USEF: THE FRAMEWORK EXPLAINED

A solid foundation for smart energy futures

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Revision History

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FRAMEWORK EXPLAINED

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USEF a short summary

An integral market design for the trading of flexible energy use

USEF has been established to drive the fastest, most cost-effective route to an integrated smart energy future. It delivers one common standard on which to build all smart energy products and services. It unlocks the value of flexible energy use by making it a tradeable commodity and by delivering the market structure and associated rules and tools required to make it work effectively. USEF fits on top of most energy market models, extending existing processes to offer the integration of both new and existing energy markets. It is designed to offer fair market access and benefits to all stakeholders and is accessible to anyone internationally.

USEF is developed, maintained and audited by the USEF Foundation, a non-profit partnership of seven organizations, active in all areas of the smart energy industry: ABB, Alliander, DNV GL, Essent, IBM, ICT Automation and Stedin.

USEF key characteristics

Delivers smart energy market opportunities

Existing roles will be adapted and new roles will be created, some of which will be appealing to all kinds of organisations, from traditional suppliers to supermarkets . By defining the individual roles, how they interact and the resulting value, USEF helps to both understand and realize smart energy opportunities. By defining the individual roles, how they interact and the resulting value, USEF helps to both understand and realize smart energy opportunities.

Accelerates smart energy transition

By adopting USEF hence building on a common standard, projects are more rapidly connectable. Learning is shared, creating a faster route to best practice. USEF's exemplary coding and reference implementation provide the groundwork to accelerate innovation, integration and scaling.

Reduces costs

By delivering a common standard to build on, USEF reduces the cost to connect different technologies and projects to the energy system. Its market-based coordination mechanism then defines the rules required to optimize that whole system, ensuring that energy is produced, delivered and managed at lowest cost.

Connects smart energy products and projects

USEF's open IT architecture provides the freedom to create unique and commercially competitive smart energy products and services without vendor lock-in. It delivers a common standard on which to build, ensuring that all technologies and projects will be compatible and connectable to the future smart energy system.

Profitable for partners, project- and product developers

Smart energy demonstration projects adopting USEF will have increased relevance and impact. By building on one common standard and exchanging insights, implementations accelerate, future connectivity is assured and solutions are rapidly scalable. Smart energy product or service developers can apply USEF to gain early market share, developing unique products and services that will be connectable and cost-effective.

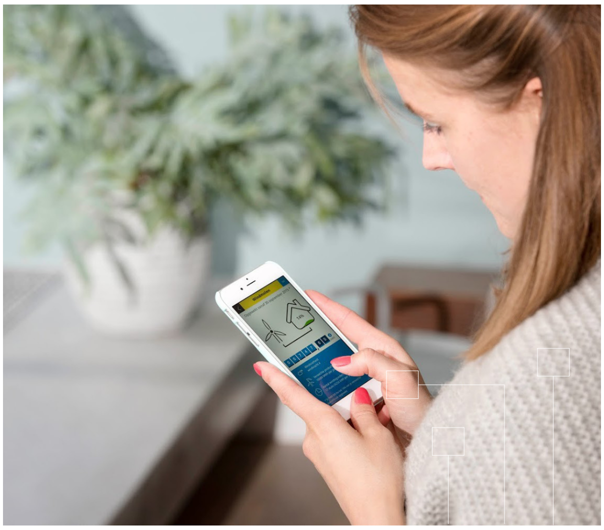
Sharing the outcome of our work

We believe that working together across roles and boundaries is the fastest route to a fair and integrated smart energy market. That is why the outcome of our work is free to download, for all to use, learn, build on and benefit from. Just visit our website www.usef.energy for more background information as well as our key publications:

- USEF: The Framework Explained
- USEF: The Specifications
- USEF: The Framework Implemented
- USEF: The Privacy & Security Guideline

Get Involved

With detailed specifications and the first real-life demonstration projects in the market, USEF is perhaps the most comprehensive, advanced initiative of its kind. Yet we want to expand our cooperation because we believe that working together across roles and boundaries is the fastest route to a fair and sustainable market. By getting involved with USEF, you can help to shape the integrated smart energy future.
If you want to get involved or would like further information, please contact us.



USEF: The Framework Explained

This publication describes the context and thought frame of USEF. First, in Chapter 1 we will address the need for a new market design and how flexibility can relieve stress in the energy system. Then we introduce the USEF Flexibility Value Chain, describing a generic way to access flexibility for multiple purposes and to serve a variety of stakeholders (chapter 2). Next the USEF framework is unfolding via the USEF roles model and the USEF interaction model (chapter 3). The basis for flexibility trading is the USEF market coordination mechanism, which is described in chapter 4. Chapter 5 provides an in-depth description of the Aggregator role, which is a key role in USEF. Different options for this role and different business models are discussed on expert-level.
This publication ends with a description about the control of devices (chapter 6), the USEF privacy & security aspects (chapter 7) and reference implementation (chapter 8).

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1 The need for a new market design

1.1 Trends in energy provision

There is a global drive to drastically reduce CO_2 emissions and to reduce our dependence on fossil fuels. This growing environmental awareness is leading us to cut down on the energy we use and to turn to renewable sources for what we do need. Fortunately, renewable energy is becoming more and more economically viable. An increasing share of it is derived from intermittent sources such as the wind and sun, making the energy system more highly dynamic. Even now, energy prices on the wholesale market run negative during peak times, so that energy consumption at these times is rewarded. In this way, the flexibility in energy consumption patterns is already being exploited. Effectively, the load on the system is starting to follow generation, which is completely opposite to the system's original design, in which large-scale generation units would be dispatched based on the current energy demand.

At the same time there is a growing demand for electricity, largely driven by the large-scale introduction of electric vehicles and other forms of electric transport and space heating by heat pumps. This increases the peak load on the system even further; however, these applications also offer excellent opportunities to provide flexibility to the market. Most vehicles are parked for more than 22 hours a day, and so the charging process can in many cases be spread out over the day. Similarly, space heating is a slow process in which the thermal buffering of buildings and storage vessels can be used to enable shifting the energy load over the day and adapting it to the availability of conventional or renewable power. To achieve this, applications need to know the energy system's actual conditions, so that they can adapt their behavior to support system optimization.

The price-performance ratio of electric vehicle battery systems has improved to the extent that the market introduction of electric vehicles has become economically viable. This trend will continue over the coming decade, driven by the commercial development of new battery technologies. Electric vehicle batteries provide a unique opportunity for the electricity system to store energy, which was until recently only possible using large-scale pumped storage hydroelectric units. This storage enables the local reduction of peak loads on the system, and hence a reduction in costs by limiting capacity usage. When sufficient storage capacity is installed, self-balancing and the trading of stored electricity can also be exploited. These storage systems provide another essential form of flexibility to the market and will gain greater public interest as the share of renewables increases.

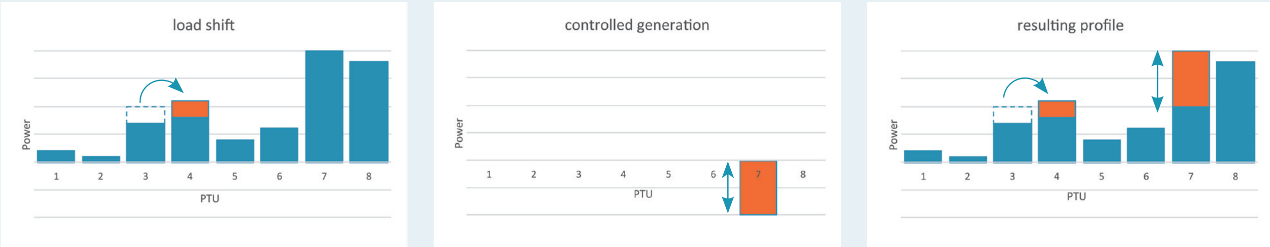
Energy conversion technologies, such as power-to-gas units and fuel cells, are also becoming market-ready. Power-to-gas units provide the opportunity to store excess power in the form of hydrogen and other renewable gases, or even take it a step further using gas-to-liquid processes. Storage needs will define which specific technology is desirable, depending on the balance between energy efficiency, storage time, volume, and price level. Similarly, fuel cells (such as those used in cars) can perform the reverse conversion to convert the stored energy back into power when it is most needed. New value chains will arise in the market that close these loops and integrate them into the energy system.

In addition to the development of these energy technologies, our society is digitalizing and giving rise to an Internet of Things. This is enabling the almost completely free exchange of information between any device and actor in the system. Since the balance between electricity supply and demand must be continuously maintained, these technologies will become crucial in optimizing and stabilizing the energy system. To that extent, all these systems will need to flexibly adjust their behavior toward one another to find the most optimal system performance.

Flexibility, the cornerstone of USEF

Electricity consuming devices and processes like heat pumps, domestic appliances, electric vehicles, HVAC systems, and industrial production processes can offer **flexibility** by changing their load profile. This is known as **demand response.** An electric vehicle for example could start charging earlier, because a wind front is coming up sooner than expected. The load profile would move forward in time. Alternatively, the charging process could be slowed down in case of grid congestion during peak times.

In USEF the definition of demand response is extended and also includes control of local generation units. The logic behind that is simple: on a system balance level the reduction of the load is identical to the increase of the generation. Hence it does not make sense to distinguish between these two options in the formal description if the system. Only the sign is relevant. Within USEF we join these two groups of applications to **Active Demand and Supply (ADS). ADS** also encompasses local storage units that can both deliver extra load while charging and extra generation capacity while decharging.



The picture above shows a simplified load profile of a residential Prosumer. Horizontally is the time in PTU, vertically the consumed power. Flexibility can for example be obtained by programming ADS's (e.g. a heat pump) to another point in time (left graph). Alternatively, another type of ADS (e.g. a local generation unit like a CHP) is able to reduce or increase the power (middle graph). The resulting profile, being the sum of the two ADS is shown in the right graph. Note that flexibility is always coupled to the underlying energy supply.

Although it is currently unclear how commercially successful each individual technology will be, taken jointly they are a disruptive development for the energy system. This development not only imposes completely new functionalities on the system; it also requires a complete redesign of our energy markets. Moreover, it creates a complete shift in existing players' positions in the energy market: for example, residential end users are no longer just consumers, but become power generators as well through their PV solar panels, micro-CHP systems, and fuel cells. They will dispatch these assets based primarily on their own needs, but without significant storage systems, it is unlikely they will be able to continuously balance their personal energy demand and production. This would, in fact, be undesirable, since it would leave their assets partly unutilized, resulting in unused economic potential. Hence they should be fully integrated into the energy market and be dispatched based on their position in the merit order of all generation facilities.

At present, these developments are expected to proceed relatively slowly—but what if, for example, fuel-cell cars become a commercial success? Their efficiency is rated higher than that of the power plant, and the total amount of power from all the car engines brought to market in one year exceeds total global power-plant generation capacity. Though this would not mean that our existing power plants would become obsolete within a year, it surely indicates that our energy system should be prepared to incorporate these technologies and let the market decide which of these solutions is the most cost-effective and sustainable one. Potential market barriers that obstruct this energy transition should be removed, and we should prepare our energy system for the twenty-first century. The vision of the European Union, on how-to transform our electricity system and be prepared for this future, is described in the next paragraph.

1.2 EU vision for the transition of the electricity system[1]

The European Climate Change Programme aims to provide reliable and affordable energy for all, to apply the efficiency first principle, and to make the European Union the global leader in renewable energy. The European Union's energy and climate objectives for 2030 are expected to increase the share of renewables to up to 50 percent of the electricity produced. Achieving these goals will require a fundamental transformation of Europe's energy system, including the redesign of the European electricity market, providing greater predictability, linking the wholesale and retail markets, and attracting further investments. This will contribute to delivering a new deal for Europe's energy consumers.[2]

Europe's electricity system is in a period of profound change. Since the adoption of the Third Internal Energy Market Package,[3] electricity policy decisions have enabled competition and increased cross-border flows of electricity. Wholesale markets are increasingly characterized by fair and open competition, and competition is also taking root at the retail level. With the introduction of market coupling and flow-based capacity allocation, electricity can be more efficiently traded across Europe. At the same time, electricity generated from renewable sources has become an important source of power, heralding a transition toward a low-carbon energy system.

These are all elements of a future-oriented energy system, but Europe still faces considerable challenges before its energy landscape is fit for purpose. To manage these changes and benefit fully from them, we must revisit the way Europe's electricity system and markets are organized and regulated. The existing market concept dates from an era in which large-scale, centralized power plants, largely fueled by fossil fuels, had the key aim of supplying every home and business in a limited area with as much electricity as it wanted, and in which consumers—households, businesses, and industry—were perceived as passive.

Today, the number of players involved is increasing and existing market roles are changing. The electricity market needs to adapt to this new reality; it needs to fully integrate all market players—including flexible demand, energy service providers, and renewables. One concrete example is the flexibility that enables industrial consumers to participate in the market and profit directly from increased competition. The market needs an effective regulatory and governance framework that reduces the need for interventions such as capacity mechanisms.

A fully functioning European market should allow electricity to move freely to where it is most needed, wanted, and valued. It should ensure that electricity is only dispatched based on market signals. Today's markets are not sufficiently flexible to integrate large shares of intermittent renewable energy sources, on either the supply side or the demand side. The new market design should ensure that energy markets can fully support this transition at minimum cost. A necessary step to achieve the successful and least-cost integration of renewables is to ensure well-functioning short-term electricity markets, running from the day before the delivery of electricity right up to the moment of consumption, which provide full access to flexible technologies.

Any revision of the market design must therefore create conditions that are conducive to further reducing the EU's energy consumption while allowing for the cost-effective integration of new types of flexible demand into the market. Moreover, new enabling technologies such as smart grids, smart metering, and smart-home, self-generation and storage equipment are empowering citizens to take ownership of the energy transition, using these new technologies to reduce their bills and actively participate in the market.

The EU's market design should ensure that the energy needs of large and small consumers can be met by innovative companies and reliable intermediaries across Europe. These entities should combine the opportunities offered by new technology with a focus on consumers to develop and deploy new products and services.

[1] This sections is a condensed version of chapter 1, COMMUNICATION FROM THE COMMISSION TO THE EUROPEAN PARLIAMENT, THE COUNCIL, THE EUROPEAN ECONOMIC AND SOCIAL COMMITTEE AND THE COMMITTEE OF THE REGIONS Launching the public consultation process on a new energy market design, COM(2015) 340. http://www.ipex.eu/IPEXL-WEB/dossier/document/COM20150340.do

[2] COMMUNICATION FROM THE COMMISSION TO THE EUROPEAN PARLIAMENT, THE COUNCIL, THE EUROPEAN ECONOMIC AND SOCIAL COMMITTEE AND THE COMMITTEE OF THE REGIONS Delivering a New Deal for Energy Consumers. EU COM(2015) 339. http://www.ipex.eu/IPEXL-WEB/dossier/document/COM20150339.do

[3] EU energy market legislation (Third package). See: https://ec.europa.eu/energy/en/topics/markets-and-consumers/market-legislation

To achieve this, the integration of the internal market should not stop on the wholesale level. To realize the full potential of the European internal energy market, the retail part of the electricity market has to offer consumers—households, businesses, and industry—the possibility of active and beneficial participation in the European Union's energy transition. This must be one of the goals of the new market design and requires a fundamental change in the role of the consumer on the electricity market.

1.3 Stakeholders

The trends and European requirements described in the previous section are relevant for all stakeholders in the energy system including the supporting technology industries. Each of them has an interest in the transformation toward a smart energy system[4]. In the following sections, we explore their interests and motivations.

1.3.1 Suppliers, balance responsible parties and producers[5]

Currently, the role of energy suppliers is to ensure that they can provide energy to their end users whenever they need it. Many industrial and commercial end users already produce part or all of their own power, and the top 100 of large industrial end users often manage their own positions in the energy market. As we have seen in section 1.1 the relationship between suppliers and their end users will completely change in the near future. Even residential end users will become prosumers—both producers and consumers of energy - and start generating power using solar panels, for example. They will store energy in battery systems in their homes and electric vehicles, and information systems will make the market transparent to them.

Ultimately customers' yearly net energy consumption will reduce down to zero. However, their instantaneous energy consumption and production will most likely not be in balance. That means that end users constantly need to compensate for their surplus or deficit in power. Various new business models are imaginable that form an ideal opportunity to step out of the current commodity market, where product and service differentiation is all but impossible.

The flexibility that end users' demand-response devices can provide is a blessing to the energy market. It provides a way to compensate for the intermittence of renewable energy sources. Doing so effectively requires accurate prediction models, making data the most important asset in the energy supply business of tomorrow. Suppliers with the most accurate prediction models and the algorithms to efficiently dispatch the right assets will gain the most competitive position in the market and make the most efficient use of the available flexibility to optimize their portfolios.

At the same time, suppliers will need to optimize their generation assets. This means they can use flexibility to reduce peak loads based on the end user's demand profile and hence prevent the dispatch of less efficient generation units—or perhaps even make them obsolete. Similarly, they can reduce their active and passive balancing costs by continuously optimizing their client portfolios and hence the complete set of all generation assets, including their customers' demand-response assets.

Suppliers can use their customers' flexibility to adapt their consumption profiles to the availability of renewable energy sources such as the wind and sun. This prevents the load curtailment of these generation units, significantly improving the business case for wind and solar power. Current wind and solar irradiation models especially lack accuracy on short timescales. This creates a need for flexibility on short timescales, ranging from several hours to several minutes, to compensate for these inaccuracies in prediction and balance out suppliers' portfolios.

[4] In chapter 3 a formal description of the market organization including the various roles, responsibilities and interactions is described.

[5] For the sake of simplicity the combination the actors that jointly form the energy supply chain: producers, balance responsible parties (BRP) and suppliers are combined and referred to as the supplier in this paragraph.

1.3.2 Distribution network operators and distribution system operators

Grid operators are responsible for ensuring that the energy in the system can flow freely between its suppliers and its consumers. This means they must guarantee that sufficient network capacity is always available. The construction of electricity grids with a long technical lifetime is a time-consuming activity with a high capital expenditure. To keep societal costs acceptable, the depreciation period is generally on the order of 30–50 years, and hence network capacity is well planned in advance.

Before we can introduce new functionalities and services on our networks, we should realize that today's distribution grids are designed for safety and reliability and provide one of the most stable infrastructures in our society. It will be societally unacceptable for innovative grid services to impact the performance of our networks. Hence new services and functionality will most likely only be adopted if they improve network stability even further. This requires extensive testing before such services are rolled out on a large scale.

The most apparent change our distribution networks are facing today is the introduction of smart meters, which enable tariff differentiation, reduce settlement costs, and provide insight to the end user. However, the trends described in section 1.1 impose a complete set of new requirements on distribution grids.

The most prominent issue to resolve is the increase in grid capacity demand caused by electric vehicles, electric heat pumps, and PV solar panels. Without incentives based on the actual local distribution grid load, the collective simultaneous response from end users' smart devices can increase the peak load on the system even further instead of relieving it. Though it is possible to increase grid capacity through grid reinforcements, this is a time-consuming and costly solution. Hence it would be wise if the flexibility provided by demand-response assets can also be used by grid operators to reduce the loads on their networks and prevent expensive grid capacity investments. As a result, the role of the distribution network operator (DNO) will change into that of a distribution system operator (DSO), who will need to actively manage the available capacity in its network and provide market services to do so.

However, the need to ensure sufficient capacity makes grid operators hesitant to exploit flexibility to reduce peak grid loads. To overcome this obstacle, the new energy system must guarantee that flexibility will be sufficiently available and that peak loads can always be reduced whenever required to maintain network stability. This guarantee should be provided on both the long term and the short term. In current energy market processes to schedule the upcoming period, operators are inclined to ensure the distribution capacity required to support the market as far as possible in advance. This may conflict with the needs of energy suppliers, who prefer to keep flexibility available up to the last moment so they can adapt demand to unpredicted changes in energy production and consumption.

Chapter **2** discusses other potential DSO services that arise in a smart grid environment and could benefit from flexibility. The common denominator among these services is that flexibility can be used to avoid grid infrastructure investments. The transformed electricity system demanded by the European Union requires that both suppliers and distribution system operators have access to the flexibility in the market; the solution must take into account the requirements on flexibility's timing and security of supply.

1.3.3 transmission system operators

Transmission system operators (TSOs) must ensure that sufficient network transmission capacity is available for energy to flow freely between its producers and its end users, while maintaining system balance. As the share of renewables increases, TSOs will play an even more active role in the power system than they do today. The intermittent character of these renewable energy sources, such as wind and solar power, requires a continuous optimization process to dispatch power plants throughout Europe in the most economical way. As a result, load flow patterns across the transmission grid are continuously changing. Under these volatile conditions, TSOs must ensure that transmission capacity and system balance are properly managed at every instant.

Currently, TSOs rely on the flexibility provided by large-scale generation units to furnish sufficient and guaranteed primary and secondary control power. As the share of renewables increases, more and more flexibility is needed. At the same time, the number of large-scale generation units is decreasing due to the shift toward small-scale, decentralized energy sources (often renewable). This means that the flexibility the current pool of generation units can provide is decreasing as well. Keeping some or all of the existing generation capacity online to provide this flexibility will result in its relatively low utilization, which in turn will result in high costs to provide balancing power. By providing smaller generation units and demand-response devices with access to the day-ahead and spot markets, part of these issues can already be resolved. However, this will not be enough as the share of renewables increases.

Another way to cancel out national imbalances in the system is to build a strong transmission grid throughout Europe, as shown by the EU's Roadmap 2050.[6] This enables shortages and surpluses of power to be averaged out throughout Europe and flexible assets to be shared across borders. It requires that the energy markets are fully integrated and that flexibility becomes tradable across European borders. To enable this transfer of flexibility and ensure that it can be settled in accordance with internationally accepted accounting principles, flexibility should be defined using a commonly accepted standard.

1.3.4 Prosumers

End users are more and more willing to actively contribute to a sustainable energy future and to invest in renewable energy production by installing PV solar panels or taking joint ownership of wind turbines. In addition, these citizens are working to reduce their energy bills by insulating their homes and making use of energy-efficient technologies such as heat pumps and A+++ freezers. To verify that these measures result in the expected savings, end users want insight into their energy bills, consumption, and production.

As these citizens become more energy aware and take ownership of power production assets, they transform from passive consumers into prosumers who want to actively participate in the energy market. To that end, many end users are starting to come together in a variety of innovative organizations. A typical example is the development of energy communities that seek to make their neighborhoods energy neutral.

The incumbent market players seem to be responding too slowly to these developments and having difficulty providing services that appeal to prosumers. Prosumers have fundamentally different needs than the classical end user; for example, they would like to charge their electric vehicles using the renewable energy generated by the solar panels on the roofs of their homes. To them it is irrelevant whether the car is parked at home or elsewhere; the network should be able to transport that energy to the vehicle. In principle, the flexibility inherent in the car's charging process could be used to automatically adapt its charging profile to the solar panels' generation profile.

End users are, in general, unaware of the current market structure and have no interest in the limitations of the existing market model. They want to have access to the system based on a level playing field and want to exercise their right to connect to the system, use their assets whenever they want, and buy and sell energy from anyone in the system. To achieve this, we must redefine the roles and responsibilities in the energy system so that the relevant energy services can be developed.

1.3.5 Aggregators and energy service companies

In the redesigned electricity market as the EU demands, new roles are introduced, such as aggregators and energy service companies (ESCos). Aggregators accumulate the flexibility they obtain from the demand-response resources owned by a set of industrial, commercial, and residential end users. This pool of flexibility is then turned into products to serve the needs of the various stakeholders, as described before. One advantage of aggregation is that these products provide reliable flexibility to the market by eliminating the risk of non-delivery inherent in depending on an individual prosumer. At the same time, aggregation prevents prosumer exposure to the risks involved in participating in the energy market.

ESCos provide ancillary energy-related services to end users, but are not directly involved in the energy and flexibility supply chain. These services can cover a very broad range. Two typical examples are the remote maintenance and operation of equipment, potentially including demand response devices, and information services to support on- or offsite energy management. Again, businesses might combine the ESCo and aggregator roles.

The customer base for these new market players will most likely be smaller than that of the incumbent energy suppliers. Hence the number of market players will increase significantly, requiring that market access conditions are standardized and certifiable. This will ensure that new market players can seamlessly participate in the market, without the prerequisite of complex market integration testing with all existing market players.

[6] Roadmap 2050 project by the European Climate Foundation (ECF). See www.roadmap2050.eu

1.4 Market solution rationale

Section 2.4 shows that there are multiple stakeholders with an interest in the flexibility resulting from Active Demand and Supply (ADS). Their interest in flexibility is formalized in the 18 flexibility services defined by the USEF Flexibility Value Chain (see 3). Each of them has its own purpose and characteristics in terms of timing, volume, location, accuracy, and so forth. Flexibility can be derived from various types of ADS from industrial down to residential. The challenge is to optimally divide the available flexibility over the different flexibility services at each point in time. What is considered 'optimal' may differ considerably among stakeholders.

A DSO for example would ideally like to see a flat load profile on its networks, so that the available network capacity is utilized maximally and grid capacity investments are minimized. A wind farm operator, however, would like to see its clients demand follow its volatile generation profile as closely as possible. Finally, a prosumer may just want to use energy whenever he desires, and not be limited in his behavior by whether the wind is blowing or what demand his neighbors are placing on the grid at the same time. It is clear that all these whishes cannot be fulfilled simultaneously. Somehow, these stakeholders must share the flexibility resulting from ADS.

What is optimal depends on the combined wishes of all the relevant stakeholders. These wishes are often competing and not equally important. The importance of each can only be assessed by the stakeholders themselves and will depend on the alternatives they have. Optimizing a smart energy system therefore requires weighing not only the importance of stakeholders' wishes, but also on each of the alternatives. These alternatives are often part of the energy system as well, such as delaying the charging of an electric car by a few hours. Sometimes, however, these alternatives lie in another domain, such as taking the bus or staying at home. The importance of the alternatives outside the system cannot be measured based on physical parameters within the system. This makes it impossible to design a control system that optimizes the division of flexibility over the various stakeholders based on physical parameters. Moreover, the alternatives may change over time, making the control system's scope undefined.

The only way to overcome this issue is to capture the importance of these wishes in a neutral parameter that expresses the value it has for each stakeholder. By monetizing this importance stakeholder wishes can be evaluated on an equal basis. This enables each stakeholder to compare the cost of the desired flexibility with that of the alternatives. This in its turn enables stakeholders to negotiate the price for the desired flexibility to the maximum that is defined by the costs of their alternatives. Stakeholders that are required to participate in a particular solution will automatically be compensated by those stakeholders that benefit most. This ensures that all stakeholders benefit and the optimal solution is created.

As long as each of the participants has a realistic alternative for which it does not need to negotiate with other stakeholders, it is possible to reach an optimal solution through free negotiations that satisfies all stakeholders, or at least to which they do not object to. For example a car owner might choose to charge his vehicle one time period later, when the price is lower, and take the bus or train now (one of his alternatives). In the long run the car owner may choose the alternative of switching aggregators or signing a standard fixed-price contract.

It is obvious that the negotiation process is complex, with a large number of stakeholders who must agree on how to optimally divide the available flexibility over the different flexibility services at each period in time. This complexity means the negotiation process must be facilitated. The most straightforward and commonly applied method in comparable situations is to use a market. Such a market should have the basic characteristics of an open market, i.e., it should provide a level playing field with fair rules, provide non-discriminatory access, be clear and predictable and moreover be transparent and sufficiently liquid. To this end information should be reliably communicated timely manner simultaneously to all users on a need-to-know basis while maintaining the level playing field and safeguarding the essential conditions for a liberalized market: freedom of connection, transaction and dispatch for everyone. The market should furthermore be scalable and replicable in scope, number of participants and locations.

Time dependent local tariffs, like time-of-use, dynamic or real-time-pricing for both commodity and local grid optimization are yet another option for exploiting the flexibility in the energy system. This is called implicit demand response. Its implementation can be relatively simple from a market point of view, but for an average end-user the resulting situation becomes far too complex to understand. Such a tariff scheme would apply to both an end-user's controllable and uncontrollable load. In principle uncontrollable loads could change their load pattern and end-users could change their behavior patterns but the financial benefits are so low that such price signals are ineffective for uncontrollable loads. As a result, the end-users pay a disproportional part of the costs to resolve the congestion and those who really contributed significantly to resolving it are barely rewarded. This results in a lop-sided distribution of the costs and benefits and fails to provide the right incentives to invest in demand response options, nor for the extension of grid capacity. And finally, such price models, are not scalable to the extent that they do not support optimizing the division of flexibility over numerous services as defined within USEF.

Overall, we conclude that flexibility is a product that truly differs from energy commodity and requires its own trading market. The trading of flexibility can be seen as a perturbation in the commodity markets dealing with short-term changes in the load pattern. Depending on the flexibility service, this trading, might have a localized character to resolve network congestions, for example.

1.5 Standardizing the technology

The transformation of the energy system into a modern, integrated system that meets the needs of all the stakeholders in the energy value chain requires the development of innovative energy products, services, and solutions. Large and medium-sized industrial companies can already profit significantly from the use of new (renewable) energy technologies and realize even more value if they adapt their energy production and consumption patterns to actual price levels on the energy markets. However, the lack of interface standardization means that medium-sized companies that are able to bring their flexibility to the market cannot easily switch suppliers or service providers.

New market players such as aggregators, energy service companies, and energy communities need access to the energy markets. Many of these market players will be significantly smaller than traditional players, and the number of parties active in the energy system will increase considerably. It is therefore essential to standardize market access for these new players; otherwise it will become impossible to serve them in a cost-effective way, and market conditions will become unmanageable.

A prerequisite for the large-scale market introduction of smart energy systems for small and medium-sized enterprises (SMEs) and residential end users is the commoditization of products, services, and solutions so that they become commercially viable; that is, it is essential to reduce the cost to serve those end users and reduce the cost to connect their appliances. Standardization of both market access conditions and interfaces will enable the mass production of the technology and IT systems required to build the energy system of the future.

1.6 The need for a universal smart energy framework

The transformation of the European energy system as envisioned by the European Union requires a redesign of the European electricity market, providing more predictability and enabling flexibility to be traded and executed. To that end, existing market roles will be adapted and new ones will be introduced. Together they can unleash the value of flexibility by unlocking even small flexible loads and bringing them to market. The role of an aggregator can add value by continuously optimizing the value of flexibility in interaction with the market. The aggregator will create scale, manage risks, and reduce complexity for the end customer.

A scalable, standardized market solution that is applicable throughout Europe is needed to ensure that the cost-to-serve and cost-to-connect are so low that, in the end, any source of flexibility can be tapped in an economically viable way. This requires an open standardization framework that prevents vendor, aggregator, and energy service providers lock-in and enables the commoditization of the required technology.

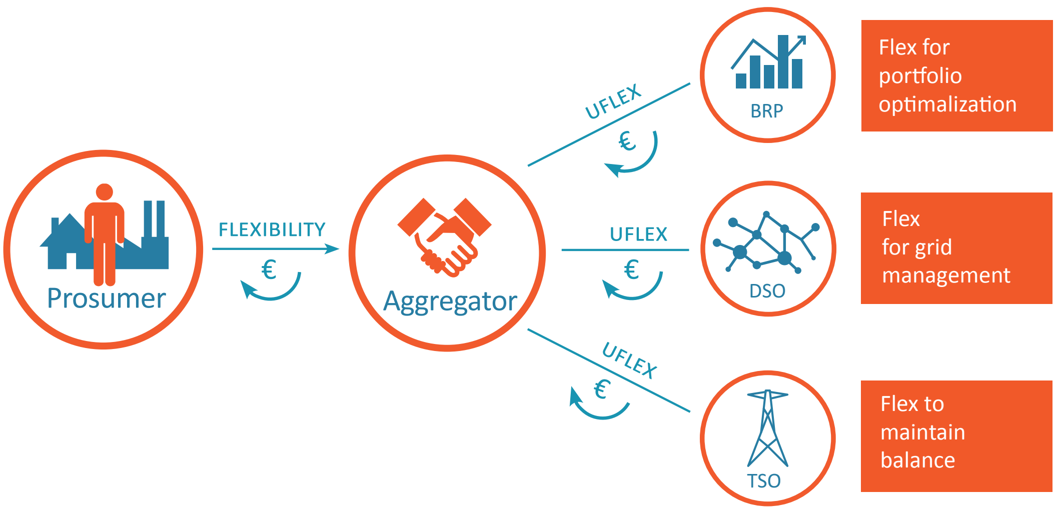
USEF delivers such a common standard and ensures that the value of flexibility can be maximized and transferred throughout Europe. Projects that build on this standard are rapidly connectable, which accelerates innovation, integration, and scale-up in the market for smart energy products, services and solutions.

2 Unlocking the value of flexibility

Demand response through load shifting and the storage and management of locally generated energy provide new means to unlock flexibility in the energy system. Within USEF this flexibility can be generically accessed for multiple purposes and used to serve a variety of stakeholders. This is called the ***USEF flexibility value chain***. Flexibility managed according to USEF's rules and guidelines is called **UFLEX**.

2.1 A central role for the Aggregator

USEF positions the Aggregator[7] centrally within the USEF 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. In return, the Aggregator receives the value it creates with UFLEX on these markets and shares it with the Prosumer as an incentive to shift its load. Through the Aggregator, Prosumers gain access to the energy markets.



USEF distinguishes four potential customers for the Aggregator's flexibility services:

1. The Prosumer
2. The Balance Responsible Party (BRP)
3. The Distribution System Operator (DSO)
4. The Transmission System Operator (TSO), which is indirectly served by the Aggregator through a BRP[8]

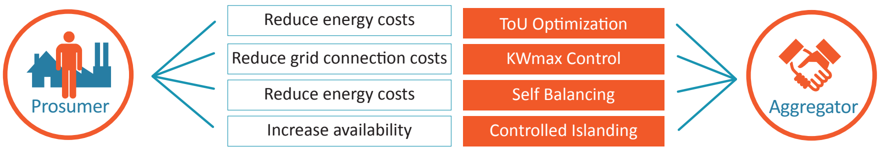
[7] In this document, capitalized terms indicate USEF-defined roles, phases, and regimes, and lowercased versions indicate broader, general energy-market concepts. See chapters 3 and 4 for definitions of USEF's roles, phases and regimes.

[8] The USEF position paper "The Independent Aggregator" describes the rationale for positioning the BRP between the Aggregator and the TSO. (version 1.1, 29 June 2015, Hans de Heer, The USEF Foundation.)

The services for the Prosumer represent the existing approach in most demand response programs; the other three represent options that will enable stakeholders to create the maximum value from demand-side flexibility and increase the energy system's security of supply, sustainability, and efficiency. By aggregating flexibility resulting from explicit or incentive-based demand response, such as has been described by SEDC,[9] uncertainties in the delivery of flexibility are canceled out and hence the Aggregator can deliver guaranteed UFLEX to the market. The same SEDC document describes implicit demand response resulting from time-varying electricity prices or network tariffs that partly reflect the value or cost of the electricity and its transportation; these are sometimes also called ***time-of-use prices***. Such tariffs provide the opportunity to enable consumers to benefit from price fluctuations on the wholesale markets by directly or indirectly exposing them to the price levels on these markets, to the extent they are willing and able to do so. UFLEX, on the other hand, provides a valuable and reliable tool to adjust load and resolve operational issues. Moreover, it enables the provider of the flexibility to be rewarded directly for the UFLEX offered.

2.2 In-home optimization services for the Prosumer

Before flexibility is offered to other customers in the energy market, a Prosumer can use its own flexibility for in-home[10] optimization, i.e. internal optimization behind the meter. The graph below summarizes the services the Aggregator[11] can provide and its value to the Prosumer.



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.

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.

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.

Time-of-use pricing and maximum load tariffs are commonly used, 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 USEF 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.

[9] SEDC: "Demand Response: Clarification of the standard processes required between BRPs and independent aggregators". http://www.smartenergydemand.eu/wp-content/uploads/2015/07/SEDC-Standard-processes-required-between-BRPs-and-independent-aggregators.pdf

[10] "In-home" means "behind the meter" and includes commercial and industrial units in addition to residential ones.

[11] Since no aggregation is required, an Energy Service Company (ESCo) can also provide these services.

2.3 Flexibility services for the Balance Responsible Party

The Balance Responsible Party (BRP) naturally aims to reduce its sourcing cost (purchase of electricity) 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.

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.

Intraday portfolio optimization closely resembles day-ahead optimization, but the time frame is constrained after closing of the day-ahead market. 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.

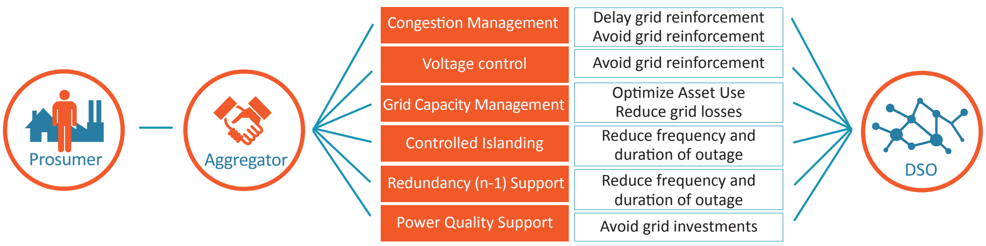
Self-balancing is the reduction of imbalance by the BRP within its portfolio to avoid imbalance charges. From a TSO's point of view, further value can be created through **passive balancing.** In passive balancing, the TSO renumerates a BRP that support the reduction of the system imbalance by deviating the balance position of its own portfolio in the right direction. If this contributes to reducing the total imbalance, the BRP may receive remuneration for its passive contribution, depending on market design.[12] The BRP does not actively bid on the imbalance market using its load flexibility (see section 3.5), 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.

2.4 Flexibility services for the Distribution System Operator

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

Congestion management 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.

[12] E.g., the Dutch imbalance market supports passive balancing, but the German market does not.

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 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 prevent 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.

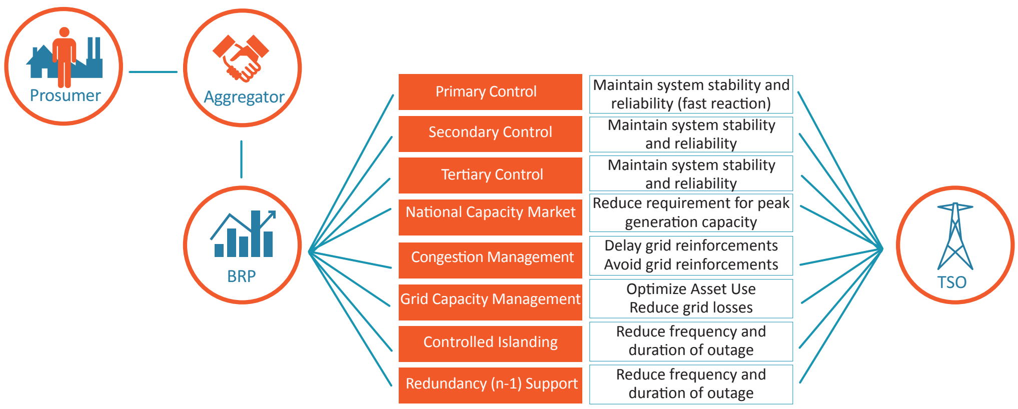
Controlled islanding aims to prevent supply interruption in a given grid section when a fault occurs in a section of the grid feeding into it.

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 millisecond 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. It is not very likely that a market-based approach like USEF is the best way to solve power quality issues. For this reason, power quality support is not included in USEF's scope.

2.5 Flexibility 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.
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, though the size of the congestion and the applicable regulations will differ. Aggregated load flexibility is a feasible service for both.

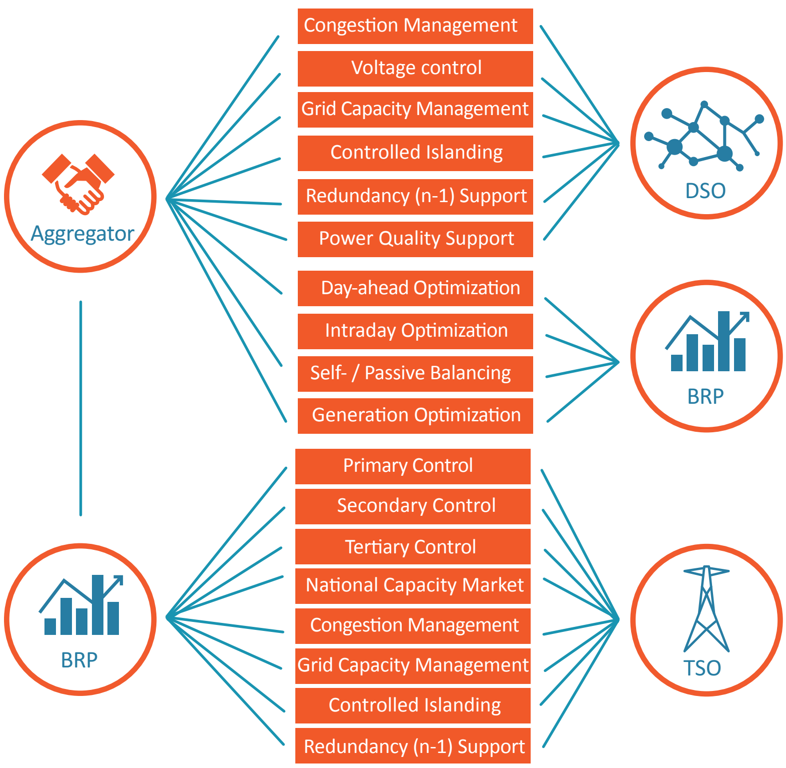
Controlled Islanding in the transmission grid is essentially the same as in the distribution grid, though the size of the region that operates in island mode and the applicable regulations will differ.

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 on 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. Nonetheless, 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.

2.6 The USEF Flexibility Value Chain

All these 18 flexibility services, introduced in the previous paragraphs, together form the USEF Flexibility Value Chain as depicted below.



3 Market organization

Smart energy markets require new services, new structures, and new roles that operate alongside existing ones. Opportunities emerge to develop new business through various manifestations and combinations of these roles. This chapter describes the roles and responsibilities in a USEF-compliant smart energy system. It also illustrates the interactions between the different roles to unlock the potential of flexibility.

3.1 The USEF roles model

USEF is based on a roles model rather than on business models. This systematic approach results 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. Several different business models can be defined based on USEF's roles model. This approach leaves the interactions between market roles unchanged and provides a generally applicable model in which the definition of each business is independent of other market participants. This enables the standardization of the flexibility market while still providing sufficient room to adapt it to local differences in market regulations.

To the extent possible, USEF has chosen to align the names of the roles used in its model with the existing business roles commonly accepted throughout Europe and defined by ENTSO-E. Though this might be a little confusing at first, the main advantage is that everyone can directly associate the right tasks and responsibilities with the roles defined by USEF. To aid clarity, we capitalize role names when referring to their USEF definitions and lowercase them when referring to the generic energy market concept.

A typical example of a USEF-enabled business model is an industrial Prosumer that also takes on the role of Aggregator. In this case, the Prosumer also assumes all the tasks and responsibilities associated with the Aggregator role. The table below explains the various roles defined by the USEF roles model.

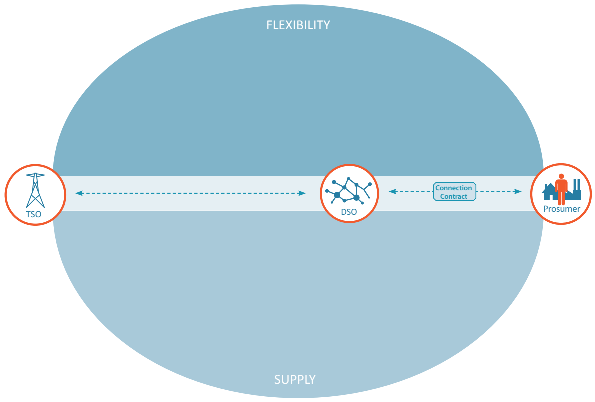
	A Prosumer can be regarded as an end user that no longer only consumes energy, but also produces energy. USEF does not distinguish between residential end users, small and medium-sized enterprises, or industrial users; they are all referred to as Prosumers.
	Active Demand & Supply (ADS) represents all types of systems that either demand energy or supply energy and which can be actively controlled. This enables the ADS device to respond to price and other signals from the Aggregator and to provide flexibility to the energy markets via the Aggregator. The Prosumer owns the device and defers responsibility for controlling its flexibility to the Aggregator. The Prosumer has final control over its assets, which means the Aggregator's control space is limited by the Prosumer's comfort settings. Hence the Prosumer is always in control of its comfort level; if the associated remuneration is high enough, however, the Prosumer might be willing to compromise on its comfort levels.
	The role of the Aggregator is to accumulate flexibility from Prosumers and their Active Demand & Supply and sell it to the BRP, the DSO, or (through the BRP) to the TSO. The Aggregator's goal is to maximize the value of that flexibility by providing it to the service defined in the USEF flexibility value chain that has the most urgent need for it. The Aggregator must cancel out the uncertainties of non-delivery from a single Prosumer so that the flexibility provided to the market can be guaranteed. This prevents Prosumers from being exposed to the risks involved in participating in the flexibility markets. The Aggregator is also responsible for the invoicing process associated with the delivery of flexibility. The Aggregator and its Prosumers agree on commercial terms and conditions for the procurement and control of flexibility.
	The role of the Supplier is to source, supply, and invoice energy to its customers. The Supplier and its customers agree on commercial terms for the supply and procurement of energy. Although the Aggregator is formally responsible for invoicing flexibility to the Prosumer, depending on the business model (see section 6.5) this flexibility might be invoiced through the Supplier.

BRP	A Balance Responsible Party (BRP) is responsible for actively balancing supply and demand for its portfolio of Producers, Aggregators, and Prosumers. A BRP is contracted by the Supplier. In principle, everyone connected to the grid is responsible for his individual balance position and hence must ensure that at each PTU the exact amount of energy consumed is somehow sourced in the system, or vice versa in case of energy production. The Prosumer's balance responsibility is generally transferred to the BRP, which is contracted by the Supplier. Hence the BRP holds the imbalance risk on each connection in its portfolio of Prosumers.
DSO	The DSO is responsible for the active management of the distribution grid and introduces the system operation services defined in the USEF flexibility value chain in section 3.4. UFLEX obtained from the Aggregators on its network is purchased to execute its system operations tasks. The DSO is responsible for the cost-effective distribution of energy while maintaining grid stability in a given region. Potentially, the DSO role could supersede the classical role of the DNO (distribution network operator) to cost-effectively maintain the distribution network, but this does not necessarily have to be the case; one could think of business models where these roles are separate legal entities. USEF only provides a roles model; such decisions are subject to market regulations and outside the scope of USEF.
TSO	The role of the Transmission System Operator (TSO) is to transport energy in a given region from centralized Producers to dispersed industrial Prosumers and Distribution System Operators over its high-voltage grid. The TSO safeguards the system's long-term ability to meet electricity transmission demands. The TSO is responsible for keeping the system in balance by deploying regulating capacity, reserve capacity, and incidental emergency capacity. The role of the TSO remains unchanged in USEF, but UFLEX provides a new source of flexibility to the TSO as input for its system operation services as defined in the USEF flexibility value chain in section 3.5. The TSO can purchase UFLEX indirectly via the BRP from the Aggregators active on its network.
Producer	The role of the Producer is to feed energy into the energy grid. In doing so, the Producer plays an important role in the security of the energy supply. The Producer's primary objective is to operate its assets at maximum efficiency. Though its responsibility remains unchanged, the introduction of demand response and changes to the merit order can alter its operating conditions quite drastically, since renewable energy sources such as wind and solar power have a relatively low operating expense and compete with existing power generation units.
ESCo	The ESCo offers auxiliary energy-related services to Prosumers. These services include insight services, energy optimization services, and services such as the remote maintenance of ADS assets. If the Supplier or DSO is applying implicit demand response through (for example) time-of-use or kWmax tariffs, the ESCo can provide energy optimization services based on these tariffs.
CRO	The Common Reference Operator (CRO) is responsible for operating the Common Reference, which contains information about connections and Congestion Points in the network.
Meter data Company	The Meter Data Company (MDC) is responsible for acquiring and validating meter data. The MDC plays a role in USEF's flexibility settlement process and the wholesale settlement process.
ARP	The Allocation Responsible Party (ARP) is responsible, within a metering grid area, for establishing and communicating the realized consumption and production volumes per PTU, either on the consumer level or on the aggregated level. The realized volumes are primarily based on actual measurements, but can also be based on estimates. The allocation volumes are input for the USEF flexibility settlement process and the wholesale settlement process.

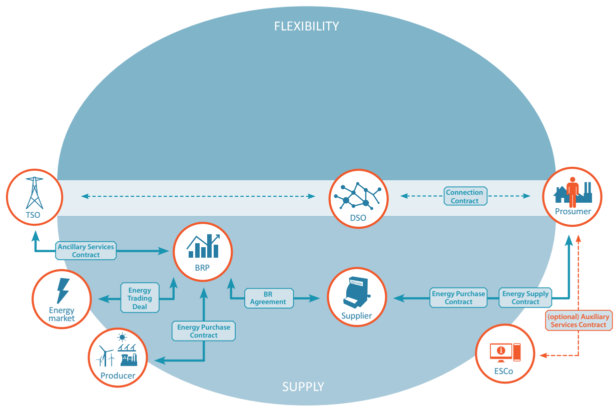
3.2 The USEF interaction model

This section describes the USEF-defined interactions between the roles in the USEF roles model introduced in the previous section.

The energy supply chain and the flexibility supply chain are separated in the USEF interaction model. The physical transport of energy underlies both chains. Energy is transported and distributed from and to Prosumers using the HV transport and MV and LV distribution networks operated by the TSO and DSO respectively. In general, the DSO connects Prosumers to their networks, and a connection contract[13] describes the terms and condition for access to the grid.

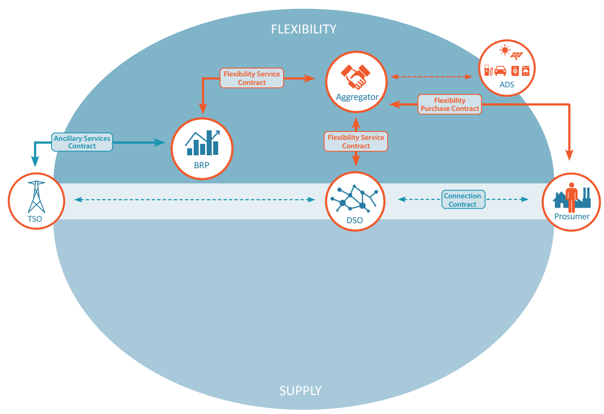


The energy supply chain remains unaffected in the USEF model and aligns with the European liberalized energy market model. The Supplier establishes a contractual relationship with the consumer for the supply and purchase of energy. The Supplier forecasts its customers' load profile and sources the energy through the BRP based on a pre-arranged BR agreement. The BRP might have a number of energy purchase contracts in place with power producers to source the energy demand of its Suppliers' Prosumers. Furthermore, the BRP has the option to arrange energy trading deals. There are multiple forms of trading: over-the-counter (OTC), spot markets, and intraday markets. These markets can be used to balance the BRP's portfolio and create additional value from auxiliary TSO services similar to the ones described in section 3.5. Here they are sourced from and supported by large-scale generation units. The ESCo can optionally provide ancillary services to the Prosumer. Relevant for the energy supply chain are the in-home optimization services described in section 3.2.



The USEF flexibility supply chain is designed to unlock and maximize the value of ADS flexibility. To that end, the Aggregator establishes a contract with the Prosumer describing the terms and conditions under which it can exploit the flexibility within the Prosumer-defined control space of the ADS asset.

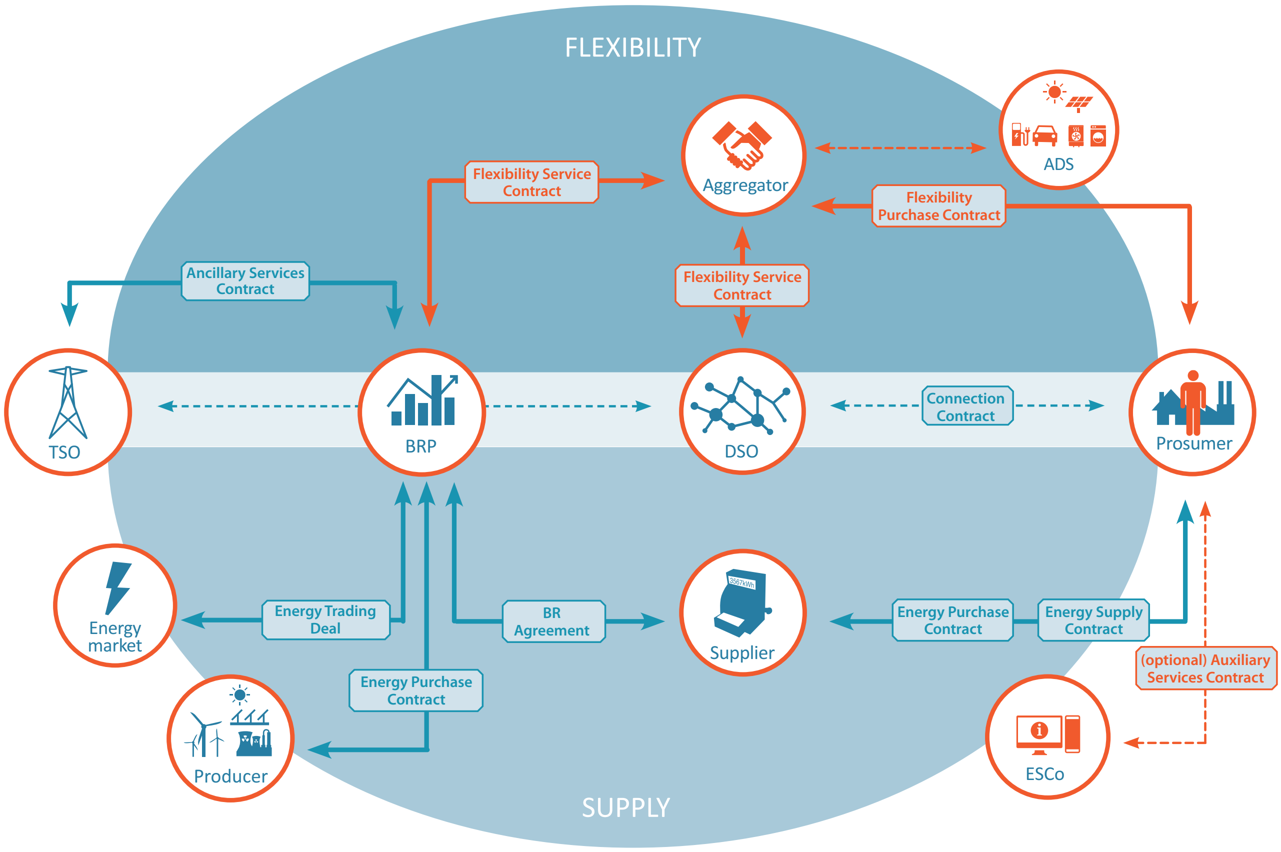
The Aggregator optimizes the value of the flexibility in its portfolio by selling UFLEX that has the most urgent need for it and hence is willing to procure it at the highest price. To that end, the Aggregator establishes a flexibility service contract with the BRP responsible for that Prosumer's imbalance. The contract specifies the terms and conditions for trading flexibility, including the settlement of imbalance resulting from UFLEX transactions.



[13] Note that Prosumers with a direct connection to the HV grid have a connection contract with the TSO. These customers are not yet taken into account by USEF.

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 latter option requires the establishment of an auxiliary service contract between the TSO and BRP.
Another source of value for the Aggregator's UFLEX are the DSO services defined in the USEF flexibility value chain. To that end, the Aggregator implicitly establishes a flexibility service contract with the DSO once the Aggregator is registered in the Common Reference. After all, the DSO is a regulated entity and hence procures UFLEX for these services under uniform market conditions, which should be reflected in the network codes. In addition, the DSO may establish long-term (LT) contracts with Aggregators to guarantee the availability of UFLEX (see section 6.2).

The full USEF interaction model combines the supply value chain interaction model with the flexibility value chain interaction model as depicted below. The roles in the supply value chain are responsible for the supply of energy, and the roles in the flexibility value chain are solely responsible for creating value through UFLEX.



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 position. After all, flexibility only manifests itself once it is activated by the Aggregator and alters a part of the commodity supply. Therefore in the standard USEF Aggregator model (see section 6.4.1), the BRP is responsible for the supply of both energy and flexibility. In the BR-contract arranges the compensation of the supplier for negative effects of the activation of flexibility.

Throughout Europe, various business models for implementing the Aggregator role are under discussion.[14] These business models can all be mapped to the USEF roles and interaction model, as we will see in chapter 5.

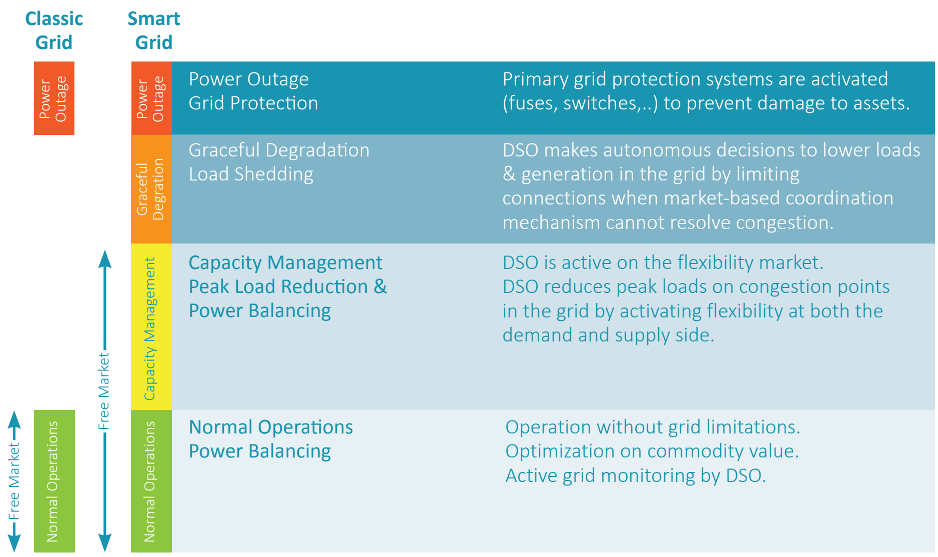
[14] See "The Independent Aggregator," version 1.1, 29 June 2015, Hans de Heer, The USEF Foundation.

4 USEF market design

To optimize the value of flexibility across all roles in the system, USEF introduces a new market-based coordination mechanism (MCM) along with new processes. The MCM provides all stakeholders with equal access to a smart energy system. To this end, it facilitates the delivery of value propositions (i.e., marketable services) to various market parties without imposing limitations on the diversity and customization of those propositions.

In the previous chapter, the roles and interaction between these roles involved in the smart energy system are described. This chapter builds further upon these models. The USEF MCM is meant as an addition to the current liberalized market model, aligning smoothly with existing processes in the energy market. It enables the trading of flexibility between roles, while safeguarding the reliability of the energy system by introducing new operating regimes. The USEF MCM is well aligned with current processes and fits on top of existing markets. This chapter defines the USEF regimes and new market processes and describes where existing processes need to be altered.

4.1 Operating regimes



USEF recognizes four different operating regimes. In the Green and Yellow regimes, the MCM assures optimal use of the flexibility available for BRPs (Green and Yellow) and DSOs (Yellow). The Orange regime is introduced as a fallback in case insufficient flexibility is available for the DSO to avoid an outage—the DSO can temporary overrule the market to avoid an outage by limiting connections.

The introduction of distributed energy resources (DERs) and the electrification of energy use will significantly increase the peak load on the distribution grid. For certain parts of the grid, demand will, at peak times, exceed the available capacity. Using USEF, the DSO will identify and publish the locations in the grid where overload might occur: the Congestion Points. A DSO identifies Congestion Points well in advance of actual overload situations occurring, based on its analysis of the trends in energy flows in its grids. It then informs Aggregators of the Congestion Points that involve connections under their purview. Using this information, Aggregators can approach their customers to provide sufficient flexibility to offer the DSO in case the Yellow regime is activated for specific Congestion Points. A Common Reference is set up for the exchange of information about connections, the associated Aggregators, and Congestion Points, operated by the Common Reference Operator.

Grid topologies

In general, we recognize three main electrical grid topologies: radial, ring, and meshed. In a radial grid, only a single end of the string is connected to the substation (either directly or via another string). This is the most common topology in the low-voltage grid, although meshed topologies occur as well, especially in residential areas. The most common topologies in the medium-voltage and high-voltage grids are, respectively, the radially operated ring and the ring.

The use of flexibility to alleviate congestion is most feasible in radial grids. It is more complex to determine the need for flexibility in the other two topologies. Taking into account the facts that most grids are operated radially and that congestion issues are negligible in ring and meshed networks, USEF focuses on radial grids.

4.2 MCM phases

The USEF market coordination mechanism, has five phases:

Contract	In the contracting phase, various contractual relationships need to be established for USEF to function properly. For example, bilateral contracts may be signed between Prosumers and Aggregators regarding the Prosumer's flexibility capacity and how it will be activated by the Aggregator.
Plan	In the planning phase, the Aggregator examines its portfolio of clients, each with its individual needs and flexibility preferences. Energy demand and supply are forecasted for the upcoming period, usually a calendar day. Both the BRP and the Aggregator carry out an initial portfolio optimization. During this phase, the BRP may procure flexibility from its Aggregators. The Plan phase results in an Aggregator plan (A-plan) agreed upon by the Aggregator and the BRP. The BRP then creates its energy program (E-program) as usual.
Validate	In the validation phase, the DSO determines whether the forecasted energy demand and supply can be safely distributed without limitations. If the prognosis predicts congestion, the DSO may procure flexibility from Aggregators to resolve it. It is important to note that there can be multiple iterations between the Plan and Validate phases: after validation, it is possible to go back to the Plan phase. These iterations continue until all the forecasted energy can be safely distributed without limitations.[15]
Operate	In the operation phase, the actual assets and appliances are dispatched and the Aggregator adheres to its D-prognoses and A-plan. When needed, DSOs and BRPs can procure additional flexibility from Aggregators to resolve unexpected congestion or to solve imbalance issues.
Settle	In the settlement phase, any flexibility the Aggregator has sold to the BRPs and DSOs is settled. This settlement comprises contracted and delivered flex as well as contracted flex that was not delivered. USEF supports the information exchange and the settlement of flexibility with transparent and unambiguous data.

The aim of USEF's Plan and Validate phases is to make optimal use of grid capacity and to maximize all stakeholders' freedom of dispatch and transaction before the actual delivery of energy takes place. The time scales in these phases range all the way from years and months down to just hours before the Operate phase starts. This broad window facilitates trading on different energy markets (such as the forward market, day-ahead spot market, and intraday spot market) and the ability to accommodate changes in the required grid capacity. USEF proposes that the national regulatory authority determine the details of the gate closure times. A current common practice in energy markets is to close one hour before delivery in the intraday process.

15. Note that it might not always be possible to resolve grid limitations with flexibility. In that case, USEF switches to the Orange regime.

Day-ahead and intraday markets
The USEF Plan and Validate phases may take place on both day-ahead and intraday time scales. The processes are similar; only the time frame differs. Day-ahead planning and validation involve the prognoses for an entire day (from 00:00 through 23:59), while their intraday counterparts only take the remainder of the current day into account.

4.3 Interaction per phase

The previous section introduced the five phases of the USEF MCM. In this section, we focus on the interaction between USEF roles during the different phases. For each phase, we provide a short introduction, then an overview of the activities per role, followed by an example of possible interaction during that specific phase.

The contractual relationships are essential to implement the generic USEF interaction model (see section 4.2):

- Flexibility purchase contract between Aggregator and Prosumer. This contract includes the operating conditions for the demand response service executed by the Aggregator.[16] It further includes details on the settlement of the flexibility the Prosumer provides.
- Framework contract between Supplier and Aggregator for all Prosumers serviced by the Aggregator. This contract includes the operating conditions for the demand response service, as defined in the contract between Aggregator and Prosumer.
- Flexibility service contract between Aggregator and BRP. This contract defines the conditions under which the Aggregator may offer its flexibility to the BRP, how imbalances caused by demand response will be dealt with and how changes in the sourcing position of the suppliers caused by demand response will be settled. These conditions should also be reflected in the contract between the Supplier and the Aggregator.
- The connection contract the DSO's has to reflect the possibility of load shedding in the Orange regime. This is however subject of the regulation conditions in the market. Most likely the connection conditions for the distribution of energy as described in the connection codes have to be altered.
- All other interactions in the Contract phase are contractual agreements, which are in line with the current liberalized market model and are not affected by USEF.

USEF does not require that Aggregators make contractual agreements with DSOs since the operating conditions for selling and procuring flexibility are covered by the MCM. In these contracts, the procedures for handling personal data—especially its exchange with other parties—must be made explicit, to respect the Prosumer's privacy.

USEF also allows the introduction of 3 optional contracts:

- Long-term flexibility contract between Aggregator and DSO. In this contract, the DSO may procure flexibility well in advance, in order to secure a certain supply of flexibility. DSOs that intend to sign long-term contracts with Aggregators are advised to set up a tendering process in advance for use when the DSO declares a Congestion Point.
- Long-term flexibility contract between Aggregator and BRP. Like DSOs, BRPs may procure flexibility well in advance to secure a certain supply of flexibility (See section 6.2).
- Contractual relationship between ESCo and Prosumers. This contract has significant freedom, since a variety of services can be defined with specific conditions based on the ESCo's own conditions.

Aggregator	■ Set up (framework) contract with supplier ■ Set up flexibility service contract with BRP ■ [optional] Set up long-term flexibility contract with DSO ■ [optional] Set up long-term flexibility contract with BRP	DSO	■ Set up flexibility service contract with Aggregator ■ [optional] Set up long-term flexibility contract with Aggregator
BRP	■ Needs new connection codes that enable use of flexibility (to be set up by regulatory authority) ■ [optional] Set up long-term flexibility contract with Aggregator	TSO	■ No changes needed

[16] This contract can also be initiated by the Supplier, who already has a relationship with the Prosumer. In this case the operating conditions for the demand response service are included in the energy supply contract

The aim of the Plan phase is to find an economically optimal program to meet the energy demands of all the Aggregator and BRP portfolios for a certain period. The Aggregator's result is reflected in the A-plan, which is similar to the current E-programs used by BRPs.
Note that unlike E-programs, the A-plan need not be in balance.

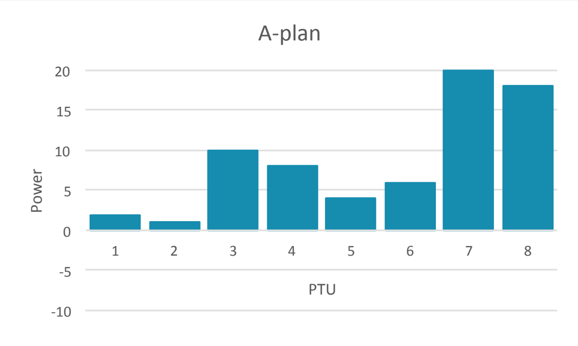
The Plan phase starts when the Aggregator collects forecasts for the Prosumers it represents. Having received the forecasts, the Aggregator optimizes its own portfolio and plans how to maximize the value of the flexibility options in its portfolio, resulting in an A-plan. The Aggregator optimizes its portfolio based on its clients' needs. For example, the Aggregator may apply in-home optimization or optimization to maximize the sharing of sustainable energy among clients. After this optimization, the Aggregator sends its initial A-plan to the BRP. If the forecasts change (e.g., because a new weather forecast is available), the Aggregator may reoptimize its portfolio, resulting in an updated A-plan.

Likewise, the BRP optimizes its portfolio of Aggregators, Producers, and Suppliers to attain an economically optimal program. During this process it will negotiate with its Aggregators to exploit the available flexibility in the market and optimize its value. For example, based on a spread in energy prices on the day-ahead market, a BRP may ask Aggregators to provide flexibility and make changes to their A-plans. If the BRP identifies market changes that may affect its portfolio, it may reoptimize its portfolio. After the Aggregators' A-plans have been aligned with the BRP portfolio, the BRP creates its E-program, which forms the basis for the imbalance settlement process between the BRP and the TSO.

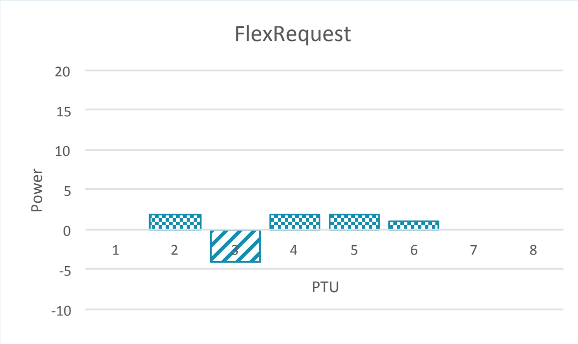
Also as part of the Plan phase, the DSO determines where congestion may take place (Congestion Points). The DSO registers these Congestion Points in the Common Reference. Note that, in contrast to the interaction between Aggregators and BRPs which takes place on a daily basis, DSOs declare Congestion Points at a low frequency, likely on the order of a few times a year. When a DSO declares a Congestion Point, the Aggregators active at this Congestion Point can decide to become active on the associated local market by offering UFLEX to the DSO.

Prosumer	■ No specific action needed ■ May change comfort settings at all times	Aggregator	■ Collect forecast information ■ Create forecast for entire portfolio ■ Optimize profiles for each Prosumer ("in-building" optimization) ■ Optimize internal portfolio ■ Generate an A-plan and communicate it to BRP ■ Trade UFLEX with BRP ■ Decide upon local market(s) for Congestion Points
ADS	■ [optional] Send forecast information to Aggregator	BRP	■ Receive A-plan ■ Optimize internal portfolio ■ Request UFLEX from Aggregator(s)
DSO	■ Determine where congestion may take place ■ Declare Congestion Points	CRO	■ The Common Reference contains a list of connection identifiers (such as EANs) for each Congestion Point, which can be accessed by Aggregators to check whether they have enough customers in the congested area to be able to offer UFLEX to the DSO.

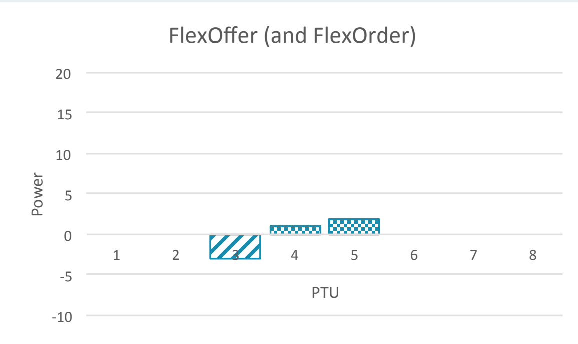
UFLEX trading between Aggregator and BRP in the Plan phase



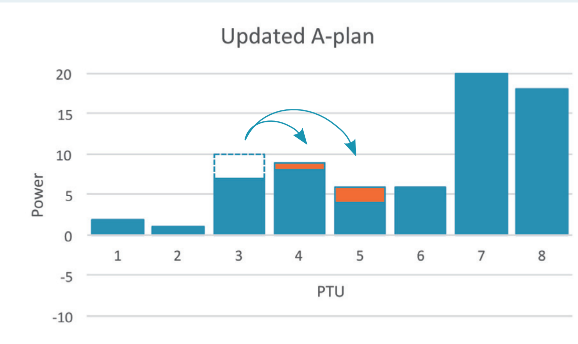
A sample A-plan. The A-plan shows the amount of energy consumed or produced per program time unit (PTU). The horizontal axis shows the PTUs in a day (simplified here; in reality, a day has 96 PTUs, based on a PTU duration of 15 minutes). The A-plan includes both the fixed load and the controllable load (i.e., the Active Demand & Supply). After receiving forecast information, the Aggregator plans how to maximize the value of the flexibility in its own portfolio, resulting in an A-plan. The A-plan is sent (day-ahead) to the BRP for validation.



The BRP uses the A-plans from Aggregators to optimize its portfolio and attain an economically optimal program. During this optimization, the BRP will negotiate with the Aggregators to exploit the available flexibility. The BRP communicates its flexibility needs by means of a **FlexRequest.** The graph here shows a request to reduce the energy load by 4 units at PTU=3 and indicates all other PTUs that have spare capacity. This is helpful in case Aggregators need to shift the load to other PTUs.



An Aggregator responds with a **FlexOffer**. As this is a response to the BRP's request, it addresses the required load reduction at PTU=3. In this example, the responding Aggregator can only provide part of the requested reduction. It offers a reduction of 3 units at PTU=3 and shifts this load to PTU=4 (1 unit) and PTU=5 (2 units). This means the BRP needs additional FlexOffers from other Aggregators to meet its goals. The FlexOffer also includes the price. If the BRP agrees, it returns a **FlexOrder** message with the same profile, indicating that the offer has been accepted.



In response to the FlexOrder, the Aggregator sends an **updated A-plan**, including the flexibility sold. Note that PTU=3 has now been reduced from 10 units to 7, PTU=4 has increased from 8 to 9, and PTU=5 has increased from 4 to 6. As long as the day-ahead gate closure time has not passed, the Aggregator is free to send an updated A-plan, in response to either changed circumstances or flexibility sold.

The Validate phase consists of two intricately linked processes, executed in parallel by different market roles: Validate-D and Validate-E. In these processes the (draft or final) D-prognosis created at the start of the Validate phase and the draft E-program resulting from the Plan phase are validated against grid constraints by the DSO and TSO, respectively. Note that the Validate-E process, performed by the TSO, is an existing process already in use in many countries. USEF does not alter the Validate-E process.

At the start of the Validate-D process, each Aggregator creates D-prognoses for all Congestion Points[17] where it is active, using its A-plan as a basis. The DSO accumulates the D-prognoses from all its Aggregators. These D-prognoses are combined with the profiles of those connections not served by an Aggregator (for which forecasting is performed by the DSO). This enables the DSO to perform a grid safety analysis. This analysis determines whether the planned energy can be distributed. If it cannot, USEF moves to the Yellow regime and the DSO procures flexibility on the market to resolve the congestion issues. If the available flexibility is not sufficient to resolve the expected congestion, USEF moves to the Orange regime.

The DSO's procurement of flexibility may impact an Aggregator's A-plan.[18] For this reason, the Validate phase is iterative with the Plan phase; that is, an Aggregator may repeatedly adjust its A-plan to the extent allowed by time and its bilateral agreement with the BRP. By the time the gate closes, all issues should be resolved and the A-plans and D-prognoses must be aligned. This is the Aggregator's responsibility.

Finally, the DSO combines the aligned D-prognoses with forecasts for those connections that are not at a Congestion Point to create a T-prognosis, which is sent to the TSO for verification.

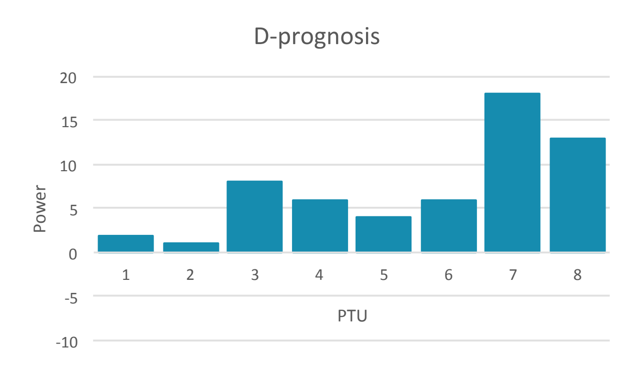
In exceptional situations where the market is not able to maintain the grid load within acceptable limits, USEF-compliant energy systems switch to the Orange regime by starting the process of ***graceful degradation***. Grid connection capacity is limited (stepwise) until the network load is once again within acceptable limits. In this Orange regime, the DSO temporarily overrules the market to prevent a complete power outage. The DSO can differentiate its connection conditions, thereby providing different levels of reliability to different types of connections. These conditions establish connection priorities, enabling the DSO to differentiate between clients who critically depend on energy (such as nursing homes) and connections where a service interruption has a lesser impact (such as public charging stations for electric vehicles). As soon as the system restores itself, the market can take over again.

	■ Create D-prognosis and communicate it to DSO ■ Trade UFLEX with DSO		■ Receive and evaluate incoming D-prognoses ■ Perform grid safety analysis ■ Request UFLEX from Aggregator(s) ■ If needed, switch to Orange regime (stepwise limitation of connections)

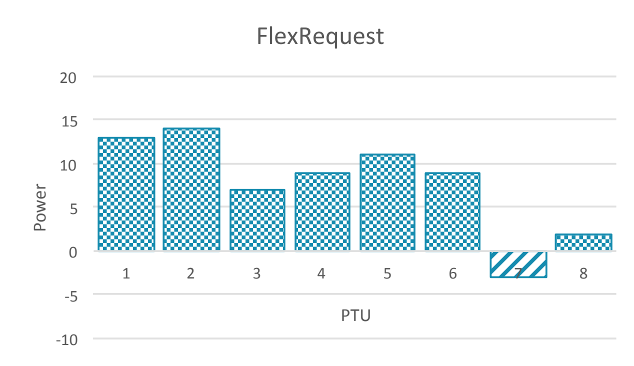
[17] The Aggregator queries the Common Reference to determine for which Congestion Points it needs to provide D-prognoses.

[18] This is not the case when the Aggregator can manage the deviation itself, such as when one Prosumer uses more energy, another Prosumer uses less energy, and the two cancel each other out.

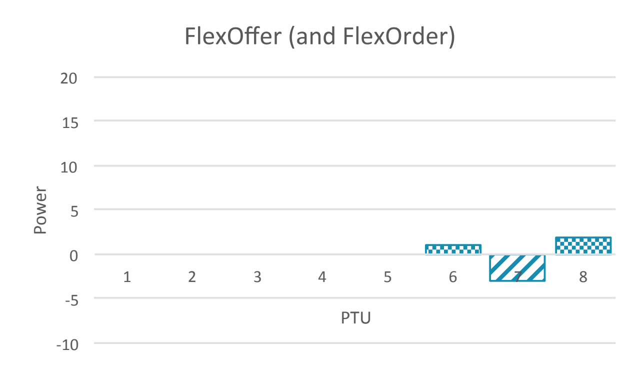
UFLEX trading between Aggregator and DSO in the Validate phase



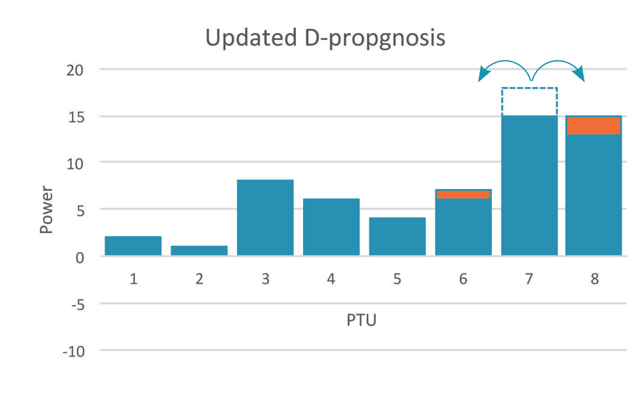
A sample D-prognosis. The D-prognosis shows the amount of energy consumed or produced per PTU at a given Congestion Point. Once it has the final A-plan at the end of the Plan phase, the Aggregator derives D-prognoses for each Congestion Point and sends them to each DSO. The DSO then states whether the D-prognosis is accepted. In the event of congestion, the DSO can use UFLEX to resolve the problem.



Assume grid capacity is limited. In this example, the DSO is faced with congestion at PTU=7. The DSO sends a FlexRequest to all Aggregators active at this Congestion Point indicating a need for load reduction at PTU=7. The message also indicates the available capacity at other PTUs.



An Aggregator responds with a FlexOffer including a price. As this is a response to the DSO's request, it addresses the required load reduction at PTU=7. In this example, the Aggregator is able to offer the requested load reduction in full. Nevertheless, other Aggregators may also make an offer, perhaps at better prices. Our Aggregator proposes to shift the load to PTUs 6 and 8. If the DSO agrees, it returns a FlexOrder message with the same profile, indicating that the offer has been accepted.



In response to the FlexOrder, the Aggregator sends an updated D-prognosis, including the flexibility sold. Since the new D-prognosis gives rise to a changed profile, USEF returns to the Plan phase, where the Aggregator reoptimizes its portfolio and, if needed, renegotiates with the BRP. Renegotiation is not always required; it is quite possible that the changed D-prognosis can be accommodated within the Aggregator's portfolio, leaving its A-plan untouched. The iterative loop over the Plan and Validate phases may continue until gate closure.

In the Operate phase, the actual delivery of energy and flexibility takes place by means of operational interactions. Aggregators deliver the flexibility they have sold to BRPs and DSOs for portfolio optimization and grid capacity management respectively. This flexibility is provided by Prosumers' Active Demand & Supply, which is controlled by the Aggregator.

As long as no deviations from the validated A-plans, D-prognoses, and E-programs occur, the energy system remains in balance with no congestion issues. However, it is unlikely that all A-plans, D-prognoses, and E-programs will be executed exactly according to plan. Deviations can arise from all sorts of sources, ranging from changing weather conditions to a football match running overtime. Deviations can lead to the following events:

- Imbalances in energy supply and demand on the total system level (affecting the BRP)
- Changes in the agreed-upon A-plan (affecting the Aggregator)
- Local congestion in the distribution system (affecting the DSO)

During the Operate phase, additional flexibility can be used to compensate for these deviations.

The Aggregator's main goal is to adhere to its agreed-upon A-plan and its D-prognoses. To achieve this, the Aggregator schedules the operation of Active Demand & Supply assets in a way that reflects the flexibility sold during the Plan and Validate phases. These settings can be adjusted before the Operate phase starts. Second, the Aggregator measures the net demand of its cluster (using smart meter data, for example) to detect deviations from its A-plan or D-prognoses. In the likely event that deviations occur, the Aggregator will have to reoptimize its portfolio. Perhaps deviations can be solved within the portfolio itself; if not, the Aggregator will have to change the operation set- points of the Active Demand & Supply.

The BRP's main interest is to minimize its imbalance costs. If market circumstances change as a result of the TSO maintaining the system balance, or if the BRP detects that it is causing imbalance by deviating from its E-program, the BRP can procure additional flexibility from Aggregators.

Although the DSO will reduce congestion risks in the Validate phase, the DSO can still ask Aggregators for additional flexibility to resolve congestion issues in the Operate phase. However, in such cases the corresponding BRP's portfolio will no longer be in balance. As a result, the Aggregator will most likely charge the DSO an additional fee to cover the imbalance risk.

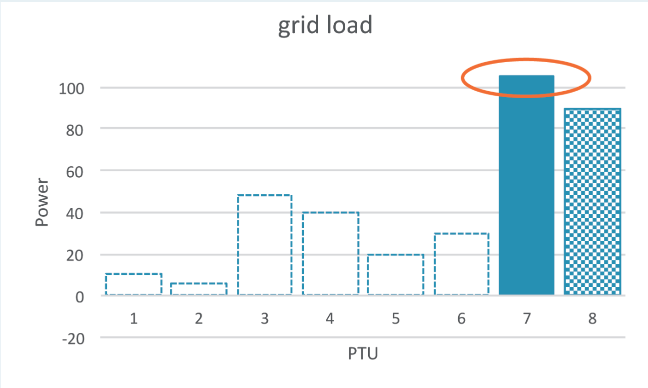
During the Operate phase the DSO monitors the grid to measure whether actual load flows at Congestion Points stay within physical limits. If the load exceeds these limits, the DSO redeems open FlexOffers, or, if insufficient flexibility is available, switches to the Orange regime and starts limiting connections in order to avoid an outage.

The TSO is responsible for system stability. In case this stability is at risk, the TSO will use primary, secondary and tertiary control reserves to resolve the problem. To this end, the TSO may procure UFLEX for one of the corresponding flexibility services defined in the USEF Flexibility Value Chain.

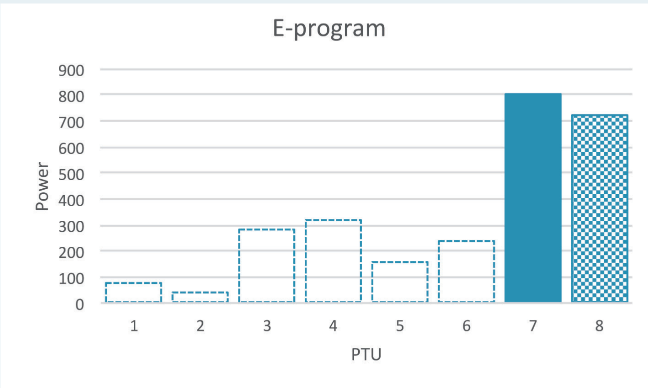
Prosumer	■ Control user settings (allowed at any time)	Aggregator	■ Adhere to its agreed-upon A-plan and its D-prognoses ■ Schedule operating conditions for Active Demand & Supply ■ If deviations occur: reoptimize portfolio ■ Control Active Demand & Supply
ADS	■ Needs to adjust it setpoint depending on the incentive provided.	BRP	■ Adhere to its E-program ■ If needed, procure UFLEX for internal balancing ■ If needed, procure UFLEX for passive balancing
DSO	■ If needed, procure UFLEX for congestion management ■ If needed, switch to Orange regime and limit connections	TSO	■ If needed, procure UFLEX to maintain system balance

Use of UFLEX in the Operate phase

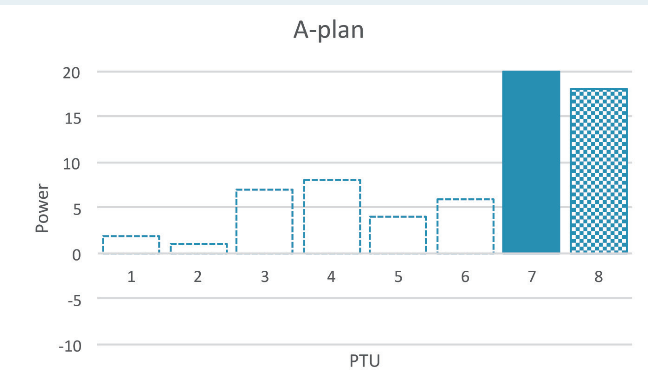
In this example, PTU=7 is in the Operate phase, while PTU=8 is still in the iterative loop over the Plan and Validate phases.



During the Operate phase, the DSO continuously monitors the status of the grid. If the actual load is higher than predicted, as is the case for PTU=7 in this example, additional or unpredicted congestion may occur. To resolve this congestion, the DSO can order UFLEX that was previously offered by Aggregators but has not yet been used. (Given the time limitations, it is too late to issue new FlexRequests for PTU=7.) If the offered flexibility is not sufficient, the DSO will switch to the **Orange regime** and start stepwise limiting connections.



Likewise, the BRP will monitor its E-program. Deviations can arise from all sorts of sources, ranging from changing weather conditions to a football match running overtime. Any deviation will lead to imbalance in the BRP's profile, which it generally prefers to avoid due to penalties imposed by the TSO. The BRP might also deliberately deviate from its profile ("passive balancing"; see section 3.2) In all cases, the BRP can order UFLEX from Aggregators to help it maintain balance.



The Aggregator's task is to stick to its **A-plan** and **D-prognoses** per Congestion Point. Any deviations may require portfolio reoptimization, resulting in a new A-plan and D-prognoses and a new control strategy (set points) for the Active Demand & Supply assets. Portfolio reoptimization is also triggered by new UFLEX FlexOrders from BRPs and DSOs. The Aggregator's process in the Operate phase generally executes on the sub-PTU level, since deviations occurring in the current PTU (PTU=7, in this example) must be compensated for. Note that changes to the A-plan or D-prognoses may also create deviations in the next PTU (PTU=9 in this example), which will be resolved using the protocols of USEF's Plan and Validate phases.

Contract > Plan > Validate > Operate > **Settle**

In the Settle phase all the energy, UFLEX, and services delivered in the previous phases are settled. USEF introduces new settlement processes between roles, namely processes for the settlement of flexibility. The BRP and DSO settle the flexibility they have acquired from the Aggregator during the Plan, Validate, and Operate phases. The Aggregator or Supplier settles the flexibility Prosumers and their Active Demand & Supply have provided during these phases. A Supplier may choose to integrate this settlement with its billing of the energy it has supplied, which may be particularly useful when time-of-use tariffs are in effect, for example.

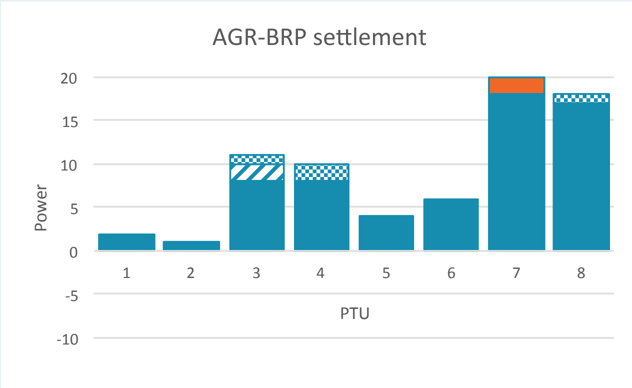
If the system has been in the Orange regime, the DSO also needs to settle its load shedding with Prosumers.

USEF identifies the following settlement procedures:

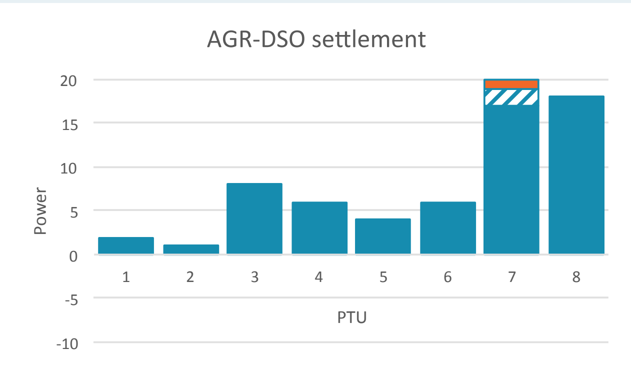
- Settlement of flexibility (Prosumer-Aggregator)
  Strictly spoken this is not settlement, but a reward for the flexibility offered by the Prosumer. Aggregators are free in their choice of Prosumer service model. Aggregators may offer a fixed fee, or only pay for the flexibility actually activated. This choice is outside the scope of USEF.
- Settlement of flexibility for grid capacity management (DSO-Aggregator)
  The flexibility transactions (and associated deviations) between the DSO and Aggregators are settled in this phase. The basis for this settlement process is the latest set of validated D-prognoses.
- Settlement of flexibility for portfolio optimization (BRP–Aggregator)
  The flexibility the BRP has procured for the purpose of portfolio optimization in the Plan and Operate phases is settled between the BRP and its Aggregators. This also covers the settlement of any differences between the Aggregator's forecast and realization, since Aggregator-initiated changes to a Prosumer's forecasted demand or supply affect the BRP's E-program.
- In the Orange regime, the DSO has the ability to shed load or curtail generation at a Prosumer directly, by reducing the maximum capacity at the connection level (all the way to zero, when needed). The impact of load shedding or curtailment is settled afterward between the DSO and the Prosumer directly. USEF does not prescribe financial settlement for this limiting of connections; it is, however, recommended.

Aggregator	■ Calculate flexibility sold to BRP, including validation ■ Calculate flexibility sold to DSO, including validation ■ Settle offered flexibility with BRP ■ Settle offered flexibility with DSO	BRP	■ Calculate procured flexibility per Aggregator ■ Validate delivered flexibility based on metering data ■ Calculate flexibility prices and penalties ■ Settle flexibility with Aggregators
DSO	■ Calculate procured flexibility per Aggregator ■ Validate delivered flexibility based on metering data ■ Calculate flexibility prices and penalties ■ Settle flexibility with Aggregators	Meter data Company	■ Gather meter data requested by BRP ■ Send requested meter data to BRP ■ Gather meter data requested by DSO ■ Send requested meter data to DSO

Sample settlements in USEF's Settle phase



The day after operation, the Aggregator's realized profile is known, enabling the BRP to check whether the ordered UFLEX has actually been delivered. The Aggregator is compensated for the delivered UFLEX in accordance with the agreements made earlier. In this example, the graph shows that flexibility has been delivered as promised in various offers at PTUs 3, 4, and 8.
Ideally, the realized profile is equal to the last agreed-upon A-plan. If this is not the case, the BRP can hold the Aggregator responsible for the deviation and charge a penalty for imbalance costs (in this example, for PTU=7).



A similar process takes place between the Aggregator and the DSO. Based on the realized profile, the DSO can check whether the ordered UFLEX has actually been delivered. The Aggregator is compensated for the delivered UFLEX in accordance with the agreements made earlier. In this example, the UFLEX delivered at PTU=7 will be compensated.

Deviation from an Aggregator's D-prognosis for a particular PTU is only penalized if the DSO and Aggregator have traded flexibility for that PTU. What's more, only deviations that lead to extra congestion are penalized; deviations in the other direction alleviate the congestion and are accepted. In this example, the Aggregator has an excess of 1 unit at PTU=7, which is penalized.

5 A central role for the USEF Aggregator

The framework provides a universal model to trade flexibility and maximize the value of it. The Aggregator is a new, crucial role, in this process. Various business model are possible to start a business and the commercial success depends on a lot of details. An in-depth description of the Aggregator business is provided including the latest models still under discussion in the market.

5.1 Setting up Aggregator Business

Creating value from flexibility is not a straight forward task. UFLEX must be guaranteed on the USEF Flex market, but an Aggregator should be aware that the underlying individual flex transactions with the Prosumers might not be guaranteed. Flexibility derived from Electric Vehicles (EV) for example, is exposed to the risk that the car owner changes his travelling plans and leaves early before the car is fully charged and the corresponding flex transaction might be interrupted. As long as UFLEX transactions consist of many individual flexibility transactions or the UFELX transaction is based on sources that can guarantee its availability, the risks involved for the Aggregator are small. But if the UFLEX transaction for a local congestion in the distribution grid is only based on two EVs the risk of non-delivery is considerable. Hence setting up an Aggregator business requires proper risk management .

Furthermore the requirements of the various flex services defined in the USEF Flexibility Value Chain can differ significantly. To be able to map the right source of flexibility on the right service at the right time, an Aggregator should have an excellent insight in both the characteristics of the ADS technologies installed at their Prosumers premises, as well as the behavior of these Prosumers. Optimizing the space heating process of building and extracting the flexibility out of a heat pump system is needs completely other skills than managing a fleet of fuel cell cars that jointly for a virtual power plant. It is up to the Aggregator to find the optimal match between the flexibility services in the market and the flex sources from its Prosumers. Various types of ADS that define these sources of flexibility and are listed in the table below:

Type	Flexibility	Examples
Controllable load	Load shifting, on/off switching, variable power	Heat pumps, air conditioning, HVAC systems, cold stores, heating or cooling processes, industrial production processes
Local generation	Controllable, variable power generation	solar PV, CHP and micro-CHP systems, fuel cells, gas turbines, UPSes
Storage	Charge and discharge. The sole task of storage is to introduce flexibility in the energy chain	Residential storage units (e.g., batteries), district storage
Electric vehicles	Smart charging and discharging plus the ability to move to another location	cars, trucks, forklifts, watercraft

USEF can deal with any kind of ADS as long as it the interface requirements meet the USEF Universal Device Interface (UDI) requirements as described in Chapter 6. Therefore it is irrelevant from the perspective of USEF to provide an exhaustive table with all potential sources of ADS. The table above is sufficient to get insight in the types and characteristics of flex sources to oversee the complexity of the field of Aggregators that might arise in the energy market.

This means that Aggregators might specialize in specific customer segments and/or specific types of ADS. Aggregators may emerge for residential Prosumers, small and medium-sized enterprises, and industrial users. Each Prosumer segment will typically require recognizable and appealing propositions. In its propositions, the Aggregator should be aware of Prosumers' appetite to risk exposure and balance it with the Prosumers remuneration for providing flexibility. Note that the value of flexibility is defined in the market process for UFLEX trading and that there is not necessarily a direct relation between the remuneration of the Prosumer for providing its flexibility.

The determination of the value of the flexibility of an individual Prosumer is a complex process. Already the fact that the Prosumer has flexibility to offer is of value even before actually activating it. The major advantage of this is that it leaves complete freedom to the Aggregator how to define appealing value propositions to its customers and attract the relevant Prosumers to them.

An Aggregator will also have to manage the price risk of UFLEX and make a trade-off between early trading with typically lower prices and less risk and later trading with higher prices but also with higher risk, e.g. market parties might already be served by other Aggregators. Hence value creating from flexibility requires carefully build a flex portfolio and the optimizing needs detailed control and risk management. As a consequence an Aggregator needs very accurate prediction models to estimate these risks and identify the opportunities in the UFLEX market.

5.2 Short Term versus Long Term Flex

In the USEF framework, BRPs and DSOs can acquire flexibility by making a flexibility request for specific program time units (PTUs). The earliest they can make such a request is after the Aggregator has supplied them with its day-ahead forecast for the next 24 hours (as we have seen in chapter 1). Essentially, USEF regards them as short-term (ST) flexibility requests. The underlying requirement is that the market is sufficiently liquid; that is, when there is demand for flexibility, supply will appear. This exposes the requesting party - the BRP, TSO, or DSO - to two risks. First, there is price uncertainty, with the attendant risk of high prices. Second, there is the risk that no or not enough flexibility will be offered.

For the BRP, both risks can be mitigated; there are other solutions that can fulfill the BRP's needs. For the DSO, however, the situation is different: aside from switching to the USEF Orange regime (described in section 5.1), the DSO has limited options if the flexibility market fails. Given the nature of its business, the DSO's investments have a very long time horizon. The DSO must therefore mitigate the availability and price risks in order to make flexibility a reliable and financially attractive alternative to grid reinforcement. This poses a clear need for long-term agreements on the supply of flexibility for the DSO and, to a lesser extent, the BRP to guarantee the security of flexibility supply.

The reverse also holds: the Aggregator needs security of demand. The Aggregator will have to invest in unlocking the Prosumer's flexibility. Without agreements guaranteeing the actual use of this flexibility, the Aggregator is exposed to the risk of no demand, which affects its return on investment.

The paragraphs above demonstrate the value of long-term (LT) flexibility agreements for both the demand and supply sides. This would enable parties to make arrangements for flexibility well before the actual flexibility requests appear on the flexibility markets defined by USEF. The framework's design specifies that LT flexibility should be offered on the USEF flexibility markets. This ensures that sufficient flexibility is available in situations where this is critical for the reasons mentioned above. Naturally, the requesting party will still buy the cheapest flexibility option offered on the market at the time it is actually needed.

5.3 Setting the baseline

If an Aggregator wants to trade UFLEX the question arises, how can the performance of the Aggregator be evaluated. Flexibility is simply a shift in a load profile, and it only exists because we can estimate what the load profile would have looked like if the flexibility had not been activated. After all, only the actual load profile can be measured; the unperturbed load profile never really existed. We must therefore set a baseline that defines the commonly accepted, unperturbed load profile. 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. 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.

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.

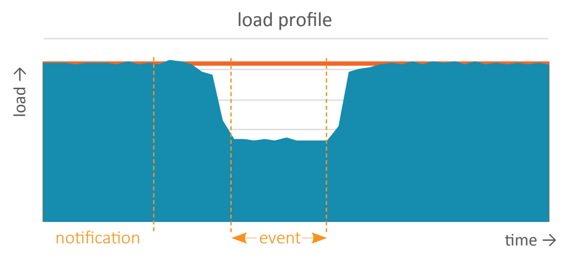
Baseline example 1: Baseline example 2: Peak load reduction of a heat pump system

Characteristics

- Industrial source
- Shed 2 MW for 3 minutes
- Notification 10 minutes prior to the event
- Performance penalty if the load is not reduced within 10 minutes

Characteristics that influence the choice of baseline methodology:

- Short duration event
- Relatively flat reference load profile in narrow time window
- The load in the 10 minutes after notification has high propensity for modification



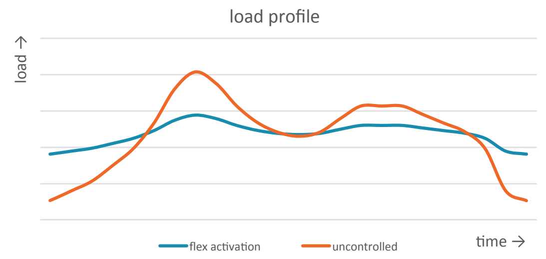
Baseline example 2: Peak load reduction of a heat pump system

Characteristics

- Residential site
- Reduce peak load in morning hours (5-9) by 1 kW
- Notification: day ahead
- Performance penalty if the load is not reduced

Characteristics that influence the choice of baseline methodology:

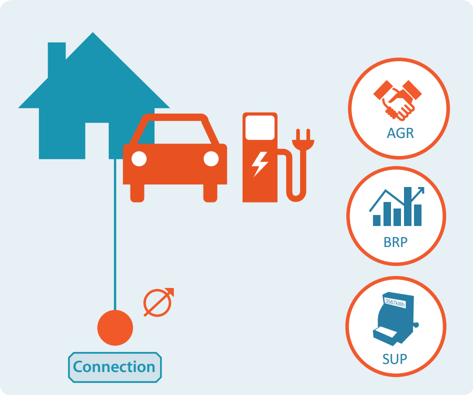
- Multi-hour event targeted for the peak portion of the load profile
- Elevated propensity for pre-event preparation and post-event load recovery
- Sensitivity to weather and calendar effects



To meet the EU's requirements for making flexibility transferable across European borders, it is essential that flexibility options are comparable and preferably identical. To that end, not only should the USEF framework be adopted throughout Europe, but also the standardized requirements for baseline methodologies should be a part of the USEF framework.

5.4 Options for implementing the Aggregator

The USEF roles model as described in chapter 3 can be applied in a number of ways to unleash the value of UFLEX and implement the various market roles.



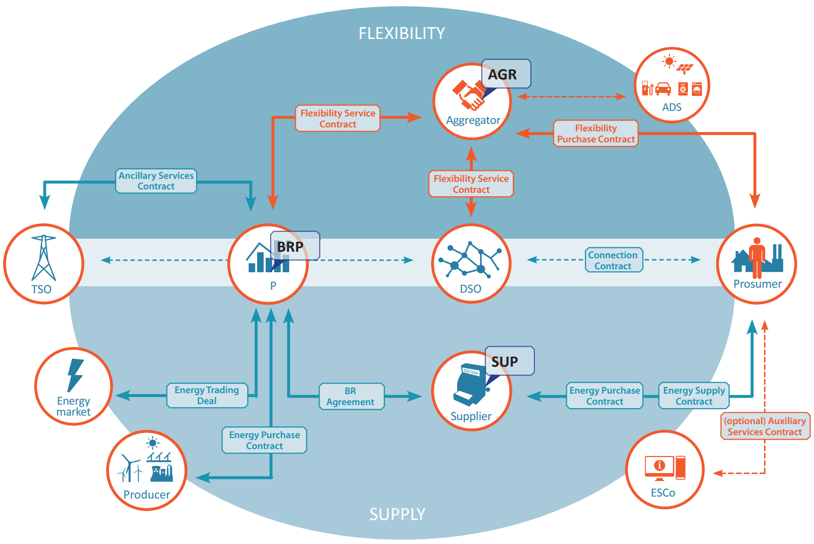
Local market regulations will influence the choice of methods. The USEF framework aims to support the anticipated market roles in the redesigned European energy market, necessary to incorporate flexibility from ADS. In this chapter, we discuss the various options for implementing the Aggregator role and the accompanying potential business models. Although the Flex-BR (section 6.4.3) is still under discussion throughout Europe in various appearances,[19] we describe its mapping onto the USEF roles and interaction models here to support that discussion and show how USEF might be applied in various scenarios.

Depending on the outcome of these discussions, the current USEF specification might need to be altered. In the rest of this chapter, we provide relevant details for the practical implementation of the Aggregator role.

5.4.1 USEF's standard Aggregator model

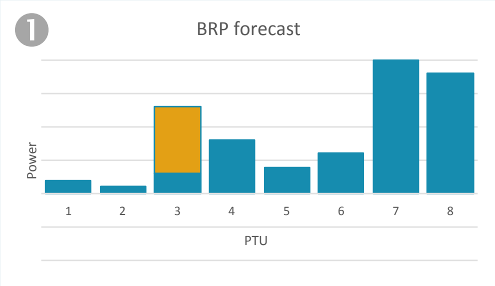
The most straightforward implementation is the addition of an Aggregator to the existing European liberalized energy market model. In this case, the Aggregator has established a contract with the Prosumer to control all of its ADS assets, within the boundaries set by the end-user (settings). The Aggregator exploits the flexibility provided by the Prosumer's ADS assets to maximize its value and create the optimal load profile. A single BRP carries the balance responsibility for both the supply and the flexibility. A three-way contractual relationship between the Aggregator, Supplier, and BRP[20] is established to define the roles and responsibilities in accordance with one of several possible business models (see section 6.5). In principle, the Aggregator, Supplier, and BRP will evaluate performance based on metering data at the connection level. In practice, however, especially at industrial and commercial sites, the Aggregator will most likely install a submeter for the ADS assets to measure their actual performance. This enables both the Aggregator and the UFLEX customer to quantify the performance of the demand response service and the provided flexibility based on actual performance.

The mapping to the USEF interaction model is shown in the diagram below. The Aggregator trades UFLEX with the BRP and the DSO. The BRP acts as an intermediary for the TSO's services. UFLEX trading between the Aggregator and the BRP targets joint portfolio optimization in order to create maximum value. To this end there is a contract in place between the Aggregator and BRP to describes the terms and conditions under which UFLEX is traded between them.

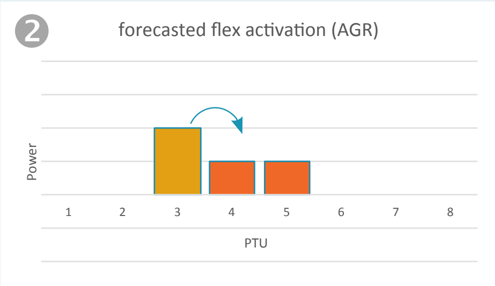


19 "The Independent Aggregator," version 1.1, 29 June 2015, Hans de Heer, The USEF Foundation.

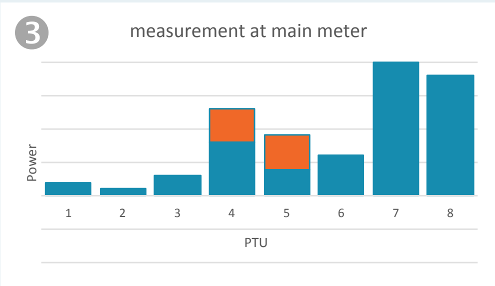
20 For the sake of simplicity the contractual relationship between the Supplier and Aggregator is not depicted in the interaction model.



The example shown on the left illustrates the standard Aggregator model.
Assume a residential Prosumer with an amount of uncontrollable load and an electric vehicle (EV) with smart charging equipment. The initial forecasted total load profile of both the controllable and uncontrollable load is shown in graph 1.



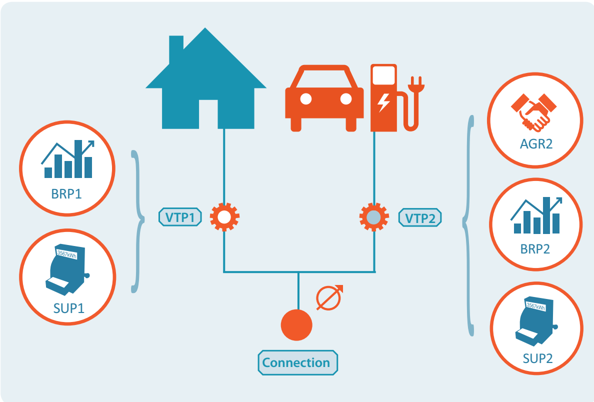
The Aggregator (AGR) is able to control the EV charging process and change its load pattern by activating the available flexibility. In the forecast, EV charging would originally take place at PTU =3. To create additional value, AGR shifts charging to PTUs 4 and 5. This is depicted in graph 2.



The measured load profile at the main meter is shown in graph 3.
The interaction between AGR and BRP is defined by USEF's MCM. If the decision to activate flexibility is made in the USEF Plan or Validate phase, the resulting impact on the BRP's portfolio is negotiated between BRP and AGR. If the decision is made in the Operate phase, AGR will face an imbalance for this connection, which it may be able to resolve within its own portfolio; if not, this imbalance must be settled between AGR and BRP

5.4.2 The virtual transfer points model (VTP model)

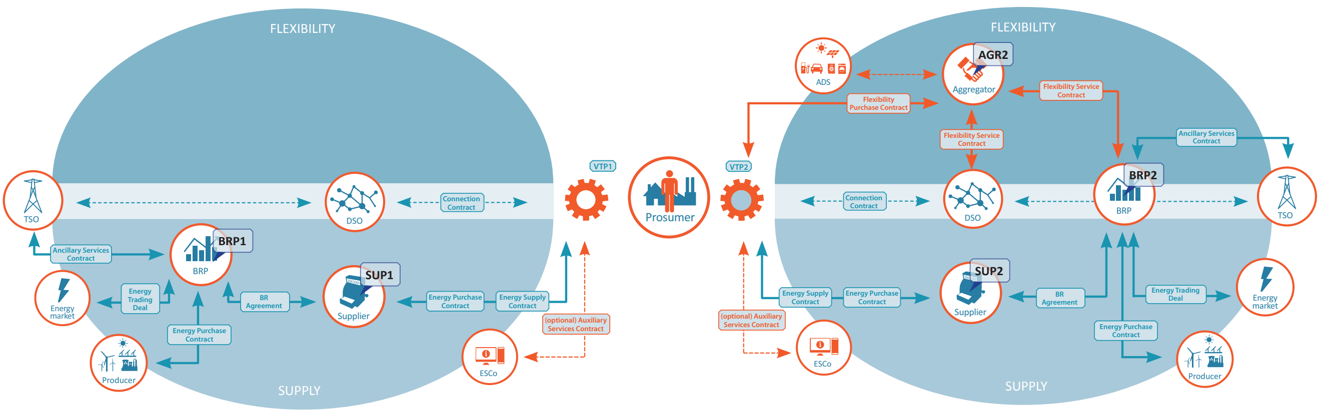
An Aggregator might prefer to manage only a single or single type of Active Demand & Supply asset. A typical example is an equipment manufacturers who already has a digital connection to its products and is well suited to aggregate the flexibility from all its devices in the field. One possible way to realize this is by introducing virtual transfer points (VTPs) on which the base load is separated from the ADS load, as shown in the diagram below . Here, VTP2 for the ADS asset (in this case an EV) is created by installing an accountable submeter. VTP1, for the remaining residential load, is created by subtracting the ADS load from the main meter. This is a possible way to implement the independent Aggregator concept currently being discussed throughout the European energy market.[21]



The Prosumer's existing Supplier (SUP1) and BRP (BRP1) are responsible, respectively, for the supply of energy and the imbalance on VTP1, that is, the total energy excluding the EV part. Although not shown in this case, USEF allows the activation of flexibility within the remaining residential load on VTP1. For the sake of simplicity, the remaining residential load is assumed to have no ADS or controlling Aggregator. The situation thus created on each VTP is identical to the USEF standard Aggregator model discussed in section 2.4 and is fully supported by the USEF specification.

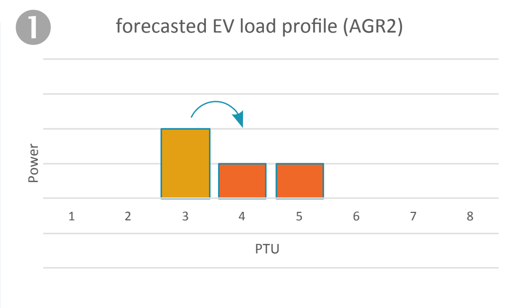
This means the ADS load on VTP2 is managed by a three-way contractual relationship between AGR2, BRP2, and SUP2, similar to the standard USEF model. The ADS asset is under the full control of the independent Aggregator (AGR2). The energy for the EV is supplied by a second Supplier (SUP2) and balance responsibility is borne by a second BRP (BRP2). AGR2, BRP2, and the DSO trade UFLEX according to USEF's MCM.

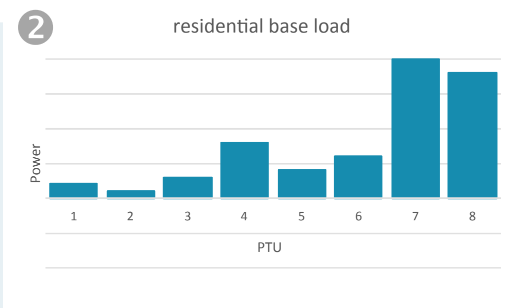
The mapping to the USEF interaction model is shown in the diagram below. The right half of the diagram represents the (EV supply via VTP2; the left half, the remaining residential energy supply via VTP1. In the right diagram, AGR2 trades UFLEX with BRP2 and the DSO. Its performance is evaluated based on the submeter readings at VTP 2.



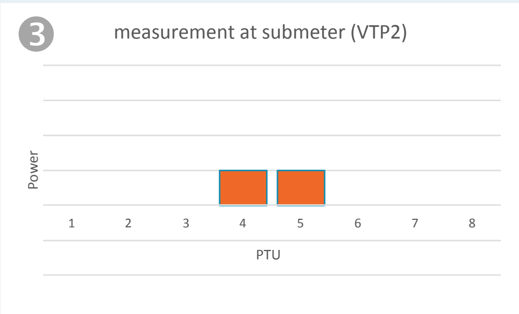
21 USEF Position paper "The Independent Aggregator," version 1.1, 29 June 2015, Hans de Heer, The USEF Foundation.

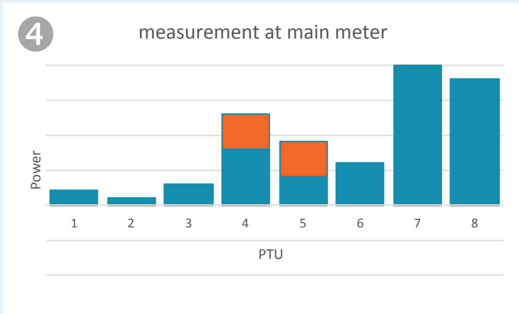
The following example illustrates the VTP model.



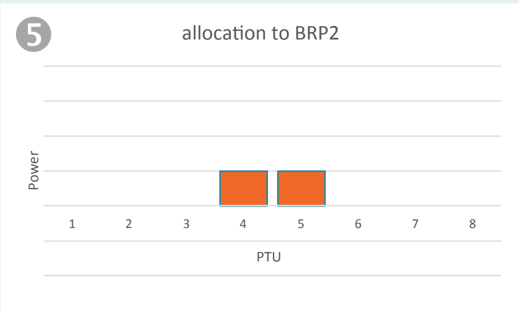


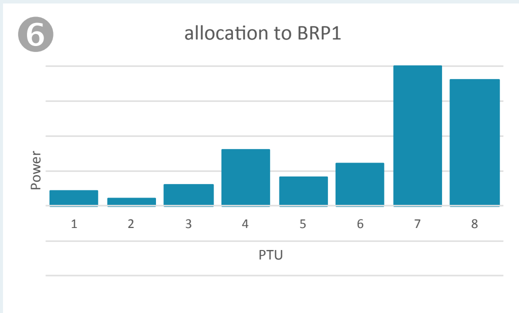
Again, assume a residential Prosumer with an amount of uncontrollable load and an electric vehicle with smart charging equipment. AGR2 controls the flexible EV load. EV charging was scheduled at PTU=3, but AGR2 decides to activate flexibility and shifts charging to PTUs 4 and 5. The forecasted EV load is shown in graph 1. The forecast for BRP1 represents the remaining residential load—that is, everything except the EV load—and is shown in graph 2. In this example, we assume there is no other source of flexibility in this part of the load.





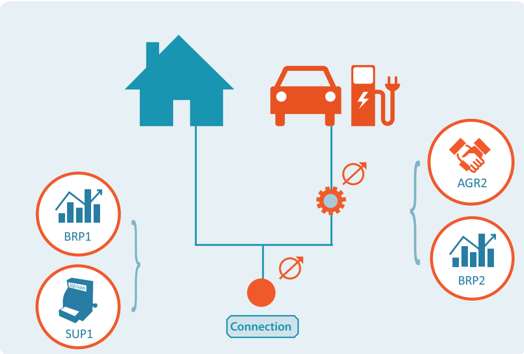
The activation of flexibility is measured at the submeter on VTP2 (graph 3). The total load is measured at the main meter (graph 4). The measurement for VTP1 is derived by subtracting the VTP2 measurement from the main meter measurement.





The allocation to BRP2 is shown in graph 5, and the allocation to BRP1 in graph 6.

5.4.3 The Flex-BR model



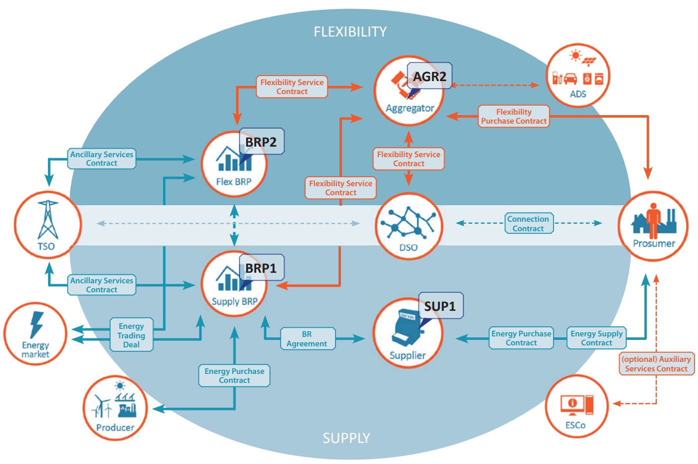
In the flex-only balance responsibility model (Flex-BR model), flexibility is completely separated from the supply of energy. The Supplier (SUP1) is responsible for the supply of energy on the Prosumer's main connection. The corresponding BRP (BRP1) is responsible for the balance at the Prosumer's main connection.

An independent Aggregator (AGR2) offers the Prosumer a flex-only service to control the flexibility of its ADS asset (or assets). When the Prosumer's ADS flexibility is activated, the BRP associated with AGR2 (BRP2) is responsible for the imbalance it causes. The activation of flexibility will change BRP1's balance position. Hence BRP1 must somehow be compensated so that the activation of flexibility by AGR2 remains neutral for BRP1 and SUP1. We provide an example below that explains the complexity it introduces for settlement to achieve that.

The Flex-BR model aligns perfect with the USEF interaction model if the BRP role for the supply of energy (BRP1 in this example) and the BRP role for the flexibility service (BRP2 in this example) are mapped on each other. Those two roles can be distinguished as follows:

Supply BRP	The Supply-BRP holds the (possibly delegated) responsibility for imbalances related to the supply and/or generation of energy on the Prosumer's connection. The Supply-BRP manages the balance position of its portfolio of Producers, Aggregators, and Prosumers and is identical to the existing BRP role in the market.
Flex BRP	The Flex-BRP is responsible for any imbalances caused by flexibility when it is activated. The Flex-BRP manages the flexibility balance position of its portfolio of Producers, Aggregators, and Prosumers and is identical to the existing BRP role in the market.

These new roles can be mapped one-to-one onto the flexibility value chain and the supply value chain of the USEF interaction model. This results in the following full interaction model.

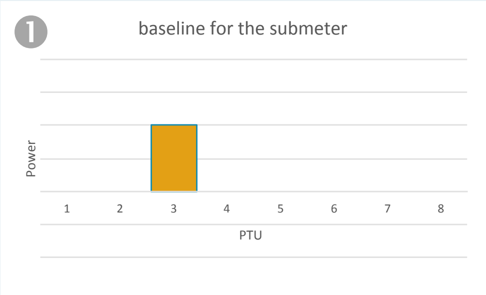


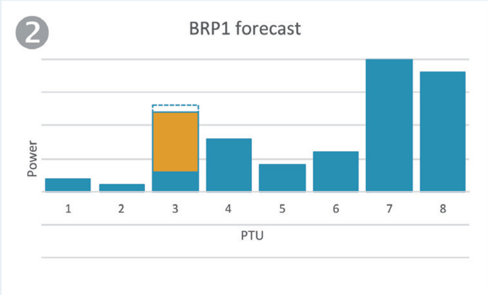
In the flex-only balance responsibility model (Flex-BR model), flexibility is completely separated from the supply of energy. The Supplier (SUP1) is responsible for the supply of energy on the Prosumer's main connection. The corresponding BRP (BRP1) is responsible for the balance at the Prosumer's main connection.

This interaction model looks almost identical to the full interaction model in section 4.2; however, in this interaction model the BRP role is split into separate Flex-BRP and Supply-BRP roles. Depending on the business model under consideration (see section 1.1), the Aggregator might establish a flexibility service contract with the Supply-BRP that describes how the Supply-BRP will be compensated during flexibility activation periods for any negative effects on its portfolio; alternatively, this might be formalized in the market's regulatory codes. To make this model work, the supply of energy needs to be fully separated from the flexibility. The Flex-BR model is still under discussion throughout Europe; depending on the outcome of these discussions, the current USEF specification might have to be altered.

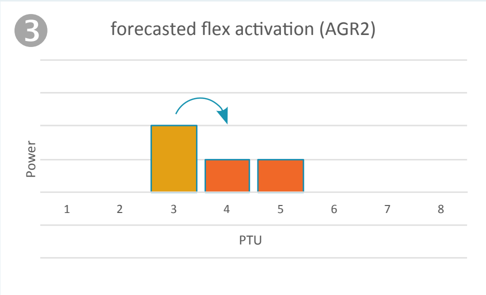
As soon as the Aggregator wants to activate flexibility in the Flex-BR model, a baseline must be set to separate the flexibility from the remaining load as measured on the main meter. Since the BRP on the main meter (BRP1) and BRP2 are competitors, an independent third party will need to set that baseline to prevent conflicts. The purpose of the baseline is twofold: first, it is needed to estimate the flexibility at the submeter and define the effect of flexibility activation, as discussed above. Second, it is needed to determine BRP1's allocation during the activation period and support the transfer of energy, as explained in the following example.

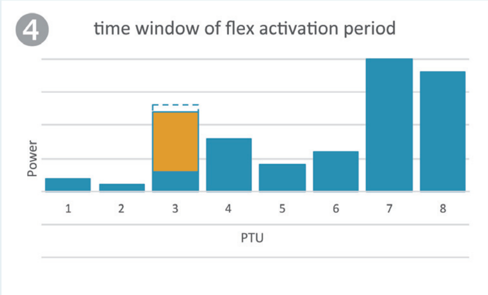
The following example illustrates the Flex-BR model.



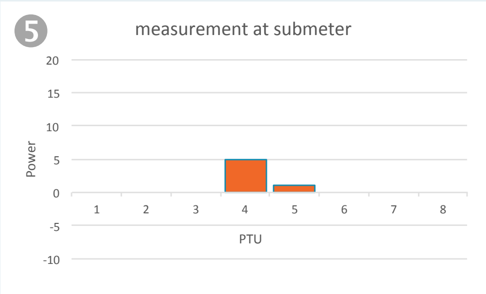


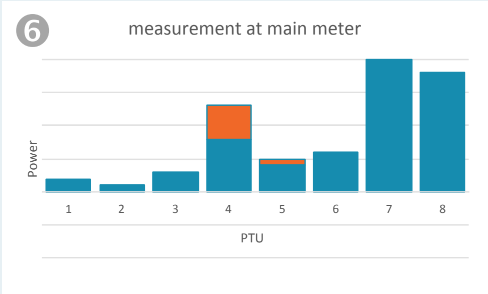
Graph 1 shows the baseline for the flexibility on the submeter. Graph 2 is BRP1's forecast for the total load on the main meter, including the initially planned ADS load for the electric vehicle.



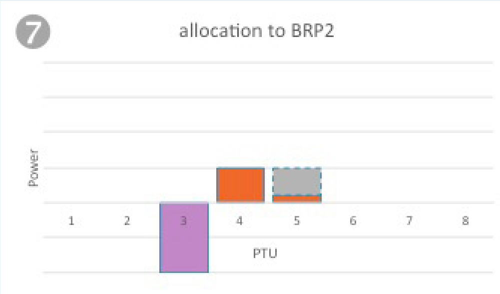


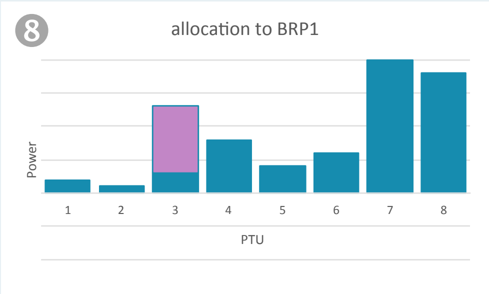
Now AGR2, responsible for the EV's flexibility, decides to activate that flexibility and forecasts that the load will be shifted and spread over PTUs 4 and 5, shown in graph 3. Within the activation period, BRP1's forecast is no longer valid, since BRP2 is affecting BRP1's position; see graph 4. The allocation to BRP1 can only be determined afterward, in the last step as depicted in graph 8.





During PTU=5 the driver of the EV decides to leave early and stops the charging process. This results in reduced energy consumption in PTU=5, as shown in the submeter measurement in graph 5, and also in the main meter measurement, shown in graph 6.





The allocation to BRP2 (shown in graph 7) is calculated by subtracting the baseline (graph 1) from the measured volumes on the submeter (graph 5). The allocation to BRP1 (shown in graph 8) during the flexibility activation period is now no longer based on its own forecast, but is determined afterward. This is done by subtracting the allocation to BRP2 (graph 7) from the actual measurements at the main meter (graph 6).

As long as BRP1's forecast and the baseline forecast are identical everything matches and things work out as expected. This requires a baseline methodology that is sufficiently accurate for both BRP1 and BRP2 to agree that it produced the correct baseline. If BRP1's forecast deviates from the baseline, however, then BRP1 will face an imbalance. Hence in this case the baseline directly affects the balance positions of both BRP1 and BRP2. In the standard model and the VTP model, the baseline only affects the activated flexibility and does not affect the BRP's balance position.

We further note that it is straightforward to define the baselines in this example and in example 1 in section 6.3. However, the second example in section 6.3 is an entirely different matter. Adapting the load profile to reduce the peak load for a continuous process (as in that example) results in a pre- and post-event rebound effect that covers the complete day. Although strictly speaking the roles of BRP1 and BRP2 can still be clearly separated, the supply of energy and the supply of flexibility get completely mixed up in such cases.

The Flex-BR model is still under discussion in various appearances throughout Europe; depending on the outcome of these discussions, the current USEF specification might have to be altered, perhaps by formalizing the Flex-BRP and Supply-BRP roles

5.5 Aggregator business models

USEF is built on roles rather than market parties; nonetheless, it can be useful to explore how different roles might be combined into businesses to see what impact this may have on the requirements for the framework. We see six[22] main business models for the Aggregator emerging in Europe:

Combined Aggregator-Supplier	In this model, the Supplier and Aggregator roles are combined to offer Prosumers a supply contract including flexibility options. The added benefit is reduced complexity, because the supply and flexibility provisions can be aligned from the start. The impact of flexibility activation on the Supplier's sourcing and sales position does not need to be compensated by the Aggregator, because the two roles are combined. The Supplier can be the incumbent Supplier, but the Aggregator can also propose a new Supplier to the Prosumer, or take on the role of Supplier itself.
Combined Aggregator-BRP	When the Aggregator and BRP roles are combined, all portfolio optimizations are generated directly within the portfolio of the combined business. As there is no need for further formal interaction between independent parties, USEF does not need to provide support for this model. The BRP can be the incumbent BRP, but the Aggregator can also propose a new BRP to the Prosumer, or take on the role of BRP itself.
Aggregator as service provider	In this model the Aggregator acts purely as a flexibility provider for one of the other roles. The Aggregator provides the means to access flexibility, but instead of selling this flexibility at its own risk, the Aggregator offers its access to one of the other players in the value chain. This will most likely be a long-term relationship, but it need not be an exclusive one and it might be terminated at some stage. Different degrees of partnership may develop, depending on how willing both parties are to disclose their portfolio and optimization information.
Delegated Aggregator	In this business a third-party Aggregator buys flexibility from Prosumers and sells it at its own risk to potential buyers (the DSO and BRP). This means all interactions with other market players have to be formalized, making this a more complex model. The Aggregator and the BRP seek synergy in optimizing the value of the flexibility. This value is shared between the two parties based on mutually agreed conditions.
Prosumer as Aggregator	Prosumers with sufficient flexibility can adopt the Aggregator role for their own portfolios. In this way, USEF enables Prosumers to directly enter the flexibility markets. Practically speaking, only commercial and industrial Prosumers can opt to take on this role; for residential Prosumers, the burden is too high and the volume too low.

[22] While USEF does not rule out a combined Aggregator-DSO model, we have not included this option because we feel that regulated and unregulated roles should not be combined if we are to guarantee a level playing field for the European market.

Aggregator based on Flex-BR model	In line with the Flex-BR model, the Aggregator controls the Prosumer's ADS during the flexibility activation period. To cover the balance responsibility during flexibility activation, the Aggregator must contract a BRP (the Flex-BRP). The Aggregator and Flex-BRP are competitors of the Supply-BRP and Supplier active on the customer's main connection . The balance position of the Supply-BRP and the supply profile are only affected during flexibility activation The Supply-BRP and Supplier must be compensated to neutralize the impact on their balance and supply positions. This compensation can be achieved in different ways1: through a regulatory framework2, through a contractual relationship, or through corrections to the Prosumer's metering data.
E-mobility role (CSO or EmSP) as Aggregator	EVs are an apt source of flexibility. In public charging situations, there is a market organization with specific e-mobility roles and business models. Two roles are key in most market organizations: the Charging Station Operator (CSO) and the E-mobility Service Provider (EmSP). The USEF position paper "Electric Mobility"3 describes how to align the e-mobility market structure with the USEF framework so that flexibility can be controlled by USEF's Aggregator role and the rest of the charging process handled within the e-mobility domain.

5.6 Aggregator Business Examples

B2B Aggregator example: Emergency power
An Aggregator may offer (through a BRP) tertiary control or strategic reserves services using a portfolio of uninterruptible power supply units (UPSes) installed at commercial and industrial (C&I) customers. Since UPSes are, in general, only active during an outage, these devices are an apt source of flexibility for such services.

B2C Aggregator example: Smart charging at home
An Aggregator may offer optimization services using a portfolio of charging units for electric vehicles (EVs) at the Prosumer's home. Since electric vehicles have a relatively high energy demand and may be charged at relatively high capacity levels, these devices are an apt source of flexibility for these services. Provided that the desired level of charge is met on time, the Aggregator is free to determine the actual charging profile. The resulting UFLEX can be used for both portfolio optimization and grid optimization purposes. Note that if many EVs are concentrated in a residential area, the associated DSO might need to procure UFLEX for grid congestion management.

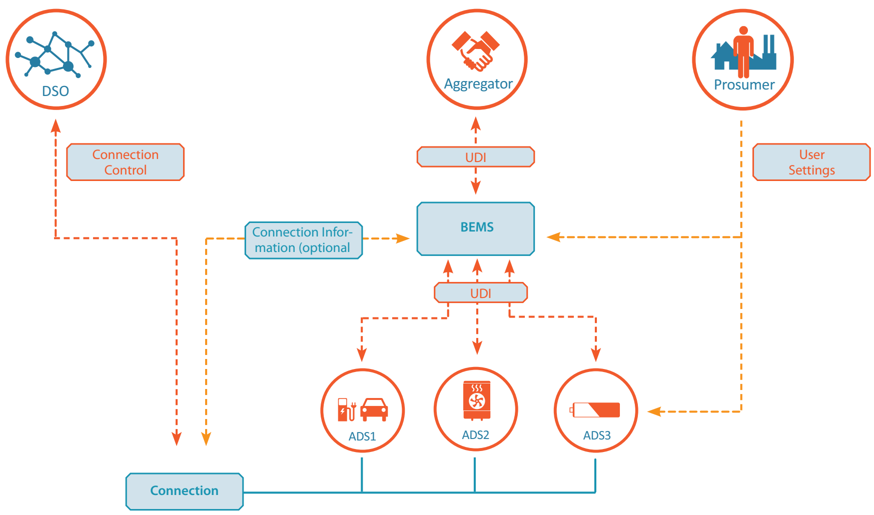
B2B Aggregator example: Managing cold stores
To facilitate food distribution, a large number of cold stores are located throughout the country. Provided that the temperature stays within acceptable limits, these stores offer a large potential for flexibility. The refrigeration temperature can be set to a lower value when energy costs are low; when the energy cost subsequently rises, the cooling system is turned off and the cold store is allowed to slowly heat up to the standard value. This is a typical demand response application. An Aggregator can offer cold store operators a discount on energy costs in return for the ability to control their Active Demand & Supply assets. The resulting UFLEX can be used for various purposes, typically portfolio optimization and aggregation services for the TSO.

B2B Aggregator example: Smart charging in public spaces
In the electric mobility domain, several new market players appear. In most market implementations there is a Charging Station Operator (CSO) that operates charging infrastructure and an E-mobility Service Provider (EmSP) that sells e-mobility services to e-mobility customers. Both are well equipped to control the charging process and retrieve flexibility from smart charging of vehicles. In other words, both could take on USEF's Aggregator role. A CSO typically operates local networks of charging stations and could trade UFLEX with the DSO for grid congestion management. An EmSP is typically related to a pool of EV owners (e.g., a company car fleet) which charge at different locations and is therefore better situated to trade UFLEX to the BRP for portfolio optimization.

6 Controlling the Active Demand & Supply

Accessing the flexibility provided by Active Demand & Supply assets requires a dedicated information structure and control protocols. USEF assumes a standardized setup linking the Aggregator, the Prosumer, and the Active Demand & Supply. This guarantees independence between the Active Demand & Supply 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.

The basic setup at the Prosumer's premises is shown in the figure above. The Aggregator controls the Active Demand & Supply (ADS). If the Aggregator controls multiple ADS assets, control typically flows through a Building Energy Management System (BEMS), which performs in-building optimization and serves as a first aggregation level. A BEMS is a logical entity and not necessarily a physical device. If the Aggregator controls a single ADS asset, a BEMS is not necessary.



The Prosumer applies user settings to achieve specific comfort levels. Examples include thermostat control of room heating and charge settings for EVs. User settings can be applied directly at the individual devices or via the BEMS.

In the USEF Orange regime (see section 5.1), the DSO directly controls the connection and limits the connection capacity. This enables the DSO to start the process of graceful degradation to meet grid constraints (see section 5.3). The exchange of connection information with the BEMS is essential to handle these situations automatically. This might result in switching off devices based on priorities set by the Prosumer. Without the implementation of this functionality, manual intervention by the Prosumer is required to handle the resulting inconvenience. The current version of USEF does not yet specify this functionality in detail.

Prosumers might want to use smart energy services from different Aggregators for specific devices, such as a smart EV charging service from one Aggregator and a heat pump optimization service from another. This can be achieved via one of the implementation options described in section 6.4. In this case the setup shown above is duplicated for each Aggregator

USEF distinguishes five control strategies that the Aggregator may apply. All five manage the flexibility provided by the ADS assets in a way that enables the Aggregator to optimize its portfolio. However, the strategies differ in five areas:

- the amount of resulting flexibility
- the response time
- the Prosumer's involvement
- the amount of device information used
- the way the Prosumer's comfort settings are handled

The control strategies are not included in the USEF specification; they serve as recommended practice for Aggregators and requirements for standardization activities at this level. See also the sidebar on the USEF UDI.

Strategy	Description	Prosumer Interaction	Device forecast	Guaranteed response
Manual	Prosumers manually change their loads based on notifications received from the Aggregator such as information on device displays, e-mails, or text messages. Although individual appliance response is not directly controlled by the Aggregator, the response can be statistically determined. Since the appliances are not controlled remotely, there is no need for a data connection, nor for a BEMS. This provides an easy-to-roll-out form of demand response at very low implementation costs. However, the amount of flexibility provided is limited and the response time is relatively slow.	Yes	No	No
Incentive-based	The Aggregator sends a control incentive to the appliance, such as a price signal via the BEMS. The appliance's control logic determines its response based on its actual state and possibly its predicted utilization in the near to mid-term future. As above, the response to this incentive can be statistically determined, or published by the appliance.	No	No	No
Predictive-based	The BEMS communicates a forecast for the aggregated load profile (production and consumption) to the Aggregator, or the Aggregator communicates its forecast to the BEMS, or both. (Hence the exchange can be either one-way or two-way communication.) This exchange may also include forecasts for additional parameters such as the control incentive, temperature, and so forth. Forecast communication enables greater economic optimization on appliance dispatch.	No	Yes	No
Transaction-based	Flexibility activation is based on a transaction between the Aggregator and the Prosumer, in which the Prosumer is rewarded for delivering flexibility according to the plan and penalized for not delivering. The basis for this type of control is a sound contract between the Aggregator and the Prosumer. The actual transactions may be automated.	No	Yes	Yes
Override	Power consumption and production are directly adjusted by the Aggregator's control signal and do not take the Prosumer's preferences or the actual state of the appliance into account. This strategy is typically used when the BEMS needs to accommodate a capacity limit at the connection.	No	No	Yes

USEF Device Interface (UDI)

To facilitate interoperability between different Active Demand & Supply devices and the Aggregator's control mechanisms, and thus to prevent vendor lock-in, we need a standardized device interface. USEF introduces a device interface (the UDI) for standardized ADS control. USEF does not define this UDI in detail, but specifies the requirements for such an interface. USEF will monitor standardization activities on the UDI level, which may lead to one or more recommended practices. The USEF reference implementation includes an example UDI, to demonstrate the USEF concepts up through the level of ADS control.

7 Privacy and security in USEF

The introduction of smart energy systems will create an explosion in the amount of energy usage data captured, from which a wealth of personal information can be distilled. Smart energy systems—like most complex information systems—deal with sensitive data and therefore require effective measures to preserve security and privacy. Privacy and security are systemwide issues; the protection of individual subsystems and components is not enough. The system is only as strong as the weakest link, and there is no way to realize a sufficiently large market for smart energy products and services if privacy and security issues undermine Prosumer trust. USEF is therefore designed with privacy and security in mind.

Privacy and security are distinct but related entities. Security is an essential foundation for managing privacy; you must implement security to ensure privacy.

The security objectives of energy networks differ from those in most other industries. For energy grids, it is vital that security measures do not adversely affect the grid's availability. Availability is the primary security goal, followed by integrity. The final security goal is confidentiality.

In smart energy systems, confidentiality becomes more important, because grid functionality is interwoven with personal data and market information.

USEF provides a privacy and security guideline[23] that provides approximately 50 design principles that together present a complete view of the privacy and security aspects associated with smart energy systems. The guideline forms the basis for the logical security architecture that is that is reflected in USEF's process flows and use cases and reference implementation. Essential insights from the guideline are shared below.

7.1 Legal framework

A multitude of national and international regulations are being developed that address the privacy and security aspects of smart energy systems, capturing society's views on the benefits and risks of these systems collecting and analyzing vast quantities of data. These regulations form the backdrop against which smart energy systems are taking shape. They strive to strike a balance between guaranteeing security of supply, protecting customer privacy, and enabling value creation through high-quality, innovative energy services.

USEF is designed to comply with the new European General Data Protection Regulation, which is scheduled to replace the current Data Protection Directive no later than 2015, and to embody the principles of legal protection by design.[24] All data on energy consumption is treated as personal data and subject to a Data Protection Impact Assessment. Data streams based on necessity, such as those serving the public interest or a legal obligation, are separated from those based on consent, such as for value-added services.

7.2 Value creation through data sharing

Through analytics and predictive profiling, a wealth of information can be distilled from the usage data generated by smart energy systems. Individuals and businesses can both benefit from sharing certain privacy-sensitive data. Such sharing makes it possible to tailor propositions to the Prosumer and to manage the grid more efficiently.
The value benefits for grid operators and energy service providers include proactive network maintenance, reduction of adverse events, improved operational efficiency, and better asset management. Customers are empowered to become Prosumers, realizing greater efficiency and monetary savings and, depending on the sophistication with which smart energy systems are integrated, other benefits such as integrated home management and automated and remote energy control. Corporations can expand their markets by providing smart energy services where the service provider and the energy provider are separate entities, or by using the information shared through smart energy technologies for other purposes, such as marketing.

[23] USEF Privacy & Security Guideline, November 2011. www.usef.info/News-Reads/Reads.aspx

[24] See "Legal Protection by Design in the Smart Grid," Mireille Hildebrandt, 2013.

The success of smart energy systems thus critically depends on the sharing of data and on large-scale Prosumer participation. Data sharing to accommodate all legitimate interests and objectives requires trust among all stakeholders, which in turn requires a coherent and transparent approach to privacy and security.

Vendors, Suppliers and other stakeholders signal trust by providing transparency and clarity to customers and demonstrating corporate responsibility. Prosumer acceptance also requires that the value created in smart energy systems is allocated to stakeholders in a fair, transparent, and unambiguous way. Users of smart energy systems are encouraged to actively participate in their own privacy protection. To achieve this, USEF enables the creation of services aimed at assisting Prosumers in making privacy choices that increase both individual and societal welfare.

Smart energy is a relatively new field, both technologically and in a regulatory sense. USEF is built on a sustainable IT framework that incorporates privacy-by-design and legal-protection-by-design principles. It provides flexibility in addressing privacy and security issues that may surface with the advent of new smart energy technologies and regulations. USEF provides a common approach to data management for all its participants that is based on risk assessments and built around the need-to-know security principle, focusing on maximizing value creation by establishing trust.

7.3 Identification, authentication, authorization, and trust

In a smart energy system, transaction supply and demand come together to reach a desired optimum. That optimum may be the lowest possible financial cost, lowest environmental impact, maximum profit, optimal resource utilization, or another desired and defined goal.

As for any real-world transaction, there must be trust between participating actors to ensure the envisioned outcome. Trust is built in a transaction when each actor does what it has promised, that is, produces or consumes the agreed-upon amount of energy at the agreed-upon time and, where applicable, fulfills its financial and other obligations associated with the transaction. Trust increases the likelihood that actors will participate in future transactions that benefit the system, and that the system will engage enough actors to function as a successful whole.

Trust increases when actors' identities, authenticity, and authorization are known and verified. Trust is further enhanced when the actual transactions are carried out satisfactorily: when all actors behave as agreed. Trust is reduced when actors cannot rely on actors' authenticity, that is, when identities can be abused (stolen, faked), when transactions cannot be properly authorized, or when transactions do not stay within preset limits. Transparency in actors' identities and behavior may therefore benefit the system. One way to create this transparency might be to rate actors (such as Suppliers, Prosumers, or device types) within the context of a transaction or even publicly: rankings are a form of explicit trust.

The USEF privacy and security guideline provides principles to address these issues. Advanced identity management supports the privacy and trust needs of a smart energy system. The use of unique identifiers, provided by smart energy identity providers, is recommended to reach economies of scale. The guideline also provides principles to guide the design and implementation of authorization and rating systems.

7.4 Data management and communication

USEF provides a common approach to data management for all its participants that is based on risk assessments and built around the need-to-know security principle, focusing on maximizing value creation by establishing trust.

In smart energy systems, several complex relationships between confidentiality, integrity, and availability exist. As an example, the likelihood of power outages is related to the integrity of the exchanged data. Incorrect data or no data at all (when data exchange itself is unavailable) may thus lead to grid unavailability. Smart energy systems introduce a dependency between the availability of the power grid itself and the supporting IT systems. USEF describes confidentiality, integrity, and availability in the context of smart energy systems and establishes principles that address their dependencies.

The focus on a risk-assessment-based approach ensures that the measures to protect data are always proportional to the potential damage incurred by a privacy or security breach. It also implies that there can be no one-size-fits-all recommendations on encryption levels, data retention times, and redundancy levels, as they depend on the outcome of risk assessments that may include subjective and context-sensitive risk quantifications. USEF contains a sample risk assessment as well as a recommended risk assessment methodology.

All data managed by USEF is subject to a data policy that specifies, at a minimum, who is the subject of the data, why it is in the system, how it can be accessed, and what its lifetime is. The use of well-defined roles for data management and explicit data policies provides transparency to all stakeholders and engenders trust.

The communication requirements for smart energy systems do not differ from those for other data communication networks such as the Internet. USEF ensures the end-to-end protection of data streams against network attacks by encrypting the data and avoiding transport nodes where data must be disclosed, rather than protecting access to the medium only.

7.5 Recovery

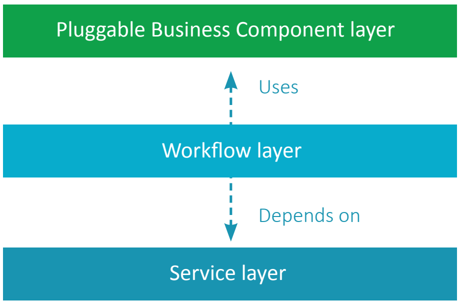
When things go wrong, we are faced with the need to recover. We must consider disaster recovery from outages or other negative events involving IT systems when designing the future power grid. Well-designed disaster recovery protocols accomplish two things: they maximize the grid’s proper, uninterrupted operation and, in the event of temporary failure, they mitigate the consequences for all stakeholders involved and ensure the continuous supply of energy to all connected parties. USEF provides principles that enable disaster recovery to be designed and implemented in a robust and, where possible, quantified fashion.

8 The USEF reference implementation

The USEF Foundation provides a reference implementation of the framework specification. It shows the viability of the design by providing a fully functional implementation. The reference implementation provides a starting point for third parties aiming to commercially exploit all or part of the USEF framework, or aiming to develop products and services built on top of the USEF framework. The reference implementation also serves as a test bed for testing extensions of, or improvements to, the framework's design that are brought forward by the USEF community. The reference implementation has passed conformance testing and is publicly available in the form of downloadable source code.
Being source code, it can easily be transferred, read, modified, and extended to suit the needs of individual customers adopting USEF.

8.1 Architecture

The reference implementation is based on a three-layer architecture (pictured below). These layers enables users of the reference implementation to adopt the layers that are fit for purpose and re-implement the others, depending on their needs.



Service layer
The service layer provides all the operational data stores required to realize the application components, a reliable set of communication capabilities, and logging and monitoring. The reference implementation uses the USEF best-practice message transfer mechanism. When selecting a message transfer mechanism, implementers should consider local market conditions. From a strictly technical point of view, implementers can select any messaging mechanism that supports the secure and reliable delivery of XML messages based on the USEF-defined recipient parameters and that meets the requirements set forth by the USEF Privacy & Security Guideline.. Possible standardized mechanisms include IEC CIM and ISO 15000 (ebXML).

Workflow layer
The workflow layer provides, for each role in the USEF roles model, an implementation of the processes and business services specified by USEF, specifically the processes defined by the market-based coordination mechanism (MCM) discussed in the preceding chapters of this document. The adoption of this layer will result in a USEF-compliant implementation for the selected roles.

Pluggable business component layer
Business decisions, such as the amount of offered UFLEX or its price, are outside the scope of the USEF and should be made by the parties implementing USEF. The pluggable business component layer enables a third party to plug in custom business logic that drives its actions in a USEF workflow process step.

The reference implementation is accompanied by a set of sub implementations of pluggable business component (PBC) to demonstrate the USEF framework. These are simple implementations that contain no complex business logic. Users of the reference implementation should replace these stubs with implementations that meet their business requirements, either by re-implementing them or by hooking into existing processes.

8.2 Implementation

The USEF reference implementation is written completely in Java 8 and designed to run on the Wildfly application runtime. By default, it uses the H2 database engine for data storage.

To facilitate the use of different database engines and application runtimes, there are no application dependencies in the workflow and pluggable business component layers. USEF's message transfer mechanism in the service layer uses libsodium to encrypt messages using a transport-independent cryptographic scheme identified as Cryptographic Scheme Type 1 (CS1).

The reference implementation's modular design makes it trivial to configure any number of instances for the various roles.

A time acceleration feature is available to enable faster-than-realtime simulations, as well as a utility for providing the set of default PBCs with data simulating a fictitious network and USEF flex market.

8.3 How to receive access

The reference implementation is provided free of charge to interested parties under a Copyleft license. To receive access, please visit http://www.usef.info/Framework/Download-the-Framework.aspx.

Join us

Fully implemented, USEF delivers all stakeholder interaction process models, communication protocols and even exemplary coding to accelerate software development. As a result, implementations accelerate, solutions are rapidly scalable and future connectability is ensured. Are you involved in integrated smart energy projects? Are you looking for new commercial opportunities that involve the exchange of flexibility? Contact us. USEF will increase the relevance and impact of your products or pilot projects. By 2020 USEF aims to be the de facto standard for smart energy systems. Adding new implementations, and, most importantly, new partners, is crucial for our success. We warmly invite new parties to join the USEF community, supporting the further development and roll-out of the framework. By getting involved with USEF, you can help to shape the future smart energy system and become an early adopter when it comes to developing unique flexibility products and services that will be relevant, connectable and cost-effective.

USEF Foundation
www.usef.energy