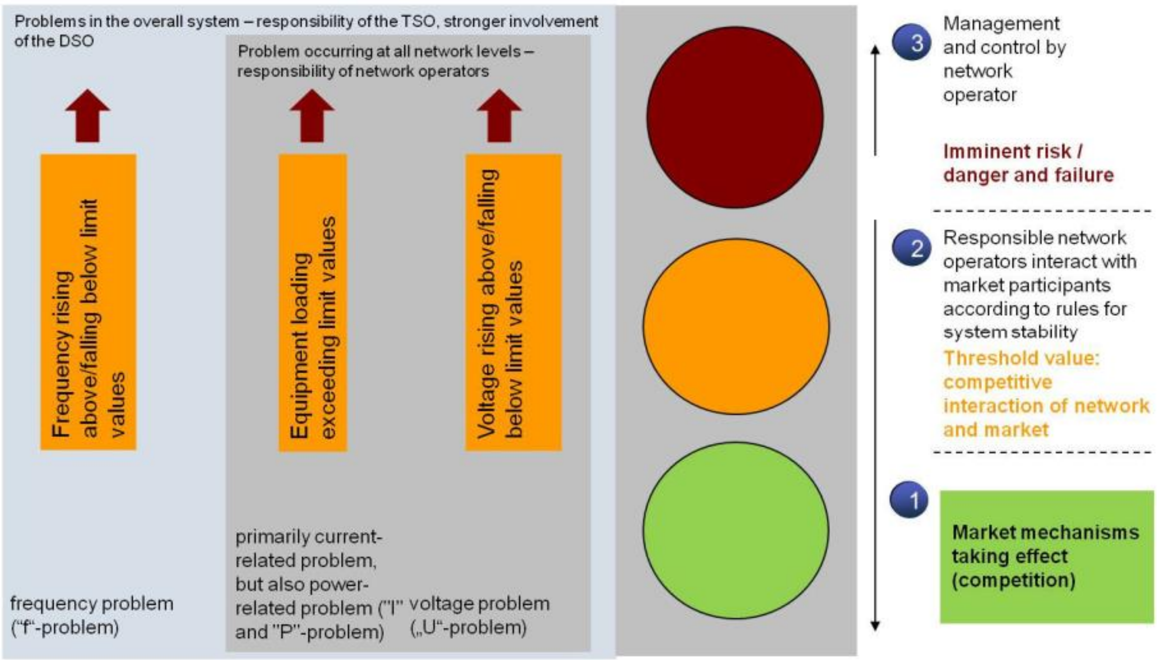



*Figure 1: Traffic light concept as defined in the BDEW Roadmap for Smart Grids [4]*

**<u>Green phase</u>**

In the green phase, or the market phase, no critical network situation exist. Network operators do not intervene in the market, and flexibility can be freely traded in the market.

**<u>Amber phase</u>**

The amber phase, or the interaction phase, is the newly defined phase in this framework. In this phase, the network operator identifies a potential network problem based on forecasts in the defined network segment. The network operator remedies the situation by demanding the flexibility offered by market participants: aggregators or suppliers.

The distribution network operators call upon contractually promised flexibility by aggregators or suppliers, taking into account the effect on the network problem. The flexibility providers update their schedule of their portfolio of flexibility providers accordingly.

These interventions are always associated with payments for the offered flexibility, as such, network users can profit from contributing to securing system stability. In addition, the market can use remaining flexibility for the benefit of the market.

**Red phase**

In the red phase, or the grid phase, there is a direct risk to the stability of the system and thus of the security of supply. In addition to the resources provided by the amber traffic light phase, the network operator has to employ non-market based regulation or control measure by controlling directly the customers' flexibility system.

### *2.1.2. Scope*

The scope of the traffic light concept is limited to the use of flexibility by the DSO (Distribution System Operator). It includes the end customer who acts as a flexibility provider, a supplier or aggregator, a meter operator and the network operator. It does not define the interaction of flexibility resources and aggregators with the BRP (Balance Responsible Party) and wholesale markets. It addresses network problems caused by frequency (transmission grid), power (congestion) and voltage. It can coexist with other options, such as feed-in management and capping peak feed-in.

The traffic light concept defines network flexibility as the flexibility used by distribution system operators to manage critical local network situations, while market flexibility and system stability can be traded in markets and used for system stability respectively. The traffic light concept thus relates only to the use of network flexibility.

The traffic light concept does not define any specific flexibility products for the DSO. Nor does it specify any relationship between an aggregator and BRP or supplier for settling unbalances or a transfer of energy.

## 2.2. **FLECH: A Flexibility Clearing House**

### *2.2.1. Description*

FLECH (FLExibility Clearing House) is a market oriented platform developed in the Danish iPower project [5] for trading ancillary services between a DSO and aggregated DERs (Distributed Energy Resources). The main vision of the iPower project is to reduce technology and business uncertainty towards smart grids and thereby adopt a new smart grid ecosystem of industries and business cases. Thereby the concept of a flexibility clearing house has been developed, allowing the DSO to manage congestion in his distribution grid using DER flexibility as economically efficient as possible.

The FLECH concept starts from the needs of the DSO, who has the choice between a long-term grid investment and the use of DER flexibility to defer this investment. Thereby, FLECH tries to open up the efficiency potential of market-based congestion management, following three design principles:

1. Minimize transaction cost for DSO flexibility services
2. Allow for further technical specifications of DSO services
3. Focus on business transaction & not interfere with distribution operations

The basic thoughts of a Flexibility market place and the corresponding stakeholders are illustrated in Figure 2. The existing market setup with the energy chain: BRP, Retailer and consumer remains unchanged. This is denoted as “ordinary electricity”. The flexible DERs of the consumers can be mobilized by aggregators in a parallel flexibility market. The Aggregators can use this flexibility to provide services to the DSO and TSO - Transmission System Operator - (via the BRP). The service to the TSO would be based on the existing ancillary services requested by the TSO, whereas services to the DSO would constitute a new market place, provided by FLECH.

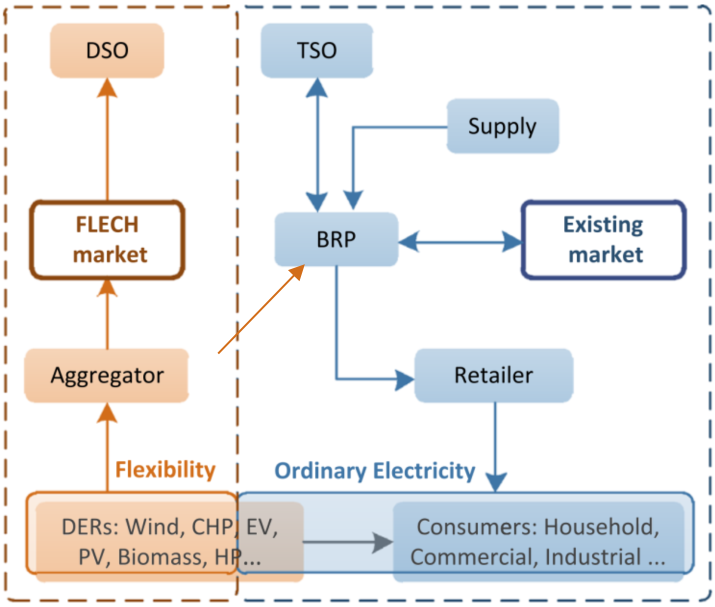



*Figure 2: FLECH parallel market setup for trading flexibility products*

Offering flexibility services to the DSO can create unbalances on the transmission level and other effects on the wholesale market. However, FLECH states that DSO services should have priority to the transmission and wholesale markets. To enable this, FLECH follows a simple approach by placing the gate closure of DSO services before the gate closure of TSO services and the energy exchange markets.

FLECH is intended to become a regular component of the energy control process in the DSO’s power system and therefore, tries to fit as much as possible into that framework. The DSO must have the choice between investing in grid infrastructure and using demand flexibility. However, a possible investment in grid infrastructure is a long-term decision and has to be planned well in advance, while flexibility required by the DSO and offered by a flexibility provider, can change over time in price and quantity. FLECH resolves this issue by introducing two separated markets:

- *Capacity Reservation market:* A long term market where the DSO can reserve sufficient flexibility to ensure that a grid reinforcement is not needed. This market is executed sufficiently long ahead before the actual potential delivery date – in the FLECH framework, they define this to be 6 months ahead – to allow the DSO to choose for the option of grid reinforcement.

- *Reservation Activation market:* A short term market close to the operational hour. At this time the DSO will know with higher certainty whether activation of the reserved capacity is needed or not. If there is no need, the DSO will not activate the reserved capacity from the Capacity Reservation market, and this flexibility could be used elsewhere. If there is a real need for flexibility, the activation of the flexibility will go through a new market. If other aggregators are able to activate the flexibility at a lower cost than the activation cost of the winning aggregator of the capacity reservation market, this aggregator will win this bid.

Figure 3 shows a timeline of the whole auction process, with the two separate markets clearly outlined. In the first phase, a DSO sends a capacity reserve request to FLECH asking for flexibility in some fixed reservation period. This might happen several months or even a year in advance. Once aggregators have placed their offers, FLECH does clearing by merit order, i.e. establishes the merit order prices for reservation price and activation price. All aggregators that get reserved are notified by the market. The second phase consists of several markets, one for every reservation activation period. Reservation activation periods do not overlap and together they cover the whole capacity reservation period. The number of reservation activation periods that a capacity reservation period is divided into is specified already in the capacity reservation market.

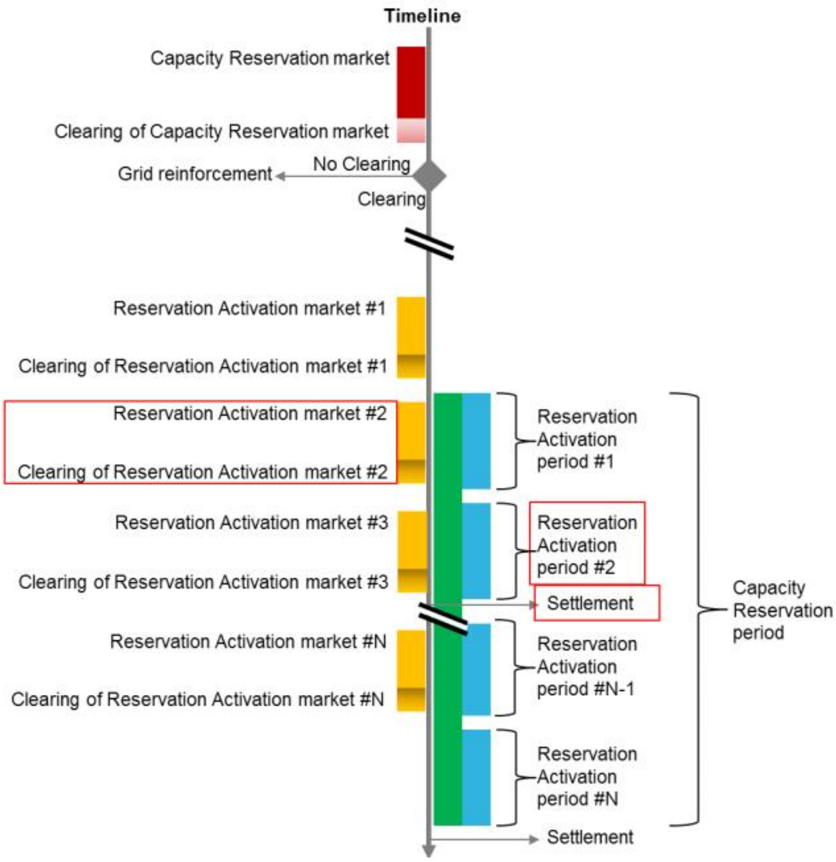



*Figure 3: Timeline of the Capacity Reservation market and the Reservation Activation Markets. The red frames indicate an active Reservation Activation market, which is executed the following day followed by a settlement. [6]*

In this regard, FLECH specifies seven flexibility services for the DSO that can be traded in this market place. Five of these services are designed for congestion management (load management), and two for voltage management (Table 1).

*Table 1: DSO flexibility services defined in the FLECH framework [7]*

| Services for load management | Services for voltage management |
|---|---|
| • PowerCut Planned<br>• PowerCut Urgent<br>• Power Reserve<br>• PowerCap<br>• PowerMax | • Voltage Support<br>• VARSupport |

### *2.2.2. Scope*

The scope of the FLECH market is mainly limited to the interaction between aggregator and DSO, although the FLECH concept do positions itself within the current market structure and the use of flexibility by the TSO. The FLECH concept is focussed on how to get a market where the DSO has an actual choice between grid reinforcement and buying flexibility. Therefore, FLECH has defined two separate markets that operate on a distinct timescale. For each of these markets, FLECH has outlined the basic parameters for the *PowerCut Planned* product. Besides, FLECH comes with elaborated general market regulations [8].

FLECH defines processes for the *Capacity Reservation market* and the *Reserve Activation Market,* for both bidding and settlement procedures. However, the FLECH concept does not define what to do with the effect of flexibility activated by the DSO on the portfolio of the BRP and Supplier, as they will face unbalance and a change in sourced energy.

The FLECH concept defines and elaborates seven flexibility services products, each which their own specifications, which should allow the DSO to efficiently operate his distribution grid and defer or eliminate the need for grid reinforcement. Five of these products relate to congestion management, and two to voltage management.

### *2.2.3. Demonstrations*

On April 8, 2014, an IT demonstration of the FLECH platform was given at IBM Copenhagen[1], demonstrating the PowerCut Planned product.

## 2.3. USEF: Universal Smart Energy Framework

### *2.3.1. Description*

In general, USEF is a more encompassing framework as the previous ones. USEF aims to be an integral market design for the trading of flexible energy use for all market participants. Thereby, USEF delivers one common standard on which to build all smart energy products and services. It

[1] Videos of the seminar can be found on: https://www.youtube.com/watch?v=oAtdpUQ-PHE and https://www.youtube.com/watch?v=oAtdpUQ-PHE

makes flexible energy a tradable commodity, *UFLEX.* USEF fits on top of most energy market models, extending existing processes for integration of new and existing markets.

**Energy & flexibility supply chains**

USEF defines roles with corresponding tasks and responsibilities, rather than business models. These can be implemented in various ways according to local markets and business needs. The energy supply chain and flexibility supply chain are separated in USEF. The physical transport underlies both chains. This separation is similar to the FLECH concept. However, USEF considers interactions between the two supply chains, while in the FLECH concept they are completely separated. The full interaction model, which depicts both value chains and the interaction between all relevant parties, is shown in Figure 4. Active Demand and Supply (ADS) is defined as the source of flexibility, thereby including not only flexible demand, but also local generation and local storage units.

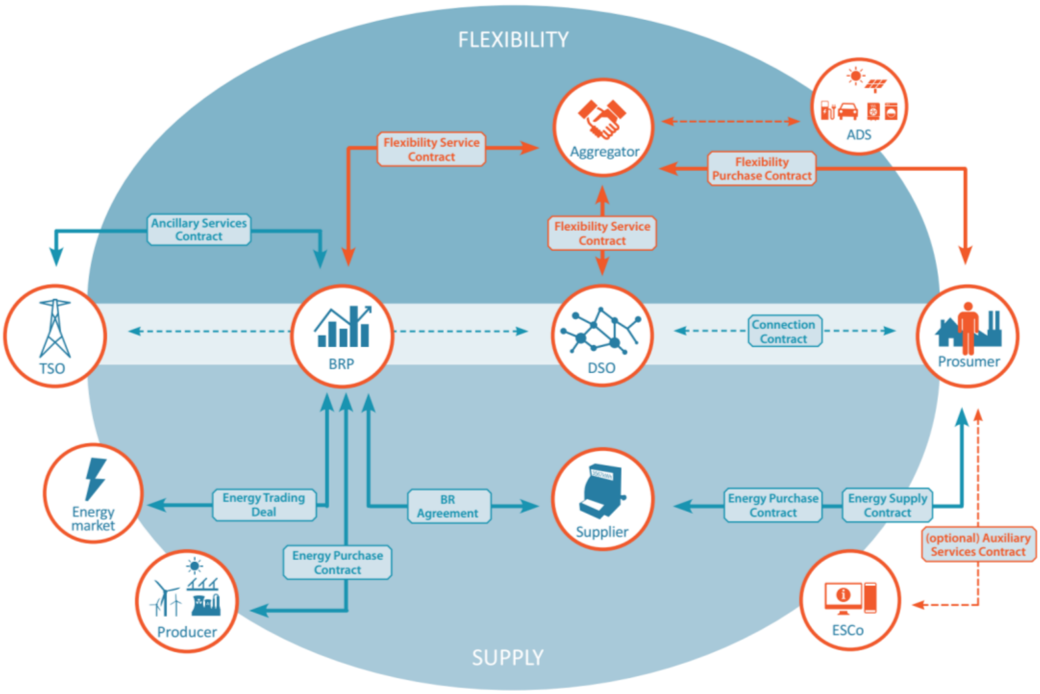



*Figure 4: The full USEF interaction model, which combines the energy value chain, responsible for the supply of energy, with the flexibility value chain, solely responsible for creating value from flexibility (UFLEX) [9].*

The energy supply chain remains unaffected in the USEF model and aligns with the European liberalized energy market model. The flexibility supply chain is concentrated around the aggregator, who has a contract with the prosumer owning some ADS. The aggregator optimizes its portfolio and sells UFLEX to the buyer with the highest prices. The Aggregator establishes a flexibility service contract with the BRP responsible for that prosumer's imbalance. The BRP can use UFLEX to optimize its own portfolio, trade it on the market or transfer it from the aggregator to the TSO. The aggregator can also sell its UFLEX to the DSO.

Although the supply of the energy commodity can be separated from the supply of flexibility, it is not straightforward to ensure that UFLEX transactions do not disturb the BRP's balance positon. USEF presents some potential solutions to this, as explained further in the transfer of energy section.

USEF does not specific business models, but presents roles models, resulting in a uniform description of roles and corresponding tasks and responsibilities, which can be implemented in various ways according to the local market and business needs. Therefore, various business models for implementing the Aggregator role can be mapped onto the USEF framework.

**Market processes**

USEF defines a new Market-based Coordination Mechanism (MCM) along with new processes. This provides all stakeholders equal access to a smart energy system. USEF MCM is meant as an addition to the current market model. USEF defines five phases in its market coordination model, depicted in Figure 5 and described in Table 2.


*Figure 5: Five phase in the USEF market based coordination mechanism (MCM). [9]*

*Table 2: Explanation of the five phases in the USEF framework. [9]*

| Phase | Description |
|---|---|
| **Contract** | In this phase, various contractual relationships have to be established. For example, bilateral contracts between prosumers and aggregators regarding the prosumer's flexibility capacity and how it will be activated by the aggregator. |
| **Plan** | Based on forecasts about energy demand, supply and flexibility, the BRP and the aggregator carry out an initial portfolio optimization. In this phase, the BRP may procure flexibility from its aggregators. At the end of the plan phase, both the aggregator and BRP have a plan for the upcoming operation period.<br>Besides, the DSO determines Congestion Points, where congestion may take place, and publishes them in a Common Reference database (however, this takes place at a lower frequency, typically a few times a year). |
| **Validate** | The DSO determines whether the forecasted energy demand and supply can be safely distributed without limitations. If congestion is predicted, the DSO may procure flexibility form the aggregators to resolve it. In this case, the aggregator goes back into the planning phase to adapt its portfolio to the requested flexibility by the DSO. In this way, multiple iterations between the planning phase and validation phase may take place. |
| **Operate** | The aggregator dispatches his assets according his plan to meet his portfolio requirements. When required, DSOs and BRPs can procure additional flexibility from aggregators to resolve unexpected congestion or imbalance issues. |
| **Settle** | Settlement of flexibility with transparent and unambiguous data. This includes contracted and delivered flexibility, as well as contracted flexibility that was not delivered. |

It is important to emphasize that during the validation phase, if flexibility is requested - FlexRequest - in a specific time slot (time slot with 'Requested' state), information about spare capacity in other time slots is also provided (time slots with 'Available' state). This is useful when the aggregator needs to shift the load to other time slots and intends to avoid the creation of new congestions Figure 6.

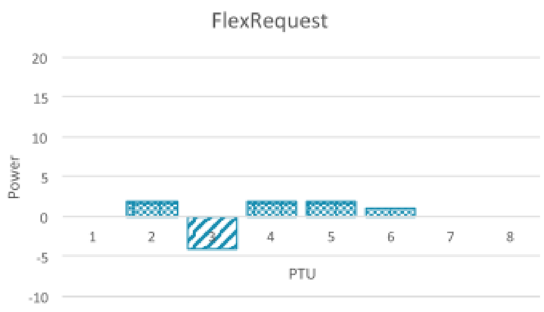



*Figure 6: Example of a FlexRequest: request to reduce the energy load by 4 units at time slot=3 and indication of all other time slots that have spare capacity [9]*

Besides five phases, the USEF MCM also defines four operation regimes: green, yellow, orange and red, as shown in Figure 7. In each of these regimes, the four phases: *Plan, Validate, Operate and Settle*, behave differently. In the green and yellow operation regime, free market mechanisms are at active, which allow flexibility to be freely traded. The green regime is the normal operation phase, where can be traded without grid limitations. In the yellow regime, there is a risk of grid congestion and the DSO is active on the flexibility market. The DSO will reduce peak loads on congestion points by activating flexibility.

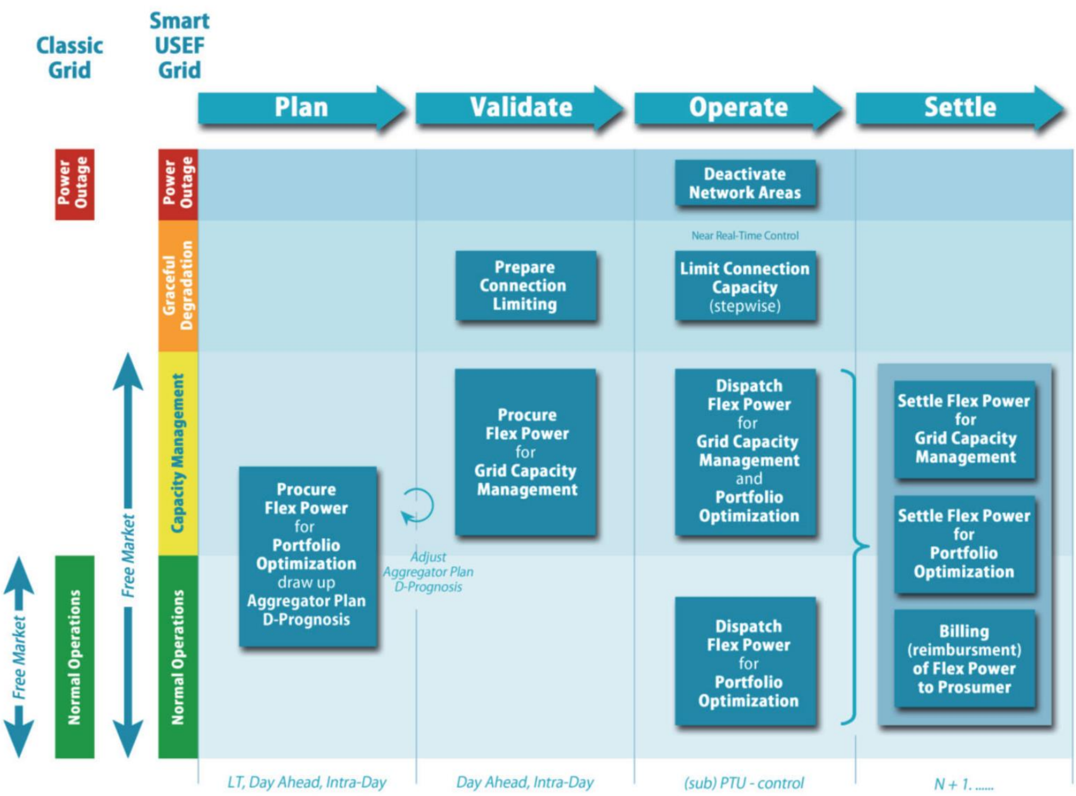



*Figure 7: USEF Operation Scheme*

In the orange regime, the market-based flexibility cannot resolve all congestion in the grid and the DSO will make autonomous decisions on limiting connections. Graceful degradation and load shedding will take place. Finally, in the red regime, there is a (partial) grid outage, by protection systems that are active. This phase should be eliminated as much as possible.

This idea is clearly similar to the traffic light concept, where amber phase corresponds to the yellow phase in USEF, and USEF has an additional orange phase defined.

### 2.3.2. Scope

The scope of USEF goes beyond that of the traffic light and FLECH concepts. USEF does not only define the market processes that enable the DSO to use flexibility, but also the use of flexibility by the BRP, who then can use this to offer ancillary services to the TSO. The defined market processes are detailed in the 2015 specifications document [10]. Besides, USEF describes the necessary adaptations to current wholesale processes to allow for the flexibility value creation model as described by USEF. USEF pays special attention to the effect of the flexibility of the aggregator on the BRP/Supplier balance position and proposes some solutions. On the other hand, USEF does not define a clearing house as FLECH would be, neither does it define any specific products to be traded.

USEF defines Active Demand and Supply (ADS) as the source of flexibility, thereby including not only flexible demand, but also local generation and local storage units. USEF only considers explicit demand response (incentive-based) and does not incorporate implicit demand response (price-based) mechanism. Besides, prosumers directly connected to the transmission grid are not yet taken into account by USEF.

The USEF MCM describes all operation regimes of the grid, from a normal, uncongested grid (green regime), to a grid with severe problems, where protection equipment has to be activated (red regime). However, USEF focusses only on radial distribution grids, not on meshed or ring topologies.

Besides its MCM, USEF also describes a service control layer, which offers generic functionality for the different flexibility service features of aggregators, suppliers and ESCos. USEF also has a connectivity layer, providing universal and interoperable access to all assets. Finally, USEF has a privacy and security guideline, to ensure confidence and trust of all stakeholders in the smart energy system.

### 2.3.3. Demonstrations

- *ProSECCo in Hoog Dalem*: an all-electric residential district, aiming to find out to which extend it is possible to reduce peak consumption and burden on the grid, by using flexibility of distributed energy resources. Thereby, it uses the USEF framework as an enabler for flexibility resources.
- *EnergieKoplopers at Heerhugowaard*: a smart energy neighbourhood of about 200 households, aiming to optimally use its energy. All households are equipped with flexible DERs. The demonstration project uses an implementation of the USEF framework.
- *Rennovates*: a holistic systemic deep renovation concept using smart services and developing smart energy-based communities resulting in energy-neutral housing [11]. A demo in the Netherlands is oriented towards the impact of a renovated district on the electric grid, thereby using the USEF framework to integrated DER flexibility.

## 2.4. **EcoGrid 2.0**

### *2.4.1. Description*

The EcoGrid 2.0 project [12] builds further on the EcoGrid EU project [13], which ran from 2011 to 2015 on the Danish island of Bornholm. EcoGrid 2.0 will include the same consumers, much of the same hardware and some of the same partners as the EcoGrid EU project.

The EcoGrid EU project was a price-based (indirect control) demand response project, where customers were able to respond to a 5-minute real-time price in a regulating power market, with a settlement each 5 minutes. In this project, the TSO played the role of aggregator, estimating flexibility in real-time and bidding it into the day-ahead and regulating market, while also performing low-voltage congestion management. In EcoGrid 2.0, this responsibility will be given to multiple aggregators, who will also attempt to deliver new services in other markets.

The EcoGrid 2.0 project will create and demonstrate a market for trading flexibility to system operators and balance responsible parties. The focus is on residential customers, that are able to freely choose their demand response aggregator, independent of their current supplier and associated BRP. This flexibility market structure will be implemented as a parallel trading platform to the existing markets, in comparison to the approach of the FLECH concept. Two clearing houses will exist in EcoGrid 2.0, one new congestion management market for location specific services, such as congestion management and voltage control for the DSO, and one for existing markets (commodity and ancillary services for the TSO) that are adapted to reduce barriers to entry for DR.

The market structure adopted in EcoGrid 2.0 is depicted in Figure 8. The TSO, BRP and DSO are the buyers of flexibility, although no TSO services will be considered in the demonstration of EcoGrid 2.0. A couple of new services for the DSO are defined, subdivided in scheduled and conditional services. The scheduled services are activated at the contracted point in time and delivered over the contracted duration of time, while the conditional services are also contracted for a certain period of time, but activated at the request of the buyer. Besides services for the DSO, a balancing service for the BRP, enabling to balance his portfolio using flexibility, is also incorporated in the project. An overview of considered services is given in Table 3.

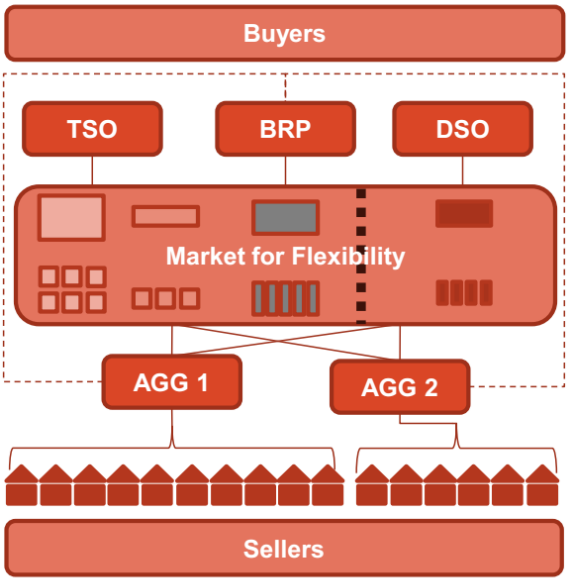



*Figure 8: Overview of market actors and their roles in the market as proposed by EcoGrid 2.0 [14]. AGG denotes an aggregator.*

*Table 3: Overview of considered services in the EcoGrid 2.0 Demonstration [12].*

| DSO Services | | BRP Services |
|---|---|---|
| **Scheduled** | Load Reduction Planned | Balancing service |
| | Load Limitation | |
| | Load Limitation Planned | |
| | Voltage Control | |
| **Conditional** | Load Reduction Slow | |
| | Load Reduction Fast | |
| | Load Limitation Fast | |

Activation of flexibility by a TSO or a BRP can result in congestion in the distribution network of the DSO. Giving the DSO the ability to curtail such control actions would be a possible solution, however, this would harm the operation of the market, as the market would depend on the approval of the DSOs. As the EcoGrid 2.0 project focusses on an early stage flexibility market, they expect the technical constraints of the DSO to be of low importance, and therefore will not incorporate any solution into the demonstration. Of course, expected congestion in the distribution will be managed through the congestion market for the DSO.

On transmission level, EcoGrid 2.0 states that activation of flexibility by the DSO will be too small to result in imbalances, so this would be no issue. EcoGrid 2.0 neither does not define which services have priority in the case where service activation by TSO or BRP and DSO is requested.

The market process defined in EcoGrid 2.0 exists out of 5 steps, and resembles the one of USEF. The main difference is the absence of the validate step of the USEF framework. In EcoGrid 2.0, expected DSO congestion is managed through a separate market than the one settling TSO and BRP flexibility. The DSO congestion market resembles a tendering process, as depicted in Figure 9.

Beside the new congestion market for the DSO, flexibility services the BRP (and the TSO, although not in scope of the demonstration) will be included in an adaptation of the existing markets, enabling the participation of flexible DERs.

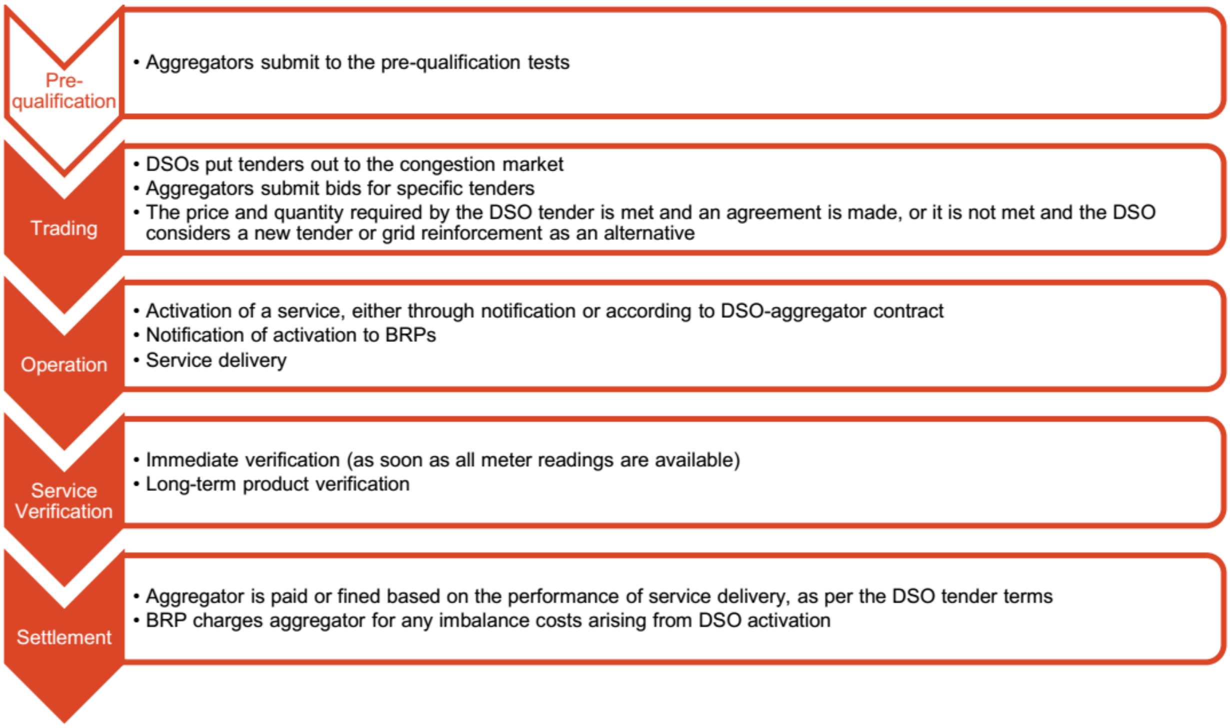



*Figure 9: Market processes for the congestion management market for the DSO [12].*

### 2.4.2. Scope

The scope of the EcoGrid 2.0 project goes beyond that of the FLECH concept and is more similar to the USEF framework. EcoGrid 2.0 defines a new, parallel market for grid management services for the DSO, similar to the FLECH concept, with a couple of demand response services specifically designed to enable the DSO to operate its grid in safe way without the need for grid reinforcement. Both scheduled services, to be always activated at the contracted time and duration, and conditional services, to be activated only when an activation signal from the buyer is sent, are defined. In contrast to the USEF framework, EcoGrid 2.0 also incorporates the market clearing houses and defines specific products to be traded.

Flexibility services for the BRP and the TSO are accommodated by adapting the existing markets (commodity markets and ancillary services markets for balancing) in such a way that demand response flexibility will be able to participate. However, in the demonstration of the EcoGrid 2.0 project, no frequency control or other ancillary services for the TSO will be included, and only one balancing service for the BRP will be considered.

Besides, EcoGrid 2.0 also incorporates detailed market processes, similar to the USEF framework. The main difference here is that in the EcoGrid 2.0 framework, the validate phase, where the DSO check the plans of the BRP and aggregator, is absent. In the EcoGrid 2.0 project, this possibility is replaced with a parallel market where the DSO can buy flexibility services.

The EcoGrid 2.0 proposes a solution for the unbalance in the BRP portfolio created by activating flexibility. A bilateral contract, settling any financial compensations between aggregator and BRP, will have be established at all connection points where the aggregator is active. Any arrangement with the supplier is out of scope for EcoGrid 2.0. A method for verification and settlement is defined, together with a method to define the baseline.

### *2.4.3. Demonstrations*

The goal of the EcoGrid 2.0 project is the demonstration of the flexibility market in the Danish Bornholm island.

## 2.5. Incorporated services for flexibility

Flexibility can offer several services which can be categorized into 22 different types of services that can be offered to four stakeholders: the prosumer himself, the DSO, the BRP and the TSO. Table 4 presents these services, together with an overview of which are included in the different frameworks discussed. The USEF Scope encompasses the most services, however, not all of them are already fully specified. The services that have got detailed specifications in USEF until now, are stated in the column USEF 2015 coverage. For more information regarding the description of these services, see [9].

*Table 4: Overview of different services and scopes of the described frameworks.*

| Customer | Ref | Service | Traffic Light | FLECH | EcoGrid 2.0 | USEF Scope | USEF 2015 coverage |
|---|---|---|---|---|---|---|---|
| **DSO** | D1 | Congestion Management | Y | Y | Y | Y | Y |
| | D2 | Voltage Control | Y | Y | Y | Y | N |
| | D3 | Grid Capacity Management | Y | Y | Y | Y | N |
| | D4 | Controlled Islanding | N | N | N | Y | N |
| | D5 | Redundancy (n-1) Support | N | N | N | Y | N |
| | D6 | Power Quality Support | N | N | N | N | - |
| **BRP** | B1 | Day–Ahead Optimization | N | N | N | Y | Y |
| | B2 | Intraday Optimization | N | N | N | Y | Y |
| | B3 | Self / Passive Balancing | N | N | Y | Y | Y |
| | B4 | Generation Optimization | N | N | N | Y | Y |
| **TSO** | T1 | Primary Control | N | N | N | Y | N |
| | T2 | Secondary Control | N | N | N | Y | N |
| | T3 | Tertiary Control | N | N | N | Y | N |
| | T4 | National Capacity Market | N | N | N | Y | N |
| | T5 | Congestion Management | N | N | N | Y | N |
| | T6 | Grid Capacity Mgmt | N | N | N | Y | N |
| | T7 | Controlled Islanding | N | N | N | Y | N |
| | T8 | Redundancy (n-1) Support | N | N | N | Y | N |
| **Prosumer** | P1 | ToU Optimization | N | N | N | N | - |
| | P2 | KWmax Control | N | N | N | N | - |
| | P3 | Self-Balancing | N | N | N | N | - |
| | P4 | Controlled Islanding | N | N | N | N | - |

# 3. The aggregator

In all frameworks, the aggregator is a key actor to provide flexibility. Generally speaking, the aggregator builds up relationships with prosumers that own controllable assets. The aggregator builds a portfolio of assets to meet the size and timing constraints of specific flexibility products. The Aggregator may choose to specialize on a single flexibility product or serving multiple products with the same portfolio.

As the aggregator naturally influences the positions of the BRP and the supplier associated with the customer, some kind of solution need to be in place. One option is a contractual relationship between the aggregator and BRP/supplier. However, this would limit clearly the market entry possibilities for new aggregators. Therefore, USEF defines the concept of *The Independent Aggregator*, defines that no contractual relationship with supplier or BRP of the customer is needed. However, a second BRP associated with the aggregator is needed. This is the flex-only balance responsibility model or simply Flex-BR model.

USEF allows for different business models, and combining different roles into one business, such as:

- Aggregator-supplier
- Aggregator-BRP
- Aggregator as service provider
- Delegated aggregator
- Prosumer as aggregator
- Aggregator based on Flex-BR model
- Charging Station Operator or E-mobility Service Provider as aggregator

FLECH does not define more specifically the role of an aggregator, nor any contractual relationships.

The traffic light concept of BDEW does not further specify the role of the aggregator.

In the EcoGrid 2.0 project, a bilateral contractual agreement between aggregator and BRP is needed for settling imbalances created by the activation of flexibility. Aggregators will likely require to agreements with several BRPs, as each metering point could have a separate BRP associated. In the project, the aggregator will provide a day-ahead load schedule and notifications of DSO flexibility activations to the BRPs of its portfolio. The BRP can also request to reserve flexibility form the portfolio of the aggregator.

## 3.1. Baseline methods

The service provided to the DSO has to be quantifiable and measurable. Otherwise, the aggregator is unable to prove that a contracted service has been provided. One approach is through introduction of a baseline concept. A definition of a baseline can be expressed as:

> *"A baseline is the consumption (or production) trajectory a DER will exhibit, if it is left running without any external control interference."*

The challenge is now, how can knowledge about the baseline be established. Both USEF, FLECH and EcoGrid 2.0 have proposed baseline methods for the aggregator.

*Table 5: Overview of the baseline methods.*

| Framework | Baseline Method |
|---|---|
| **FLECH** | The approach followed in the FLECH Technical requirements [6] is referred to as the contractual baseline. The basic idea is as follows:<br>• When FLECH clears the market, the winning aggregators are identified.<br>• For each aggregator portfolio, FLECH requests historical data from the DSO and establishes a portfolio baseline. These portfolio baselines will become a part of the contracting process with the winning aggregators (i.e. the contractual baseline).<br>• If flexibility of an aggregator is activated, the aggregator can establish a portfolio schedule based on the baseline less the offered volume. This is how the provision eventually will be checked and verified during settlement.<br>The contractual baseline is based on historical data from any given DER in a portfolio. FLECH is responsible for a robust, operational and transparent definition of the contractual baseline. Furthermore FLECH is responsible for dissemination of how to calculate the contractual baseline. |
| **USEF** | According to USEF, the baseline must be set in such a way that all stakeholders can agree to it. Otherwise, the settlement of flexibility transactions becomes impossible or at least many settlement disputes will arise, making the whole process unmanageable. The baseline must furthermore be set by an independent actor in the system who has zero interest in the flexibility. Otherwise, opportunities for gaming and market manipulation may be introduced.<br>The A-Plan and D-prognosis act as the baseline for the trading of *UFLEX*. The way an independent verification should be incorporated in the framework is still under discussion.<br>There are several methods for defining the baseline, but there is no one-size-fits-all methodology that meets the requirements for each combination of flexibility service and flexibility source. USEF therefore proposes to categorize flexibility services and sources based on similar characteristics and to define the requirements for the baseline method in terms of precision, integrity, flexibility, reproducibility, and simplicity. This enables us to standardize the baseline methodologies and ensure that the chosen methods will be broadly accepted by the market. This approach makes the process transparent and provides the market with the necessary confidence to make the settlement of flexibility possible. |
| **EcoGrid 2.0** | In the EcoGrid 2.0, consumption of flexible DER units will not be metered separately, and thus only aggregator can be controlling all flexible resources of the customer. In this case, the aggregator will be responsible (instead of the BRP) for forecasting the entire consumption of the metering points. In the case that the aggregator does not respond to day-ahead signals, the load schedule and baseline definitions are the same. In the EcoGrid 2.0 demonstration, it is expected that flexibility will not be used in the day-ahead market and therefore, the baseline used in the EcoGrid 2.0 project will be the same as the load schedule of the aggregator. |

## 3.2. Transfer of Energy

The transfer of energy is an important concept when trying to define flexibility markets. As an activation of flexibility by an aggregator at a consumers site inevitable leads to a change in balancing position of the BRP associated with this consumer, and the sourced energy of the supplier, they will need to be compensated for this.

However, of the four frameworks described above, only USEF and EcoGrid describe a mechanism for the transfer of energy. Both the traffic light concept and FLECH do not have any recommendations about this. The FLECH framework does state that, by having the closing time of the DSO activation market before any spot, intraday or balancing markets, priority is given to the DSO market, and the other markets could take the sold flexibility to the DSO into account.

USEF on the other hand takes on three different approaches to the problem, in its paper A*n Independent Aggregator* [15]:

1. *A Regulated Model:* the DR operator and supplier act independently, and the DR operator pays the supplier an amount determined by regulation. The flexibility activation is corrected in the BRP perimeter by a third party.
2. *A Corrected Model:* In this case, the customer's metering data are corrected from the curtailed *en*ergy. Payment and BRP perimeter adaptation is realized through the metering data correction.
3. *A contractual model:* The DR operator and supplier make a contractual agreement of payments.
4. *Virtual Transfer Points:* based on sub-metered locations behind the connection point. In this case, flexibility resources have a separate meter and thus can have a supplier and BRP of the aggregator – different than the rest of the load on the connection point.

In the EcoGrid 2.0 project, a bilateral agreement between aggregator and BRP is needed as explained above, settling a transfer of energy when needed. Any arrangements with the supplier are out of scope of the EcoGrid 2.0 project.

# 4. Detailed market processes

## 4.1. Traffic light concept

In its traffic light concept, BDEW has elaborated a practical example of how the DSO can use the flexibility. In a first stage, the supplier or aggregator needs to have a flexibility supply agreement with the end customer and a supplier framework agreement with the DSO. This makes the distribution network operator aware of and contractually guarantees the flexibility potential. Then, depending on the colour and thus state of the grid, the flexibility can be activated, following the processes depicted in Figure 10.

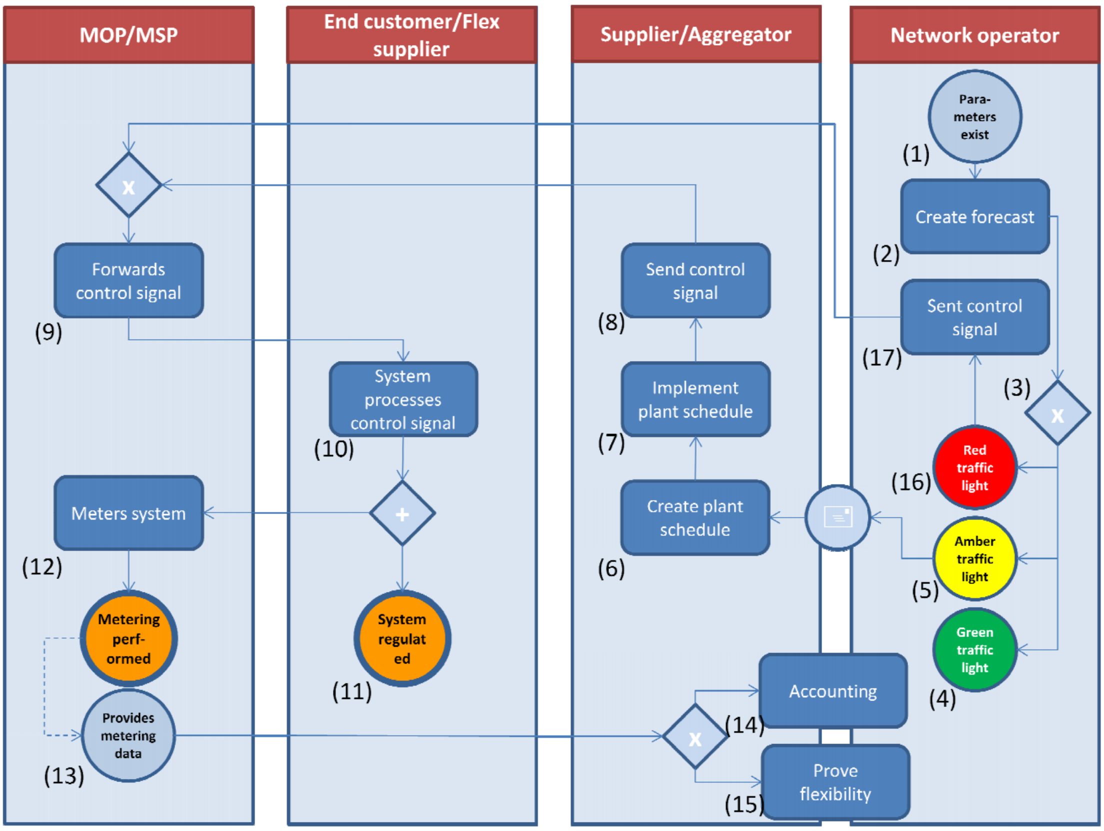



*Figure 10: Process of using flexibility in the traffic light model [3].*

## 4.2. FLECH

FLECH defines four distinct phases in which the DSO and the aggregator interact, as depicted in Figure 11. The FLECH clearing house will carry out the functions that are central in the green block.

- **Planning:** The DSO uses all available information to forecast the state of his grid. Based on his needs, the DSO request flexibility services. At the same time, the Aggregator forecasts the activation of his flexibility portfolio and the remaining flexibility he can still offer as DSO services.
- **Scheduling:** The DSO evaluates the offered flexibility, and updates his planning tools with the scheduled services. The aggregator takes the winning bids and converts them into operational schedules.

- **Operation:** The DSO evaluates the need real-time need for flexibility and activates the contracted services if necessary. The aggregator executes any activated flexibility from the DSO.
- **Settlement:** The DSO evaluates grid performance based on metered data. Performance can be analysed and settlement can be verified and finalized based on the contractual baseline. The Aggregator will do settlement with the involved DER portfolio. If requested by the DSO, the Aggregator will send documentation of DSO service provision to the DSO.

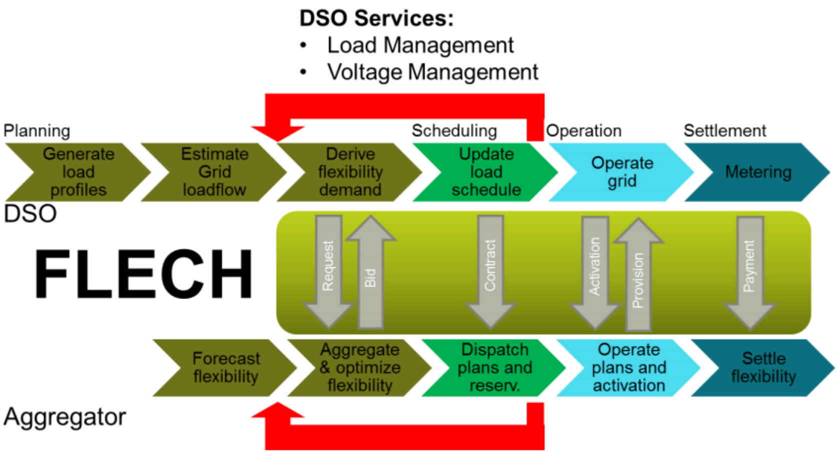



*Figure 11: Overview on the FLECH interaction between DSO and aggregator*

### *4.2.1. Capacity Reservation Market*

As explained before, FLECH defines two market that operate at two different timescales. The Capacity Reservation market works on a long term time horizon, closing about 6 months before actual delivery of flexibility, and should allow the DSO to make the decision between investing in grid reinforcement and using flexibility.

Figure 12 shows the processes in the capacity reserve market in case of a successful clearing. FLECH will use merit order when the clearing is performed.

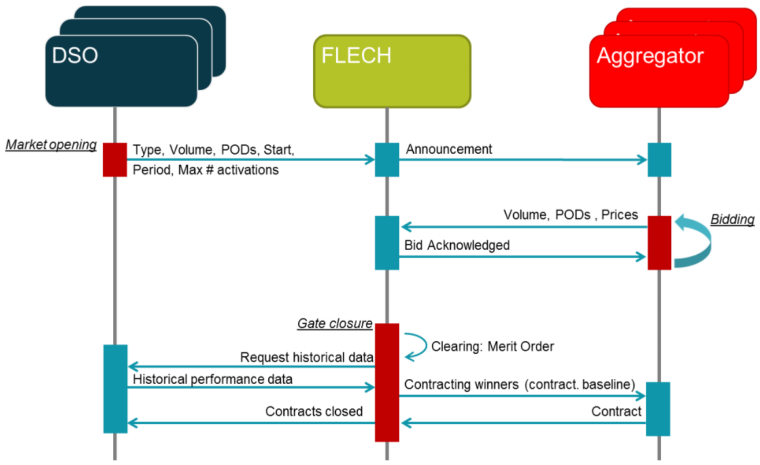



*Figure 12: Overview diagram of the bidding and clearing processes in the Capacity Reserve Market [6].*

### 4.2.2. Reserve Activation Market

The processes occurring in the reserve activation market, shown in Figure 13, are similar to the ones of the capacity reservation market. However, the DSO sets a maximum activation price in this market: the activation price of the won contract in the capacity reservation market. However, is an aggregator is able to offer an activation at a cheaper price, FLECH will award the activation contract to this aggregator.

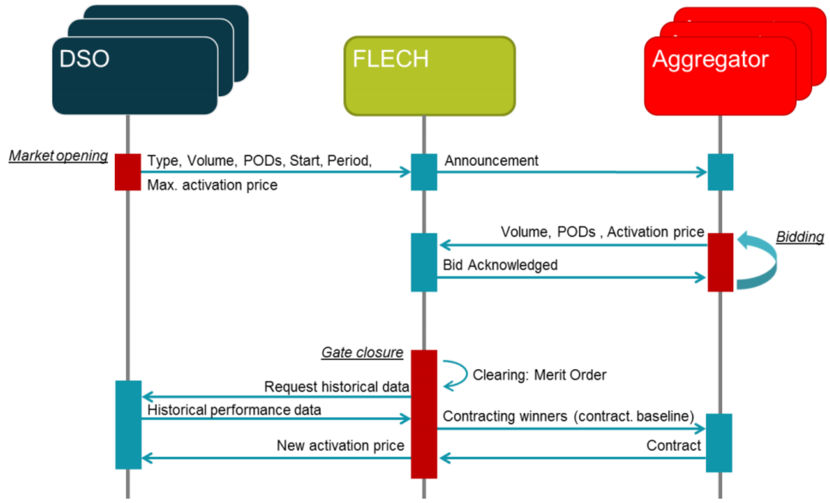



*Figure 13: Overview diagram of the bidding and clearing processes in the Capacity Reserve Market [6].*

## 4.3. USEF

USEF describes all market processes in great detail in their specifications document [10]. As explained above, the USEF market process consists out of 5 phases: contract, plan, validate, operate and settle. In the plan phase, the aggregator is able to trade flexibility with the BRP. This results in a so-called *A-plan* with the forecast of the aggregator, and an *E-program* with the forecast of the BRP. The E-program is sent to the TSO for validation. The interaction between BRP and aggregator in the plan phase are depicted in Figure 14.

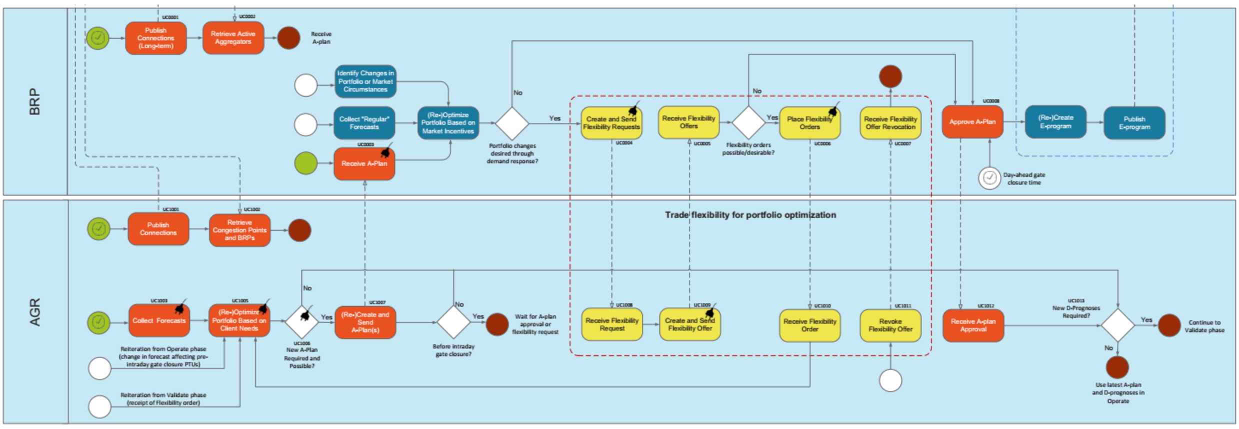



*Figure 14: Interaction between BRP and aggregator in the Plan phase [10].*

The validate phase, Figure 14, consists of two intricately linked processes, executed in parallel by different market roles: the *Validate-D* and *Validate-E* processes. In these processes, the draft *D-prognosis* and draft *E-program* that result from the plan phase are validated by the DSO and TSO respectively. The *Validate-E* process, performed by the TSO, is an existing process, which is already in practice in many countries. USEF is designed in such a way that the *Validate-E* process is not altered. The draft *D-prognosis* is created by the aggregator per declared congestion point of the DSO. The DSO analyses the submitted *D-prognosis*, and evaluates if the limits of the distribution grid are going to be reached. If flexibility is needed, the DSO procures this flexibility, and the *A-plan* of the aggregator will have to be changed. Therefore, the validate phase is iterative with the plan phase, until the *A-plan* and the *D-prognosis* are aligned.

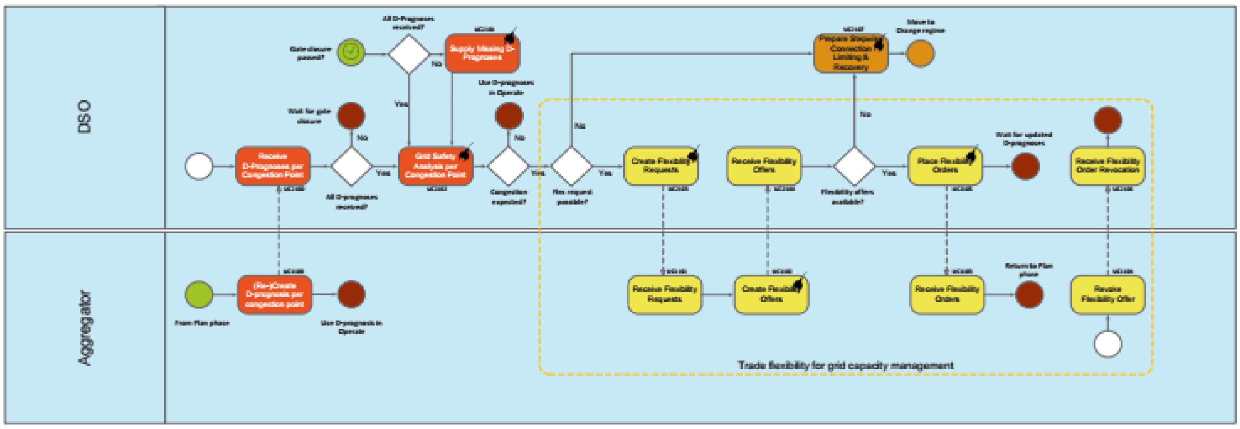



*Figure 15: Process flow of the Validate phase. New processes are depicted in red. Processes depicted in yellow refer to the grid capacity management regime [10].*

## 4.4. EcoGrid 2.0

Figure 16 depicts the detailed market processes and messages defined in the EcoGrid 2.0 project. As explained above, two clearing houses exists, one containing the new congestion market for the DSO and one the adapted existing markets. In Figure 16, the new congestion market is displayed left, while the adapted existing market is right.

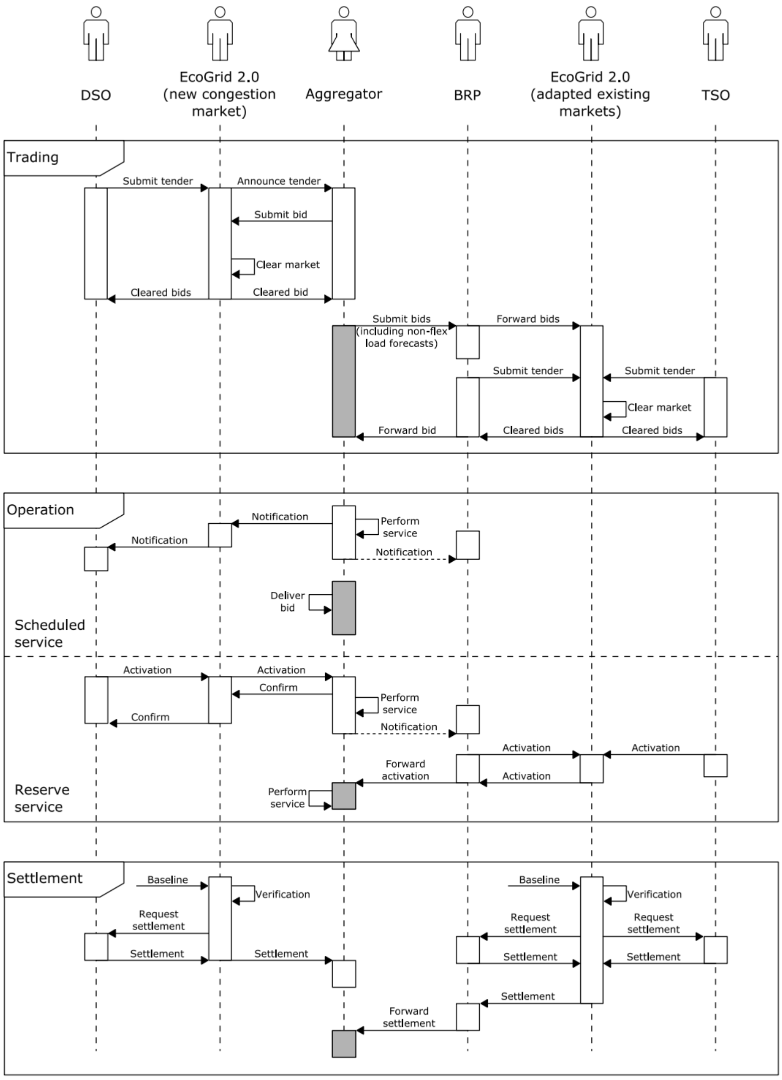



*Figure 16: Detailed market processes of the EcoGrid 2.0 concept. Gray blocks indicate aggregator actions in the TSO market. [12]*

# 5. Control of local flexibility

Accessing the flexibility provided by flexibility assets requires a dedicated information structure and control protocols. USEF assumes a standardized setup linking the aggregator, the prosumer, and the flexible DERs. This guarantees independence between the flexible DER products and the aggregator's services and hence prevents vendor lock-in from either side. Moreover, a standardization of interfaces is a vital component of ensuring a low cost-to-connect and a low cost-to-serve. A basic setup as defined by USEF is shown in Figure 17.

FLECH nor the traffic light concept of BDEW specify any interface with appliances. EcoGrid 2.0 will use the infrastructure of the EcoGrid EU project [13].

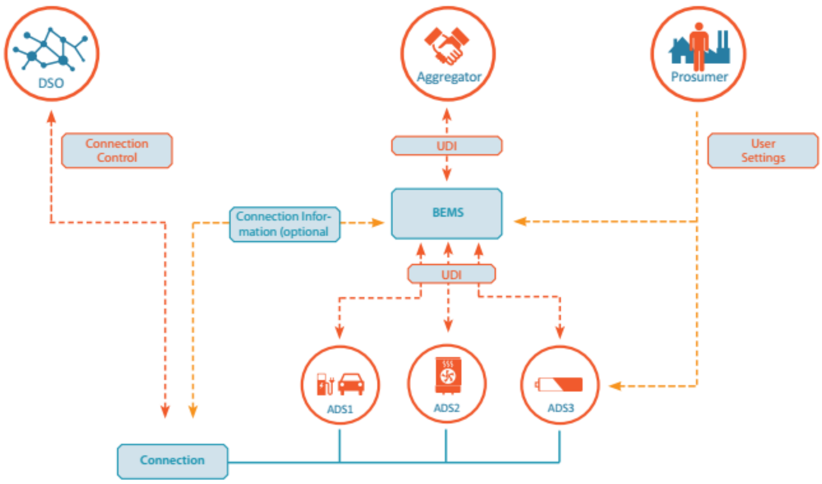



*Figure 17: Basic setup at the Prosumer's premises, as defined in the USEF framework [9].*

Chapter 10 of the SmartNet deliverable "D3.1: ICT requirements specifications" [16] provides an excellent overview of information standards and protocols. This section focuses on a selected set of protocols and interfaces to control local flexibility. The selection is based on popularity of the protocol within the industry and on work currently going on in standardization.

## 5.1. Flexibility trading protocols

### 5.1.1. OpenADR

Open Automated Demand Response (OpenADR) is an open and standardized way for electricity providers and system operators to communicate DR signals with each other and with their customers using a common language over any existing IP-based communications network, such as the Internet. As the most comprehensive standard for Automated Demand Response, OpenADR has achieved widespread support throughout the industry. OpenADR 2.0b is published by the IEC as a Publicly Available Specification IEC PAS 62746-10-1:2014.

In this aspect, USEF and OpenADR have signed a memorandum of understanding that enable the two organizations to cooperate [17]. As USEF defines a market framework with roles and interactions, it can clearly integrate the OpenADR standard of communicating with demand response devices.

OpenADR uses the definitions of Virtual Top Nodes (VTNs) and Virtual End Nodes (VENs). Generally speaking, a VTN acts as the server, providing information to the VEN, which themselves respond to the information. For instance, a VTN would be the entity to announce a DR event; VENs hear about DR events and respond. The response may be to reduce power to some devices. The response could also be to propagate the signal further downstream to other VEN's. In this case, the VEN would become the VTN for the new interaction [18]. An example of VTN and VEN relationships is depicted in Figure 18.

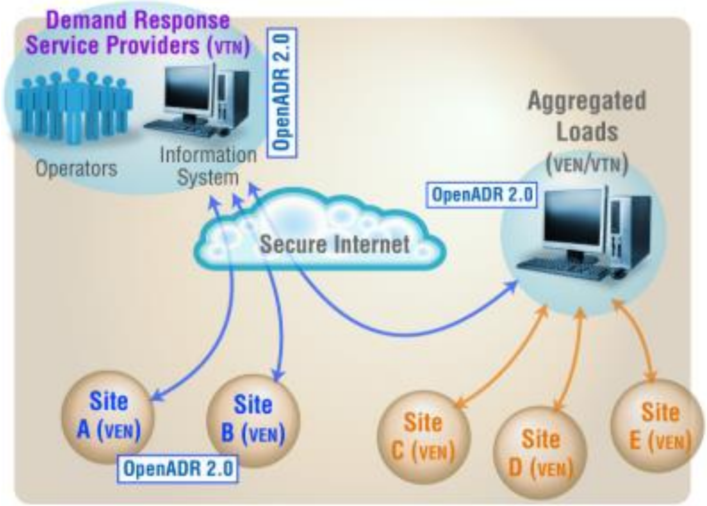



*Figure 18: Example of VTN (virtual top nodes) and VEN (virtual end nodes), as defined by OpenADR. [18]*

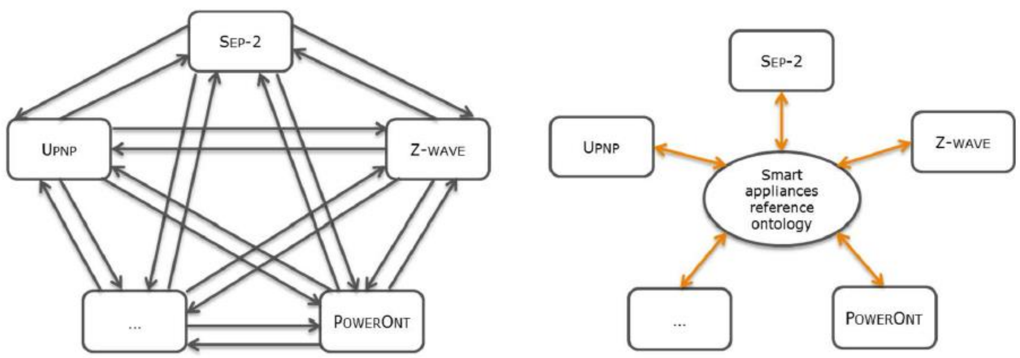
### 5.1.2. SAREF and SAREF4ENER ontology

To address the issue of the multiple overlapping and competing standards within the smart home - between the smart appliances and the home/building energy management system- the European Commission/DG CONNECT ordered a study on “Available Semantics Assets for the Interoperability of Smart Appliances: Mapping into a Common Ontology as a M2M Application Layer Semantics" [19].

The study resulted in the creation of a reference ontology of consensus called SAREF (Smart Appliances REFerence ontology) covering the needs of appliances related to energy efficiency, and expandable to future intelligence requirements. Subsequently SAREF was mapped on the ETSI M2M Architecture. The European Telecommunications Standard Institute (ETSI) participated actively in the process of SAREF creation and accepted to cover the communication aspect and provide the necessary standardization process support.

SAREF is conceived as a shared model of consensus that facilitates the matching of existing semantic assets in the smart appliances domain, reducing the effort of translating from one asset to another, since SAREF requires one set of mappings to each asset, instead of a dedicated set of mappings for each pair of assets (see Figure 19).

Figure 19: The role of SAREF in the mapping among different assets [20]




Different semantic assets share some recurring, core concepts, but they often use different terminologies and adopt different data models to represent these concepts. Using SAREF, different assets can keep using their own terminology and data models, but still can relate to each other through their common semantics. In other words, SAREF enables semantic interoperability in the smart appliances domain through its shared, core concepts.

Table 6 lists the ETSI SAREF and oneM2M base ontology related standards. ETSI released the second version of the SAREF standard (ETSI TS 103 264) in March 2017. The SAREF standardization work was also included in second release of the OneM2M initiative. SAREF standardization work contributed largely to the work and concepts of semantics and creation of its own oneM2M Base Ontology.

SAREF is the core model to connect smart appliances from all domains (environment, building, energy, health, transport,…). As different domains have different information needs, extensions of SAREF will be defined to tune the standard for a domain. An example of such an extension is SAREF4EENER. The EEBus initiative [21] and Energy@Home association [22] extended SAREF with mainly energy related use cases and named the extended version SAREF4ENER. SAREF4ENER is described in ETSI TS 103 410-1 V1.1.1. and specifies the capabilities at data model level to exchange energy and flexibility related data. For instance the power profile data element can be used to exchange a power profile of the last day, a requested power profile for the next day, and so on.

*Table 6: ETSI SAREF and oneM2M base ontology related standards*

| Standard | Release date |
|---|---|
| ETSI TS 103 264 V2.1.1: “SmartM2M; Smart Appliances; Reference Ontology and oneM2M Mapping”. | 03-2017 |
| ETSI TR 103 411 V1.1.1: "SmartM2M; Smart Appliances; SAREF Extension Investigation". | 02-2017 |
| ETSI TS 103 410-1 V1.1.1: "SmartM2M; Smart Appliances Extension to SAREF; Part 1: Energy Domain". | 01-2017 |
| ETSI TS 103 410-2 V1.1.1: "SmartM2M; Smart Appliances Extension to SAREF; Part 2: Environment Domain". | 01-2017 |
| ETSI TS 103 410-3 V1.1.1: "SmartM2M; Smart Appliances Extension to SAREF; Part 3: Building Domain". | 01-2017 |
| ETSI TR 118 517 V2.0.0: “oneM2M; Home Domain Abstract Information Model” | 09-2016 |
| ETSI TS 118 112 V2.0.0: “oneM2M; Base Ontology” | 09-2016 |
| ETSI TS 103 267 V1.1.1: “ SmartM2M; Smart Appliances; Communication Framework” | 12-2015 |

Although the SAREF ontology was originally focusing on smart appliances and the interface with Customer Energy Management system (CEM), a new follow-up study (2017) “Interoperability for Demand Side Flexibility” [23] has broadened the scope by including the interface from the CEM to the energy service company (ESCO). The results of the study will be published at the end of 2017.

SAREF is backed by the European Directorate General DG Connect and DG ENER.

### 5.1.3. SPINE/SHIP

Initiated by the EEbus Initiative e.V., and backed by the European smart energy / smart home-initiatives AGORA [24] and Energy@Home, EEBus defined a common data model and language, called SPINE, for the Smart Home.

SPINE stands for **S**mart **P**remises **I**nteroperable **N**eutral-message **E**xchange and defines a neutral layer which helps connecting different technologies to build a smart home system. SPINE defines the messages and procedures on application level (ISO-OSI layer 7) and is independent from the used transport protocol. SPINE covers use cases concerning every kind of control and monitoring of smart appliances, with a focus on the sectors of smart energy, smart home & building, connected devices and E-Mobility. SPINE can be considered a technical realization of the SAREF/SAREF4ENER ontology.

Similar to SAREF in the previous section, SPINE is extending its initial scope, viz white goods, by including energy storage, HVAC and eMobility (electric vehicle charging) into the scope. The work related to the whitegoods domain has been progressed the most and resulted in the SPINE specifications [25] and the draft/planned standards listed in Table 7, prepared by the WG 7 (Smart Household Appliances) of Technical Committee CENELEC TC 59X (Performance of household and similar electrical appliances).

*Table 7: prEN-50631-x standardization (status June 2017)*

| **Standard** | **Status** |
|---|---|
| prEN-50631-1: Household appliances network and grid connectivity - General Requirements, Generic Data Modeling and Neutral Messages .<br><br>*Part 1 defines general requirements, generic data modeling and generic neutral messages without relation to any specific communication technology or any product specific layout.* | Draft standard |
| prEN-50631-2-x: Household appliances network and grid connectivity - Product Specific Requirements and Specifications<br><br>*Part 2 lists and specifies product specific requirements and implementation guidance based on the generic data model and generic neutral messages.* | planned |
| prEN-50631-3: Household appliances network and grid connectivity – General Test-Requirements & Specifications<br><br>*Part 3 defines Test-Requirements and Test-Specifications.* | planned |
| prEN-50631-4-x: Household appliances network and grid connectivity – Technology Specific Implementation and Test Requirements<br><br>*Part 4 defines the mapping of neutral messages to examples of typical communication protocols like ZigBee, KNX, OIC, SHIP, Echonet light, Thread and so forth. These communication protocols are neither mandatory nor to be seen as complete spectrum of communication protocols.* | planned |

SPINE is split up in two parts: the protocol part, specifying the generic mechanisms to exchange SPINE information, and the resource model part, specifying the data model. SPINE is setup as a modular model, so depending on the appliance and the functionality modules can be added to or removed from the data model.

Smart Home Internet Protocol (SHIP) is the application protocol, defined by the EEBus initiative, on top of IP and based upon the SPINE specification. SHIP is the straightforward solution, but not every manufacturer will opt for this solution, as appliance and CEM manufacturers have well-founded preferences and interests. Another option is to incorporate the SPINE resources (data model) in other protocols like the Internet of Things (IoT) protocol from the Open Connectivity Forum (OCF) or the Thread protocol. The third option is to map every data model protocol used in the smart home to the neutral interface defined by SPINE. Any application on top of this interface is then independent of the used underlying data model and protocol. This is similar to the EFI (see next section) concept, except that SPINE is not constrained to flexibility applications and is more feature-rich than EFI.

### 5.1.4. Energy Flexiblity Interface (EFI)

EFI, developed by the Flexible Power Alliance Network (FAN) [26], defines a common language for energy flexibility. This allows smart appliances to communicate with Demand Side Management solutions without having to develop custom adapters/drivers for each combination. The intention is to provide an interface for communicating information about and only about energy flexibility and its allocation. These EFI messages relate to a single device, so no aggregated info can be exchanged via an EFI interface. In contrast to SPINE, which is feature-rich, EFI is a lightweight protocol with a minimal amount of information to describe the device's flexibility.

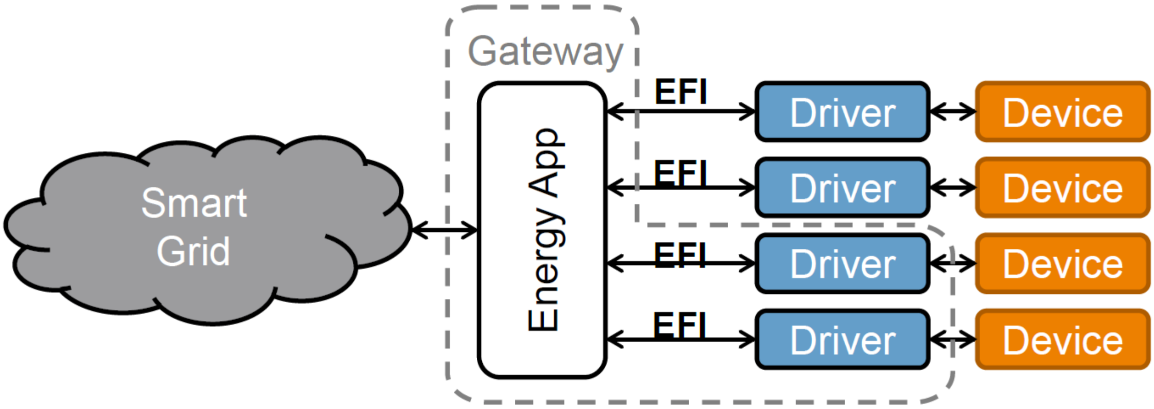



*Figure 20: EFI [27]*

The EFI categorizes Energy Flexibility in four different types:

- **Inflexible:** Has no actual flexibility, but is measurable and may provide forecasts. Examples of such devices are Photo-voltaic panels or domestic loads like a TV.
- **Time shiftable:** the application of the device process can be shifted in time. Examples of such devices are washing machines and dishwashers.
- **Storage:** these devices are flexible in production and/or consumption level, but are bounded by a buffer. Examples of such devices are freezers, CHPs, heat pumps, batteries and EV.
- **Output Adjustable:** these devices are flexible in production and/or consumption level and are not constrained by a buffer. Examples of such devices are generators or Dimmable lighting.

Besides the interface the Flexible Power Alliance Network offers also an open source software platform, called the Energy Flexibility Platform & Interface (EF-Pi), that incorporates the EFI interface, and PowerMatcher™, software providing a smart grid coordination mechanism to match supply and demand of electricity.

Although the FAN website and the open source development of the EF-PI platform doesn't show much activity the last year, the Flexible Power Alliance Network joined the CENELEC working group CLC/TC 205/WG18, Home and Building Electronics Systems to promote EFI. The EFI principles are incorporated in the high level architecture in draft EN 50491-12-1. The EFI details will be described in the 2nd part, CENELEC EN 50491-12-2.

### 5.1.5. IEEE 20305 / Smart Energy Protocol 2.0

The IEEE 2030.5 protocol (the IEEE adoption of Smart Energy Application Profile 2.0 / SEP2) is an application protocol aimed primarily at in house smart grid solutions, also called "home energy management". It supports concepts like demand response, load control, time of day pricing, management of distributed generation, electric vehicle charging, etc.

Although conceived by the ZigBee alliance the protocol runs on top of IP (Internet Protocol) and is independent of the underlying transport mechanism. The standard defines the mechanisms for exchanging application messages, the messages exchanged, and the security features used to protect the application messages. The protocol follows an IETF RESTful (Representational State Transfer) architecture in which clients use HTTP methods GET, POST, PUT, and DELETE to engage with servers hosting resources. The data model used by the protocol is based on the IEC 61968 common information model and the IEC 61850(-7-420) information model for DER.

The protocol is selected by the United States National Institute of Standards and Technology (NIST) as a standard profile for smart energy management in home devices. There are several pilot projects using SEP 2.0 in the US and in South Korea. It is not clear if many implementations of SEP 2.0 are currently deployed in Europe.

### 5.1.6. SunSpec

The SunSpec Alliance Interoperability Specifications [28] describe information models, data exchange formats and communication protocols used in distributed energy resource systems. The focus of SunSpec is on information models for the components comprising a solar plant. Among the supported devices are meters, inverters, panels, energy storage and charge controllers. The information models are inspired by the IEC 61850 information model. The information model structure has a flexible modular design, meaning an information model can be the combination of two or more models. A common model is always part of the information model.

The information models can be used to convey device data between any two communicating entities by mapping them to the communications protocol appropriate for the entities. SunSpec information models are communication protocol agnostic and can be mapped on different communication protocols.

## 5.2. Blockchain technology

Although not a flexibility trading protocol blockchain technology is mentioned in this document because it could have an impact on the flexibility trading architecture concept.

Blockchain can be regarded as an electronically distributed ledger. A distributed ledger is essentially an asset transaction database that can be shared across a network of multiple sites. All participants within a network can have their own identical copy of the ledger. Any changes to the ledger are reflected in all copies in minutes, or in some cases, seconds. The assets can be financial, legal, physical or electronic. The security and accuracy of the assets stored in the ledger are maintained cryptographically through the use of 'keys' and signatures to control who can do what within the shared ledger. Entries can also be updated by one, some or all of the participants, according to rules agreed by the network.

The uniqueness of this technology lies in the fact that blockchains are maintained by a shared or 'distributed' network of participants (so-called 'nodes') and not by a centralised entity, meaning that there is no central validation system; this is also called disintermediation. Transactions can be created collaboratively by multiple writers, without either party exposing themselves to security threats. This is what allows delivery versus payment settlement to be performed safely over a blockchain, without requiring a trusted intermediary. Another important feature of distributed ledger technologies (DLT) is the extensive use of cryptography, i.e. computer-based encryption techniques such as public/private keys and hash functions, to store, secure and validate asset transactions.

The blockchain technology has the potential to make trading processes far more efficient, lower the cost of trading, improve regulatory control and eliminate unnecessary intermediaries. Security, privacy, non-repudiation, traceability, immutability, availability are fundamental characteristics inherent to blockchain technology. Its decentralised approach and peer-to-peer architecture makes it very robust. A failure of a single node or even multiple nodes will not break down the entire system. Also, real-time processing, the capability to process mass data and payment/settlement as a by-product in the trading process are characteristics of this technology [29].

This technology has the potential to provide the fundamentals for a multi-market energy/flexibility trading domain coordination scheme. For instance, some roles might not be addressed by a business actor, but by smart contracts on top of the blockchain.

The blockchain technology has also shortcomings such as: the large amount of energy needed by the computational work for the proof-of-work; how to deal with dead data versus active data; performance compared to centralised databases; lack of privacy; visibility of transaction data; its use still requiring a common data format and communication protocol [30]. On the other hand, blockchain technology is not yet a mature technology. The use of blockchain in the energy domain is currently still in the very early stage. The technology is evolving rapidly and many players are experimenting with different blockchain variants.

However, this technology is regarded as a potential disruptive technology in many domains, including the energy domain with markets moving to a spot market. Blockchain could provide the transaction and control layer for the smart-grid.

## 5.3. Protocol applicability

OpenADR is a standard for demand response focused on commercial and industrial customers and on communication with entire premises. However, direct communication with end-devices at the customers' (also residential) premises is included in OpenADR 2.0. SEP 2.0, on the other hand, has traditionally focused on residential customers and on communication within the Home Area Network (HAN). OpenADR 2.0 has a more focused scope, meaning demand response, than SEP 2.0. The two standards can work together quite well, for example, using OpenADR to communicate from the utility to an Energy Services Interface (ESI)/Smart Grid Connection Point( SGCP), and then using SEP 2.0 to communicate from the ESI/SGCP into the home (see Figure 21).

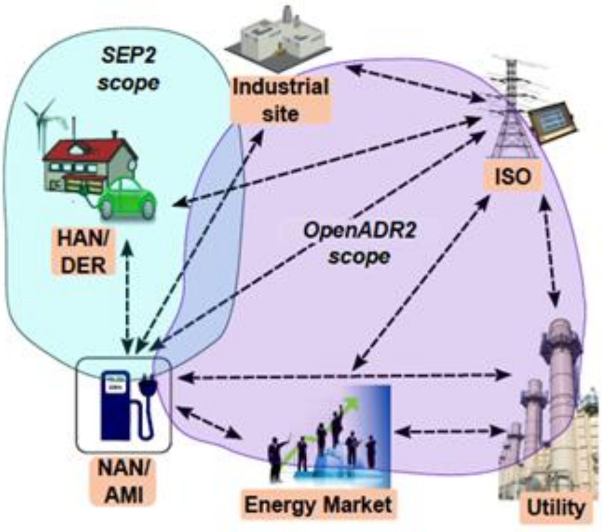



*Figure 21: SEP 2.0 versus OpenADR 2.0 scope [31]*

In providing a neutral information interface between the different communication domain specific network technologies (ZigBee, SEP, KNX,…) and the applications using this interface SPINE is similar to EFI, except that SPINE is a more feature-rich interface and not only focused on flexibility management. SHIP can be considered as SPINE on top of IP. In that way SHIP is a competitor to SEP 2.0. Actually the fact that the EEBus initiative is seeking collaboration with other (IoT) protocol alliances like Open Connectivity Foundation (OCF) [32] or Thread to incorporate the SPINE resources in these protocols, results in additional protocols that can be used between the CEM and the device agent/controller.

*Table 8: flexibility trading protocols*

| **Technology** | **Interface** | | | | |
|---|---|---|---|---|---|
| | Utility - Aggregator | Aggregator - CEM | Aggregator – Device agent | CEM – Device agent | Device – Device agent (mapping) |
| OpenADR | X | X | X | | |
| SPINE | | | | | X |
| SHIP | | | | X | |
| SEP 2.0 | | | | X | |
| PowerMatcher$^{TM}$ | | X | X | | |
| EFI | | | | | X |

A clear trend in standardization work regarding interoperability is the focus shift towards semantics (information layer). Also the fast evolving IoT world and related (big) data capturing and data analytics architectures have an significant impact on the energy domain. Standardization organizations from the energy domain and the telecommunications domain are collaborating to align information models and architectures in both worlds. This can also be noticed in commercial and research projects were technologies from the telecommunications/IoT world are combined with information models from the energy domain.

# 6. Callia flexibility architecture

In Callia the final aim is to develop "a grid operational management approach, based on local DSO area balancing and implementation of agent-based RES components, combined with improved DSO-TSO coordination supplemented with (cross-border) inter-DSO power exchanges".

The envisioned system architecture for WP2 aims to facilitate an advanced interaction scheme for electricity flexibility trading. Flexibility can be offered by expressing capability and willingness to deviate from the local optimal or expected power profile in return of a suitable incentive to compensate for the deviation. The envisaged system architecture (Figure 22) connects several energy resources (electrical storage, renewable energy sources and flexible loads) with cluster agents, cluster agents with aggregators and aggregators with the market.

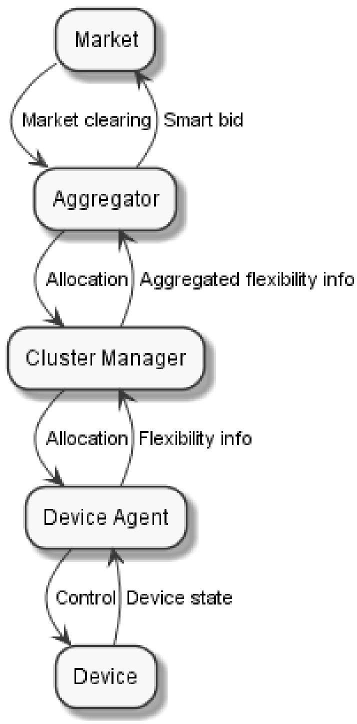



*Figure 22: Overview of the architecture*

At the bottom level, physical devices are connected to a device agent able to read out the status and features of the device and convert it into a generic flexible device representation. Device agents send their power profile to the cluster agent who aggregates them into one large virtual power profile.

The interaction between the aggregator and cluster manager, includes three steps(Table 9):

- Configuration - aggregator agent sends to the cluster manager information about the time window, time step and unit to be considered in the flexibility negotiation.
- Flexibility negotiation - this phase begins with the aggregator sending a flexibility request to the cluster manager. The flexibility request contains the number of fundamental offers to be provided by the cluster manager and corresponding variations (samples). A target flexibility profile may be included at this stage. In order to provide flexibility offers, the cluster manager asks device agents for their flexibility and aggregates it. The required number of fundamentals and samples is then selected according to some criteria. Cost is also computed at this step.
- Activation - at this step, a message is sent to the cluster manager asking for the activation of a specific power profile (trace). Cluster agent is then responsible to disaggregate the request to the correspondent device agents and assure that the agreed power profile is provided. Information to be exchanged between cluster manager and device agents includes the power profile.

*Table 9: Information to be included in the several steps.*

<table>
<tr><th colspan="2">Step</th><th>Information to be included at the different steps</th><th>Example</th></tr>
<tr><td colspan="2">Configuration</td><td>• Time window;<br>• Timestep;<br>• Unit concerning the flexibility requests.</td><td><code>Config: {'tracesDuration': 3600, 'stepSize': 900, 'unit': 'kWh'}</code></td></tr>
<tr><td rowspan="2">Flexibility negotiation</td><td>Request</td><td>• Number of flexibility offers to be provided by the cluster manager - fundamentals;<br>• Number of variations for each fundamental;<br>• Power profile to be achieved (not mandatory).</td><td><code>FlexRequest: {'target': None, 'id': 'ex123', 'numberOfFundamentals': 2, 'numberOfSamples': 5}</code></td></tr>
<tr><td>Offer</td><td>• Power profile of the flexibility offers - fundamentals (Figure 23) and variations;<br>• Unique identification for each fundamental;<br>• Cost of the fundamental</td><td><code>FlexOffer: [{'requestId': 'ex123', 'fundamentals': [{'id': 't1', 'traces': [-250.0, -250.0, 0.0, 0.0, -500.0], 'cost': 3.0, 'nodeId': 'node1'}, {'id': 't2', 'traces': [-250.0, 0.0, 500.0, -500.0, -500.0], 'cost': 9.0, 'nodeId': 'node1'}, {'id': 't3', 'traces': [250.0, 500.0, 250.0, -500.0, 0.0], 'cost': 6.0, 'nodeId': 'node1'}, {'id': '4', 'traces': [-250.0, -500.0, 0.0, -250.0, 500.0], 'cost': 6.0, 'nodeId': 'node1'}]}]</code></td></tr>
<tr><td colspan="2">Activation</td><td>• Identification of the selected fundamental</td><td><code>Activation: {"selectedFundamental": "t1"}</code></td></tr>
</table>

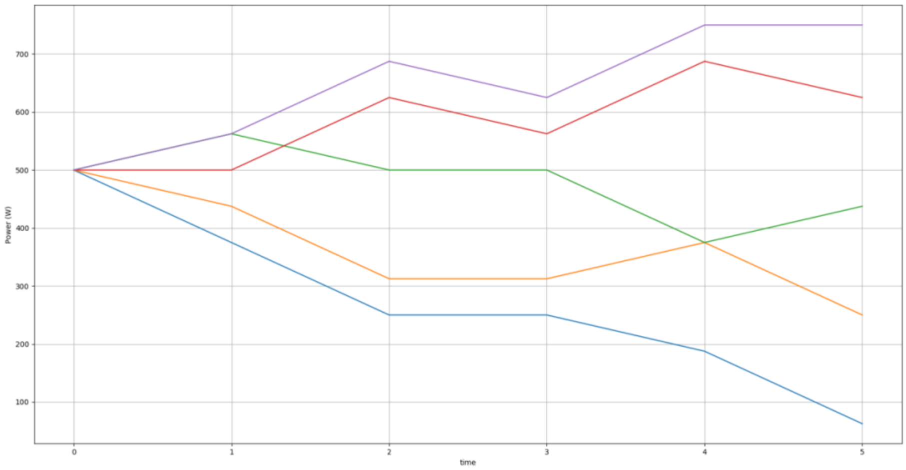



*Figure 23: Example of 5 traces*

# 7. Conclusion

The main aim of this deliverable was to give an overview and compare different frameworks that enable DERs to offer their flexibility to a distribution system operator, who can use it to enhance the operator of its grid and defer grid investments. More specifically, four concepts, the *traffic light concept, FLECH, USEF and EcoGrid 2.0* are described. Although they all address the same issue and there are quiet some similarities, they differ in solution, market structure, considered services and interaction with other market parties.

The most elaborated framework is USEF, which encompasses not only flexibility for the DSO, but also flexibility that can be offered to the BRP and interaction with the major other market players, specific market roles and advices towards business models that incorporate these roles. The traffic light concept, being more a concept than a completely elaborated framework that can be applied directly, has the smallest scope. However, the traffic light concept is basically integrated in USEF's operation framework, which also defines a normal state, a state where the DSO actively interacts in the market, and an emergency state, where the market is overruled by the DSO.

USEF, FLECH and EcoGrid 2.0 all separate the delivery of flexibility to the delivery of energy. However, in USEF there does not completely separate them and defines interactions between the flexibility supply chain and the energy supply chain. This in contrary to FLECH, that separates the DSO flexibility market completely from other markets, while it is not clear how the interaction with the energy and TSO ancillary services market will occur. EcoGrid 2.0 does consider interactions between the flexibility provider (aggregator) and the BRP or TSO (although the latter not in the real demonstration), however not as elaborated as USEF.

The market processes defined in the frameworks all follow more or less the same timeline (albeit with different names): contracting – planning – (validation) – operation – settlement, where the validation step is specific for USEF. In this step, the DSO validates if the schedules of the aggregator and BRP violate the distribution grid constraints. If this is the case, the DSO opens up a market for the use of local flexibility, and the aggregator and BRP goes back to the planning phase. However, it is not clear if this iterative process will converge and it is absent in the other frameworks.

Of the four frameworks, USEF is the only one who gives a solution to the possible transfer of energy needed and imbalance generated by activation of flexibility for local services. EcoGrid 2.0 only gives a limited solution for the imbalance generated, in the sense that a bilateral contractual agreement between aggregator and BRP is needed. In the FLECH and Traffic light concepts, this is out of scope.

The FLECH concept gives, with the definition of a long term Capacity Reservation Market and a short term Reservation Activation Market, a clear answer to the needs of the DSO, who has to choose between long term grid investments, or the activation of short term flexibility. It is not clear if in the other frameworks, the DSO is able to make this choice on an equal bases, as flexibility markets only operate on a short time frame.

An introduction to the information protocols for the control of flexibility is also provided together with a brief overview of the Callia flexibility architecture. This architecture will be elaborated more in report D2.3 "Validation of trading protocols".

# Bibliography


[1] Smart Energy Demand Coalition, „Mapping Demand Response in Europe Today 2015,” 2015.

[2] T. Deutsch, F. Kupzog, A. Einfalt en S. Ghaemi, „Avoiding grid congestions with traffic light approach and the flexibility operator,” in *CIRED*, Rome, 2014.

[3] BDEW, „Discussion paper: Smart Grid Traffic Light Concept,” Bundesverband für Energie- und Wasserwirtschaft e.V., Berlin, 2015.

[4] BDEW, „BDEW-Roadmap „Realistische Schritte zur Umsetzung von Smart Grids in Deutschland“,” Bundesverband für Energie- und Wasserwirtschaft, Berlin, 2013.

[5] J. Østergaard, L. Hansen, N. Nordentoft, P. Kjær, H. Madsen and P. Meibom et al., "White Paper Regarding iPower Vision and Stragey," iPower Project, 2012.

[6] L. H. Hansen, O. Sundström, S. Harbo en R. Villefrance, „FLECH - Technical Requirement Specification,” iPower, 2013.

[7] D. Nordentoft, C. Hansen en B. Brath et al., „Development of a DSO-market on flexibility services,” iPower, 2013.

[8] S. Harbo, L. Henrik Hansen en A. Birke, „FLECH - General Market Regulations,” iPower, 2013.

[9] USEF, „USEF: The Framework Explained,” USEF Foundation, Arnhem, 2015.

[10] USEF, „USEF: The Framework Specifications 2015,” USEF, Arnhem, 2015.

[11] „Rennovates,” [Online]. Available: http://rennovates.eu/. [Geopend 19 10 2016].

[12] „EcoGrid 2.0,” [Online]. Available: http://ecogridbornholm.dk/. [Geopend 17 Oktober 2016].

[13] K. Behnke en P. e. a. Eriksen, „Ecogrid EU—A prototype for european smart grids,” in *2011 IEEE Power and Energy Society General Meeting*, 2011.

[14] J. Mehmedalic, E. M. Larsen, D. E. Morales Bondy en A. Papakonstantinou, „EcoGrid 2.0 - Market Specification,” EcoGrid 2.0, 2016.

[15] H. D. Heer, „Position Paper: The Indepedent Aggregator,” USEF, 2015.

[16] R. R. a. others, „SmartNet D3.1 ICT requirements specifications,” 18 11 2016. [Online]. Available: http://smartnet-project.eu/wp-content/uploads/2016/12/D3.1_20161118_V2.3.pdf.

[17] „OpenADR - News,” [Online]. Available: http://www.openadr.org/index.php?option=com_content&view=article&id=141:openadr-and-usef-sign-mou&catid=21:press-releases&Itemid=121. [Geopend 06 10 2016].

[18] OpenADR, „OpenADR 2.0 - Profile Specification - A Profile,” 2011.

[19] „smart appliance study,” [Online]. Available: https://sites.google.com/site/smartappliancesproject/home.

[20] „ETSI TS 103 264 V2.1.1: “SmartM2M; Smart Appliances; Reference Ontology and oneM2M Mapping”,” 2017.

[21] „EEBus,” [Online]. Available: https://www.eebus.org/.

[22] „energy@home,” [Online]. Available: http://www.energy-home.it/SitePages/Home.aspx.

[23] „Ensuring Interoperability enabling demand side flexibility,” [Online]. Available:

https://ec.europa.eu/digital-single-market/en/news/study-ensuring-interoperability-enabling-demand-side-flexibility-smart-20160082.

[24] „AGORA," [Online]. Available: http://www.reseau-domiciliaire.fr/.

[25] „SPINE specifications," [Online]. Available: https://www.eebus.org/en/specifications/.

[26] „Flexiblepower Alliance Network," [Online]. Available: http://flexible-energy.eu/.

[27] FAN, „Introducing Energy Flexibility," 11 2016. [Online]. Available: http://www.google.be/url?sa=t&rct=j&q=&esrc=s&source=web&cd=1&cad=rja&uact=8&ved=0ahUKEwiwubWC-s7UAhWSUlAKHVXGDUcQFggjMAA&url=http%3A%2F%2Fflexible-energy.eu%2Fwp-content%2Fuploads%2F2016%2F11%2F161121_Introducing-Energy-Flexibility.pdf&usg=AFQjCNFGB9vrTz.

[28] „SunSpec Alliance," [Online]. Available: http://sunspec.org/.

[29] M. Merz, „ Potential of the Blockchain Technology in Energy Trading," 2016. [Online]. Available: http://www.ponton.de/downloads/mm/Potential-of-the-Blockchain-Technology-in-Energy-Trading_Merz_2016.en.pdf. [Geopend 11 1 2017].

[30] SmartNet, „SmartNet project: D3.2 ICT Architecture Design Specification," 2017. [Online]. Available: http://smartnet-project.eu/publications/.

[31] R. Kyusakov, J. Eliasson, J. v. Deventer, J. Delsing en R. Cragie, „"Emerging Energy Management Standards and Technologies - Challenges and Application Prospects", Proceedings of 2012 IEEE 17th International Conference on Emerging Technologies & Factory Automation," IEEE, 2012.

[32] „OPen Connectivity Foundation," [Online]. Available: https://openconnectivity.org/.

[33] CREG, „Studie over de middelen die moeten worden toegepast om de deelname aan de flexibiliteit van de vraag op de elektriciteitsmarkten in België te faciliteren.," 2016.

[34] Smart Grid Task Force, „Regulatory recommendations for the deployment of flexibility," Brussels, 2015.

[35] F. Geth, C. del Marmol, D. Laudy en C. Merckx, „Mixed-integer second-order cone unit models for combined active-reactive power optimization," in *IEEE International Energy Conference (ENERGYCON)* , Leuven, 2016.

[36] S. Nakamoto, „Bitcoin: A Peer-to-Peer Electronic Cash System," [Online]. Available: https://bitcoin.org/bitcoin.pdf. [Geopend 11 01 2017].

[37] D. Burgwinkel, „Blockchain technology. Einführung für business- and IT manager," de Gruyter GmbH, 2016.

[38] UK Government Chief Scientific Adviser, „Distributed Ledger Technology: beyond block chain," 2016. [Online]. Available: https://www.gov.uk/government/uploads/system/uploads/attachment_data/file/492972/gs-16-1-distributed-ledger-technology.pdf. [Geopend 11 01 2017].

[39] M. Merz, „Potential of the Blockchain Technology in Energy Trading," 2016. [Online]. Available: http://www.ponton.de/downloads/mm/Potential-of-the-Blockchain-Technology-in-Energy-Trading_Merz_2016.en.pdf. [Geopend 11 01 2017].

[40] R. R. a. others, „D3.1: ICT requirements specifications," 18 11 2016. [Online]. Available: http://smartnet-project.eu/wp-content/uploads/2016/12/D3.1_20161118_V2.3.pdf.