*local **E**lectricity retail **M**arkets for **P**rosumer smart grid p**OWER** services*

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Abbreviations and Acronyms

Acronym	Description
BM	Balancing market
CHP	Combined heat and power
CM	Cross market
CSU	Central storage unit
D-FCM	Daily flexibility cross market
DFP	Daily Flexibility Plan
DFPR	Daily Flexibility Plan and Reserve
DFR	Daily Flexibility Reserve
DR	Demand response
DSO	Distribution system operator
EP	Energy plan
EU	European Union
EV	Electric vehicle
FCM	Flexibility cross market
H-FCM	Hourly flexibility cross market
HFP	Hourly Flexibility Plan
HFPR	Hourly Flexibility Plan and Reserve
HFR	Hourly Flexibility Reserve
LD	Local deviation
LM	Local market
LREC	Local and renewable energy certificates
PoCC	Point of Community Coupling
PX	Power exchange market
SESP	Smart Energy Service Provider
TSO	Transmission system operator
WP	Work Package

1 Executive summary

This report constitutes the deliverable from task T6.3 in EMPOWER. It describes the trading concept proposed for EMPOWER. This concept is rooted in previous work reported in deliverables D6.1 and D6.2 as well as D3.2 and work from Work Package 2, D2.1 and task 2.2 which is still in process. The local market is established within a community of prosumers, consumers and regular suppliers and relates very strongly to a platform based business model. A business model of this kind presently supports multiple communities who are involved in network based trade. Ebay, Amazon, Uber and AirBnB are just a few examples.

The concept proposed relates to a local market for trade in electricity based on renewable resources that can be accommodated within a setting which is both connected and physically disconnected from the central market. The latter pertains to a situation whereby trade takes place within the boundary of a microgrid or similar and is often called "island mode" or "island operation". The former suggest an unlimited flow of electricity across the boundaries of the local market and the remaining energy world. In between these two principal states there may be situations where temporary constraints and congestions can occur. All three stereotypes are addressed.

In principle, the disconnected mode demands only a simple trading model, though the technical challenges related to load, frequency and voltage management will be much higher. This responsibility may have to be placed under the wings of the Smart Energy Service Provider (SESP). It is our proposition to use a simple pool model and exchange forward contracts by means of simple "over-the-counter" trade or call auctions. The choice depends on number of participants and the maturity of the community. Focus on the island mode also helps to understand certain general market mechanisms that have general implications. One is that all participants will need to cooperate to maintain sufficient balance and stability within the island in order to avoid problems of supply and possible collapse. Pure self-interested trade will be less pronounced since collaboration is a necessity. This suggests a dual revenue conception whereby people are honored directly for their involvement peer-to-peer and through their activity on behalf of the community. This aspect of solidarity is brought forward to the type of local markets that have an unconstrained connection of supply and demand to the central market. One is the introduction of long-term contracts. These take on the form of derivatives well known in the securities market. They pertain to the same trade as forwards, futures and options and can be traded accordingly. Long-term contracts yield permanency and outlook for all parties involved. The community and the SESP will be mutually supportive in staying loyal to these contracts. The SESP takes the overall responsibility for this, but both suppliers and consumers can incorporate end-user control to ensure compliance with the long-term contract within certain limits. Thus the long term contract can incorporate various degree of flexibility that can be directly honored within the contract.

For many communities an open channel to the central market is imperative as local resources and demand may vary in such a way that pure physical matching is impossible. The mismatch must be covered by trade in the central market. Hence the local market will be subject to a strong price signal from the central market. In order to maintain sufficient independence and contain as much demand and production within the boundary of the local market new incentives must be created. This includes capitalization on end-user flexibility and trade in regular services and energy related products such as controllers, PV panels and apps. End-user flexibility can be applied in different ways. All this can be organized in different ways. The EMPOWER platform should be adaptable and flexible enough to handle this and allow itself to be customized for different regions and regulatory regimes. By standardizing the trade and settlement model it is predominantly the definition of the contract templates that would determine the degree of customization.. We believe that this can be very helpful in order to realize an adaptable system. In principle it is shown how a local energy market could operate with or without any relation to a certificate market. Flexibility trade for the benefit of the community members, the DSO and the central market is also shown. Moreover it is revealed how trade in services can be accommodated. It is argued that flexibility is better traded in conjunction with energy as there is an inherent danger of gaming when there exists a significant price different between energy traded in kWh and flexibility traded in reduced power (kW). Both services and flexibility can be used to cross-subsidize energy trade in the local market or yield interesting kick-backs for the players in the local market. This is a common approach with platform based business models and can help to accelerate interest in the local trade and retain existing members. It can also be used to regulate incentives to balance local production against local demand. The report describes different forms of combined markets and contracts that will be singled out and tested out with end-users at the different pilot sites.

Due to the fact that the local market may have to operate in a symbiotic form together with the central market a specific responsibility is assigned to the SESP for just that purpose. Cross-market operations can be very important and the interests of the community can be optimized by mobilizing the inherent market power that resides with the community. A decision whether to apply flexibility for internal control, to sell it to the local DSO or in the balancing market is just one case in point. Its outward directed role the SESP takes on the responsibility of an aggregator. However, the external operations need to be suited to the internal tasks and vice versa, adding an extra dimension of complexity. Scheduling and constant prognostication to establish the most optimal actions at all times is essential. The revenues generated from this can be fed back to the community members in full or in part depending on the type of ownership that controls the SESP. It will contribute to kick-backs according to members' level of involvement and loyalty like in any other shopping club.

The market design and associated trading concept stand out as pure hypotheses at this time. According to common principles of science it is the project's ambition to prove the potential and viability of the proposed market design and trade in full scale experiments that will take place at the different pilot sites. Experiments will be formulated and the concepts will be translated into use cases in other work packages. These use-cases will constitute the framework for the experimental effort at the different pilot sites.

2 Task description

Task 6.3 in WP6 has, according to the project plan, been partly based on the work in T6.1, T6.2 and input from WP2. Due considerations have been made to input from WP3 and WP7 too. A continuous dialog between WP5 and WP6 has been maintained throughout the effort. Task 6.3 has continued the investigation of different trading concepts and associated trading principles and rules as drawn out in deliverable D6.2. However, in Task 6.3 these elements have been used to create one concept. The idea, as stated in the project plan and work package description, has been to create the basis for the specification of a suitable market arena and an agent based trading concept. This should also involve the management of the trading place and balancing strategies. All this must be in sync with what is physical possible to control and which will be further specified in WP5.

This report defines the final trading concept chosen for EMPOWER. It is presented as theoretical model and foundation for the practical work that will follow. In task T6.4 that has overlapped T6.3 for some time the concept is concretized further and more details added. This has been done to related the concept more strongly to the technical platform that we envision for the project. It has been an important objective to define a general idea and describe all its different facets. Some aspects are based on history and parallel research and are more proven. Others are quite novel. Later in the project tests and experiments related to different aspects will be tried as part of the pilot work. Our belief has also been that it is important to establish a concept that is sufficiently redundant and that can be customized and accommodated in multiple ways to suit any instance of the business models defined in WP2, for different technical support and for different regulatory regimes. Consequently this report aims to describe the EMPOWER market and the associated trading mechanisms from a more theoretic perspective. We have also adopted an educating approach. This has a general purpose as we wish all members of the project team to grasp the fundamentals of the EMPOWER concept. Some of the ideas presented in this report divert quite extensively from practices maintained in the current energy business and may appear foreign without sufficient explanatory support.

The final market and trade specification will be fully detailed out in task T6.4. In fact some elements from task 6.4 that directly extend the concepts developed in task 6.3 have already been incorporated in this document.

3 Introduction

As stated in the task description the ambition of this report is to describe the proposed concept for trade in EMPOWER. The trade concept derived at can be accommodated within the overall market design described in previous deliverables. Operations in this market, including the trade itself, will be supported by business concepts drawn out in WP2 and further processed in WP6. Pivotal to all of this is the platform business model that supports the community organized by the Smart Energy Service Provider (SESP).

Different stakeholders in the energy business and beyond have been confronted with the ideas presented here and invited to share their opinion on our early project work. Both workshops and interviews have been made. Their feedback has been very educating for the project team. Yet, many discussions have often paid attention to only parts of the EMPOWER model. It is natural that deliberation starts from the one corner of the world where one finds himself in. Some persistently insist on using the whole sale market approach as a template for local markets. Others have been entirely focused on demand-response issues and the benefit that this can bring to the energy system. The advantages of flexibility to the DSO thus dominate that part. A third group spell end-user orientation. Their opinion is often based on their own role as energy consumers. Some have familiarized themselves with networked markets like AirBnB and GooglePlay and platforms for auctions and broker services such as eBay and Hotels.com.

The notion that energy is an important enabling ingredient in the lives of individuals and play and important role for the economic and social development of their community is close to the heart of many. Here environmental concerns are also included.

Focus on price alone as a single market parameter distracts discussion from the real heart of the matter. How can more value be brought to the people? Personal value is composed of many matters, economic rationale ones as well as emotional. This suggests a utility oriented approach rather than a price focus.

All of this has amplified the need to communicate the EMPOWER model in a stepwise, top down manner. Some parts of this report may therefore appear superfluous to some as they are well familiar with the core of the matter. But for many, including the project's own developers, a more popular description should be welcome. Thus an overview description is provided first. The ambition is to communicate the novelty, adaptability and robustness of the EMPOWER concept in as simple and comprehensive way as possible. In this process references to popular conceptions that non-experts may already be familiar are made. In subsequent chapters more details intended for the implementation work in EMPOWER will be presented.

Altogether, all feedback has fuelled a positive process that has also contributed to increased confidence in the work presented here. Then we offer a final word. The market and trade concept derived at, and which is described in the following still remains a hypothetical concept until it is proven. Sufficient proof must be established in the pilots in order to promote with force the concepts and associated findings for the benefit of further exploitation and dissemination. One of the most important reasons is tight coupling between the business model chosen and the market design developed. This suggests experiments in the pilots that blend concerns related to technology, renewable energy resources, business and people.

4 Problem description

4.1 A network market based on a platform based business model

In deliverable D6.1 the overall market design for EMPOWER was presented. Due considerations related to applicable business models and end-user involvement, as they are described in D2.1from WP2 and further pursued in the forthcoming D2.2, were made and presented too. In D6.2 we explored state-of-the-art and discussed previous research on local energy markets.

The task reported in this deliverable has been to describe the market concept in more detail and design a suitable model for trade that can support the integrated market for exchange of energy, flexibility and services. The result should support the development of an integrated ICT system for local trade as proposed in WP4 and elaborated on in WP5. This concept stems from the platform based business model that was first introduced in D2.1 and D6.1.

The local market presented is a network market (Parker 2016) (see also WP2 for this) for local exchange of energy. This should not be confused with network as in an electrical grid. It pertains to how users interact on a web based platform using features that have been pioneered by systems such as Facebook and eBay.

However, end-user flexibility and insourcing of services within the concept have profound effects on the viability of the concept. This claim build on a chain of reasoning developed in “D2.1 Business Models” and ideas related to the community oriented approach that was proposed in D6.1 and D6.2. Efforts will be made to describe what advantages modern ICT (i.e. Internet and Internet of Things) can offer to realize such ends. The latter has constituted an important part in cooperation between WP5 and 6.

The local market is set within a community and consists of local producers, prosumers, consumers and storage. It is preserved and facilitated by a Smart Energy Service Provider (SESP). The SESP is the entity responsible for providing the most vital functionalities with respect to local market operation and recruitment of local market participants. In particular, these relate to the provision of consolidated and integrated ICT platform, the organization and facilitation of a neighbourhood community and the establishment of a trading floor for energy and energy related services. Further on, the EMPOWER local market is considered as consisting of three key elements of brokerage/sale: energy, flexibility and other services. Thus, a value stack for local trade is being built based on three specified market structures: local energy market, local flexibility market and local market for other services. Moreover, the local certificates market promote the investment in local and renewable generation.

The separate markets could be characterized by the following purposes:

- The local energy market:
    - Improve the operation of the grid: postpone investment in grid extension (alleviate bottlenecks in the local grid)
    - Help for the increase in local generation as the grid will be better suited to fit in the locally generated energy through local trade. This is the core of the EMPOWER project and a most important goal.
    - Community members can trade local renewable energy – to support the core goal above
- The local flexibility market:
    - Improve the operation of the grid: postpone investment in grid extensions; help DSO and TSO to cope with stringent situations.
    - Support system balancing by providing flexibility towards the TSO and balancing market
    - Community members can make profit by offering their flexibility resources
    - Cross-subsidies to benefit local energy trade
- The other services market
    - Increase the level of service that community members can enjoy
    - New opportunities through innovative services
    - Cross-subsidies to benefit local energy trade
- The combined market
    - Combine offers to create added value
    - Balance value assessments of flexibility and energy
- The local certificates market
    - Promote the local and renewable generation through negotiable certificates

      Reward consumers that buy certificates with services

4.2 The “local” in local markets

Figure 1: Two neighbourhoods with a local market, each organized as a community by a SESP. An enterprise can consolidate multiple local markets

As pointed out in D6.2, various definitions of local markets have been proposed, often in a tacit way. In EMPOWER the minimum market unit has been defined as a neighbourhood that is linked together at the point of community coupling (PoCC). This is where the Smart Energy Service Provider (SESP) maintains direct control, and this defines the local community which was introduced in D6.1. This choice of definition resembles what is sometimes referred to as “micro-markets” (Krovvidi 2010, Cox 2011), but it is not limited to that. Several minimum markets can be consolidated, possibly within one organization or portfolio (see Figure 1). This suggests a hierarchical system where as SESP in ways similar to an aggregator may amalgamate operations in multiple local markets. As we will show later operations could benefit significantly from this type of hierarchical consolidation. It also suggests a scalable and, to some extent, an adaptable system. The concept will support commercial concepts well known from other commercial domains. A SESP franchise hasbeen proposed earlier (D6.2) and is in line with the deliberation on local versus global operations introduced in D6.1. Business in other domains that have adopted the network market platform idea we relate to in EMPOWER have all a global ambitions while organizing its resources towards smaller groups or lesser geographical areas. (Parker 2016).

Nevertheless, in the following, when local markets and neighbourhoods are discussed we will stick to the local and leave the global aspect mostly to ongoing work in WP2. We uphold that the minimum market associated with a PoCC is our prime focus and this will be the basic reference for the remaining discourse.

4.3 Different states of the local market

Figure 2: The three possible main states of a local market. V1 and V2 are user value that is created by participation in the local market and the central market respectively

Three different possible states of operation for a neighbourhood delineated by a PoCC have been identified and constitute a basis for the work presented here. This is illustrated in Figure 2. Basic social economic theory suggests that a large unrestricted and unified market could yield the best possible surplus and welfare. From a business perspective tearing down market barriers could represent both a blessing and a curse. For the competitive enterprise unconstrained market access offers an attractive growth potential. However, less competitive enterprises might find its local market intruded by others and thus undermine its ongoing business. The customers are the likely winners, regardless. They will usually benefit from increased choice and lower prices. Bottlenecks and distance create a different situation. Transportation costs might favour the local supplier who will be exempt from such expenses. Permanent or temporary bottlenecks might cause a local deficit or surplus of goods and services that will impact prices. During periods of constrained central access a local market will emerge and come into play. The extreme case would be a full decoupling from any central supply. This island mode (Case B in Figure 2) will of course enforce a local market solution.

The most interesting case in Figure 2 is Case C. In this state, the only way that makes a local supplier attractive to a local customer is when the supplier can offer additional value on his own or by means of his or her alliances. The basic reason for a supplier to focus locally would usually be that the local customer is willing to pay more. Other factors such as market knowledge, tradition, patriotism, fewer costs could also turn the supplier's decision in favour of a local operation. The platform business model and the community concept introduced offers yet another way to hedge around the "local".

This issue was discussed in D6.1 and D6.2 and constitutes a major reason for introducing the combined market for energy sale, flexibility and other services. So far in EMPOWER it has been argued that flexibility and many services already have a local focus. Local production is another case in point, although present regulations in Europe, do not always differentiate between local and central energy supply like in other domains. Practices surrounding transportation cost and possible waivers for damages related to transport. Usually the price that customers need to pay reflects the true costs for transferring the goods from seller to buyer. This would include the transportation costs and any insurance paid for potential loss. Usually the more extensive that transfer operation is the more costly it becomes.

In general this is not true in the energy domain. Local energy will not impose the same amount of load or loss on the grid as centrally supplied energy would do, but the default is that local energy exchange should be subjected to the same tariffs as energy purchased through the central system. Having stated this it is also obvious that some local assets, such as end-user flexibility, can be valued higher in the central system than in the local. However, critical mass is required and local contributions will usually have to be aggregated beyond the PoCC. On what terms and in what way requires a local market. Summing up, we have identified different facets of local trade that we have treated in task T6.3 of WP6 and which has been included in the integrated model that will be described in this report. This is shown in Figure 3.

Figure 3 Possible commercial relationships within the local market. Relationships marked in red are considered more important.

A red colour in Figure 3 indicates a potentially important, commercial relationship. White colour stands for “possible” commercial relationship. “Local to local” specifies that both buyer and seller are found within the local market and the community that organizes this. “Central to local” defines import across the local boundary. “Local to central” suggests the opposite. In this discourse, “central” could also allude to more than present whole-sale market. It could also suggest trade with other corporate units controlled by the SESP, or any standalone, neighbouring unit.

Recruiting non-professional end-users as persistent sellers may not prescribe success. In a start-up phase the number of active suppliers or prosumers with sufficient surplus may be lacking too. This calls for a simple “over the counter” approach often referred to as OTC. In popular cases a competitive auction might be most appropriate. Auctions could be permanent or temporary. Temporary auctions could stem from regular fixed price practices for OTC operations. In periods where a fixed price system experiences imbalance between demand and supply a market maker may adjust the selling price up or down.

In neighbourhoods with abundant local production and storage more emphasis are likely to be placed on “local to local” operations. The opposite case would require more interaction with the central market. In places where the general spot price for energy is very low increased emphasis on services and flexibility is required to generate funds for a viable operation. This will be discussed in more detail. A bearing point, however, is that the community constitutes an attractive market segment for local and central suppliers of energy related services and products i.e. solar panels, insurance, energy efficiency. This interest is here translated into a shopping club related concept that in turn helps to boost local trade. Like many other network market platforms EMPOWER promotes the use of cross-subsidies to benefit the participants in the local market and the community that hosts the market. In this discourse we will also show that it is important to couple price for flexibility offered by local players to energy prices to avoid speculate behaviour. A low energy price and a high price for end-user flexibility cater for gaming. Increased rate of consumption will increase the degree of flexibility that can be traded.

5 The overall market and trading in EMPOWER

5.1 The general perspective

5.1.1 The Common Point of Coupling

Figure 4: A community with different resources and devices with a single PoCC. A sub-station will often be the most obvious Point of Common Coupling

The general local market concept is organized around a neighborhood that shares a common point of coupling (PoCC) in the distribution grid, most frequently a sub-station (see Figure 4). However, the unifying reference may also be a common storage facility or even a building with particular assets or needs. In the world of the SESP this constitutes the basic unit of its specific realm and the nucleus of the end-user community that it manages. It is important to note that community membership is voluntary so there households belonging to the same neighborhood who are not members of the SESP community. In fact, at times, it may be beneficial for such a community not to recruit all end-users. Hence looser coalitions or no coalitions with some consumers or suppliers may be more appropriate.

Moreover, a SESP may face competition from other SESPs or regular aggregators. Consequently the SESP operates in a competitive environment and must, together with the members of the community, promote its business like any networked market. It is also appropriate to emphasize that any player taking the position of a SESP may replicate the business at one PoCC and introduce it in other areas and regions. The

SESP role may take on an overall business management responsibility. As pointed out earlier, scalability is an inherent ambition for most network market models.

In some cases, the PoCC may be closed temporarily or for longer periods. In such a case, the neighborhood will be organized technically as a microgrid. A microgrid is an electrical system that includes multiple loads and distributed energy resources. It can be operated in parallel with the broader utility grid or as electrical island. The local market and the microgrid can be seen as potential symbiosis, one taking the technical perspective and the other a commercial one. The microgrid demands a market solution, however simple as it may be. A market solution situated in a neighborhood may benefit from micro grid technologies, but this is not mandatory. Hence we will also explain how a local market will function when it is connected to the Central Market (CM). This connection may be fully open with no physical capacity limitations at PoCC, or it may be a connection that is temporarily or permanently subjected to capacity constraints. The concept described here will encompass both, but details are relegated to later chapters.

5.1.2 Energy, flexibility and services

Figure 5: The local market connected to the wholesale market interaction model

In general the local market can be seen as a cell in a broader context (Figure 5). The local market place will suit its offer to the local population and offer energy, flexibility and services in an integral manner. We have previously called this a “value stack” where energy sale constitutes the basic element, with flexibility and services instituting the value boosting elements[1]. In order to explain how this can be done we will address the energy part first and then expand to include all the three elements.

5.2 Physical matching and the platform business concept

When a consumer switches on his heater today the central energy system responds instantly. The necessary current with the correct frequency and voltage comes to life in the heater. A perfect physical match between supply and demand is established in real time. The power system operators need to keep a close eye on the situation. Temporal, frequency or load mismatches cannot be tolerated. To reduce the challenge of instant compensation forecasts are important. This requires the capacity to know up fronand the capacity to react on an instant.The price settlement in the market yields a fair indicator of what demand and supply to expect over the next few hours.

A house disconnected from the grid could typically use a regular generator or a micro-CHP to achieve something similar. As long as demand is kept within certain limits the generator or CHP will deliver the matching batch of supply for the period needed. If demand ends the generator can be turned off.

When a single supplier of solar power and a regular consumer engage each other their needs may not necessarily fit that well. A physical mismatch between supply and demand is likely. However, reshaping both energy demand and supply to create a perfect, physical match can be possible. The most important instrument for this will be a buffer. With the advent of more affordable storage solutions and controllable generators that use climate friendly fuel, energy buffering will also become practically at a larger scale. The supply is switched on and off for that particular purpose. The required volume is supplied when needed for the duration demanded (see Figure 6). Perfect matching is possible. When physical matching of this kind becomes feasible, physical delivery and trade can be more closely coupled one way or the other. Peer-to-peer trade is simplified. The merchandise is sold and bought in batches. Examples of such include trade in crude oil, cement and fish. Emerging peer-to-peer trade, demonstrated by new, “shared economy” concepts, applies this too. The networked market concepts, such as Uber is

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[1] This idea has been tested on multiple market participants across Europe during the course of the project. Presentations based on the work in D6.1 and D6.2 have been embraced by individuals from the industry and academia alike – heralding a future dominated by energy oriented services. The most outspoken deliberation on the topic that has been noted is one by Marcus Warnke and Florian Umbreit of Hamburg based MGM consultants who claimed that energy services should constitute the backbone of the future energy business, not energy itself (Umbreit and Warnke 2016).

a case in point. It applies a smart phone supported IT platform, which organizes peer-to-peer contacts between a driver and a passenger. The concept is inherently locally

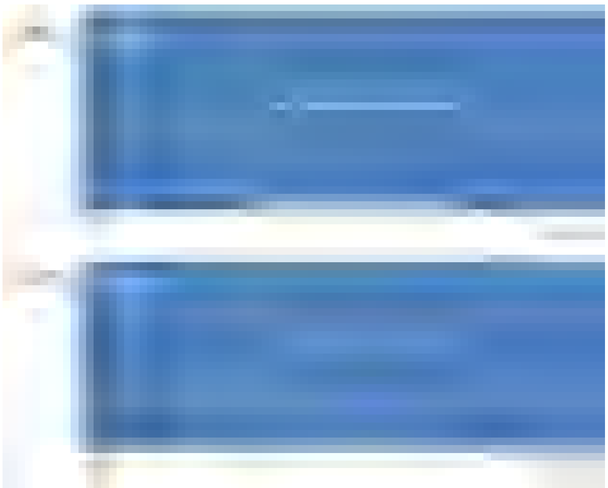

Figure 6: Generation (up) and consumption (down) pattern curves during a certain period. An example of a good match between need and offer in terms of volume and timewise

oriented. The platform-based business model challenges the traditional taxi service. The exchange of a batch of energy and the notion of a ride purchased through Uber is not so foreign as it may seem at first glance.

Even when demand and supply represent continuous processes, we can still think of them as a string of batches similar to a long ride across Europe consisting of different legs and different drivers linked together in a seamless manner without latency. Each leg could be negotiated separately or the whole ride could be priced as one somehow. In fact this is what Uber and its competitor Lyft offer commuters. Another parallel would be a long term contract where a passenger is offered the same ride every day for weeks. Uber, AirBnB, eBay, parts of Amazon embrace a non-commodity approach. The more traditional services have tried to the opposite for years - to make the ride as general as possible. Today you can hardly distinguish one ride from another. The auctions supported by the new market platforms is often based on several criteria, not price alone. Quality and reputation matter. User (both driver and passenger) assessments offer an important additional currency.

Other criteria for choice of offers constitute and essential part of platform based business models (see D2.1 and Parker 2016). Of course, one criterion could be how well things physically match. Mobilization time is essential. Lead time is typically a function of traffic and distance from the pick-up point. The computer algorithms that Uber applies use this as a basic auction mechanism. Drivers indirectly ask for a ride by being signed on to the Uber system and by means of their whereabouts relative to the the place where the potential passenger is positioned[2]. Choice of driver may also be determined by the driver's reputation. Although the system will propose "a supplier" the final decision is left to the passenger who might reject the offer leaving the next in line as a potential option.

When trading a ride with Uber, for instance, car and driver are directed specifically to the buyer after the deal is done. Based on the endorsed agreement the buyer will be transported the number of kilometers necessary to reach his or her destination. The passenger will be charged for the ride by Uber and both parties will be requested to assess and grade the ride. In return the IT platform will route the payment through a credit card company, PayPal or similar to the driver's account and update the driver's reputation. This reputation score can in turn be used to rank future offers.

A basic concept that fuels business development for platform based business models has been explained by Parker et al. (Parker 2016). These authors make an extensive review of emerging and mature business concepts like Uber, eBay, AirBnB and YouTube, including their own ideas for a network market for renewable energy in New York. Each operate a hub that attracts buyers/sellers[3]. This creates a network where the hub becomes the nucleus of all operations. This nucleus typically resides over a pool of assets. The size of the pool is dependent on the degree of asynchronous matching that need to take place.

In the case of Uber, the idea is to generate more dynamics by involving more drivers. That produces better geographic and timely offers which in general can improve the volume of supply within the system. The lack of matching rides means that prospective Uber passengers will still have to resort to traditional taxi service or other means of transportation. However, with increased coverage there will be faster pick-ups and less driver downtime. The latter will yield lower prices. Both will increase demand, which in turn will recruit more drivers.

Consequently a network platform like this must anticipate an evolution and try to generate as much positive network effects as possible. More precisely, the fluency of the operation is dependent on how mature the concept has become in a particular town or city. A critical mass is needed to establish a competitive alternative to the established passenger transportation services that a business model like that of Uber competes with.

[2] In fact this works like a reverse English auction. Drivers ask for a ride for a fixed price, but pick-up time is used as the principal settlement criterion. This phenomenon can be observed in various ways as drivers tend to home in on typical hot-spots at certain hours e.g. restaurants, railway stations etc.

[3] Keep in mind that buying and selling for many platforms use non-monetary currency such as recognition while financing their operation by means of different sourcing.

Similarly, in areas where energy prices are low the additional services offered could still tip competition in favor of the new concept.

Several European cab companies can boast not too high fares and a pick-up time that is already very good. This amplifies the challenge for new ventures like Uber. At the same time the non-professional drivers are subjected to the same traffic problems as everyone else. But here an advantage of the new concept is also buried - that is a greater distribution of drivers. Better geographic coverage of drivers offers some relief to latency and congestion problems. Issues related to traffic apply to many aspects of the local energy business too, often in a more severe way. Still additional incentives might have to be introduced. For Uber the answer has been surge pricing[4]. This is typically activated when there is an imbalance between demand and supply In such cases Uber acts like a market maker (Gurley 2014). Usually Uber offers fixed prices, but in cases when waiting time for passengers exceeds a certain limit prices are raised to attract more drivers. Critics has been raised by passengers who have complained about very high prices during such peak periods. Uber defends its policy by arguing that services would otherwise not be sufficient and waiting time unacceptable to passengers. But as a means to reduce such peaks Uber also sends out messages to potential passengers when it expects surge time to be over. Those who are flexible can benefit from this information as they will not be exposed to the higher fees.

The trade and market model that can be associated with IT-platforms such as Uber offers a very good reference for EMPOWER. Though some distinct differences and weaknesses of the “shared economy model” have been identified it is a type of model that EMPOWER pursues. But without important extensions and compromises the basic network market model discussed by Parker et al. (Parker 2016) will not necessarily work for the energy market.

5.2.1 Imperfect, physical match and energy pools

As pointed out and illustrated with the Uber example any mismatches between supply and demand (see Figure 7) need to be managed. Close to physical peer-to-peer match can be achieved in energy trade by means of generators and storage and suitable control measures that allow synchronization as well as up and down regulation of supply and demand. Batch oriented transaction could then be performed and direct peer-to-peer

[4] http://www.idrivewithuber.com/riders/uber-basics/what-is-uber-surge-pricing/

deliveries could be achieved. Even when technically feasible the cost involved can be proven too high today. However, this may change soon (Navigant Research 2014).

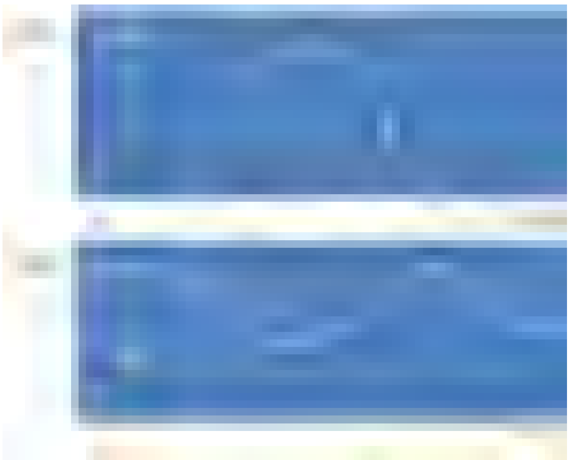

Figure 7 Photovoltaic generation curve (up) and consumption curve (down)
The demand situation for energy might not suit the supply situation and vice versa

A more important question is whether individual buffers provide a better option than a centrally controlled storage unit (CSU) or the traditional "energy pool". Current tariff structures in certain parts of Europe may discourage the use of a central repository. On the other side a CSU or a pool will decouple trade somewhat from the physical transaction. The peer-to-peer element will therefore be demoted and the notion of "local trade" might fade. But at the same time the platform provider will enhance its control and reinforce its business model. The viability of this concept has already been proven in other domains. One case in point is YouTube where prosumers and consumers do not interact directly with each other. Instead, all can enjoy a pool of videos for entertainment, education or as inspiration for new videos.

In any case, all transactions between members of a local trading community will use the same infrastructure. Latencies and irregularities must still be closely monitored and regulated. Physical balance needs to be achieved on a continuous basis. A centrally controlled pool or buffer structure (even if it is physically distributed) is therefore imperative. This task has already been assigned to the SESP. Hence a centrally controlled storage and energy pool system will be introduced in EMPOWER to cope with present cost issues related to storage, to enhance the chosen business model and to achieve the necessary local balance. This, however, does not exclude any consumer or prosumer to invest in private storage. In fact, a shared solution could be beneficial; especially within a community oriented setting that needs risk mitigation and increased resilience.

5.3 The trade principles of a simple, disconnected market (island mode)

Figure 8: The local market disconnected from the wholesale market
The figure illustrates when the community organized by the SESP operates in the island mode.

A local market fully disconnected (see Figure 8) from the central system lends itself to a relative simple trading model, albeit the technical implementation of such a model is going to demand much more of the neighborhood seeking such a solution than a connected version. We also know that external references such as prices in the central market will still determine attitudes and perceptions regarding costs, income, benefits, service levels etc. However, the underlying assumptions associated with this model are that circumstances, meaning the realities related to deficits and surplus, dominate and therefore govern the trade within the island.

To understand the essential elements of EMPOWER trading model we will address the island case first. It offers a self-contained, self-sufficient case where SESP is attributed a number of technical responsibilities that it is relieved of in the connected version. Technical infrastructure in the connected phase is working and roles for successful operations are assigned to the DSO and TSO. However, a local market approach in this setting demands much more in terms of market economics and business acumen. That is why the island case offers a better starting point for the model description. To explain the concept a simple illustration (Figure 9) focusing entirely on energy trade within the island shall define the basis for the rest of model description. This is especially important to understand since EMPOWER needs to address this in the context of platform based business model that was described in D2.1 and referred to in D6.1 and D6.2.

5.3.1 Basic trade

Trade starts with somebody realizing a need or somebody wanting to sell. A prosumer (or a pure supplier) has surplus to sell. The consumer needs energy. If both are self-interested traders they will seek to optimize their gains. Through direct negotiations or by means of a broker such as the SESP an agreement on price can be reached. Nash equilibrium is satisfied (Figure 9). The notion of equilibrium in trade

Figure 9 Example of an equilibrium agreement between a purchaser (P) and a seller (S) for a certain volume and price (p) electricity through the SESP. Equilibrium is reached when the two parties agree on a certain volume to be traded at a given price.

was extensively discussed in deliverable D6.2. If a clearing price cannot be reached the parties involved may resort to typical measures applied in various markets. Of course both may haggle about the price, but as time to delivery approaches, a settlement is likely to enforce an agreement between the traders. This convergence is independent of the size of the market and happens all the time, for instance, in the stock market. Another approach is to use the SESP as a market maker when the spread between the lowest price of the seller remains higher than the highest price that the buyer is willing to pay (see Figure 10). This may well happen with few active participants in the market. "Stale mate": A spread shows a situation where no agreement on price is met. A market maker can decide to side with either seller or buyer to close the gap and ensure increased dynamics

Figure 10: Example of a non-equilibrium situation with a single purchaser (P) with low demand and a single seller (S) with high demand. All information flows to the SESP

The SESP can therefore side with one of the traders to accelerate a settlement. As a buyer or a seller the SESP may create a shortage or a surplus that will influence the price up or down, respectively. However, this intervention will require consent from the two other parties when they first enter into the market, and they will have to compensate the SESP for it. Furthermore it requires capital to purchase energy and storage capacity to manage what has been purchased. The risk imposed may inhibit the solution. In practical terms it would imply that the SESP determines the price to balance demand and supply.

A third strategy often applied by traders to reach an agreement is to add more or take away something when they bargain. This may balance supply and demand better, but avoid further change of the price. This concept is called *value matching*. In the context provided here this could also imply added services like delayed payment, financing, buffering of energy, up-front payment, insurance etc. They are either added to “sugar the pill” or taken away to leave the seller a chance to sell the surplus elsewhere. The concept so far adheres to common trading standards, but it also shows how a commodity like energy can be combined with services as part of the same contract.

The contract that defines the energy transaction could address the traders specifically in a bi-lateral agreement and cover a number of legal aspects and rules required to honor this. The other alternative is that the SESP , like Uber, issues predefined contract templates and manages the endorsed contract between traders. Most of the legal aspects could then be excluded from the actual contract. Instead these could appear as rules of market conduct, provisions for membership and general requirements for all trade within the island. This is not uncommon in existing market places. This also paves the way for transferable contracts. A transferable contract will give any holder the duties and privileges that the original holder was granted as a supplier or a buyer. This could pave the way for a secondary market if more traders enter into the arena[5].

5.3.2 Solidarity

Even if the two traders that have been introduced are entirely self-interested they are likely to benefit more from a lasting relationship. Energy consumption and many forms of generation are continuous. Short-sighted optimization of a single transaction may yield to the need for a mutually fruitful and lasting relationship. This lasting relationship suggests some degree of cooperative effort. The SESP can still play the negotiator and market making role, but the notion of solidarity will help to reduce its risk. Prices for such long-term contracts can basically be settled periodically in an “over the counter” manner. With more participants on both the supply and demand side a simple auction could be more practical and fairer. A growing number of participants with longer term contracts

[5] And could be well managed by means of a block-chain approach too (Tapscott 2016)

will further mean increased risk reduction and less vulnerability to failure both on the demand and the supply side. Like for wholesale markets it will be important for all those involved that the local pool of energy is sufficient and liquid. This collective and shared interest is likely to establish a degree of collective solidarity by itself with the SESP as the pool manager. The risk will again be more distributed although the self-interest, maximum gain focus will not disappear. But potential losses could be better contained and that is in the interest of all participants.

Coalitions play an important role in game theory (Shoham 2009) and models from this will be used to describe the benefit of less selfishness to the local market and its members. In fact, the solidarity that each member offers within a coalition of the type that EMPOWER promotes also implies an additional value. In addition to the risk reduction solidarity infers recognition of a common cause that can help to overcome the shortages and limitations that individuals, even within a larger group, may be exposed too.

5.3.3 Balancing and the need for flexibility

As was depicted in Figure 6 (above) the physical match can be poor. The realities may deviate significantly from whatever commitment has been made. In the disconnected situation balancing must be ensured by the players themselves within the island. The default in all trade is that each party makes sure that the contractual agreement is fulfilled. The buyer must expect to pay more if he extends his demand. The seller is responsible for the delivery according to the commitment made. But as energy is not discrete, neither in form nor in terms of time, the match between delivery and consumption must be perfectly balanced down to the split second. Perfect synchronization is required within the island as is the case for the general energy system. The responsibility for this can be assigned to the SESP. However, his means for balancing may vary. In EMPOWER the SESP will use the participants' own flexibility as an instrument. If costs allow it may make use of a central storage unit (CSU), CHP or a generator too. The concept is illustrated in *Figure 11*.

Figure 11: Upward and downward regulation can be centralized, distributed or shared between all parties in the community.

The buffer does not need to absorb full level generation or consumption. A small battery pack or a minor CHP facility applying bio-fuel supplied locally could serve this purpose. In any case the SESP must coordinate all this. However, the prevailing principle should be that the trading parties must stay as loyal as possible to the commitments that have been made. Reservations for energy procurement or sale must be fulfilled in terms of both time and volume.

Longer term contracts allow the SESP to determine the general volume to be exchanged. Generation and consumer profiles can be established and associated with such contracts. The trading parties themselves can provide this. But the effort is sometimes better outsourced to the SESP. Historic records could offer a powerful instrument for prognosticating both generation and consumption for a season as well as for the next day. Machine learning is going to be essential for this.

The stipulated profiles determined through contracts or forecasts constitute the references for operation and the trading parties are obligated to stick to these references. Already at the contract stage it is possible to establish the degree of physical mismatch that can be tolerated and identify the need for compensating measures. As deliveries are not made along dedicated lines, connecting sellers and buyers, but into a pool, more sellers and buyers will help to even out differences and increase the match. This will be exploited by SESP. But more participants within a limited geographical area do not automatically rule out the need for an extra balancing capacity. Covariant effects within a concentrated area may in fact increase the need for such capacity (see Figure 12). The effects of such positive covariance are well known in investment and portfolio theory (Levišauskait 2010). A tighter coalition would probably suggest that the trading community within the island should all pitch in to create such a buffer.

Figure 12: Compensating SESP measures according to the number of participants in the SESP community and the Consumers' demand covariance

In spite of this SESP should be prepared to take on the task or invite a specialized service provider. The curves show the margial impact of non-conformances relative to the number of participants in the system. Increased dependencies between the participants will increase the need for compensating measures.

When the need for flexibility is outsourced and distributed among the participants in the market to secure balancing capacity, it is important to link this flexibility to their primary interest in order to avoid speculative behavior. In the case of EMPOWER we propose that rewards for reserved and demonstrated flexibility is linked to the energy price in order to control inflation of energy use.

To illustrate how this can be done a well-known concept from the aviation industry will be explained. When purchasing an airline ticket from A to B many travelers have been presented with three choices. The most expensive ticket allows rebooking with no additional fee (and promises better service onboard, higher frequent flyer bonus and extra luggage). The supplier (the airline) will grant flexibility at an additional cost.

The less expensive ticket will offer the passenger some flexibility (and less service) while the most affordable ticket will allow no flexibility. The risk lies entirely with the passenger buying the most affordable ticket. If the passenger fails to check in according to contract the cost for this error will be his alone. The price difference between the most expensive and the cheapest ticket reflects the value of the flexibility offered. As many travelers have experienced, the value of that flexibility can be considerably higher than the cost of the cheapest ticket. But the cost is still related to the basic fare for travelling from A to B. In the 70-ies and 80-ies a reverse form of this flexibility principle was more common. In those days the airlines *procured* flexibility. Again a priority ticket, a non-priority ticket and a stand-by ticket were default. The prices were different despite procurement of the same, basic product. The stand-by passenger was honored for his flexibility. The priority customer would be willing to pay more because his situation was more rigid. Again the price differences between the three tickets determine the value of extensive and less extensive flexibility - but that value was still related to the basic price of the ticket.

A similar approach will be applied for the local market in EMPOWER. The priority end-user will offer no flexibility and leave that entirely to his trading partner or the SESP. That would be reflected in the price defined in the contract. In contrast, a high-flexibility, end-user would benefit from lower prices. But in general the participants in a local market could benefit significantly by reciprocating flexibility along with their energy commitment, one or the other way. Typically, he or she would install the means to down- or up-regulate according to the volume and profile defined in the contract. This would reinforce prognostication to be done prior to the actual trade. Continuous regulation could help achieve the necessary balance. If every participant stuck to the contract made there would be no deviations recorded. It makes forecasting a lot easier and the job of the SESP a lot simpler. However, it would not exclude the SESP from requesting additional flexibility if a failure or major mismatch should occur. So the following is enabled:

- The rigid end-user buys, in fact, flexibility from other participants and passes the risk and costs of any change of behavior onto them.
- The flexible end-user could activate his or her elasticity on a continuous basis or on signal from the SESP.

A flexible end-user who adopts continuous control takes full responsibility for honoring any trading agreement made and is honored for that. Naturally, the job could be outsourced to SESP or a provider of remote services of this kind. However, a local PI/PID controller would be possible to use for this purpose. The contractual profile defined in the sales agreement [6] could be used as the controller's reference value at all times.

A flexible, but more passive end-user, would change his load or surplus output at the will of the SESP. How this will be done will be embraced by the contract and the rules of the market. A proper clause can be included where the SESP is reserved the right to intervene in a certain way. This option may or not be invoked, but the end-user will still be granted a compensation for reserving such flexibility.

A trading community can level out extensive irregularities from the projected purchase and delivery plan simply by the share number of traders. As a consequence it may be smarter to handle the aggregated deviances rather than each individual. However, for this to happen the degree of covariance between the individual non-conformities must be low (see Figure 12). In the central market this mechanism tends to work well. But a prerequisite for this is that no common denominator governs the deviations across different prosumers, suppliers or consumers connected to the system. As pointed out earlier this is not always true for a local area. Sudden mishaps or changes in temperature, parking situation (EVs), wind and cloud situation could create stronger interdependencies and a more uniform behavior across a concentrated area and influence all participants at the same time. In fact deviances may rather amplify rather

[6] This concept is not so foreign as many reviewers have remarked. People use thermostat controlled heaters/coolers and automatic light dimmers already to keep costs down – all can be categorized as proportional (P) controllers, possibly with an integral (I) element. What we propose here is to honor systematic use of this and other types of controllers to facilitate management of the local market. Installation and use of such does not rule out the user's possibility to take part in any additional flexibility directed program that the SESP might issue on behalf, say, of the local DSO.

than level out. As a consequence a pure centralized solution, with no distributed control could be placed under great pressure and be subjected to extensive risk. A distributed solution would inevitably allot the risk and increase redundancy against system failure. A shared solution as suggested in the table below is more recommended. Table 1 shows a proposed regime using both demand-side, supply-side and central resources.

Table 1: Duration of demand-side, supply –side and central response, possible enabling means and the responsible party. (Due to the multiple roles assigned to SESP it is very much involved)

Interval	Flexibility provider	Means	Responsible
Less than 1 minute	SESP	Batteries, power routers and other microgrid technologies	SESP
1-15 minutes	SESP	Batteries, power routers and other microgrid technologies Distributed demand-response	SESP
1-15 minutes	The self-regulating end-user (special contract)	Locally controlled devices and appliances. Reidential batteries.	SESP
15 minutes to 3 hours	SESP, flexible end-users	Remotely controlled devices, batteries and appliances, CHPs, hydrogen or bio-based generators and central storage	SESP
More than 3 hours	Reserve power provider, SESP	CHPs, hydro or bio-based generators	SESP

5.3.4 Services

Services or other products bundled with a commodity have already been mentioned in passing and is not uncommon. It serves to de-commoditize the trade and can be used as a bargaining element both by the seller and the buyer as explained above to reach a price agreement. Some services can be adopted for the benefit of the community as a whole. A prosumer offering an add-on service or contribution like that may not necessarily target an individual end-user, but the community as a whole. These kind of bundles have been advocated in the EMPOWER project form the start. Services and products that are naturally linked to energy can be extremely important motivators for both seller and buyer in a low-price energy market. In a disconnected mode services related to balancing and market making are likely to be in high demand. A selection, which may typically have a local origin and local buyers have been listed in Table 2.

Table 2 shows a selection of services that can be offered and consumed within the island

Service/product type	Consumer	Prosumer/supplier	Others
Market making	Seller	Seller	Seller
Storage service	Buyer/Seller	Buyer/Seller	Buyer/Seller
Maintenance support	Buyer/Seller	Buyer/Seller	Buyer/Seller
Cleaning	Seller	Buyer/Seller	Buyer/Seller
Apps (energy calculators, alarms, etc.)	Buyer/Seller	Buyer/Seller	Buyer/Seller
Financing, credits	Buyer	Buyer	Seller
Technical diagnosis and repair	Buyer	Buyer	Seller
Manuals, instructions, advice	Buyer/Seller	Buyer/Seller	Buyer/Seller
Temperature alarms (notifications of problems stemming from excessive or too low temperatures in certain rooms)	Buyer/Seller	Buyer/Seller	Buyer/Seller
Remote control and monitoring services	Buyer/Seller	Buyer/Seller	Buyer/Seller
Information sharing (e.g. “home” or “away” signal)	Buyer/Seller	Buyer/Seller	Buyer
Energy related data	Seller	Seller	Buyer
Green Certificates	Seller	Buyer/Seller	Buyer/Seller

Neighbors could watch over each other’s solar panel, they could share instructions and promote green energy solutions and ensure on-line monitoring through specific groups on social media. All this could be organized and formalized as part of the resource pool within the community and traded by means of the IT platform (e.g. smart phone).

In addition to these services there may be other types that are not necessarily bundled with the actual exchange of energy. Some of the services and products offered could be obtainable as additions meant to make community membership more attractive. They may not necessarily relate to a specific energy transaction, but be part of a trade that is more dissociated from the rest. They can instead be used to facilitate firmer and more frequent interactions between members in the local market. Revenues generated on transactions made as part of the shopping club concept could be used to increase energy prices for local sellers and reduce prices for local buyers. This type of subsidy policy is not uncommon among platform oriented businesses[7].

A regular contract specifying exchange of energy with a degree of flexibility could also yield a direct discount or benefit. Such immediate value adding services could make any offer more attractive or to yield a higher or lower price. A contract could then relate to multiple elements, all defined within one standard contract and one price:

- Delivery of a certain volume of energy according to a particular daily profile and for a specific period
- Specification of a percentage flexibility daily
- Specification of a percentage flexibility on demand
- Payment service
- Remote energy management included
- On line diagnosis of private energy system
- Discount rates for other products and services
- Loyalty rewards

Services of the kind described here also provide another important function. Service providers would be permitted into the community and promote services and acquire data on conditions that members benefit from discounts, special offers and certain privileges. The SESP could also negotiate a cut of every transaction and use this to reinforce and facilitate trade and membership growth.

5.3.5 Adding up the basic principles of an isolated market

The principles drawn out above provide obvious implications for the local market and trade concept chosen. The island mode has been used as a case study to better highlight the dependencies between different elements.

- EMPOWER market concept is a networked market concept that can be supported by means of a business model using an ICT-platform as exchange medium.

[7] Google is a case in point here. The search engine that links content providers with content seekers is free for all users. Revenues from advertisements offering services and products cover the cost of operation. This benefits the primary users of the search engine and increase general activity which in turn make advertising more attractive.

- The contracts established could integrate delivery of energy, flexibility and services within the same legal structure.
- Trade will imply a negotiated match between seller and buyer with the SESP as a broker, as a balancing responsible and as a possible market maker.
- Depending on the number participants and liquidity of the local market, internal trade can be based on “over the counter” principles or simple auctions. With multiple players and longer term contracts a more extensive call auction can be introduced. This implies that the market is cleared at distinct intervals and not in a continuous fashion.
- Flexibility and services can be added to the energy trade as an inherent and value adding part. This de-commoditizes the energy trade to some degree.
- Services that take no immediate part in a transaction can boost trade in local energy through cross-subsidization.
- Flexibility can take different forms and be distributed among different stakeholders to compensate for forecasting errors and failures. A central repository and capacity service controlled by the SESP must be contemplated despite extensive distribution of flexibility to handle physical mismatches.
- Trade in flexibility and energy should be linked to avoid unfair speculative behavior.
- Establishing lasting agreements would further help to reduce self-interest focus and encourage a collaborative effort to maintain stability. In a local setting this is both possible and wanted. The solidarity aspect will draw attention away from individual actions based on pure self-interest towards a shared-goal-shared-responsibility type of operation. This can be further manifested in a community approach where each participant is a member. The risk is shared. The longer term gains may yield a better dividend for each involved.
- The community approach reinforces shared interest operations that are likely to benefit the market. The concept of a SESP based community has been introduced in EMPOWER earlier and has been discussed at length in both D6.1 and D6.2.

5.4 Proposed trading concepts for the disconnected market

This section explains how the principles laid out in the previous section determines the proposed trading model in EMPOWER. This trading model is comprehensive and covers diverse forms of trade due to its integral nature. The reason for this is to make the EMPOWER concept as adaptable as possible.

Trade in non-discrete items all have in common that the trade is based on long term contracts of duration D. All contracts are settled at time T before they are actually implemented. D and T is a variable that will be investigated as part of the experimental work. We assume an initial default for a solar dominated local market to operate with a D=3 months and T= 1 month. The different forms of trade should be catered for in EMPOWER. Regulatory regimes and local preferences may not embrace all, but a selection. However, EMPOWER should be adjustable and cater for such discriminations. Ideally there should be one system that can handle different types of contracts for slightly different markets.

5.4.1 Local OTC trade

The governing entity that controls the SESP (i.e a private enterprise, the community itself, a retailer) may wish to apply an over-the-counter policy. For small and local markets in its early stage this could possibly be the best solution. A purchase price and a sales price can be determined by the SESP or the body governing the SESP. Typically a sales price and a purchase price for a given product will be shared with the community members prior to the contract period.

This prices will be typically compared with competing alternatives that others may offer members of the community. Reward, subsidies and bonus prospects will also be aligned and promoted accordingly. The OTC solution is sufficiently robust to offer and request different products at the same time. Such a practice lends itself well to pure energy sale, flexibility, trade in other products and services as well as combination of all these.

Despite the external price signals and offers the SESP and the community members operate in a stand-alone market. Supply and demand are confined within the boundaries of the physical system. As a default the SESP takes all risk and incorporates this either as a direct fee on each transaction or as part of the membership fee. But measures can be taken to share some of the risk by encouraging end-user flexibility. However, profits from alternative trade can help to reduce the overall economic risk and maintain attractive energy prices still.

As briefly explained earlier, the SESP may acquire the position of a market maker in order to boost trading. The SESP will be in a position to estimate both future demand and supply within the community. Lack of demand may be due to lack of interest among the consumers. Lack of supply may be due to few producers of surplus. General interest in selling through the community may be falling. As a consequence the SESP may have to create additional incentives in order to achieve a better balance between demand and supply. At this point the SESP may come forward with bundles that make sale or purchase through the local market more attractive. A prosumer could then be offered a set of services for a very low price mark-up to make his offer better. Same policy could be applied to boost activity among consumers. An alternative to this would be to change the price. If demand is low compared to energy consumption, the sales price could be lowered accordingly. If supply is low the opposite could happen. In such situations the OTC regime replaces its fixed price strategies with a blind, reverse auction. If more supply is needed the SESP calls for supply by raising the purchase price. The process stops until demand is covered. If demand is comparatively low it may lower its sales price in a similar way until local supply is covered.

In general, for the isolated market the sales price for energy alone would be higher than the price offered to suppliers. Trade volume in energy alone will then determine SESP revenues. However, in regions were people in general experience low energy prices or strong competition, price for supply might have to be jacked up, Consumer prices might have to be lowered in a similar way, leaving the SESP with none or negative revenues for each transaction made. This can be solved by means of cross subsidies where profits from flexibility related operations and services offers cover the cost. This issue is more important for cases where the local market maintains an open channel to the central market and is explained in a later section. However, the general idea is to consider energy and in particular renewable energy as the basis for all other trade, but leave the profit making to all the add-on possibilities that the local energy trade creates.

5.4.2 Simple call auction

For a more mature local market with several members and potentially a good balance between supply and demand the OTC should be replaced by a simple call auction. A call auction is non-continuous and price clearing is done at a specific point in time. (Schwartz 2013). We have considered two types of call auctions for EMPOWER. They are similar, but with a distinct difference.

- Open Limit Order Book
- Price Scan Auction

In both cases the SESP organizes the trade and acts like a broker. This is shown in *Figure 13*. Note that prosumers can be both bidders and askers depending on the state of their surplus. Trading takes place at fixed points in time. These can be arranged according to season or at even intervals. The SESP monitors the pool and operates a balancing resource with sufficient capacity. The community has a board that specifies the contract templates to be used. The SESP issues contracts when a deal between parties has been settled. The SESP also takes on the full system responsibility. However, SESP's failure will penalize all involved and it is therefore in the interest of all members to provide the SESP all necessary support. The governance rules of the community should handle this.

Figure 13 Trade is non-continuous and price clearing is done at a specific point in time. P = prosumer, S= pure supplier & C = pure consumer

In a call auction the result is a single price. This is a common model upheld also in markets such as NordPool. It has also made its reentrance in the stock market (May 2013) with the advent of electronic trading (Schwartz 2013). This proposal is quite different from those local trade initiatives that have been previously proposed and that were investigated in D6.2. A non-continuous trade concept offers good control and makes the transition from a state where the OTC prevails to an auction oriented trade more seamless.

5.4.2.1 Open Limit Order Book

At a given point in time the market opens. Asks and bids are invited. All asks are ranked according to descending price. All bids are ranked in ascending order. A clearing price is posted at different intervals. This reflects the state of the trade before the market closes. The governing clearing price at the time when the market closes is defined as the crossing point where demand and supply meet.

EMPOWER assumes an open call where all members of the community can see the order book. This is especially important for a community oriented market. The more efficient a market is at incorporating information the more efficient and stable the price discovery process will be. This will generate trust. Order book withdrawals can be allowed without penalty. In EMPOWER we discourage the use of direct monetary penalties, but trust the governance ability of the SESP and the community. However, inspired by shopping clubs a track record will be maintained to promote or demote members of the community. Members would know that this could impact their chances of long term benefits. Partial orders can be accepted. Unfulfilled orders can be managed centrally or at the side of the participants and put in play later. In the first case the SESP or a service provider operating on his behalf can offer a vaulting service where suppliers can deposit its unsold surplus for a fee. Buyers that experience uncovered demand may abstain and try or reduce its demand or "borrow" energy for a fee defined by SESP.

The ability to withdraw and reenter is also meant to encourage activity in a small market and reduce the number of partial matches. It should increase the liquidity of the market with less intervention of SESP. The generator or the storage helps SESP to increase market liquidity. This means too that SESP may have to enter a bid or an ask to physically match demand or supply. In addition it will have to compensate when different traders fail to meet their obligations during the period of the contract.

- Ask (p1, V1*)
- Ask (p2, V2*)
- Ask (p3, V3*)
- Ask (p4, V4*)

…………..

- Bid (p6, V6*)
- Bid (p7, V7*)
- Bid (p8, V8*)
- Bid (p9, V9*)

The notation p_i above suggests the price offered or required. V_i* suggests a certain volume required over a period. We also propose that the specification of volume is associated with a weekly consumption or supply profile per hour (average projection for the next contract period) whenever such records are available. Where hourly metering (AMS) is available the contracts proposed can address a higher time resolution. The contracts could then operate with two segments, day and night or even hourly. In such a case the order book could be divided into two or 24 sections respectively, but the trade and clearing principle would be the same.

5.4.2.2 Fulfilling orders

Once the market is cleared and contracts are settled the SESP is left with the sole responsibility assuring that the physical supply and demand is matched. The importance of aggregate flexibility becomes very important. The aggregated mismatches need to be managed by the SESP, but as explained above, incentives for reducing the central flexibility reserves can be part of the trade. The value of that flexibility must be settled in accordance with what other flexibility resources are available to the SESP and the community. The SESP would benefit from the use of a Central Storage Unit (CSU). This would typically be a battery pack. The CSU should be filled when excess surplus is available. In the opposite case the CSU should be discharged or a generator ramped up to create the necessary balance.

The prognosticated demand or supply stated in the contracts defined by the settlement should at all times satisfy the equations:

$$Vmatch\ (t) = Vd^*(t) - Vs^*(t)$$

$$Vmatch(t) = 0$$

Here *Vd*(t) refers to the volume of demand that must be delivered. Vs*(*t) refers to the supply during the same period. trefers to an appropriate time slot within the contract period, typically one hour. This is the ideal case. In real life there will always be a residual *ε(t)* that can be expressed in terms of *Vmatch(t).*

$$Vmatch\ (t) = Vd^*(t) - Vs^*(t) + \varepsilon(t)$$

ε(t) is a stochastic variable and defines the difference between the projected (in contracts) and the actual physical match. This difference will be the result of errors tied to the forecasting that was made before the asks and the bids were entered into the order book. But it could also be due to technical errors. Besides this there may always be short-lived outliers from the projected norm due to changes in temperature, clouds etc. Deviations of this nature require systematic use of flexibility resources including storage. These resources must be scaled according to the distribution describing these errors and incidences that might occur. A Gaussian approximation will be suitable to define the required capacity of the flexibility resources. A 100 percent capacity could be expressed in terms of the mean (μ) and standard deviation (σ), $\varepsilon(t) = \mu + 3{,}9^* \sigma$.

5.4.2.3 Price Scan Auction

A Price Scan Auction is very similar to an Open Limit Order Book process (Economides 1995). The difference in EMPOWER would be that the SESP calls out price proposals and in return harvests the bids and asks for that price. It is an iterative process that terminates when the best balance between buy and sell orders is found. Otherwise, this type of call auction is not very much different from the other. The list of orders would appear the same. Its advantage is that the SESP can alleviate the burden of the community members with respect to determine the opening price for an ask and a bid. This type of auction operates in a “pull” fashion which is easy for non-professionals to understand and take part in. This suggests more efficient process, increased trade volume, greater community engagement and more liquidity. In addition it can be more efficient in an environment where there are strong price signals emitted from beyond the community. Moreover, any transition from an OTC concept for a local market in earnest to an auction based practice for a more mature market will be close to seamless. For each call the SESP and the trade participants make a reevaluation of their offer. All can follow the process which produces a learning curve for all.

5.4.3 Auctions with combined energy and flexibility products

5.4.3.1 Blending flexible and non-flexible orders

Forecasting errors related to the projected generation and consumption volume and profile defined in the contracts will be inevitable and needs to be dealt with the way it was explained earlier. The SESP can manage this, but also issue bid and ask templates that would incorporate end-user contributions to manage this. Flexibility is thus taken into account. The principle is illustrated in Figure 14 Open Limit Order Book. Those traders who opt for the flexibility alternatives (stand-by, non-priority) must assure that forecasts are met or respond to the signals that are emitted from the SESP. The former requires a demand-side or supply-side controller monitored by the user's own software agent. As explained earlier this could be a simple controllers or more advanced self-learning agents that require less tuning. When the SESP controls this and emits a signal the concept assumes a regular demand-response concept. The value of the flexibility incorporated in the contract can be historically based and fixed before each contract renewal. But it can also be determined by means of marginal flexibility cost curve for a battery or other kind of storage unit applied by the SESP. The SESP should make continuous prognoses

Figure 14 Trade in combined flexibility and energy Δ = flexibility (or rigidity)

about generation and consumption the simplest case the call auction would consist of asks and bids that specify whether the trader is flexible or rigid. Flexible means that some means of maintaining the projected profile and volume in the contract has been installed at the end-user's side.

- Ask (p1, V1*,Δ)
- Ask (p2, V2*,~Δ)
- Ask (p3, V3*,~Δ)
- Ask (p4, V4*,Δ)
- ….

- Bid (p6, V6*, ~Δ)
- Bid (p7, V7*, ~Δ)
- Bid (p8, V8*, Δ)
- Bid (p9, V9*, Δ)

Here ~Δ suggests that control is left entirely in the hands of the SESP. Δ suggests that the trader invokes his own flexibility and guarantees full compliance with the contract. Flexibility will typically be specified by the SESP as a typical value (or more) expressed in watts. As a consequence the regulating capacity of the SESP directly under its control can be reduced accordingly. In this case the SESP and the community are the immediate beneficiaries of the distributed control. The other players are less affected.

The value of the flexibility in this market relative to the volumes traded is calculated by the SESP and distributed among the traders of flexibility. This suggests that the price associated with Ask (p1, V1*,Δ) is presented to buyers with a lower price and appears as Ask(p1',V1*). A Bid(p2,V2*,Δ) is revised and presented in a similar way with a higher price (p2',V2). As a consequence, traders offering their own flexibility will be more attractive in the market. In addition liquidity is likely to increase as people may decide to throw their flexibility into the bargain or not. The operation translates the order book accordingly and produces a different ranking before the market is cleared. This is illustrated below.

- Ask (p2, V2*,~Δ)
- Ask (p3, V3*,~Δ)
- Ask (p1, V1*,Δ)
- Ask (p4, V4*,Δ)
- ….

- Bid (p8, V8*, Δ)
- Bid (p6, V6*, ~Δ)
- Bid (p9, V9*, Δ)
- Bid (p7, V7*, ~Δ)

The price adjustments carried out made could be compensated by those who are more rigid. Their offers would then be adjusted, albeit in the opposite way. The cost of outsourced flexibility could be deducted or added to the final payment depending on the available rest capacities for compensation that the SESP has. The estimated needs for compensation will invoke considerations explained earlier (see Figure 12). The cost and gain reference would be the marginal cost of a centralized storage, generator or other flexibility resource directly operated by the SESP.

5.4.3.2 The marginal gain can be calculated

The marginal gain and thus value of the decentralized flexibility support can be calculated. If the capacity unit cost is **c,** and the max capacity, **K**, required to manage the accumulated non-conformances from N number of users the marginal gain of the decentralized flexibility can be calculated.

Let **f(n)** express the accumulated variance. With an increasing number of independent users this can be expressed by means of a Gaussian distribution function due to the central limit theorem[8].. In small statistical populations or when covariant aspects prevails a modified distribution is required. We have found that a fair approximation for the general case in EMPOWER can be expressed in terms of a simple logarithmic function on the form **f(n) = A*ln(n)** where **A** is determined by the volume of energy in play and the degree of covariance between the traders.

$$K = f(N).$$

Here K is the absolute flexibility that must be mobilized in case an imbalance occurs. If no other participant relinquish flexibility K is the capacity that the SESP must be muster. This has a cost. Assume then that **j** number of end-users take care of themselves as we have described. Then the capacity requirement required by the SESP would decrease according to the formula:

$$K - f(n-j) = K - A*\ln(n-j)$$

The value (Gain) of that relief, assuming a linear cost function, would be

$$\text{Gain} = c*(K - A*\ln(n-j)).$$

This gain can be distributed between the flexible participants. It will vary depending on the number of contracts issued and the statistical dependency between each holder of that contract. The value of private end-user initiatives to contain their own non-conformances decreases with an increased number of traders and trading volume, but

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[8] See https://www.khanacademy.org/math/statistics-probability/sampling-distributions-library/sample-means/v/central-limit-theorem for an introduction to this topic

increases with stronger covariance between the players. Hence, the value of individual initiatives may be very welcome in a start-up phase.

5.4.3.3 Flexibility in Price Scan Auctions

A Price Scan Auction offers the advantage that two prices can be called out during the price scan enabling market participants to better determine up front the benefits associated with a flexible order. First the SESP would call the basic energy price and secondly the increment for flexibility. If up front calculations of the type explained above and made by the SESP are reliable (an aided by historic data from operations up to that point in time) the increment plus or minus would remain pretty stable during the auction.

5.4.4 Trade in services and related products

As explained in D6.2 a community could offer an attractive target group for suppliers of products and services. Some could be in the form of maintenance and repair, some could be financial e.g. customized insurance, some could offer online diagnosis of equipment, other services could include temperature control, online energy calculators efficiency programs and equipment like controllers, solar panels and wind generators etc. A good part of this could be in the form of apps that could guide and support the end-user. Professional suppliers of such could be invited in and target the members of the community with customized offers. A good part of such services could be offered by the non-professional members of the community too. The Apple Store and Google Play embrace offers from professionals and non-professionals alike. This could also be true for the platform offered in EMPOWER. The SESP would charge professional service providers for enhanced access to potential customers. That is the shopping club way. Revenues gained can be used to cover cost of operations, market making and investments in generators, fuel or storage and to expand the community. The latter is especially important in the beginning. Some offers are better traded as stand-alone items, while others could be bundled with the energy and flexibility exchange.

The platform offered could encompass both over-the-counter offers and auctions. The default concept will be similar to that found on eBay and Hotels.com.

The seller is invited to post an offer and ask a price for that. The price could be fixed or sold to the highest bidder as explained earlier. The latter indicates an ordinary English auction. The trading platform and the SESP will take the broker’s role. The market is cleared at a given time, when the seller is happy or when there are no more incremental bids. A buyer could announce his interest in a service. Then the process is partly reversed. An inverted English auction could then take place. The process would terminate in a similar way. Payments can be channeled through the SESP in ways that are common to all forms of trade within the community. Extra credits (e.g. bonus points) are given to those buyers and sellers who conclude transactions.

5.4.5 Trade in combined energy, flexibility and service products

The former trading processes in energy and flexibility could be further expanded to include calls for relief/reinforcement or other kinds of services in the same call. Such services would offer more transparency to the SESP, increase resilience of the community and yield further control to SESP. All services that increase transparency of operations will make it easier for SESP to make choices. For instance a “Home or Away” signal indicates whether or not a house is occupied. Calendar sharing is another way of increasing transparency of operation. The SESP could then better estimate the surplus of a prosumer, his flexibility and the need for closer monitoring. “Away” might also indicate that basic duration limits for disconnection could be extended or reduced beyond the ordinary (of course with the proper compensation). Other types of services are those that help to mitigate risk. Online diagnosis, instant repair, daily monitoring and cleaning of solar panels are examples of such. The following nominations could be foreseen:

- Ask (pi, Vs*, Δi, s)
- Bid(pj, Vs*, Δj, s)

For the consumer it could suggest something like this, “*I will need Vs* volume of energy with my specific consumption profile over the next period. I am offering the price pi. At the same time I am offering a flexibility volume of Δi per hour. My offer includes state signals about the use of my home, e.g. Home & Away, and yield the SESP or anyone that it engages the full access to my home for instant repair.”*

Both OTC related practices and call auctions could be expanded to manage this. In the case of an auction the degree of partial matches in the auction would determine whether combos of this type are useful to the community. However, the highest bid may not win. To illustrate the point how auctions could be organized to facilitate this single askers and single bidders as well as coalitions of such could enter an order for an energy Volume, V*, together with certain services and guarantees A, B and C. A, B and C denote a set of legitimate services/products, including flexibility. This could be abbreviated to an expression like this, (V*, p, A, B, C). Assume that a supplier presents such a combo. One bidder offers the price p1 for the full suite. Another bidder bids p2 < p1 for V* and C (partial order) while a third offers p3 < p1 for only (A and B). Assume that p2 +p1 > p1, then the order will go to the two “lowest” bidder since the seller will gain more in this way. Combined offers can be made very attractive whereby local community members can create alliances with external service providers and therefore increase common interest in the market. Partial offers are likely increase trade volume, but could also prove the trade in extensive combos obsolete. IN that case thehe service and product part would be better separated from the bids and asks and managed separately. The rest is settled in the manner explained earlier. In this context services are first and foremost treated as a kind of goodwill. However, the participants are at liberty to reflect the value of the service offered or demanded in the price volunteered making himself less or more competitive. In spite of this, extra services offered and traded will be honored by means of internal ranking (i.e. preference in activation) and when common gains generated by the SESP will be redistributed at period end (or later).

5.5 The connected local market

In many regions there may be insufficient local resources to satisfy the need of local consumers. In other parts there may exist periodically a significant surplus that cannot be consumed or stored locally. In early stages of the local market this might constitute the default case. This alone caters for a sound connection to the local market. Even in areas where better balance between local supply and demand can be achieved, temporal mismatches would still favor an open connection to the central market in compliance with free trading principles.

The principles governing basic energy trade in the disconnected state (island mode) as described in the previous section will also be pertinent to a local market connected to the central market. One possible perspective is to view the central market, or a representative who enables such access, as a regular participant in the local market. The inevitable consequence is that all other participants in the local market will become more or less price takers. This calls for different strategies depending on whether the retail price stemming from the central market is persistently low or much higher. In regions where the retail prices are high and where the commission or barriers for sale is significant the local market can help to increase competition and reduce the power of the gatekeepers to the central market.

If the retail prices are already very low this may not be viable. A strong price signal from the central market may then prove local price negotiations trivial or even obsolete. Then quality elements such as “energy produced locally” or“100% renewable energy” need to be used as differentiating elements. Incentives for local trade on energy alone have been listed in the table below Table 3. These could be related to multiple factors where cost, regulations, sourcing, availability and quality constitute the most important.

Table 3 Incentives for trading locally even with open channels to the central market

Factor	**Prosumer/supplier**	**Consumer**
Undersized	May not have the critical mass [kWh] to operate directly in the central market	Little influence
Oversized	Due to regulations there may be a ceiling with regard to feed-in volume or power	Little influence
Cost of access to the central market	Commission paid to an aggregator may make internal trade favorable	Price-mark-up offered by the general retailers may be too high
Taxation & tariffs	Locally sold energy will be imposed less tax or tariffs than centrally imported	Locally purchased energy will be imposed less tax or tariffs than centrally imported
The power of the local	Patriotism may cater for a small price mark-up	Buying local yields a satisfaction of social responsibility
Green energy	Climate concerns could favor local suppliers of green energy as long as there is no fossil mix in the pool	Some customer segments are willing to pay more for guaranteed clean energy. Gives added value.
Improved quality of supply	Supply that improve voltage situation could yield a higher margin. Reduction of brown-outs also offer improved supply.	Segments subjected to periods with fluctuations in voltage may be willing to pay more
Cost of operation	Local operations may be simpler and more readily available. Scalability is possible through ICT platform.	Less important

Less rigidity	A local market may offer increased springiness and resilience and then adjust to life style changes more effectively	A local market may offer increased springiness and resilience and then adjust to life style changes more effectively
Increased choice of retailers and aggregators	Challenges the dominant player. Provides competition.	May drive down end-user prices at the cost of the dominant supplier
Availability	Can provide valuable emergency power and reduced number of outages due to increased redundancy with two options.	Less risk
Cross-subsidies	The associated service and product market could enable funds to subsidize energy sold locally.	The associated service and product market could enable funds to subsidize energy procured locally.
Local coalition	Reduces individual risk. Better alignment with customers. Increased market power.	Reduces individual risk. More alignment with customers. Increased market power.
Solidarity	Risk sharing, greater long term benefits	Risk sharing, greater long term benefits

All of the factors listed above provide incentives for local trade with IT-platform. Despite the strong price signal emitted from the central market it would still be more favorably to trade locally with a selection of these incentives added. Improved cost differences, less “fuzz”, more influence, increased social and climate value as well as risk mitigation all contribute to this. As already pointed out the margins gained in some regions may be too low to really mobilize in favor of the local market. But in regions where energy prices are already very low and quality of energy supply fair the local competitiveness might need a boost. As explained before flexibility and service trade can offer this. Both can help to cross subsidize the energy trade to boost incentives for use of locally produced energy.

5.5.1 The SESP manages the connection to the central market

In EMPOWER, connection to the central market will be managed by SESP on behalf of the community and its members. Management principles could differ as described in D6.1. The responsibilities allocated to SESP are likely to be distributed or outsourced to other entities. Nevertheless, we will assume that SESP alone takes a firm and uniform responsibility of all operations towards other communities and the central market.

Interactions with the central market could be directed towards the regular spot market, the intra-day market as well as the balancing market. Primarily, SESP would use the central market as a source to assure local balance whenever needed. This responsibility should not be confused with the responsibility of DSO or the obligations that SESP must take on in a disconnected market. Rather, the SESP's responsibility in the connected market is to assure that the obligations of the local market and its stakeholders are met. In addition the SESP may take the positon of a security funds manager. This implies that it trades in the central market to leverage the benefit of the community based on the contracts that have been established in the local market.

The use of the central market as a buffer does not make local demand side regulations and storage obsolete. It simply increases the resilience of the local market and offers additional opportunities. This call for optimization too where asset play can be important. It is a way for the community to gain added revenues too. In addition it may reduce the risk that the SESP is exposed too. At the same time the SESP's role as a potential market maker will wane. With a suite of PoCCs that the owner behind the operator controls the more power can also be imposed on the central system too. The community concept, longer term contract and the use of call auctions would again be appropriate in the connected, local market.

5.5.2 Local OTC trade in connected mode

As for the isolated case the OTC approach is viable also for the local market, which could be connected permanently or frequently with the central market. But the SESP needs to coordinate things with the rhythm of the central market. This is explained later. Also new considerations will have to be made because of the price taking role. Furthermore the SESP and the community members will operate in an extended market environment with competitive energy prices, and in part, also competitive opportunities for flexibility trade. The long term contracts offered will inevitably take the form of financial forwards. As an OTC player this leaves the SESP with increased risk, but also increased possibilities.

5.5.3 Auction

We advocate a Price Scan Auction in this mode. The SESP makes the price calls and may distinguish pure local and green energy from the mix purchased from the central market. The SESP and all other participants are fully aware of the standard opportunities that the central market offers. The price signal offered emitted by the central futures market combined with other prognoses creates a very strong reference for the SESP and all participants in the local market. It is therefore important that the specific assets offered by the local market are made transparent and attractive from the start. Asks and bids would include quality preferences in addition to energy volume and basic control. The order book would therefore consist of order of the type:

- Ask (p1, V1*,Δ, ~g)
- Ask (p2, V2*,~Δ,g)
- Ask (p3, V3*,~Δ,g)
- Ask (p4, V4*,Δ,g)

  ………………..

- Bid (p6, V6*, ~Δ, g)
- Bid (p7, V7*, ~Δ, ~g)
- Bid (p8, V8*, Δ, g)
- Bid (p9, V9*, Δ, ~g)

The **g** assigned to an offer or a contract would, for instance, indicate preference for "green, local energy" while the **~g** would indicate indifference. This suggests that that the prosumer or supplier is indifferent to whether the energy produced is exported and mixed with other supplies of with a different carbon footprint. The **g** marker would designate the local, green production for local consume. Similarly, a buyer would use the same markers as preference markers in a similar way. The market will be cleared in two steps. All the orders marked as **g** will be settled first. This will be followed by the rest.

As the SESP should also operate local energy reserves and storage, in addition to its access to the central market (Figure 15) it can decide what instrument to use to facilitate the local trade. This requires an optimization approach to mitigate risk and to make sure that the community as a whole benefits.

Figure 15 Basic, local energy trade in the connected mode. The SESP can use the central market (CM) as an additional resource to maintain contract conformity and optimize outcomes for individual and collective alike.

5.5.4 The impact of flexibility

5.5.4.1 Meta-flexibility

As emphasized earlier end-user flexibility is inherently local. But in the connected situation there are more options for capitalizing on this than in the disconnected situation. End-users may therefore exploit their flexibility in different ways. In fact, the trade in end-user flexibility may put the local market and its participants in an entirely different position with respect to the central market. It may probably create more value, than basic energy commodity alone. A well-established market regime for exploitation of up and down regulation as described for the disconnected market may impact the central market in a profound way. The strategic sourcing resides at the end-user side. Aggregated flexibility may offer valuable relief both for the central market to dampen price volatility and offer relief to the technical side of the power system. Hence the SESP can take on both the technical and commercial aggregator role to facilitate the local market. But one major distinction must be made between the task of SESP and regular aggregator. SESP does not organize a standard portfolio, but a community where each member can choose where, when and how to sell flexibility. We can call this *meta-flexibility*. A prosumer, pure supplier or consumer has a freedom of choice that the member of an ordinary aggregator portfolio does not have. They are offered increased latitude regarding when to offer flexibility and to whom. In turn, this could help determine the true value of local flexibility. An illustration of this is shown in Figure 16. Four alternatives are presented. The trader represented by the consumer in the community depicted must decide how to reserve his flexibility to honor the personal energy contract that governs the cost of his energy usage.

Figure 16 End-user flexibility (represented by a consumer) can be customized for different demands for different pricing. The Δ that a consumer (or prosumer) can sell for a price can be used for the benefit of other community members, to alleviate DSO or be part of an aggregate that is offered to the central balancing market. This illustrates a kind of meta-flexibility.

5.5.4.2 The various flexibility options

An end-user thus have the following options for his flexibility:

- It can be used to strictly honor the contract for energy sale or purchase.
- It can be reserved for the benefit of other traders in local community via SESP.
- It may be traded in the central market.
- It may be reserved for the local DSO.

The importance of the first two options has been already highlighted for the disconnected, local market. Engagement versus the DSO and the central market will be discussed later. The flexibility could possibly be distributed among different targets if regulations allow this. End-user flexibility thus has different applications and different value at different times. What yields the best gain is an optimization problem that non-professional may not be up to. Again the SESP or other service providers could offer a deal of this nature through the local trading spot.

5.5.5 Inflated flexibility

Earlier we pointed out how sale of flexibility could be integrated with the exchange of energy and be reflected in the price offered. One inherent problem with flexibility sale for energy purposes is that the sourcing can easily beinflated, especially among consumers. This can be especially true in the connected market where energy might be more abundant for a lower price than the basic price of flexibility[9].

[9] We currently observe this with the introduction of power tariffs at the future pilot site, Hvaler. Weekend users of cottages tend to abandon former practices where they decreased energy consumption during the working week. Former practices implied a

The basic principle is, the more consumption the more volume can be relinquished. This is typical where heating/cooling represent a significant base load. A high consumption rate opens up for increased sale of flexibility. The lower the price of energy compared to the price of flexibility measured in power, the more attractive it becomes to ramp up or maintain a high consumption rate[10]. This is illustrated in Figure 17. The continuous line shows the basic energy profile of a consumer. The area under curve determines the energy cost. The area under the red line represents an inelastic consumption. The parts exceeding this level are more flexible. The area above could be surrendered for a price. If the price of that flexibility is much higher than the energy price it could pay off to increase the base load just to be able to yield more flexibility for a higher price. If flexibility and energy consumption are not treated as a pair speculation can occur.

Figure 17 Flexibility in the form of demand-response is typically illustrated by means of load reduction. The continuous line shows the basic energy profile of a consumer. The area under curve determines the energy cost. The area under the red line could suggest the part of his consumption that is very inelastic. The parts exceeding this level are more flexible. That part could be expanded by increasing the base load.

Thus a tight price or cost coupling between energy and flexibility is required. This can be catered for in the contractual phase illustrated with the aviation example. The concept illustrated for the islanding situation and the airline example given therefore lends itself well to the connected state too.

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significantly lower temperature during the week. Remotely operated heaters were turned on just before the next weekend (Bremdal 2015) creating a power peak that now incurs an additional cost higher than the energy cost to maintain a stable, high temperature during the week.

[10] Which is well illustrated in areas with very low energy prices and high power tariffs

5.5.6 Pure flexibility trade

Figure 18 Pure flexibility trade towards the DSO and the balancing markets using community flexible resources

Flexibility trade (see Figure 18) could be directed towards the local DSO only. But operations in the tertiary balancing market could also be an option if the necessary provisions for this are met. The local principles of trade will be similar. The SESP can negotiate different contracts with the DSO. Typical contracts could be continuous valley filling to avoid thermal wear and tear on the system operator's infrastructure. It might be anticipated peak shaving on local substations and lines. Another contract might be related to voltage control in remote parts of a long radial. The DSO might wish to secure a ceiling for local energy feeds in some of its infrastructure. It might also want to negotiate emergency measures and controlled recommissioning after outage. Different contracts for each situation might be discussed.

A contract, compound or each one separately, will specify the flexibility volume that needs to be reserved, the activation process, duration of the contract, remuneration principles and other things. The contract will typically be a kind of option, but with a specified reservation fee. In addition an activation fee should be negotiated. The SESP will turn around and organize a reverse auction whereby tranches of the contract with the DSO are posted as a request for quote RFQ). Ideally the sum of the tranches sealed will add up to match the needs of the DSO. In the opposite case the SESP can apply resources that it controls directly. The auction will follow popular principles whereby quotes for load increments are invited. For instance, quotes will define a price for the first 0,5 kW for the next 0,5 kW (yielding 1 kW altogether) and so forth. The demand side flexibility curve typically follows a quadric function due to the classic double humped consumption profile. A supplier curve is dependent on the type of energy resource applied. A micro-CHP might be very flexible, but have higher marginal costs. A PV panel without a battery might only be disconnected. The final result will typically be an order of merit curve for the supply where the availability of the first 0,5 kW is more abundant than the step from 2 to 2,5 kW.

Figure 19 Principles of flexibility trade with one buyer: The marginal cost of flexibility supply against an almost fixed demand defined in the SESP-DSO agreement. Y-axis indicates a price regime. X-axis define the aggregated flexibility of the community and the demand for flexibility channeled through the SESP

Figure 19 shows how the flexibility volunteered for sale will approach a squared function with distinct steps representing marginal cost of flexibility. The price-cross represents max price paid. X-axis defines the aggregated flexibility of the community and the need of a major customer such as the DSO channeled through SESP.

A prerequisite for breaking the DSO contract into tranches as described above and conducting an auction accordingly is a fixed set of intervals for disconnection. The SESP might choose to use the same intervals specified in the contract with the DSO. However, this could be too long for some households. Consequently the SESP will have to break the basic contract with the DSO into tranches of lesser duration. If the local market consists of equal equipment i.e. heat pumps and same sized PVs the tranches could use a fixed flexibility volume but create contracts with different duration. A demand curve similar to the one depicted in Figure 19 would be the result. But the order of merit would be based on duration of the required downward or upward regulation. In a community with a variety of flexibility instruments it is recommended to auction different flexibility volumes for a specific duration at a time. An example is given below:

Upward regulation for less than 30 minutes at a time. Responses on the form will be noted in the order book:

Ask(p1, Δ1)

Ask(p2, Δ2)

Ask(p3, Δ3)

……..

Ask(pk, Δk)

The entries are organized according to ascending price. The auction closes when the required volume has been met or when there are no more entries in the order book. The process might be repeated for intervals of up to 1 hour, 2 hours and 3 hours.

5.5.6.1 Bids and asks are flagged with a flexibility potential

Bids and asks can be flagged with a flexibility potential. Again using price scanning as a driving force, we apply a similar auction to the one described for the isolated case.

The SESP will issue contract templates on the form Ask (ps, Vs*, Δ*) and Bid (pd, Vd*, Δ*). In addition slots for quality and services could be added i.e. Bid(ps, Vs*,g, f, Δ*,s). Δ*refers to a volume of flexibility for a given period. As can be noted the process required will now put distance to the regular commodity trade. The trade is becoming more productified. It resembles more the financial markets than the commodity markets. In the stock or financial option market you may trade for different stocks with different characteristics. To simplify it is recommended that the templates issued by the SESP operate with fixed alternatives for qualities and flexibility. Based on its internal calculations it may determine the best resolution of tranches both time wise and in terms of volume per disconnection. The number of options will be finite and customized to the needs of the community, the DSO and whatever opportunities that may be exploited in the central market. How this can be done will be explained later when the SESP's operation with respect to the outside world is described. One great advantage is that the SESP achieves *meta-flexibility*.

Since SESP will be able to estimate a likely flexibility volume based on historic records a suggestive price could be presented to the various end-users. The idea is to scan a price area in order to find the best possible match between demand and supply. Each call will include a price for each flexibility increment. One supplier is then in a position to evaluate different flexibility options depending on what means of control exists.

- Ask (p1, Vs*, Δ*1)
- Ask (p2, Vs*, Δ*2)
- ….
- Ask (pn, Vs*, Δ*n)

A consumer must assess the situation in the same way.

- Bid(p1, Vd*, Δ*1)
- Bid(p2, Vd*, Δ*2)
- ….
- Bid (pm, Vd*, Δ*m)

The variables p and Vs* are meant for the end-users to decide.

The order book is organized according to the standardized tranches of Δ*i. Bids and asks are invited for each tranche. The process will resemble that of the basic call auction for energy introduced previously. An example is shown here.

Ask1 (p1, Vs*, Δ*1)
Ask2 (p4, Vs*, Δ*2)
Ask3 (p7, Vs*, Δ*3)
Ask4 (p10, Vs*, Δ*1)
…..
Bid1 (p13, Vd*, Δ*4)
Bid 2 (p16, Vd*, Δ*1)
Bid3 (p19, Vd*, Δ*4)
Bid4 (p22, Vd*, Δ*3)

Δ*1 = 0 implies no flexibility. In some cases Δ*2, Δ*3 and so forth could refer to more than power reductions and periods, but standardized equipment installed and controlled by SESP. Δ*2 could then refer to "boiler" or "500w". Δ*3 could encompass "boiler" and "heat pump" (or 2500 W). Whatever holds the lower order of merit (less rigid) is listed first. Note that Vd* and Vs* are portrayed as invariant variables. This is unlikely. Variations should be expected. Contracts and market could be further divided into two. One set of offers relate to peak hours, another to off-peak hours.

Ask1 and Bid5 represent the offer from supplier 1 and 5 respectively. Pi refers to the reservation fee only. The activation fee is determined by the SESP and may be determined later by the SESP or it may the subject of a new, short term auction among those who have reserved flexibility.

When there is a strong price signal from the central market this helps to estimate available flexibility and then the price increments that can be offered to prosumers and consumers. The concept has been described in Figure 20.

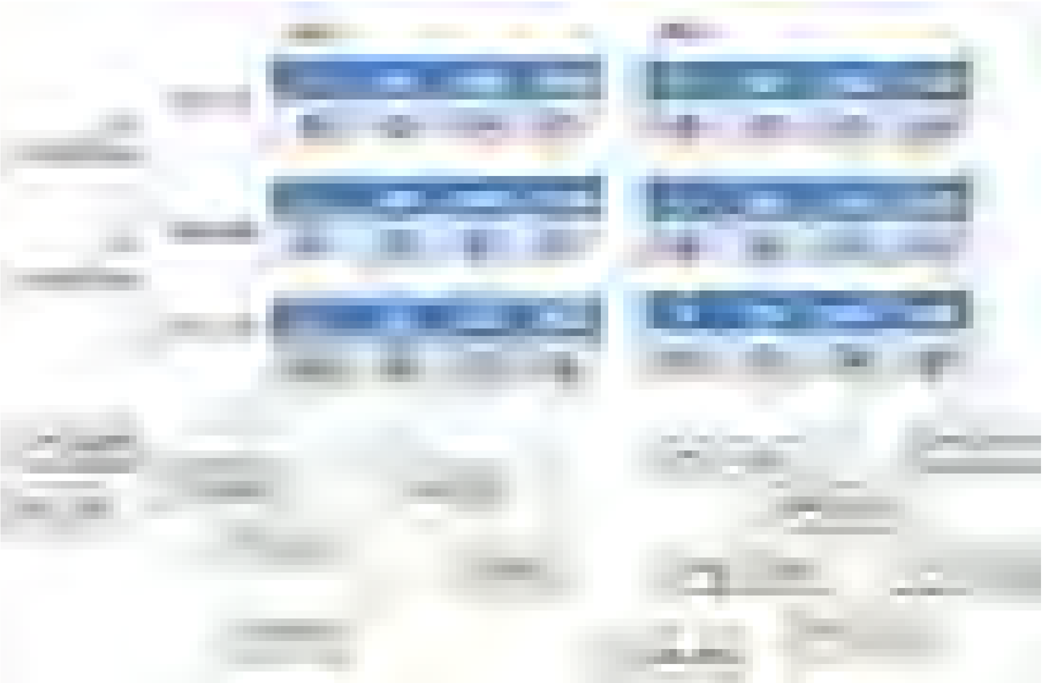


Figure 20 Price Scan Auction example of energy with flexibility.

V*I represents the volumes nominated by buyers and sellers. In addition they commit a degree of flexibility along with the energy order. The SESP calls out a tentative price for energy and a price for flexibility. The latter is based on calculations for desired flexibility reserves specifies the gain produced for flexible nominated flexibility. Before a new call is made the buy-sell situation as well as the flexibility nominations are evaluate. The price is cleared when the best coverage between demand and supply is me. When the market clears two bidders may experience different prices due to the fact that one is flexible and the other is not.

As described earlier a buyer will nominate a volume for a given base price as usual. However, as he sees the gain offered for different flexibility offers he will now that when the market clears he will gain a price advantage if he or she commits a flexibility volume in addition. The market clears in the usual way when price scanning is involved. If positive incremental balance is no longer obtained the market closes. Otherwise it keeps on until scheduled termination of the market (see *Figure **21***. SESP can help achieve balance by adjusting the flexibility incentives on both sides. As can be seen from Figure 20 incentives will usually be asymmetrical depending on what is needed most, more supply, more demand and more flexibility altogether. This example also shows the gap between final compensation of the seller and the price the buyers pay. This gap defines the value of flexibility overall.

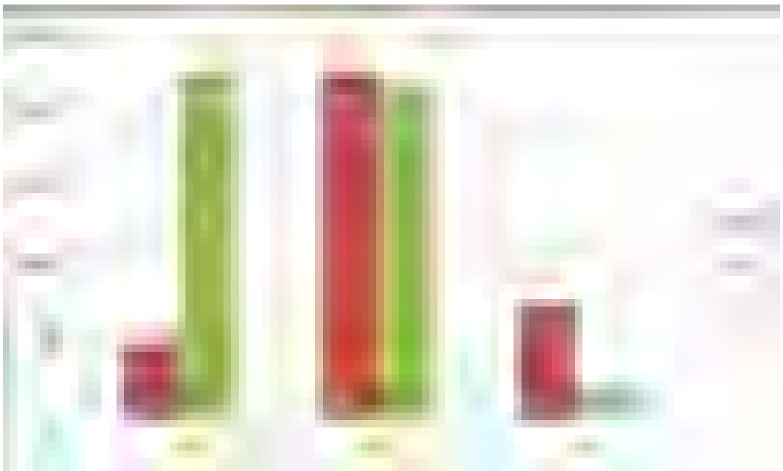


Figure 21 Seller and buyer cost at different prices for the example presented in Figure 20. Better balance will be achieved at price 28 rather than 20 and 35.

5.5.6.2 Cross subsidies

Figure 22 The SESP can translate the nominated flexibility into a price reduction for consumers. This can be mirrored for the flexible suppliers.

In order to honour flexibility as described in the previous section and propose different prices accordingly, the SESP resorts to cross subsidies. This is commonly used for network markets and lends itself to the business models nominated for EMPOWER in WP2. Once the SESP has estimated the aggregated flexibility and evaluated its various options it can offer a subsidy **p1-p2** for production that will benefit the consumers in the local market (see Figure 22). Similarly the same could be used for the supply side. Then subsidy. The flexible suppliers would enjoy a new price p3. The total unit subsidy would then be **p3-p1**. This cost should be distributed in part among the rigid participants if possible. The main bulk could be covered by the income generated from the contract with the DSO, part of the membership fee, service trade and operations in the central balancing market.

5.5.7 Trade with local and renewable energy certificates

Local and renewable energy certificates (LREC) represent an important asset. A LREC represents one kWh of energy produced by a producer or prosumer with renewable generators and injected to the local grid. The LREC purchased by a consumer represents that the energy consumed comes from a local and renewable generator and the extra-payment compensates installation costs.

Trade in certificates, documenting sale and consumption of only renewable energy can be combined with energy trade or trade of other services, but also be treated as a separate asset in a distinct market arena. The similarities to other derivatives or securities are close. When there is an offer for LREC and a bid at the same price there is a match leading to LREC transaction. This suggest a strong resemblance with trades in stocks and bonds.

At certain intervals e.g. a month, SESP defines the volume of LREC that a producer or a prosumer can sell in the Certificates LM during the trading month. This volume is the energy that SESP expects a member to produce or export during the following month. The exported energy is the surplus energy that a prosumer cannot consume by himself.

The SESP is responsible for predicting total monthly local production and opts for a conservative forecasting approach to reduce errors. During the trading month, SESP members can negotiate for LREC. Once the operational month begins, the current Certificates LM session is closed and the next session is opened. The LREC purchased or sold in the Certificates LM together with the exchange price will be included in the electricity bill/invoice of each SESP member.

In order to motivate local trading for LREC, SESP will publish the ranking of consumers with LREC purchased every month. Additionally, members with higher LREC at the end of the year will receive SESP services free of charge like a PV or a battery installation report including its cost-benefit analysis. Finally, if a consumer with a certain amount of LREC get discounts in their SESP membership fee for the following year.

In the Local certificates market, SESP assumes the role of a market operator that receives offers and updates exchange prices. Additionally, SESP operates the End-user trading platform to interact with SESP members. The role of a SESP member is to participate in the market directly through the End-user trading platform or by means of an intelligent autonomous agent. Furthermore, the Blockchain technology could be a system to implement the Certificates LM to promote its transparency. Moreover, the

Ethereum Blockchain as a Service (EBaaS) on Microsoft Azure, could be an appropriate development environment to implement it.

5.5.8 Services and products

The connected mode does not present a major change in terms of services compared to the isolated case , which was described in the previous chapter. The role of services that was described earlier is as pertinent to the connected mode as the islanding situation, if not more. The services can leverage the local aspect, local resources and added value compared to the pure commodity oriented whole sale market. Services will be even more instrumental in order to recruit participants and to make trade in the basic value unit of the community, namely energy, more attractive. The community can capitalize on the combined market power of its members. This can generate revenues that in turn can be used to subsidize local production, lower the threshold for those who want to become flexibility sellers and who need to install equipment for this. This aspect of the platform model has long been common place on the Internet. Google and Facebook are two cases in point. The basic value offered by these are financed by third parties, which are allowed to promote their products and services within the boundary of the platform.

With a strong price signal (**p_m**) from the central market the SESP may choose to offer the local suppliers and prosumers with a surplus with a mark-up **Δp1.** Thus they will enjoy a unit price of **p_{m}+ Δp1.**

It may also provide the local consumers with a discount of **Δp2.** The price would then be **p_{m}- Δp2.** The SESP may decide to introduce both mark-ups and discounts in the same local market. Membership will, of course, be mandatory in order to enjoy such as privilege. **Δp1*V1 + Δp2*V2** will then have to be covered by means of the access fees or transaction cuts that the community will charge providers of services and products.

For this to yield the underlying business model behind, SESP must be able to scale up. This suggests an overarching system that organizes multiple local markets the way it has been explained here. Consequently global players with big marketing budgets would be attracted to provide specific offers for different regions. In return they could achieve valuable market data with high geographic, sociographic and demographic resolution.

5.5.9 Trading energy and flexibility bundles in the connected market

In some areas sale of flexibility will dominate and will perhaps be the only thing that may be permitted. However, if possible, sale of flexibility in combination with energy as we pointed out earlier would be recommended. In EMPOWER we have introduced and wish to test out a new type of contract combos that can be traded within the local market to study the potential of this. The same concept that was described in previous paragraphs can be reapplied. Flexibility is simply added to the asks and the bids for energy. However, this time the nominations would include flexibility that should not only compensate for forecasting errors, but possibly also the needs of DSO and SESP for market operations. This complicates matters a little and the internal processes will have to change a bit.

5.6 Other network markets

Previously references were made to popular platform based network markets such as Uber to generate a better understanding for the EMPOWER ambition. There are obvious parallels and EMPOWER should exploit the as much experience and insight from operation of such platform based businesses as possible.

A pertinent question to be asked is whether some of the extensions proposed here would still be pertinent to the systems from which initial inspiration has been gathered. The answer is clearly positive. Some of the extensions described for the EMPOWER market in this discourse have already or are beginning to emerge in the most popular network models based on the shared economy idea.

For reasons of continuity and shared perspective, EMPOWER does not recommend the use of short-term contracts. The consumption and production processes are lasting. The short term variations are basically taken care of by the SESP with the aid of flexibility related elements in the energy contracts. IN this discourse we have also argued that long term contracts cater for increased solidarity within the community proposed.

In the context of the taxi business, longer term contracts would imply that a passenger could subscribe to multiple rides from A to B over a period with specific duration. The UberPool for commuters has been launched with this idea in mind. Up to 8 week passes can be purchased. Two week passes have become very popular in a city like New York. In fact it is a concept that their competitor Lyft Line has offered for some time already.

Another aspect that has been given much attention regarding EMPOWER is that of flexibility. Would such a quality be relevant for other systems? Again, we will use an Uber analogy to answer this. An immediate response will be that flexibility is already demonstrated with many of these systems already. If the top line offer for a limousine is not available a regular ride is offered for a special price. During peak hours people who can wait are offered information that encourage them to do so in order to save money.

Energy comes from the opposite side. Instant response has always been an absolute requirement. Flexibility in traffic refers to timely slack, alternative hours of operations and use of alternative routes. When a driver passes a toll road the cost imposed will be covered by the fare charged to the passenger. If the passenger insists on using a route without toll to save the tariff alternative behavior is demonstrated. This indicates a degree of flexibility like the one we have described above. The issue could become more acute if peak hour tariffs were applied. Then the driver and passenger would have to agree on whether to pass through, advance the start of the trip or choose another route. In all three cases, cab fare could be affected. Consequentially some of the concepts described here are already part of well-established market concepts comparable to that of EMPOWER.

Assume that traffic authorities anticipate road congestions on a busy stretch of road. It may proclaim the threat and appeal to people's flexibility and encourage them to pick other roads or take the train. They could also approach service operators like Uber and by various means encourage the use of other roads, albeit longer, or adjust traffic to avoid peak hours. Uber could even be paid for this and propose that to its members. Those who comply will enjoy a share of the compensation. Drivers will be paid more. Passengers will be pleased by the discount for their flexible behavior. The whole taxi and car pool market in a local area could then be organized according to specific hours.

The ordinary taxi business and public transportation system represent the established passenger transportation system in any given area. Lack of Uber drivers is likely to result in poor geographical coverage at times. Pick up rates may suffer. A business like Uber may then be unable to offer prospective passengers the service that they hope to get. A likely approach would be to leave the problem to the passenger. A better strategy would be to connect with the regular taxi service and assure that the passenger is taken care of. In fact, some platform operators e.g. AirBnB offer subsidies to compensate for the problem and in this way make sure that the user will stay in the network. Confidence in the network market is strengthened. It is also possible to experience the reverse thing. Established services can enter the network to make use of the "community effect" and compensate for weakened pick-up capabilities at certain times or in specific areas. During a special event, for instance, the lack of cabs or accommodation might require reinforcement. Networked passengers will of course seek resolve within communities such as Uber and AirBnB. But agreements between the platform operator and the established business operators will not be far off. Request from the established partners may be channeled into the network like any other request. A relief channel is the created for which the platform owner and the community members are likely to be compensated for. The parallels here to the EMPOWER concept should be apparent too.

5.7 Local Markets in European Regulatory Regimes

The European electricity market liberalization created the retailer business model and it is in charge to buy electricity in the wholesale markets for end-consumers. The SESP presented in EMPOWER project could be an aggregator like German law allows to sell and buy electricity through the same company. This company should be a Balance Responsible Party who has an energy surplus during certain periods or has an energy deficit and it participates in the wholesale markets. Otherwise, in other countries like Spain and Italy, the aggregator entity is not defined legally and the SESP should have a company for selling electricity and another one for buying. This topic will be analysed in WP2-T2.4 in the regulatory regime analysis.

5.8 Summing up - Trading in Energy, Flexibility and Services

The local market is a trading platform for structured negotiations in energy, flexibility, services and combined products. It trades in forward contracts, futures and specific flexibility options. The connected mode opens for commercial opportunities than the island mode while the technical challenge is reduced. At the same time competition increases and incentives for sustained engagement and continued trade becomes even more important.

- The local market design and trading concept proposed for EMPOWER resides on a platform based business model and adheres to principles applied in emerging network markets such as Uber.
- The local markets can consist of a single or multiple trading arenas with different focus. This is essential for EMPOWER.
- The use of long-term contracts increases common outlook, yield good references for sound operations and can help to non-commoditize energy. The latter opens for increased end-user value. The use of short-term deals could be introduced as an addition, but will not dominate the EMPOWER market.
- Both “over the counter” sales and call auctions can be applied, depending on state, number of members and scarcity of a given resource.
- The SESP issues standard contract templates suitable for a particular market. The templates will be used by local traders. Some of these contracts may apply default variables to standardize trade.

- The local market with its long terms contracts may attain the structure of a securities market and allow end-users to buy local fungibles related to renewable energy with a price guarantee for a given period i.e. a week, a month or a season.
- The SESP manages the interests of the community for the best of its members. Multiple ways to make the local market and community membership attractive can be introduced. The strength and attractiveness of the community constitutes the strongest element of “added value”.
- The added value that the community offers can be translated into monetizing effects for the community as a whole and for each member. A community can attract service providers that can gain immediate access to a fairly homogenous set of potential customers. Services can be traded stand-alone or as part of a bundle. Access fees or cuts on transaction costs can boost local market activities through bonuses or direct subsidies on energy traded locally. The latter can be very important in regions where strong price signals from the central market exist and where there are few barriers for sale and purchase of energy in central market.
- In regions where the value of flexibility measured in kWh/h is rated much higher than the price of energy measured in kWh flexibility inflation is a pending problem. In such cases trade in flexibility should be linked to the energy trade. We have proposed a model for managing the trade of such a bundle.
- End-user flexibility traded stand-alone or as part of bundles are both possible. End-user flexibility is important for the local trade in energy itself, not only in a market operating in island mode. It helps to assure contract conformance. This is important as local markets are susceptible to strong covariant impacts. One cannot expect strong elimination of deviances due to increased number of participants. End-user flexibility should be attractive to the local DSO and could play an important role in the central balancing market too.
- Within the precincts of contracts established in the local market and preferences of the prosumers and consumers in the local market it trades in the central spot market. The energy requested or offered in this market ensures full compliance between supply and demand. But it can also leverage the value of contracts for arbitrage purposes and other gains. These gains will be fed back to the community, in part or in full. Thus the SESP can trade on behalf of community members or to fulfil its own role as the local market manager and local market maker.
- In the central market the SESP will trade a certain volume and a certain price with a time resolution of one hour. The result of this type of operation is the Energy Plan with the scheduled resources for every member.

- In a similar way the SESP may manage flexibility on behalf of the community members. Operations will have a resolution of 15 minutes per hour and cover multiple consecutive periods. End-users energy needs and non-conformances will be defined 24 hours ahead of actual execution. At this time available flexibility will be estimated according to forecasts and state of contract fulfilment. This will determine individual and collective flexibility capabilities to be nominated day-ahead different purposes. Altogether the full suite of flexibility resources can apply to four distinct objectives:
  - To avoid non-conformities with respect to individual long-term contracts
  - To solve a DSO request
  - To participate in the Tertiary reserve of the wholesale balancing market
  - To correct local deviations from the Energy Plan.
  - During the delivery day, their Local Controller will receive control signals from SESP to operate their flexibility assets.
- The concepts introduced remain hypothetical, but multiple references to existing platform markets have been made with the ambition to illustrate the potential power and viability of the EMPOWER concept.

6 Structures and processes

6.1 The SESP perspective

The SESP has multiple roles both market wise and technically. In a connected market it is relieved of several technical responsibilities. Instead, the commercial responsibility is expanded. This has already been made transparent. It should also be reemphasized once more that we allocate the all the multiple roles to the SESP for convenience sake.

Within the described local market setting the SESP is to operate within all three market structures and attempt to integrate them. It organizes the local market and acts as a broker and clearing central. In the connected state it also operates as an aggregator and is a responsible body for organizing the trade with flexibility services both within and beyond the PoCC – e.g., selling to the highest possible bidder: DSO, TSO or trading in the balancing market. When it comes to the local energy market the SESP handles local consumption and generation. It can also sell aggregated surplus or compensate for aggregated deficit at the power exchange or central OTC. Not less important, the SESP offers value added services via the local market for other services.

Besides exercising the roles of an aggregator, retailer, local market operator and provider of value added services, SESP is to serve as a balancing responsible party (BRP) to compensate for deviations incurred by the members of its portfolio. In the disconnected mode this resembles that of the system operators in the general grid. In the connected mode the balancing responsibility is more related to portfolio management and commercial concerns. Seen from the wholesale market the SESP is the principal negotiating party. As an aggregator it is capable of selling or buying electricity as retailers currently do. This is illustrated in Figure 23. In contrast, SESP is the local market operator from the end-user point of view supervising the trading platform.

Figure 23 The SESP pictured from the side of the wholesale market

6.2 The relationships between stakeholders and the SESP

To administer SESP's role towards the three market structures considered, the basic concept presented in Figure 9 of D6.1 has been extended and shown in Figure 24. The various relationships linking SESP to other stakeholders have been described in Table 4 below.

Figure 24 The SESP's relationships through the three local market structures towards other markets and energy system operation. On the figure the green colour indicates strong willingness to participate in local market initiatives

Table 4 Relationships between the local market actors. Numbering refers to Figure 1.

#	Interaction	Description
1	Producer1-SESP$_{FLEX}$	Contract for delivery of flexibility services (e.g., reducing production in certain periods)
2	Producer1-SESP$_{EN}$	Contract for delivery of energy - 2 basic cases: ▪ Use of SESP$_{OS}$ for forecasting/estimating profile: SESP is the BRP and has to compensate the deviations ▪ Contract that includes penalties for deviations. But penalty should depend on the performance of the overall system)

3	Producer1-SESP$_{OS}$	Forecasting/estimating generation profile; maintenance; financing; security; visualization; insurance; and others…
4	Posumer1-SESP$_{FLEX}$	Contract for delivery of flexibility – this could be related to: ▪ Power generation ▪ Consumption based DR ▪ Utilizing storage A remote control system should be used. We assume the SESP has full control over all devices. Deviations of flexibility contracts: ▪ In case the prosumer violates on purpose the remote control system, he should be penalized for the deviation (could be deviations due to participants being reckless, and not necessary on purpose) ▪ The SESP should be compensating for deviations that are involuntary and that the prosumers should not be considered responsible for. Such deviations may be covered collectively by the community members (e.g., by a common for all price margin that is reflected into the prices they get from the SESP or by some form of membership fee that participants pay).
5	Posumer1-SESP$_{EN}$	Contract for buying and selling locally produced energy. Overproduction sold with priority to community members and /or utilized towards the central market for the benefit of the community.
6	Posumer1-SESP$_{OS}$	Forecasting/estimating generation and load profile; maintenance; financing; security; visualization; online diagnose and repair; energy efficiency; insurance; and others…
7	Consumer1-SESP$_{FLEX}$	Contract for delivery of flexibility - consumption based DR.
8	Consumer1-SESP$_{EN}$	Contract for buying locally produced energy, over demand to be covered by trade in the PX.

9	Consumer1-SESP$_{OS}$	Forecasting/estimating load profile; maintenance; financing; security; visualization; online diagnose and repair; energy efficiency; insurance; and others…
10	Storage-SESP$_{FLEX}$	Contract for delivery of flexibility – storage based DR Contract for utilizing capacity of storage facility in order to: ▪ Compensate for deviations ▪ Trade flexibility offered by the storage unit towards the DSO,TSO and Balancing market, e.g. for the purpose of distribution/transmission deferral, relief of transmission congestions, resource adequacy, black start, voltage support, frequency regulation, spin/non-spin reserve, energy arbitrage
11	Storage-SESP$_{EN}$	Contract for delivery of flexibility – storage based DR Contract for utilizing capacity of storage facility in order to: ▪ Compensate for deviations ▪ Utilize trade with locally produced energy ▪ Trade at the PX Contract for delivery of specific customer services, e.g.: ▪ Backup power ▪ Increased PV self-consumption ▪ Demand charge reduction ▪ Time of use bill management
12	Storage-SESP$_{OS}$	Maintenance; financing; security; visualization; online diagnose and repair;
13	Consumer2-R$_{X}$	Conservative consumer that chooses to buy its energy from Retailer X, rather than locally produced energy via the SESP. A consumer with a contract to extern retailer cannot have a contract for flexibility with the SESP (and the other way round).
14	SESP$_{FLEX}$-DSO	Contract for delivery of flexibility to improve the grid operation and alleviate peak load situations. Violations should be compensated for by the SESP itself.
15	SESP$_{FLEX}$-TSO	The SESP acts as a balancing responsible party (BRP). When the SESPs' bids at the PX are not complied with (could

		be both on the production or consumption side) the SESP has to carry the costs.
16	$SESP_{FLEX}$-BM	The SESP can offer balancing bids at the balancing power market. Profits to be distributed among the community members to actually provide the respective balancing load. Also, a minimum share of the benefit could be distributed to all other participants in the community.
17	$SESP_{EN}$-PX	Overproduction, load from storage capacity and demand that cannot be covered by the local market may be traded at the PX
18	$SESP_{EN}$-R_X	Demand that cannot be covered by the local market may be bought from a retailer (intermediary).
19	$SESP_{EN}$-OTC	Overproduction, load from storage capacity and demand that cannot be covered by the local market may be traded OTC
20	$SESP_{OS}$-$VENDORS_{OS}$	The SESP may involve various vendors to facilitate the delivery of value added services.

6.3 End-user perspective

6.3.1 End-users as community members

Every household, commerce, small scale industry, building and property owners in the same neighbourhood will be invited to become a SESP community member with all the rights and obligations that this entitles. Membership is voluntary. In some instances the community may decide not to accept membership applications. This may have to do with consumption and production rate and policies. But in general it would be beneficial for the community to accept all applicants. End –users will be confronted with the community's rules of governance and market conduct. These may not be much different from those practiced by shopping clubs and other markets.

All members must respect and observe the community and market rules. As pointed out in D6.1, the party who is in control of the SESP makes a difference. Such control may be executed by the community members themselves or by a professional commercial player. A mix between the two may also be relevant. A DSO may also take this position.

However, under some regulatory regimes only flexibility sale may be allowed if a SESP is DSO controlled.

The main SESP community are mainly non-professional market participants (see

Figure 25). The local market provides an opportunity to become more active and yield an increased degree of freedom. The community offers members a better way to manage distributed resources and leverage capitalization on such. It also offers a way to systematically benefit from flexible consumption and generation. As the community grows it will also become more attractive to regular service and product providers. The new member will then be able to enjoy greater discounts on products like controllers, PV panels etc. Equipment, goods and services owned by members can be auctioned and rented out for mutual benefit.

Figure 25 A community of prosumers and consumers, with a shared storage capacity using the Community electricity storage unit.

The very engaged users are likely to take advantage of all possibilities. They are willing to take direct action too and participate in the system operation in order to secure their interests, offers and results, they will be able to actively send and receive information through the SESP communication channels. These members are known as "active members". The less active members, "passive members", can outsource multiple tasks to service providers as well as the SESP itself.

Both active and passive members will be equipped with software agents that are reserved specifically for their use and benefit. These agents communicate with the control cloud and trading floor managed by the SESP. The meaning of active or passive involvement is going to be different in each local market and present the characteristics of passive and active members in Energy, Service and Flexibility Local Market respectively. Moreover, this is an open option and a member can be active in a local market but passive in the others, this is up to the member.

When consumers, suppliers and prosumers in the community have signed contracts for sale or purchase of energy they are responsible for fulfilling this. SESP endorses each contract and needs to manage the collective set of contracts to ensure that obligations are met. Local controllers are installed that monitor the usage of flexible resources like EVs, water heaters and heating, ventilating and air conditioning (HVAC) systems. Controllers can be monitored by the local agent and resources in SESP's control cloud.

User interface

Depending on the type of markets that the community wish to offer and what contract templates the SESP issues facilities will be made available for the community members (see Figure 26). Each end-user will have access to the local market in the way it has been described. Ways to trade pure energy and services will be part of the portfolio offered to the end-users. Means to trade flexibility will be available to those who sign up for this part, and who have the proper equipment installed to take part.

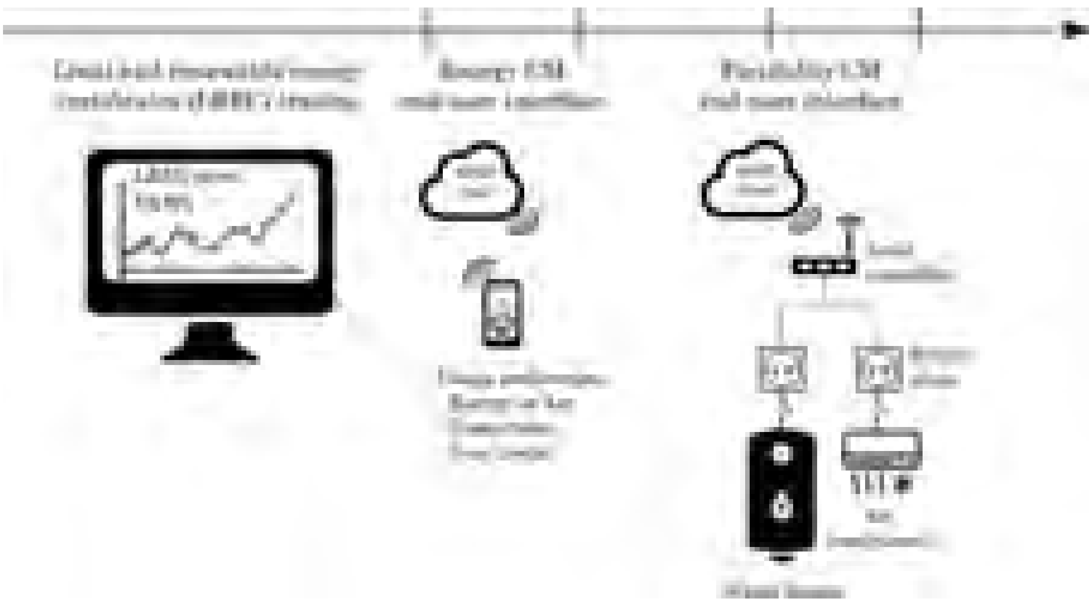


Figure 26: End-user interfaces with the local market and the SESP cloud

6.3.2 Engagement

In Figure 27, the process that engages new community members has been depicted. The major steps are explained as follows:

Recruitment

The recruitment step is a consequence of promotional activities. The member is guided through the application part of the process. Web documents spell out the privileges that the new member will enjoy together with the rules of conduct. They will also describe the member benefits, prime offers from suppliers of products and services, including discounts, bonus points, historic prices of energy sold and energy bought.

:

Figure 27: End-user process: Engagement of community members. Arrows indicate sequence of steps that the community goes through from top left to the right, then down and to the left again.

Membership application

This includes a membership form that requests personal information required to manage an account. The membership form is associated with a payment process. Payments are channelled through PayPal, a credit card company or similar. In the future this could be managed through a block chain ledger (Tapscott 2016).

Downloads

Once a member the end-user may download apps or gain access to classified areas on the web where bargains can be made. This facility resembles any commercial web site or app platform like Google Play. The most important download is the trading agent and the associated controllers, the personal account manager and access to the SESP's Order Book and settlement process.

Request for access to flexibility market

Access to the flexibility market requires relevant equipment that must be connected to the control cloud and placed under SESP management. In years to come each user may already be in possession of appliances and gadgets that are already part of an Internet of Things regime. These may include one or more connectivity options and include different equipments. On the demand side, these would typically include Coolers, Freezers, Air conditioners, Boilers, Different types of heat pumps, Heated floors, Heaters and Batteries. On the supply side, these would include Micro-CHP, Bio-fuelled generators, Batteries and Switches that control PV panels. The end-users decide which appliance to leave under remote control of the SESP. The SESP will make recmmendations fior such according to its own plan. Once an agreement is reached it qualifies the user to trade in the flexibility market.

Installation

In the nearest future IoT enabled appliances may not be common place. The control and communication must be deployed as part of a separate task. This involves a highly manual job where units meant to control the different loads specified in the former step are physically installed. The task further implies that this equipment is made available for the SESP. Communication and control is established through a specific protocol and must be tested well before commissioning. In the near future this is a more unlikely scenario. All this is likely to introduce a latency of a day or two before the end-user can actually engage in the flexibility trade. What is more important is that this step enables the SESP to estimate the maximum end-user flexibility that is possible to control.

Set-up

Set-up defines a step where the user is specifying his overall preferences. This includes which market and type of contracts to participate in. Terms for participation must be endorsed. This step also involves initialization of the software agent and any controller installed at the end-user side. Both are the responsibility of the user, but their operation may be outsourced. The agent will reside in the control cloud operated by the SESP, but will serve only one-end-user according to the specifications that this user has provided during set-up. To accomplish the tasks that the end-user has selected the agent will need access to different data sources i.e preference specification, the end-user’s calendar, consumption and production history, weather forecasts, temperatures, controllers, sensors etc.(see Figure 28). It applies this to operate on behalf of the end-user in the service, flexibility and energy markets. It also needs access to the trading floor. Agent behaviour, in terms of trade, is specified by the prosumer or consumer. This includes limits, incremental steps, and references of different kinds.

The end-user is further encouraged to use the downloadable calendar to specify certain periods where his connected equipment is more or less available. The details and resolution of this can vary. Simple “Home or Away” specifications are especially encouraged. The calendar defines end-users’ overall needs and energy flexibility. This can help the personal agent to respond properly to signals from SESP control. Credit cards may be registered. On the user side, a member account is created and initialized.

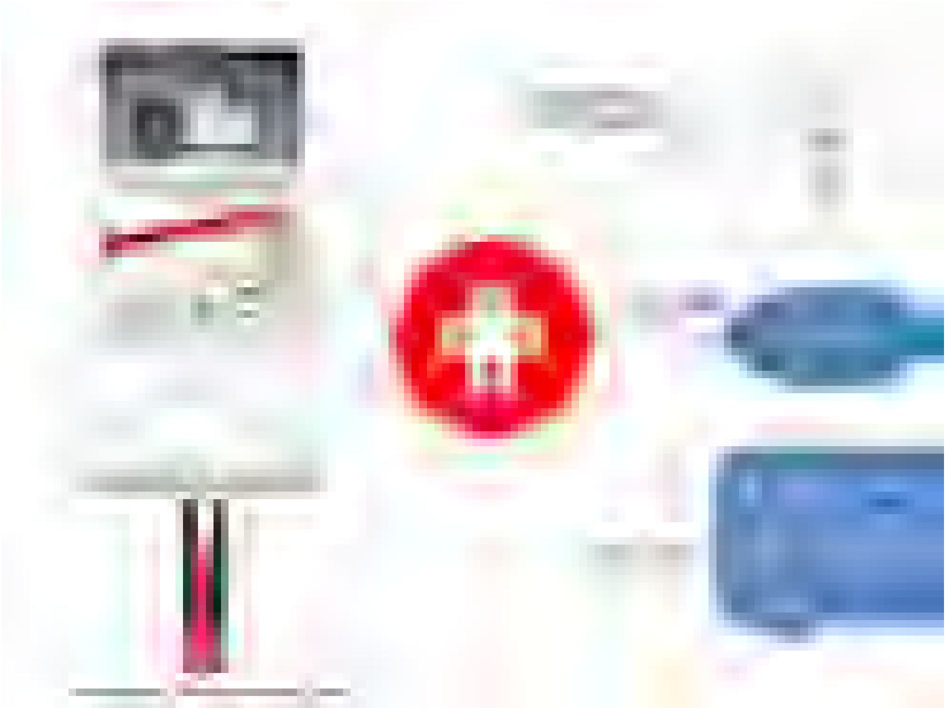


Figure 28: Software agents that operate on behalf of the end-user needs access to different data and apps. It communicates with central SESP control and operates in different markets. It may monitor and control the performance of the appliances and production equipment that the end-user has installed.

Trade and trading agents

The end-user may choose to take part in the actual trade directly or leave this entirely in the hands of the agent. The principal interactions portraying the proposed mandate of the end-user agent is illustrated in the interaction diagram in Figure 29.

The columns in the diagram refer to resources associated with the ICT platform for tarde. The end-user instructs his agent. The diagram shows how the agent pulls preference and policy information from the end-user. The extent of this will depend on what type of agent technology is deployed. But essential information such as limits, extent of flexibility etc. will be essential. Agents may also subscribe to status and forecast services provided by the SESP or any other service provider. It will present its market strategy for the end-user prior to launching the first offer in the auction. For a zero-intelligence agent this could be a very simple parametric specification such as starting bid, maximum incremental step and limit. When the SESP makes a call or another agent makes a bid the user's agent may automatically respond with an offer in line with the strategy that has been adopted. It may reassess its offer later and suit it to a new call, assuring that the best deal is achieved within the limits that it must recognize and until the market is cleared. A more sophisticated, reinforcement learner (Shoham 2009) could absorb more information and develop a more sophisticated strategy over time.

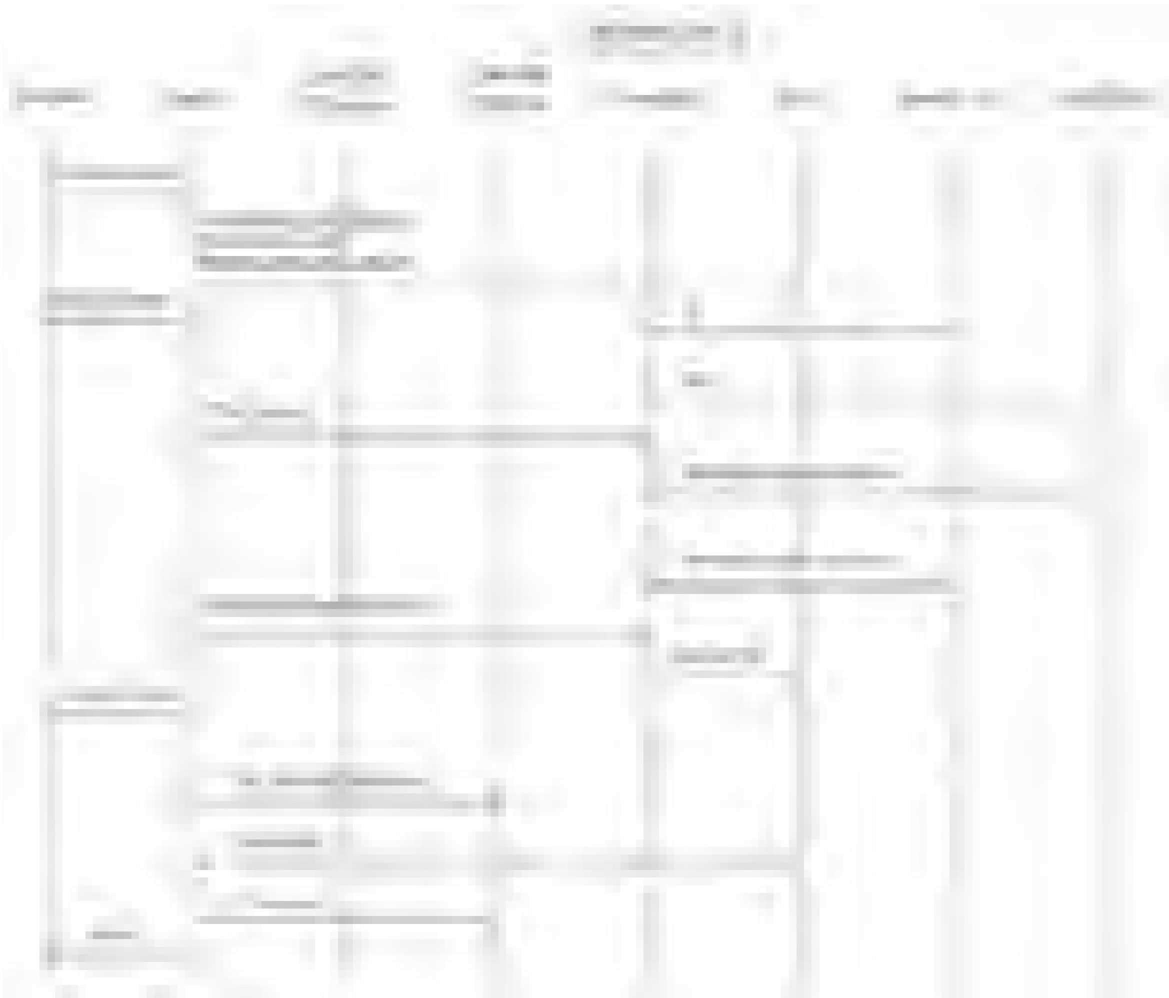


Figure 29: The principal actions that a software agent will participate in.

Once a deal is done further control of the equipment encompassed by the new contract is either left to the SESP or kept within local control as explained earlier. Note that SESP control will have to pass through the agent, which will suspend regular monitoring and control operations. An instance of local control is depicted in Figure 30.

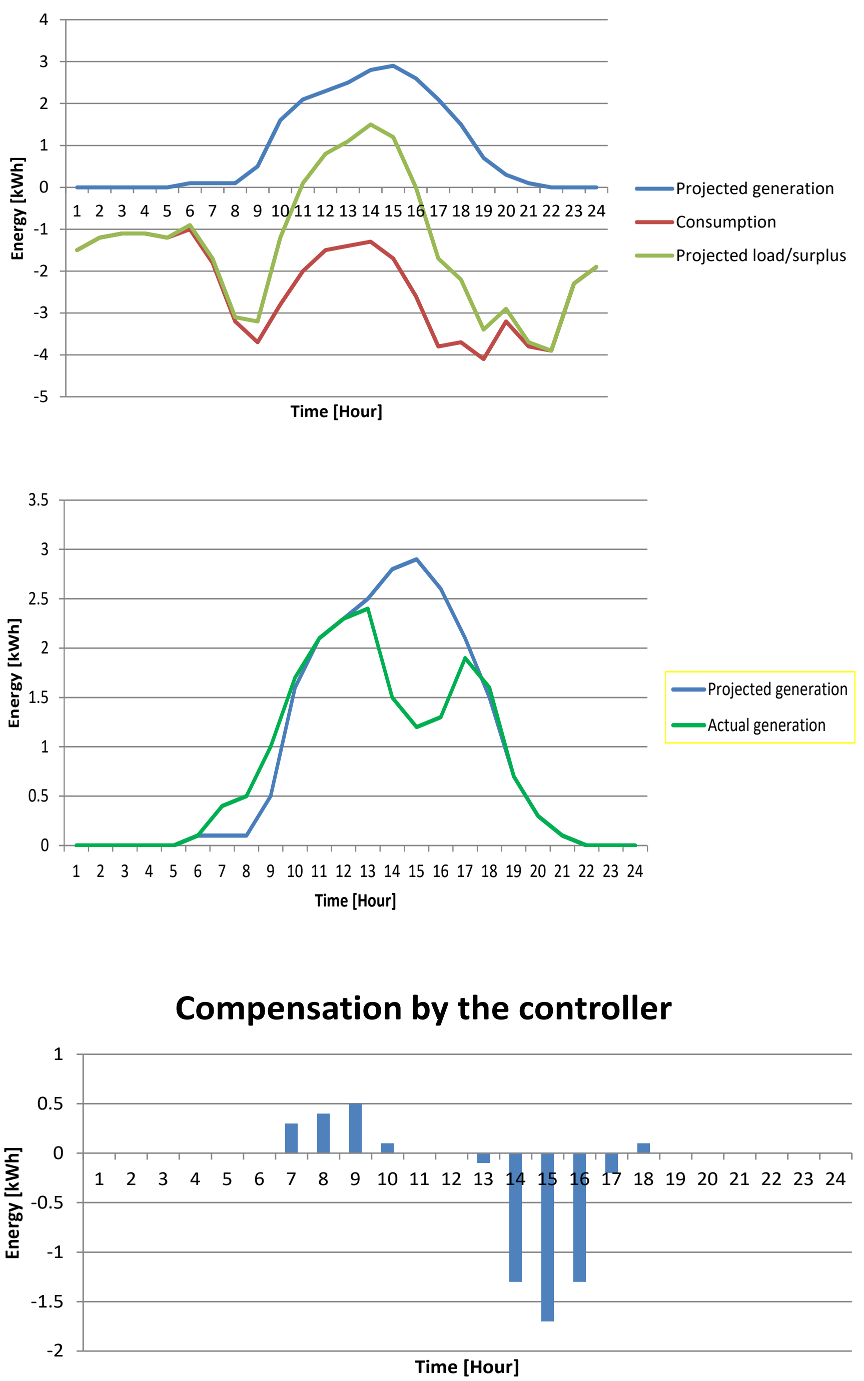


Figure 30 Upper: Projected consumption and generation for a consumer resulting in a surplus that may be traded and manifested in a contract. Middle: Actual generation plotted showing non-conformance with the forecasted generation. This implies the need for compensation and adjustment. Lower: The controller is activated. The required compensation follows the same timeline as diagrams above. Positive compensation would imply that controller activates stand by loads i.e. heater or washing machine or charges a battery. Negative compensation would imply the discharge of a battery unit or reduction of consumption i.e reduced heating or cooling

Inaccurate forecasts can be managed locally. The projections specified in the contract will be used as a reference. Simple fuzzy or PI controllers could deal with this. The derivative component of a PID controller could probably be omitted since compensations will be made in terms of minutes and not seconds.

Membership status

The Membership Status app provides insight into end-user's account. Access to this is possible at any time. Any member will get full transparency into all transactions made. Different types of credits and debits will be posted on the statement prepared for end-use. This includes direct costs or income related to different trading, It also includes accumulated bonus points and shares of bonuses that the community generates through SESP's operation. Finally it may include reputation credits, praise or other kinds of encouragement (see Figure 31) such as "In week 32 90% of all electricity consumed in the neighbourhood was produced locally. The biggest producer that week was Josh Samson who contributed with 200kWh. A diploma has been awarded".

Figure 31 Members may enjoy multiple forms of credits and earnings

It is important to stimulate active participation and the membership status statement is an important means for this. However, pull alone is not regarded sufficient. When an-end-user such as Josh Samson makes a milestone the SESP will pass on messages which pay attention to such. Recognition and praise are important means of end-user relationship management. It should be noted that bonuses, discounts, honours etc. are likely to have disciplinary effect on all actions in the market. It helps to reduce focus on individual short-term optimization. It makes it also meaningful to permit the SESP to make adjustments that otherwise would demand a short-term negotiations/auctions to settle mismatches.

7 Contracts and timing

7.1 The long term contracts (future market)

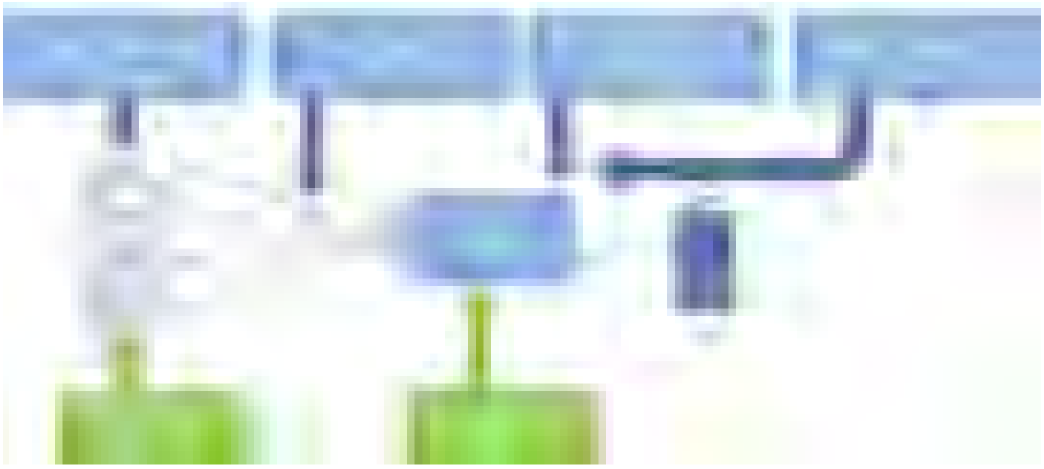


Figure 32 Energy trade in local, long-term/future market. Blue boxes are contract and trade related activities. Green boxes define post-trade actions.

The kingpin element in the local market is a long term contract. The duration of the contract could be a week, a month or cover a full season. The long term contract provides an outlook that will benefit all parties involved in the trade. At the same time it opens up for extended risk sharing. This means that the parties involved in a trade may take on shared responsibilities to maintain balance or contractual conformance. The process involved can be illustrated as in Figure 32.

- Step 0: Community members are recruited.
- Step 1: The SESP defines standard contract templates for sale and purchase. The basic concept will include a price for energy purchased or sold, a specification of the energy volume, the quality (i.e. local and green versus unspecified) and an energy profile. The latter implies an estimate of hourly consumption or generation for each day of the contract period. This estimate will be based on historic records and whatever modifications to life style or household an end-user will share with its agent. Two methods may be applied:
  - A general statistically based curve with acceptable tolerances specified for working days and weekends
  - A calendar function specifying a similar curve for each day of contractual period

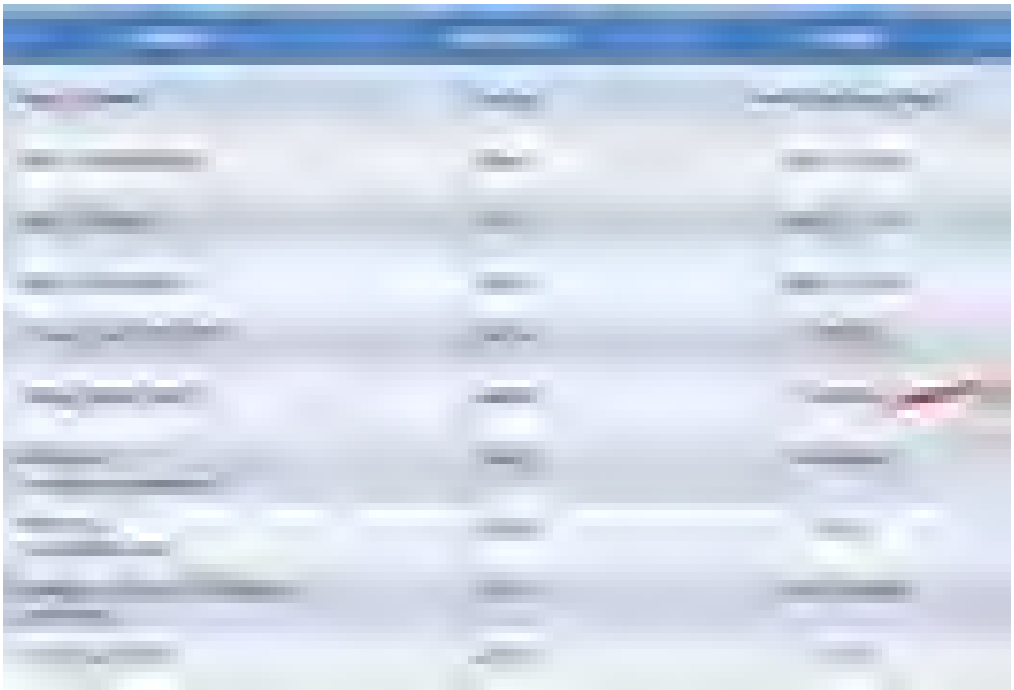
After that, during the local or cross energy market:

- Step 2: Auction

- Step 3: Clearing and settlement
- Step 4: Manage non-conformance and unbalances using the local or cross flexibility market.

The estimation of energy profiles would typically require a fair amount of calculations. This may be provided by SESP or other service providers specialized in Big Data on demand from the user-agent. In addition to the information specified, basic contract may also include a clause that states that end-user will be responsible for maintaining contract conformity. This implies the type of end-user control that manages deviances within certain limits without involving SESP. An example tentative contract is shown in Table 5.

Table 5 Example contract: Simple energy sale



The contracts will be established between the SESP and the end-user after settlement, not between the consumer and the supplying parties. Since the contracts are bilateral in nature they will take the form of forwards. If they are also made transferable and fully standardized they will resemble more the futures traded in security markets.

One of the primary aspects of the platform business model proposed was to enhance the attractiveness of the community and recruit service providers. This would converge with the shopping club concept and allow end-users discounts and SESP a cut of each transaction made. The earnings from this sale could in turn be used to subsidize energy

Figure 33 Cross subsidized energy trade in local, long-term/future market. Blue boxes are contract and trade related activities. Green boxes define post-trade actions.

traded in the local market. The energy price experienced by end-users would then always be different from the prices of the central market. The model thus requires that negotiations with service providers have taken place and that such are signed up prior to the energy trade (Figure 33). Yet, to do so, SESP must be able to boast a critical mass of community members. Typically this is a “chicken-and-egg” problem that many platform providers struggle with. However, if successful it may ramp-up things rapidly. How to deal with this is an issue tñhat is currently treated in WP2.

7.2 Trade in the local flexibility market for the local DSO

An extended local flexibility market directed towards the DSO can be established in regions where the DSO experiences problems in the local grid - e.g. there are congestion issues, feed-in ceilings and voltage problems. The SESP can prove to the DSO that to engage in contracts with the SESP will be beneficial.

The process in local trade engagement can be divided in the following steps:

- Step 0: Community recruitment in the case that previously there is no community with long term contracts.
    - Preconditions: some basic teasers
    - Expected results: signed up membership; data shared by members

The recruitment process is to include promotion, membership sign up, payment of membership fee and a preference survey (i.e., to find out who may be interested in demand response).

- Step 1: Negotiate a contract with the DSO and share information about the grid and its different parts
  - Prerequisites:
    - The DSO does have a problem
    - Completed profitability analysis
    - Standardized template, compatible with the DSO system
- Step 2: Bilateral back-to-back contracts between the SESP and the DSO

This step is to be facilitated by evaluating of flexibility potential at appliance level and enabling demand response (DR). In the process end-user metering and other data kept by the DSO as well as the preference survey carried in Step 0 will be important. A professional should connect the controllable devices needed as specified earlier. An illustration of the stepwise process is provided in Figure 34 and described in detail in the next section.

Figure 34 A general case for contracting within the local market: illustration through a stepwise process

7.3 Contract templates

7.3.1 Contract with the DSO for delivery of scheduled flexibility

A contract template will be suitable when DSO wants to reserve an option for curtailing peak loads that occur within fixed time intervals (such as during the morning and in the afternoon/evening). An example of this is shown in Table 6. The contract is typically for a longer term (e.g., 1 month to 3 years) and can be considered as a more affordable option for the DSO that can increase the effectiveness and efficiency of the grid.

Table 6 An example of contract template between the SESP and the DSO for delivery of scheduled flexibility

Attribute	Specification	Example

Name of DSO	string	Fredrikstad Energi Nett
Type	string	Scheduled
Date of endorsement	date	Feb. 1, 2016
Date of initiation	date	Feb 8, 2016
Date of termination	date	April 1., 2016
Contract renewal type	{automated | by negotiation}	Automated
Max load per activation	number	100kW
Max number of activations in period	number	60
Days of activations	Calendar days	Monday, Tuesday, Wednesday, Thursday, Friday
Permitted interval in morning	{hours | DSO signal}	6:00 – 12:00
Permitted interval in evening	{hours | DSO signal}	15:30-20:30
Max allowed activation time	Number of hours	2,5
Tolerance	Percentage deviation of requested load shedding per activation	+/- 1%
Strike price	NOK exempt VAT	40.000
Activation fee	NOK exempt VAT per hour activated	4000
Non-conformance clause	text	See small print

7.3.2 Bilateral back-to-back contracts between SESP and community members

An example of a back-to-back contract that mirrors the deal that has been established between the SESP and the DSO (See subsection A and Table 6 above) is shown in Table

7 below. As can be noted this contract represents only a tranche of the source contract with the DSO. The source contract can be split up in terms of duration, increments of power reduction or both.

The community members to bid and sign up for such contract are qualified as capable of providing demand response resources of certain size and during given period. In fact offers for securing resources to take part in this market will be offered at the time when members are recruited.

Table 7 An example of contract template for a bilateral back-to-back contract between the SESP and community members

Attribute	Specification	Example
Name of contract holder	string	Robert Seguin
Type	string	Scheduled
Date of endorsement	date	Feb. 16, 2016
Date of initiation	date	Feb 17, 2016
Date of termination	date	April 1, 2016
Contract renewal type	{automated | by negotiation}	Automated
Max load per activation	number	1,5kW
Max number of activations in period	number	60
Devices controlled	{boiler|heated floor|heat pump|lights|heaters|battery}	Heated floor, boiler
Min temperature (or max temperature for cooling)	{temp in C room or boiler | «not applicable»}	15C
Max ramp-up temperature	Max temperature if room needs to be thermally charged prior to disconnection	22C

Days of activations	Calendar days	Monday, Tuesday, Wednesday, Thursday, Friday
Permitted interval in morning	{hours | DSO signal}	6:00 – 12:00
Permitted interval in evening	{hours | DSO signal}	15:30-20:30
Max allowed activation time	Number of hours	2,5
Tolerance	Percentage deviation of requested load shedding per activation	+/- 0,5%
Strike price	NOK exempt VAT per hour activated	100
Activation fee	NOK exempt VAT per hour activated	45
Non-conformance clause	text	See small print

7.4 Trade in services and products only

Figure 35 Overall process: Trade in services and products

Trade in regular services and products is simple and follow the patterns of any on-line web site or smart phone-based venue i.e. eBay, Amazon, Google Play, Finn.no. Conventional rules like those found in classic shopping clubs apply. The SESP, once more, constitutes the hub in the trade and makes sure that the transactions are properly managed and payments are successfully accomplished. The overall process is shown in Figure 35. Direct contact between service provider and community member is not recommended. This reduces the potential cut of any transaction and devaluate the data accumulated. Over time this can be a very important asset for the SESP and the community. The settlement managed should translate to the type of contract that the service provider offers as default.

The process shown in Figure 35 corresponds to the steps of the other services market and they are as follows:

- Step 0: Community recruitment. Needed if there is no community already established
- Step 1: Service provider/DSO recruitment and negotiations. Service providers recruitment using the community portfolio as a pull.
- Step 2: Sell or auction. Service providers offer their potential support to the SESP.
- Step 3: Buy or Bid. Community members explore and buy services in the other services market.
- Step 4: Clearing and settlement. If it is needed, the price for each service can be settled by auctions.
- Step 5: Activate service
- Step 6: Apply service

7.5 Trade in combined products

The structures and processes related to trade in combined products do not depart much from the processes and contracts already described. This is intentional. EMPOWER should therefore be able to embrace different types of bundles of the type already described in detail. Trade in combined energy products represent a novel aspect. Placed in a local setting it stands out as a new type of experiment, more than anything else in EMPOWER. Contracts incorporating energy, flexibility and services/products appear potent, but their practicality needs to be tested. This is one of the ambitions that will pursued onwards in EMPOWER.

7.6 Trade beyond the local market

7.6.1 Trading in wholesale markets

The SESP has to negotiate for energy surplus or deficit in wholesale electricity markets. According to 38, the wholesale market has different markets in which retailers buy or sell energy and these are the derivate, day-ahead, intraday and balancing markets.

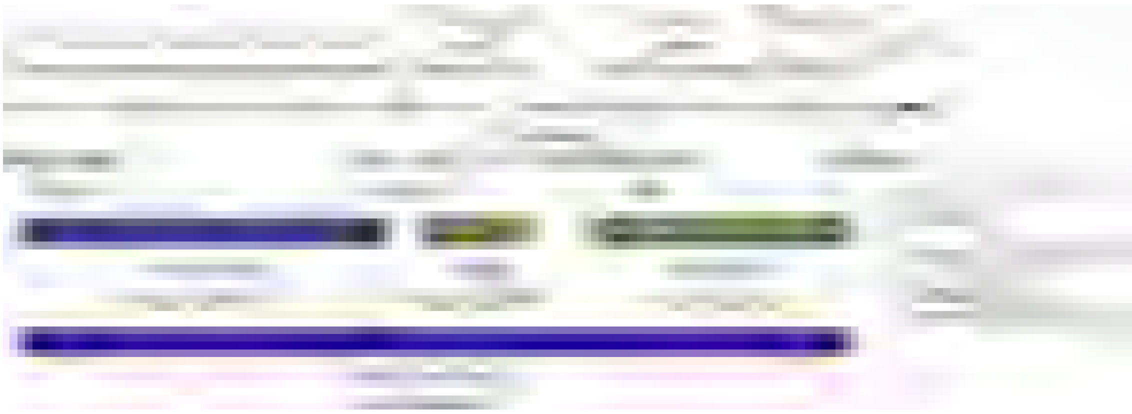


Figure 36 Negotiation periods of wholesale and local markets

A similar philosophy is used to design the local market:

- Future local market allows all community members to buy a certain local electricity volume at a certain price as explained earlier.
- Energy local market allows scheduling all energy resources and to determine if the community has to purchase or sell electricity during each period.
- Flexibility local market allows re-scheduling the energy resources in case of deviations or technical problems.

Additionally, the specific local market for services organizes complementary functions that the SESP want to offer to the members. Considering both the flexibility and energy sides of the local market, as well as the possibility to trade local energy resources towards other actors in the central market (besides the DSO), the concept presented by Figure 36 above can be extended to the following two forms as shown in Figure 37.

Step 0 is the starting phase with community recruitment. Steps 1A and 1B represent the contract negotiations with respectively the DSO and TSO, while Step 2 reflects the bilateral back-to back contracts with the end-users. In general, Step 3 represents the activation of flexibility resources. This could be done to meet the contract with DSO (Step 3A), TSO (Step 3B) or to trade flexibility at the wholesale market or OTC (Step 3C). If SESP is going to take advantage of the Central Market and simultaneously serve the local DSO – all for the benefit of the community and the integrity of the local market, well synchronized operations, both external and internal, are required.

Figure 37: The process of aggregating and trading flexibility.
Note: blue colour represents contract phase; green colour represents activation phase.

7.6.2 Time horizon

Time horizon explains the chronological dependencies between the actions required by different players associated with the local market. The various interactions are shown in Figure 37 and their interaction as it is shown in Figure 38.

During the previous month before delivering, the Certificates LM allows SESP members to negotiate for consuming local and renewable electricity. SESP members can send offers for a certain volume at a certain price for local electricity.

During Energy CM one day-ahead, the SESP receive the offers from professional members and prepares the Energy Plan. The SESP sends this Energy Plan to the DSO and the DSO responses with power curtailments if needed. The SESP applies the changes needed and send the offer and bid to the PX. Afterwards, the SESP creates the Energy Plan* based on the energy committed in the PX.

During the Flexibility CM the SESP executes the Daily Flexibility CM algorithm to refresh the Energy Plan* based on new foresights and end-user usage preferences and creates the Daily Flexibility Plan and Reserve. The SESP sends this information to the DSO and it responds with power curtailments if needed.

During the operation day, the SESP executes the Hourly Flexibility CM algorithm each hour to schedule the following hour and the adjustment algorithm to correct deviations during the operation hour. The Hourly Flexibility CM and adjustment algorithms produce the control signals that SESP members’ units receive.

Figure 38: Local market time line

8 DSO distribution grid supervision algorithm

Activities in the local market could threaten the distribution grid in certain situations. This could be in the form of power quality reduction, overloading of electric assets, or possible collapse it in the worst case. For example, decisions in the local market may cause excessive consumption. This could cause a damage in a line or a secondary substation. To avoid this, SESP needs to know what is happening in the grid to make appropriate decisions considering grid constraints. There are different approaches to solve this issue and EMPOWER project has studied them considering all the stakeholders involved.

From the SESP point of view, the best way to take the optimal decisions should be to implement a power flow-based local market algorithm to consider the grid constraints and then to ensure that all technical issues are considered in the solution obtained. But this option has a fundamental problem: all grid data as for example transformer characteristics, line capacities and characteristics, grid topology and consumer data have privacy and security implications and the DSO is in charge to protect it.

Talking about this issue with different DSO from different countries all of them are against the idea to publish all the crucial data for security issues. This issue is not new, and there are some initiatives studying potential alternatives to publish some data for aggregators and energy service providers usage. The German association of the electricity industry (BDEW) published on March 2015 a discussion paper on the traffic light model in the DSO area entitled “Smart Grid Traffic Light Concept. Design of the amber phase” (BDEW, 2015). This document describes the problem presented before and it indicates the direction to solve this issue. One of the main conclusions from this document is the needed interaction between third parties and the DSO. In order to avoid grid expansion extra charges, DSO needs third party companies to execute demand response programs or flexibility services. Meanwhile, third parties need information about the grid status to schedule its flexible resources without creating grid bottlenecks.

EMPOWER project proposes a similar solution adapted to SESP and its members’ needs entitled “Distribution grid supervision algorithm”. This algorithm has two phases: a negotiation & planning phase and an operations phase.

8.1 Negotiation & planning phase

The objective of the negotiation & planning phase is to reach an agreement between SESP and DSO to determine which information will be shared and when. Third parties have highly restricted access to grid information as it has sensitive implications for grid security and consumer privacy. Moreover, current power sector regulations and policies do not allow the DSO to publish all the grid information. In order to solve this problem, EMPOWER project proposes a simplified grid model based on consumer's clusters defined by the DSO. The DSO is in charge of clustering the grid into zones according to the grid topology and configuration. Figure 39 shows an example comparing the real distribution low voltage grid on the left and the clustered version on the right. This simplification allows third parties like SESP to have a reference model to plan new investments like batteries and to operate without overloading lines or transformers.

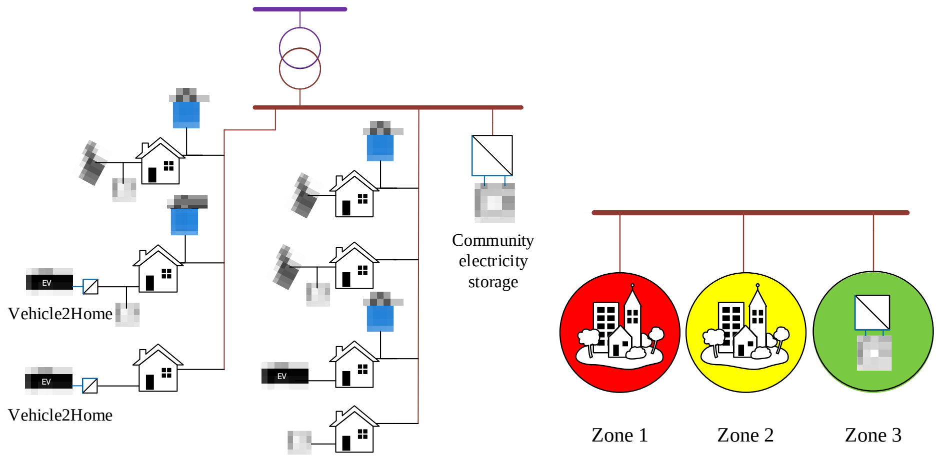


Figure 39: Low voltage distribution grid (Left), Simplified distribution grid in three zones (Right)

Due to privacy concerns, DSO will not share any information with SESP about zones where SESP does not have a member base. Moreover, DSO and SESP have to reach an agreement about the services SESP will offer for a certain price such as consumption or generation curtailment based on demand response, production control or battery management signals. Also, synchronization of operation between DSO and SESP needs to be clarified during the negotiation process to define the interaction rules between DSO and SESP. The proposed DSO-SESP interactions are categorized into three operation modes: scheduled, normal and emergency mode. In scheduled operation, DSO has knowledge of day-ahead or week-ahead overloading problems with certain confidence margin and requests SESP in advance to activate flexibility assets on an automated basis. In normal operation, depending upon grid constraints, DSO may request SESP an hour-ahead to activate flexibility assets. In an emergency, DSO can order SESP to activate flexibility assets at any moment in order to avoid criticalities in the grid.

8.2 Operation phase

During the operation phase, SESP sends the day ahead Energy Plan to DSO before 12:00. DSO's response to SESP indicates if power curtailment is needed or if the Energy

Plan is accepted as such. A similar process occurs at 21:00 the day ahead as well, when SESP sends the Daily Flexibility Plan and Reserve to DSO and it responds with a correction or an acceptance message. During the operation day, SESP sends the hour-ahead Hourly Flexibility Plan and Reserve and the DSO responds accordingly. The SESP-DSO interaction time lime is shown in Figure 40. DSO needs this information (Energy plan, Daily Flexibility Plan and Reserve, Hourly Flexibility Plan and Reserve) to check if planned operations are feasible in the local grid. Information exchange between SESP and DSO at different times of the day allows SESP to avoid problems during the operation phase and optimize the local market operation. The DSO-SESP interaction process during the operation day is shown in Figure 41 and detailed as follows:

Figure 40: Distribution grid supervision algorithm time line

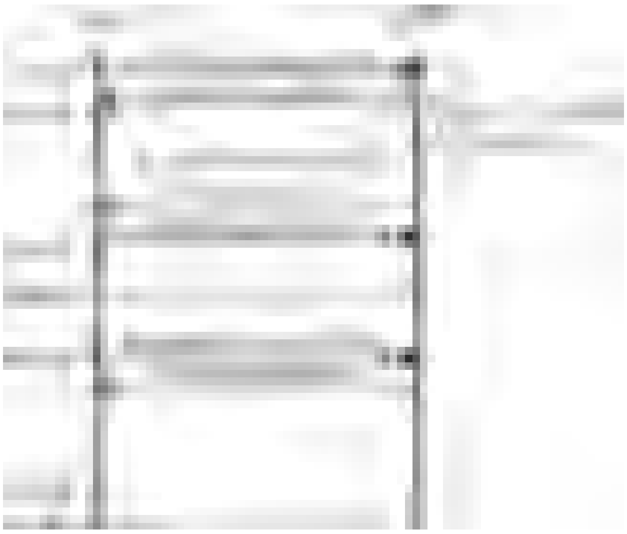


Figure 41: Distribution grid supervision algorithm hourly basis

- In normal operation mode, DSO sends an hour-ahead request to SESP if required. SESP responds with an agreement message.
- 50 minutes ahead, SESP executes the Flexibility CM algorithm to prepare the Hourly Flexibility Plan and Reserve for the next hour and sends it to DSO.
- If needed, SESP can adjust the bid sent to TSO for balancing services before sending the Hourly Flexibility Plan and Reserve to DSO.
- During the hour of operation, DSO can send an emergency request for the next few minutes according to the DSO-SESP contract conditions.

During the operation hour, the SESP executes the Adjustment algorithm to ensure that the Hourly Flexibility Plan is achieved. It is important to note that the DSO requests are based on the previous plans sent by the SESP in order to have a common reference point of operation. The operation algorithm flow diagram is presented in Figure 42. Purple boxes represent the functions implemented in the DSO supervision system and the final output is the DSO response. The description of various functions in the supervision algorithm is as follows:

- Demand/Generation forecasting: DSO knows exactly how members are connected and what their capabilities are in terms of production or consumption. The result of this function is the consumption and production forecast for the next periods and this information is needed for the power flow analysis.
- Power flow analysis: To calculate the voltage and currents through the lines based on the consumption and production foresights and grid data for every period.

- Adjustment calculations: This function transforms technical issues such as reactive power, voltage drop or substation overload to active power curtailments. It is assumed that power quality control is solely the DSO's responsibility.

Figure 42: Distribution grid supervision algorithm flow diagram

The DSO has its own load/generation prognosis and an example is provided in Table 8. We assume that the DSO somehow possesses the capability to estimate the aggregate loads of SESP members in a particular zone because the SESP has shared member information with DSO. The local grid in this example has the following constraints based on DSO estimation and they include a security margin, they are not the physical limit:

- Zone 1: ±250 kW
- Zone 2: ±250 kWh
- Zone 3: ±250 kWh
- Zone 1+2+3: ±650 kWh

Table 8: DSO generation and consumption forecast in the local grid

	DSO evaluation (kWh)			
	Zone 1	**Zone 2**	**Zone 3**	**Z1+2+3**
T1	179.3	150.7	228.8	558.8
T2	200.2	-44	231	387.2
T3	231	-77	236.25	390.25
T4	228.8	-11	231	448.8
T5	237.6	154	203.5	595.1

DSO response will be according to the Energy Plan sent by SESP and local constraints. For example, Table 9 shows an Energy Plan with lower generation and consumption than DSO prediction, therefore DSO response can be a mere confirmation. Table 10 shows an Energy Plan with higher consumption than the local grid capacity during periods T2-T4 in zone 3. Consequently, DSO sends signals to reduce power consumed or produced for every period and zone as shown in Table 11. Notice that the DSO applies power curtailment signals for zone 3 to allow only 250 kWh.

Table 9: Energy Plan with lower consumption than the local grid capacity

Energy Plan (kWh)				
	Zone 1	**Zone 2**	**Zone 3**	**Z1+2+3**
T1	163	137	208	508
T2	182	-40	220	362
T3	210	-70	225	365
T4	208	-10	210	408
T5	216	140	185	541

Table 10: Energy Plan with higher consumption than the local grid capacity

Energy Plan (kWh)				
	Zone 1	**Zone 2**	**Zone 3**	**Z1+2+3**
T1	163	137	208	508
T2	182	-48.4	266.2	399.8
T3	220	-84.7	272.25	407.55
T4	208	-12.1	254.1	450
T5	216	140	185	541

Table 11: DSO power curtailment sent to the SESP based on the Energy Plan from Table 10

Power curtailment (kWh)				
	Zone 1	**Zone 2**	**Zone 3**	**Z1+2+3**
T1	0	0	0	0
T2	0	0	-16.2	0
T3	0	0	-22.25	0
T4	0	0	-4.1	0
T5	0	0	0	0

9 Local certificates market trading

The Local certificates market (Certificates LM) was introduced earlier in section 5.5.7. The process needs to be synchronized with SESP. The asset traded is named LREC (Local and Renewable Energy). A LREC certificate represents one kWh of local and renewable energy. The Local certificates Market (Certificates LM) is a platform for SESP members to trade local and renewable energy certificates (LREC).

Community producers and prosumers receive LREC from the SESP according to the amount of energy produced or exported and in turn, sell their LREC to consumers. LREC serve as an acknowledgement that a consumer is promoting local and renewable generation. Notice that, the SESP caters to that local consumption based on local and renewable resources. It goes before purchasing energy from wholesale markets. This is the basic operating principle of the SESP community. Moreover, SESP consumers contribute to motivate local generation with LREC incentivizing local production.

The process is initialized by the SESP who informs energy sellers about the amount of energy produced or exported, which is the number of LREC available during the trading period. This trading occurs one month prior to the energy production.

Once the amount of LREC available is published, energy sellers offer LREC at a certain price awaiting an offer from a consumer to buy them. Consumers offer their bids for LREC and they can purchase as much LREC as required irrespective of their expected consumption during the following month. Producers and prosumers are allowed to buy LREC when they expect higher prices in the following periods. All SESP members are allowed to exchange LREC free of cost as well. Once the trading month is over, the amount of LREC is settled and process start again for the following month.

The end-user interface between participants in the Certificates LM is the End-user trading platform. This platform allows market participants to send offers, check current LREC prices and receive information about matched offers. The EMPOWER mobile application and web site will provide access to the End-user trading platform.

SESP members not interested in investing time in the Certificates LM would like to automate their participation in the market. The SESP will equip its members with autonomous intelligent agents to buy or sell LREC based on their preferences. These preferences could be in terms of the energy volume traded, maximum energy price, maximum budget allowed for trading, etc.

On the other hand, members interested in trading directly can always make use of the End-user trading platform to check current price and send offers for selling/buying LREC.

For the sake of simplicity, LREC exchange between SESP members will be anonymous. This way, the deviations from SESP's energy forecasting could be simply ignored or neglected and be unaccounted in the market without affecting trading prices or volumes.

Figure 43 shows the Certificates LM timeline and the relation between SESP members and SESP as a middle party. The timeline represents the communications between a consumer, a prosumer and SESP during a month and the LREC value changes. The following interactions take place in the Certificates LM:

- At the beginning of each trading month, SESP sends a message to all producers and prosumers with the energy expected to be exported during the following month that can be exchanged as LREC in the Certificates LM.
- Producers and prosumers send offers for selling LREC to the SESP through the End-user trading platform.
- Consumers send offers for buying LREC to the SESP through trading platform.
- Once the SESP has two offers at the same price, it updates the current price in the Certificates LM and informs the seller and buyer about the amount and price of LREC exchanged.

Figure 43: Local certificates Market timeline example interaction. Black: messages, blue: SESP actions

The functions needed for the Certificates LM are:

- Receive offers from SESP members: This function establishes the format of information exchange.
- Offers matcher: This function matches two offers at the same price for a certain LREC. Once matching is achieved, transacting members receive a message from the SESP about the LREC exchanged.

- Price updater: This function refreshes the Certificates LM price in the End-user interface after each LREC match.

10 Cross market energy trading

10.1 Concept

Any retailer or aggregator must bid in the day-ahead electricity market, also known as spot market or PX, to have access to intra-day and balancing markets. SESP acts a retailer from the energy market point of view, so it must bid at least in the day-ahead market. SESP schedules local resources and prepares the corresponding bids to optimize community benefits for periods with local energy surplus or deficit without compromising the local grid functioning. In order to optimize community benefits in the day-ahead market and other goals explained before, SESP executes the Energy Cross[11] Market (Energy CM) and the ICT trading platform allows all SESP members to take part in an active or passive manner. Active participation refers to professional members capable of estimating their own consumption/production and taking part in the market directly. Passive participation refers to non-professional members on behalf of whom SESP estimates consumption/production and participates in markets.

In Energy CM, SESP has a dual role: market operator and aggregator. SESP, as market operator, receives offers and bids from professional SESP members and executes the clearing algorithm. Prior to carrying out the Feasibility checks, SESP aggregates non-professional members, prepares their bids, and includes them in the Energy CM. Furthermore, SESP acts as an aggregator when it participates in the day-ahead market in order to purchase or sell energy needed during every period.

Energy CM algorithm is presented in section 10.2 and corresponding functions are explained in section 10.3. The execution of Energy CM results in the Energy Plan that contains information about energy purchased or sold for each grid zone. Table 12 is an example of an Energy Plan for 5 periods and 3 zones. Positive values mean that the zone consumes electricity and negative ones mean that the zone produces electricity.

[11] The term cross market refers to the combination of the local and the wholesale market when the SESP interacts with the wholesale market to buy or sell energy.

Table 12: Energy Plan example

	Energy Plan (kWh)			
	Zone 1	**Zone 2**	**Zone 3**	**Total**
T1	163	137	208	508
T2	182	-40	232	374
T3	220	-70	244	394
T4	208	-10	210	408
T5	216	140	185	541

10.2 Interactions and timeline

Figure 44: Energy local market algorithm flow diagram

Figure 44 shows the Energy CM operation algorithm flow diagram. Blue boxes correspond to SESP functions, red box represents the final output or Energy Plan, orange boxes represent interactions with external agents like DSO, and green boxes represent inputs from other parties or algorithms. The first step in the Energy CM is to forecast the non-professional SESP member energy consumption/production (Demand/Generation forecasting). SESP takes this responsibility as it has the information needed and the general overview. Moreover, the aggregation effect allows for reducing forecasting errors over individual foresights. Based on energy foresights, SESP prepares non-professional members' bids/offers (Bids/Offers formulation). The forecasting confidence intervals can be included in non-professional bids/offers to manage the risk of energy surplus or deficit. In addition, flexible resources like EV, heat pumps and others can be included in consumption bids. Moreover, the offers and bids from professional SESP members will be included in the algorithm (Community offers). Bids and offers from all community members are combined to create the Energy CM auctions. The auction results constitute the Energy Plan.

There is no local energy price for the energy exchanged in the Energy CM. This is because SESP wants to prevent price manipulations from dominant/professional market participants. This is important especially in small markets with low liquidity levels. In addition, SESP prepares the majority of bids/offers on behalf of non-professional members and the price could be misleading. Besides, SESP wants to attract new members with attractive products like constant price contracts and there is no historic energy prices to guess what prices could be in the future.

Once the auctions conclude, SESP sends Energy Plan to DSO for feasibility check. DSO responds with an acceptance message or amount of power curtailment needed. Thereafter, SESP sends bids and offers to PX and once the prices are announced, SESP receives the energy and price committed for every period. The energy committed in the PX, including the local trading, constitutes the Energy Plan*.

Figure 45 shows how a commercial building manager bids and a CHP owner sends offers in the Energy CM to consume/produce electricity during the following day based on their own costs. Non-professional member offers are not represented here because they are prepared by the SESP itself. Finally, after the algorithm is executed, when the SESP has defined the Energy Plan*, it communicates the committed energy to professional members. Non-professional members do not need to be informed.

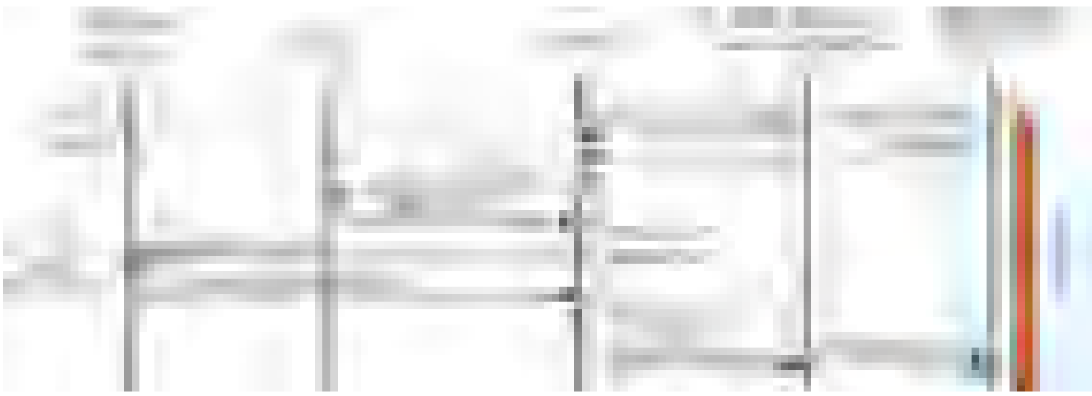


Figure 45: Energy Local Market timeline (CHP: Combined Heat and Power)

10.3 Functions

The bids and offers must be sent to the Day-ahead market before 12:00.

- Demand/Generation forecasting of the energy consumed/produced during the operation day in one-hour periods by non-professional members based on their records and weather foresights.
- Bids/Offers formulation uses energy foresight, member's contracts and forecasting confidence intervals to create stepwise curves.
- Energy CM clearing algorithm uses bids and offers, from professional and non-professional members, as inputs. The outputs are the bids and offers for each period.
- Energy CM clearing algorithm* uses the DSO response as an input to correct the Energy Plan, the bid and the offer to the PX market.

Table 13 to Table 16

Price [c€/kWh]	Energy [kWh]
0.9	180
1	140
5	80
7.1	30

Table 16 provide examples of inputs and outputs for two consumption zones (1 and 2) and a generation zone (3) during one period of Energy cross market. Table 13 is the bid of SESP members for base and flexible loads. 50 kWh is the base load and the others are different loads with different prices. Table 14 is the local generation offer from SESP members. Mixing the bid and offer, we can obtain the aggregated bid and offer shown in Table 15 and Table 16 respectively. For example, according to the aggregated bid, if the wholesale price is 4 c€/kWh, the local generation will be 60 kWh, the local consumption will be 200 kWh, and the power through the PoCC will be 140 kWh as the aggregated bid specifies.

Regarding the local constraints, note that the energy consumed at 0.9 c€/kWh should be 200 kWh because all consumers are willing to consume at this price, but producers are not willing to produce at this price. Due to grid constraints, say a saturated transformer, only 180 kWh of energy can be imported. Therefore, the difference of 20 kWh has to be curtailed and re-scheduled according to DSO response. In case of flexible loads like EV, SESP will re-schedule them according to their constraints. If they cannot be completely shifted, the SESP will apply solutions like discharging the community and/or the distributed storage units.

Table 13: Consumption bids

Price [c€/kWh]	Energy[12] [kWh]	Zone
11	50	1
9	30	2
8	70	1
7	50	2

Table 14: Generation offers

Price [c€/kWh]	Energy [kWh]	Zone
1	60	3
5	60	3

Table 15: Aggregated bid

Price [c€/kWh]	Energy [kWh]
0.9	180
1	140
5	80
7.1	30

Table 16: Aggregated offer

Price [c€/kWh]	Energy [kWh]
8.1	40
9.1	70
11.1	120

- The Energy Plan* is energy consumed or produced by SESP members in each grid zone, including energy committed in the PX. Notice that during Flexibility CM, SESP transforms the Energy Plan into the Control Plan as shown in Figure 47. Following the previous example, if PX price is 4 c€/kWh, the total power exchanged with the main grid (Z1+Z2+Z3) is 140 kWh. The results are presented in Table 17.

Table 17: Energy Plan Example

Zone	Energy [kWh]
1	120
2	80
3	-60

11 Cross market flexibility trading

Once the Energy Plan is settled for the day, the trading platform for exchanging energy moves to the Flexibility CM. The SESP role in the Flexibility CM is a market operator and a market participant requesting flexibility from the members. SESP members can specify their flexibility conditions in flexibility contracts to establish the exchange offer price, the volume and time interval available for flexibility.

[12] The additional energy consumed or produced at a certain price in the zone

11.1 Concept

The applications of Flexibility CM are three-fold as shown in Figure 46 and they correspond to the meta-flexibility options introduced earlier. Flexibility CM is used for:

- Complying with DSO's requests to solve local problems in the distribution grid caused by SESP members or others connected to the same grid. Thus, Flexibility CM allows DSO to postpone grid reinforcements.
- Compensating local deviations due to forecasting errors or other issues to reduce deviation penalties for SESP in wholesale markets. In order to avoid large deviation penalties, SESP uses information collected from member's meters through the ICT platform and sends control signals to compensate these deviations.
- Bidding in the tertiary reserve balancing market to manage SESP members' flexible assets. These bids will support system operation thanks to SESP's capability to increase or decrease consumption or generation.

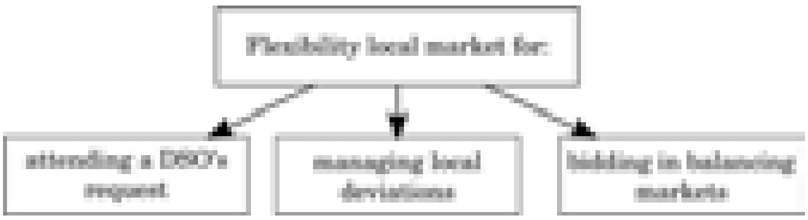


Figure 46: Flexibility Local Market purposes

The Flexibility Local Market structure has three stages: attending DSO's requests, managing local deviations, and bidding in balancing markets as shown in Figure 47. The Daily and the Hourly Flexibility Local Market are structured as follows:

- After the Energy Plan is made and before the operation day begins, Flexibility CM re-schedules local resources. This is due to the fact that SESP now has new information and updated foresights, information published by the DSO, and the committed energy in the PX. After this process is complete, the SESP produces the Daily Flexibility Plan and Reserve (DFPR) for the entire day.
- During the operation day, for every hour, the SESP executes the Hourly Flexibility CM and calculates the Hourly Flexibility Plan and Reserve (HFPR). This plan defines the control signals received by the SESP members' devices and the reserve defines the availability and status of flexible resources.
- Finally, the Adjustment algorithm is executed every 15 minutes to correct deviations from the Hourly Flexibility Plan and resend control signals if needed.

Figure 47: Local Market plan sequence

The time resolution of the HFPR is fixed to 15 minutes because tertiary balancing markets are divided into periods of 15 minutes and the SESP has four opportunities to compensate hourly deviations.

The clearing optimization algorithm to schedule the local resources during this stage is based on double-sided or single-sided auctions between SESP and members offering flexibility, depending on the situation. Flexibility auctions are based on the bids from SESP with energy deviation forecasted and/or power curtailment request from DSO. On the other side, offers show community members' flexibility capabilities sorted in ascending order of price as shown in Figure 48.

Figure 48: Flexibility local market auction

The Hourly Flexibility CM during the operation day results in the Hourly Flexibility Plan that contains information about the energy purchased or sold for each grid zone and SESP members for the following four quarters. Negative values indicate decrease in current consumption or increase in current generation. Table 18 shows an example Hourly Flexibility Plan before the first quarter of the operating hour.

Table 18: Hourly Flexibility Plan before Q1 of the example.

Member ID	Zone	Quarter 1	2	3	4
12256	1	-1	-1	0	0
55236	2	-2	-2	-1	0
25576	2	-1	0	-1	-1
55776	1	-1	-1	0	0
64312	2	0	-1	-1	-1
12345	1	0	0	-2	-1
78442	1	0	0	0	-2
Total energy (kWh)		-5	-5	-5	-5

11.2 Flexibility reserve

One of the key issues in Flexibility CM is to determine the available flexible resources to be used during following time periods. This implies three questions:

1. Which devices are qualified to be part of the flexibility portfolio?

To involve consumers and prosumers in the flexibility business successfully, they have to remain in their comfort zone without having to go through big lifestyle changes. All flexible devices can be managed as long as all members' needs are covered. For example, members may be willing to accept changes in their heater settings within their minimum and maximum comfort temperatures. Also, they may be willing to wait until the dishwasher is finished in exchange for a compensation, but are not willing to wait for the oven during dinner time. In order to harness the required flexibility, EMPOWER project recommends to focus on thermal loads, electric vehicles and batteries.

2. When are the flexible assets available?

The power consumed during certain periods by flexible assets could be shifted to following periods for avoiding technical problems or economic over costs. However, a mere list of flexible resources is not enough because in order to be useful in the flexibility market, current appliance status is equally important. For example, a water heater full of hot water at its maximum temperature cannot be used for flexibility because it does not need to consume more. A fully charged electric vehicle cannot be used for flexibility either, assuming that it has no discharge capability. Similarly, on the generation side, a photovoltaic panel under a cloud without generation capacity cannot be used for flexibility either. Accordingly, SESP needs to constantly monitor the status of flexible resources to determine the extent of flexibility during the following periods.

3. How to manage the flexible resources portfolio for future needs?

To enable Flexibility CM, SESP needs to have adequate flexibility reserve that can be regulated in both directions (i.e., increase or decrease consumption) in every period considering members' needs. SESP uses Determine state of flexibility resources function that is capable of estimating the state of flexibility reserve. This function will define the flexibility capacity available for up-regulation (increase generation or decrease consumption) and for down-regulation (decrease generation or increase consumption) during each period. At the beginning of each week, SESP executes this function for the following week to send the available flexibility capacity to DSO. During the Daily Flexibility CM, SESP executes this function in order to create the Flexibility reserve for the operation day based on SESP members' energy needs. The flexibility reserve takes into account that some flexible assets may not be available during the operation phase due to technical issues or forecasting errors. In order to avoid problems with scheduling flexible assets that are not available, SESP estimates the fraction of all flexible resources will be not available during the operation phase and this amount will not be scheduled in the Flexibility reserve. Depending on the end application, Flexibility reserve is categorized into three distinct groups and the SESP is free to choose how to allocate the flexibility resources between these applications to optimize profit/community welfare.

- Flexibility reserve for DSO

This part of the reserve is allocated to cater to DSO requests for up or down regulation. During the negotiation phase between DSO and SESP, they need to decide when SESP will publish the flexibility available for DSO and the price for reserving this energy instead of bidding in balancing markets or managing local deviations. This group gets the highest priority in SESP operations because it helps in solving local grid problems. It is possible that DSO could also request to know the available flexibility for entire week a few days ahead if it knows the time periods of the week that require regulation. This is a very demanding request for SESP to handle, but SESP is free to enter into a scheduled contract with DSO depending upon its prediction and optimization capabilities. Additionally, DSO can negotiate a dedicated flexibility reserve with SESP purely for emergency operations.

- Flexibility reserve for local deviations

This flexibility is reserved to manage future local deviations and the amount of flexible assets reserved for this purpose is related to the expected deviations. SESP offers an availability fee to SESP members for making their flexible assets available and, if SESP activates flexible loads, SESP member receives an activation fee. If SESP does not activate any flexible assets, SESP members will only receive the availability fee. This mechanism is similar to capacity markets that reward generators for their availability regardless of their activation.

- Flexibility reserve for TSO

If SESP has additional flexibility at its disposal, after catering to DSO requests, SESP can choose to bid in the tertiary reserve markets or manage local deviations. This choice will depend on SESP's ability to accurately forecast balancing prices and local deviations. However, this is possible only if SESP has a large enough flexibility portfolio that qualifies for participation in such markets. During the initial stages of community formation and SESP operation, engaging the TSO is almost impossible due to the strict requirements (for example, minimum volume of 10 MWh), but over the course of time when SESP has established its operations, it could have the required volumes to participate in tertiary or even secondary reserve markets. Having said that, in this project, we have included the TSO in the flexibility cross market operations as an academic endeavour to prove that it is possible for the SESP to engage with the TSO and that the mechanism is in place even though it may be used in the pilots right away.

11.3 Flexibility Cross Market timeline

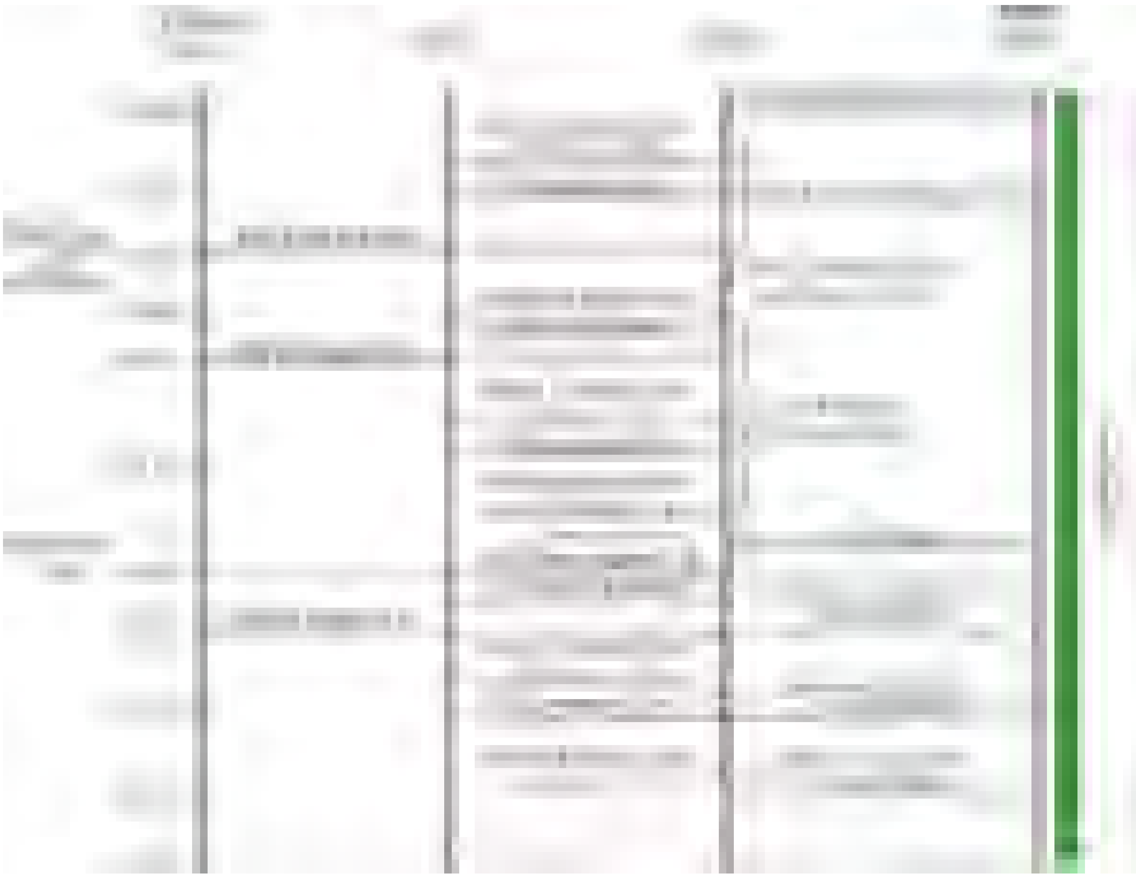


Figure 49: Flexibility Local market timeline

Once the opeation day begins, SESP executes Flexibility CM. The Daily Flexibility Plan serves as a reference plan for the operation day. Finally, the Flexibility Reserve lists the flexibility assets ready to be used during the operation day.

The action sequence of Flexibility CM is as follows:

- At 20:30, the SESP members send their day-ahead usage preferences like their EV usage or special requirements for thermal loads as agreed in their contracts. This information is used to create the Daily Flexibility Reserve (DFR).
- Afterwards, the SESP sends the DFPR to the DSO. The DSO needs this information to estimate the maximum consumption or generation that can flow during the next day from flexible assets.
- At 21:00, the DSO sends its response for the operation day based on the DFPR.
- Afterwards, the SESP executes Daily Flexibility CM algorithm to schedule flexible assets for next day. This algorithm produces the DFPR* for operation day.
- Before 21:30, SESP sends its bids to the balancing market for next day based on DFR*. This is because the BM gate closes at 21:30 in Norway. This can be different in other countries and the LM timeline can be adapted easily to fit other regimes.
- At 23:00, the DSO may request a power curtailment for next hour between 12 a.m. and 1 am. The SESP will refresh the DFPR* to check if it has resources to attend to the request. If the SESP can achieve this request, the SESP sends an acceptance message. In case that the SESP cannot cater to the request, the DSO will have one hour to ask another SESP for the same service.
- At 23:15, the SESP has the opportunity to adjust its bid sent to the TSO for the following hour if the DFPR* has changed and the TSO reserve has decreased.
- Before 23:45, SESP executes Hourly Flexibility CM algorithm to schedule flexible resources for next hour divided in quarters. This algorithm produces the HFPR.
- DSO receives HFPR and at 23:45, sends its response for next hour (0:1).
- If DSO response requires SESP to apply changes in HFP, SESP executes Adjustment algorithm to refresh previous results, thereby creating HFP* and HFR*.
- SESP sends control signals to SESP members' assets based on HFP* for the following hour.
- During the operation hour, SESP executes the adjustment algorithm every 15 minutes to check if everything is going according to the plan or if it needs to apply changes and send the corresponding control signals.

11.4 Daily Flexibility Cross Market algorithm

Daily Flexibility CM (D-FCM) is the process executed before the operation day in order to re-schedule local resources for maximum community profit. Time resolution used in this stage is one hour, the same as Energy CM, and the scope of operations is the entire operation day. This algorithm presents an opportunity to monitor SESP member's status, correct forecast deviations, and schedule flexible resources aptly. Flexible resources like batteries, EVs, and thermal loads, have temporal constraints such as battery state of charge or building thermal inertia. For this reason, the Daily Flexibility Clearing Function includes temporal constraints and is jointly optimized for all periods. Figure 50 shows the algorithm flow diagram and presents the functions needed.

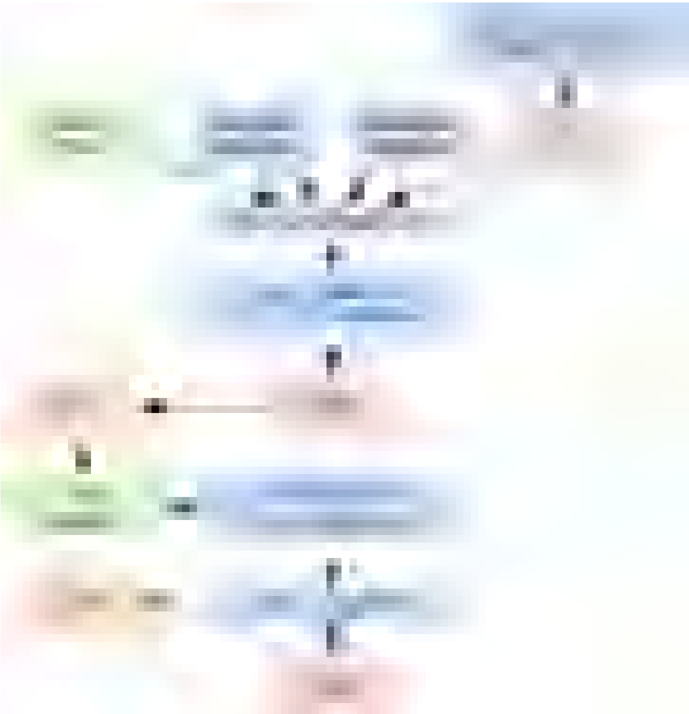


Figure 50: Daily Flexibility Local Market flow diagram

The first step is to forecast the energy consumed and produced in the community (Demand forecasting and Generation forecasting). This forecast must include the base load and flexible resources. Afterwards, the SESP has to determine the DFR. This is a database of available flexible assets and contains information about the direction and amount of power available during every period. Then the bids and offers from each grid zone are updated (Refresh offers&bids) with the new information and the Energy Plan.

SESP then executes the Daily Flexibility Clearing algorithm with new bids and offers and produces the Daily Flexibility Plan and Reserve. DSO will update its response and this information will be included in the clearing function. Table 19 shows an example of the DFR aggregated by zones for one period. Moreover, the table compares the estimation of flexibility during the Energy CM and the DFR. Notice that in zones 1 and 2 the flexible capability is 5 kWh and 10 kWh lower than previous estimation, and energy committed in day-ahead market is 140 kWh. Thus, the local deviation for the moment is -15 kWh.

Table 19: Daily Flexibility Reserve compared with the estimation during the Energy CM

Local market	Price [c€/kWh]	Energy [kWh]	Zone
Energy CM	8	70	1
	7	50	2
Daily Flexibility CM	8	65 (-5)	1
	7	40 (-10)	2

The Daily Flexibility Clearing Algorithm receives the DSO response, bids and offers, and DFR. The result of this function is the Daily Flexibility Plan and Reserve (DFPR). The DFP is the optimal flexibility schedule to maximize community welfare. DFR is a database with the available power for every period from each flexible asset reserved for future needs. Table 20 shows the DFR for the example of 5 periods, and 2 DFP examples are shown in Table 23 and Table 25. The period previously analysed in the Energy Market corresponds to the 3rd period.

Table 20: Daily Flexibility Reserve example. Energy in kWh

Flexible resource ID	Zone	Period 1	2	3	4	5
44568	1	30	25	30	35	25
45672	1	30	20	35	40	35
28973	2	25	20	25	20	10
33476	2	10	10	15	10	10
	Total	95	75	105	105	75

The following section continues with new figures of the example to aid the reader in understanding this algorithm. There are two examples, the first is the scheduling of a battery for flexibility purposes and the second is the management of an EV fleet. Both examples have the same energy plan as the starting point. After the Energy Market and the day-ahead auctions are completed, the Energy plan obtained is shown in Table 21. Price is referred to the day-ahead market prices committed.

Table 21: Energy Plan example

Zone	Period 1	2	3	4	5
1	84	102	120	108	132
2	56	68	80	72	88
3	0	-36	-60	-36	0
Total energy	140	134	140	144	220
Price [c€/kWh]	4.7	5.6	3	6.7	9
Electricity cost	6.58	7.504	4.2	9.648	19.8

Table 22 is the Energy Plan updated for the 3rd period with new energy forecasts.

Table 22: Energy Plan example updated with new foresights before Daily Flexibility clearing algorithm

	Period				
Zone	**1**	**2**	**3**	**4**	**5**
1	84	102	115 (-5)	108	132
2	56	68	70(-10)	72	88
3	0	-36	-60	-36	0
Total energy	140	134	125 (-15)	144	220
Price [c€/kWh]	4.7	5.6	3	6.7	9
Electricity cost	6.58	7.504	4.2	9.648	19.8

Table 22 shows that periods 3 and 5 are the cheapest and the most expensive ones of the Energy plan respectively. Based on this information, SESP executes the Daily Flexibility algorithm to schedule the community batteries in zone 1 and 2, and the obtained result is shown in Table 23. In zones 1 and 2, the consumption is increased during T3 to store electricity in the battery and during T5 it is discharged. Notice that the battery efficiency is 80% and hence, there are 12 kWh that are not discharged during T5.

Table 23: Daily flexibility plan including a community battery with charge/discharge efficiency of 80%

	Time				
Zone	**1**	**2**	**3**	**4**	**5**
1	84	102	150(+35)	108	108(-24)
2	56	68	100(+30)	72	72(-16)
3	0	-36	-60	-36	0
Total energy	140	134	190	144	180
Price [c€/kWh]	4.7	5.6	3	6.7	9
Electricity cost	6.58	7.504	5.7	9.648	16.2

Table 24 shows that, even after consuming more electricity as planned in DFP, the electricity cost for the community is reduced by 4.4%. Notice that there aren't any deviation penalties or operation battery costs for simplicity.

Table 24: Results obtained with the Energy and Daily flexibility plan including a community battery

	Energy Plan	**Daily flexibility plan**
Electricity consumed [kWh]	778	788 (battery losses!)
Electricity cost [€]	47.732	45.632 (Δ=-4.4%)

- Flexibility local market for EV management

EV fleet consumption is reduced during T4 and T5 and increased during T1, T2 and T3 as shown in Table 25. Notice that the original Energy Plan had 778 kWh but the DFP only has 769 kWh. Thanks to the Daily Flexibility algorithm, energy cost is reduced by 5.5% by re-scheduling EV charging and refreshing the energy consumption forecasts.

Table 25: Daily flexibility plan re-scheduling electric vehicles

	Time				
Zone	**1**	**2**	**3**	**4**	**5**
1	108(+24)	126(+24)	115	84(-24)	108(-24)
2	72(+16)	84(+16)	70	56(-16)	72(-16)
3	0	-36	-60	-36	0
Total energy	171	174	140	104	180
Price [c€/kWh]	4.7	5.6	3	6.7	9
Electricity cost	8.037	9.408	4.2	6.968	16.2

Table 26: Results obtained with the Energy and Daily flexibility plan in re-scheduling EVs

	Energy Plan	**Daily flexibility plan**
Electricity consumed [kWh]	778	763 (no losses)
Electricity cost [€]	47.732	45.122 (Δ=-5.5%)

Using the example of EV management and its DFP, the Flexibility reserve required for decreasing consumption during period 3 is shown in Table 27. Notice that the community batteries are still available for flexibility purposes in this case and their power capacity is 50 kW each. During T3, the total flexibility is 205 kWh considering thermal loads (75 kWh), EVs (30 kWh) and batteries (100 kWh). During D-FCM, the flexibility scheduled is 120 kWh and the total flexibility reserve is 85 kWh divided in 4 groups: for DSO, local deviations, TSO and a margin for forecasting errors and non-available flexible assets.

Table 27: Flexibility reserve

Thermal flexibility	75	kWh
EV flexibility	30	kWh
Battery flexibility	100	kWh
Total available flexibility	205	kWh
Flexibility scheduled in the DFP	120	kWh
Total flexibility reserve	85	kWh
Flexibility reserve for DSO	30	kWh
Flexibility reserve for LD	20	kWh
Flexibility reserve for TSO	15	kWh
Flexibility reserve margin	20	kWh

The SESP can use the Flexibility reserve for bidding in the tertiary reserve market. For example in Norway, the offers must be sent to the TSO at 21:30 during the day before and offers can be modified 45 minutes before the delivery period. This means that the SESP needs to execute the D-FCM before sending the offers to the TSO.

11.5 Hourly Flexibility Cross Market algorithm

Once the DSO sends a request and the SESP receives the signal, the SESP has to check if the DFR* has enough resources to cater to the request. If the SESP has the required flexibility, it sends an acceptance message. Moreover, the SESP refreshes the bid sent to the TSO 45 minutes before the period begins based on the DFR*. However, the TSO signal to activate these bids can come at any moment and the SESP has to consider all this in the scheduling process. The Hourly Flexibility CM algorithm is a mechanism to organize the Local Market auction to schedule the SESP resources during the next hour divided by quarters.

The bids have three segments: the bid for the DSO, for LD and for the TSO.

- The bid for DSO is the energy requested by DSO for next hour and the price is established in the DSO-SESP contract discounting a SESP fee. This bid can be divided by quarters if DSO request is only for a certain period shorter than an hour.
- The bid for the LM is the energy deviation expected for next hour at a certain estimated deviation penalty price.
- The bid for the TSO is the DFR for next hour available at a certain price based on SESP members' offers. The SESP needs to establish a strategy for managing the offers from SESP members in the DFR.

The offers are the energy available from flexibility assets and their corresponding prices established in contracts. As shown in Figure 51, after receiving the DSO request, SESP checks if available resources can offer flexibility at a price lower than the price stipulated in the contract for catering to DSO request with the function Determine state of flexibility resources.

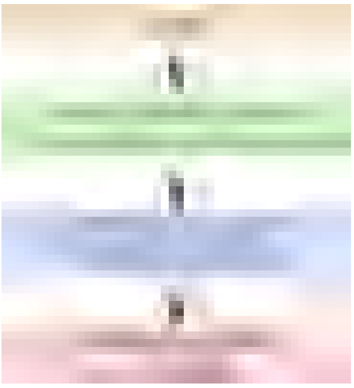


Figure 51: Flexibility Local Market for DSO requests flow diagram

Once the DSO request is received and accepted the SESP prepares the TSO offer for the tertiary reserve balancing market. Figure 52 shows the flow diagram that the SESP executes 45 minutes before to update the previous bid sent to the TSO. This bid needs to be updated because the demand or generation forecast could change and local deviations could happen. The balancing market price forecast is needed to estimate if

SESP member offers could be cheaper than the market price. the DSO request could modify the TSO flexibility reserve and the SESP has to correct the DFPR.

Figure 52: TSO offer refresh for the tertiary reserve banlacing market flow diagram

Some minutes before the operation period begins, the SESP has to define the HFP scheduling the flexible assets that will support the bids sent to DSO, TSO, and the local deviation. As shown in Figure 53, in order to schedule the appropriate resources, it is necessary to determine the status of flexible resources and forecast local deviations, and BM prices or deviation costs. After this, it is necessary to merge the bids sent to DSO and TSO, with the bid for the local deviations. The offers come from the SESP flexible assets and the contracts with the corresponding SESP members. Once all the information is defined, the SESP executes the Hourly Flexibility Clearing Algorithm to schedule the flexible assets for the following four quarters of an hour. The flexible resources allocated in the auction and the remaining assets are registered in the Hourly Flexibility Plan and Reserve HFPR modifying the DFPR*.

Figure 53 Hourly FCM Clearing flow diagram

11.6 Adjustment algorithm

Deviations due to forecast errors have to be measured globally because the SESP could be penalized for the global result, not the individual. Moreover, members cannot be penalized in any way for these deviations because they cannot do anything in their power to improve them. However, deviations due to violations of flexibility contracts have to be measured individually and penalized if necessary. They could cause an overcharge in a substation or in a line and the consequences could be disastrous. Both sources of deviations have to be managed by the SESP and their consequences have to be transparent for members. This document delves deep into both issues and establishes participation rules for the members. Figure 54 shows an example with two periods and the corresponding 8 quarters with deviations in both directions, for more consumption/less production and the other way arround. For local deviation purposes, the balance that matters is the hourly one, quarters can be deviated without penalties.

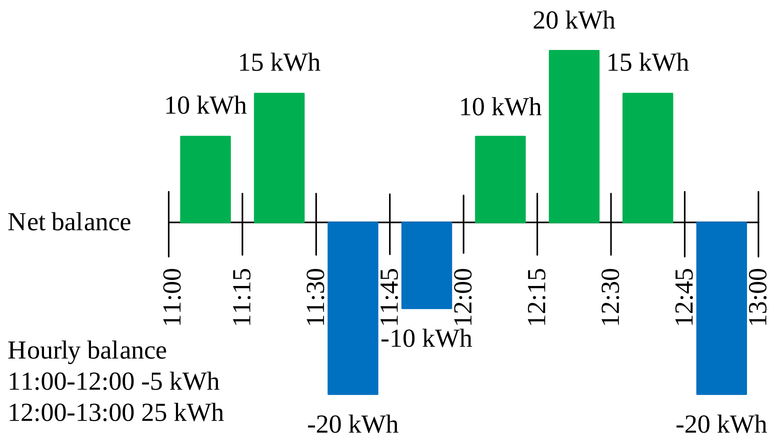


Figure 54: Deviations measured with the net balance: difference between committed and forecasted

11.6.1 Forecasting errors

Forecasting errors in generation and load side can occur frequently and the SESP has to deal with them because deviations result in extra-costs. The SESP could apply an economic margin to the energy contract price to account for energy deviations. This is quiet similar to business model that retailers are currently applying in liberalized power markets. Nevertheless, the SESP has the opportunity to establish new strategies to reduce these deviations in the flexibility market by taking advantage of data from the meters, flexibility programs and distributed energy resources (DER) like storage units, flexible generators and electric vehicles. The FCM could be the trading platform to send offers to members for reducing deviations before they occur.

It seems clear that the additional cost of deviation could be paid by all participants mutually. Furthermore, SESP has to establish strategies to detect deviation sources and mitigate them by installing storage units or special flexibility contracts. Deviation sources could be participants who have random consumption profiles or prosumers with photovoltaic panels located in an area where fogging and clouding are quite common or even a public EV charging station with stochastic EV connection. This raises the following question: should SESP refuse participants that cause deviations? The answer is no, as it seems logical that a discount system could incentivise good practices with bonuses or special offers. Accordingly, SESP applies the following solutions:

- Local deviation Flexibility Local Market for the operation level
- Decision algorithm to reduce deviations for the planning level
- Discount system at market and business levels

11.6.2 Load deviations with flexibility contracts

Load deviations from flexibility contracts at household level could happen frequently due to high power non-flexible loads like ovens, cooktops or others. The following example shows a potential load deviation in a household with flexible loads. It is explained step by step:

1. At a certain instant, the DSO detects a potentially dangerous situation and it requests the SESP to reduce the power flowing through the substation.

2. SESP activates flexibility contracts to reduce the power consumption and the heat pump of a household is switched off. The power consumed by the household is reduced by 1 kW and the member is rewarded for this action.

3. However, it is possible that minutes later, the same member decides to switch on the oven and the power consumed increases by 2 kW.

Figure 55 shows the power consumed in this example. If this happens during an emergency, the DSO is still in danger and the SESP has to compensate for this new consumption to avoid the substation being overloaded. Furthermore, this is not the member's fault because the oven cannot be controlled and there was no request for curtailing its operation. However, without the flexibility program, the situation could have been worse. To avoid difficult situations, the SESP should establish only one contract for all the needed appliances during a certain period. Lastly, the SESP needs to receive information about the system status often enough to detect situations with a consumption increase even switching on flexibility contracts.

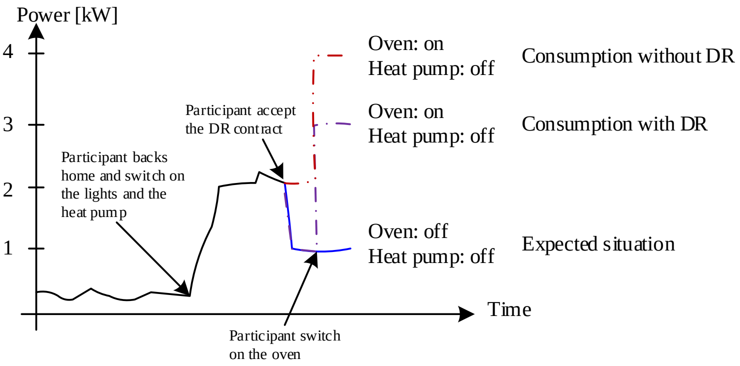


Figure 55 Power consumption in the household

Other examples also could show situations like the previous one. For example, after SESP activating a flexibility contract, the EV of that SESP member could be connected and charged. Consequently, the SESP could need to activate another flexibility contract to compensate the EV, or could need to switch off the EV.

11.6.3 Violations of Flexibility contracts

First, it is necessary to know if it is possible to violate the remote control system by manually overriding the SESP control signal. If yes, it is necessary that the local control system monitors the consumption of each flexible load to distinguish their individual consumption and then take decisions accordingly. Finally, SESP has to establish a penalty mechanism for member who failed in the flexibility request and this system has to be included in the contract between SESP and the member.

11.6.4 Adjustment algorithm

During the operation hour, some flexible assets may become unavailable for operation or forecasting errors could modify the needed flexibility to support the DSO. In order to supervise the status of the SESP community, the SESP will execute the adjustment algorithm every 15 minutes as shown in Figure 49. The algorithm re-calculates the HFP based on the current status and the new plan is referred to as HFP* and HFR* for the next four quarters. The flow diagram is the same as the Hourly FCM shown in Figure 53 and includes inputs from the SESP community status and the current consumption and generation. Moreover, the local deviations can change based on new foresights.

11.7 Examples

11.7.1 DSO request case

Figure 56 shows one quarter hour auction in a situation where only the DSO has requested flexibility services. In this case, the DSO requests to decrease a certain amount of power and the EVs and some water heaters are willing to be disconnected. According to the auction, all EVs are disconnected, but water heaters are more expensive than EVs and the SESP does not need to disconnect all of them. Once the offers and bid are established, the Flexibility Clearing Algorithm is in charge of calculating the auction price and the volume. In case that the DSO has a multi-period request (more than one quarter hour) the clearing function must be multi-period to include temporal

Figure 56: DSO-FCM auction for a quarter hour

constraints as the Daily Flexibility clearing function does. Auction price rules follow the same rules as day-ahead markets - the price for all offers accepted is the last accepted offer, also known as marginal price. Table 28 shows the previous example DFP with the re-scheduled EVs. In this case, DSO requests a consumption reduction or increase in generation of 20 kWh for all periods. SESP executes the DSO-FCM algorithm to attend to this request. Notice that the Flexibility reserve has 30 kWh reserved for the DSO.

Table 28: Daily Flexibility plan of the example

	Time				
Zone	**1**	**2**	**3**	**4**	**5**
1	104	126	120	84	108
2	67	84	80	56	72
3	0	-36	-60	-36	0
Total energy	171	174	140	104	180
Price [c€/kWh]	4.7	5.6	3	6.7	9
Electricity cost	8.037	9.408	4.2	6.968	16.2

Table 29 presents the results after each DSO-FCM algorithm execution for each quarter hour during T3. Notice that Q1 has had a deviation of one kWh that is compensated in the next quarter hour by reducing the consumption to 39 kWh instead of 40 kWh as indicated in the Q1 Flexibility Plan. A similar issue appeared during Q2 and Q3, but not after Q4. After Q4, the SESP has reduced 20 kWh as requested by the DSO.

Table 29: Evolution of the Hourly Flexibility plan after each DSO-FCM algorithm execution. In blue the energy measured in the community

Hourly	Quarter				
Flexibility plan	**1**	**2**	**3**	**4**	**Total**
Without DSO-FCM	60	45	50	45	200
Before Q1	55	40	45	40	180
Before Q2	56 (+1)	39	45	40	180
Before Q3	56	38(-1)	44	42	180
Before Q4	56	38	43(-1)	43	180
Real	56	38	43	43(0)	180

Notice that zones are not represented for simplicity, but grid constraints are always considered. Table 30 shows the control signals sent to SESP members before every quarter in order to cater to the DSO request. Before Q2, the SESP decreases 1 kWh to one SESP member because one control signal didn't act as expected during Q1.

Table 30: Control signals sent to SESP members to reduce their consumption

	Quarter			
Member ID	**1**	**2**	**3**	**4**
12256	-1	-1	0	0
55236	-2	-2	-1	0
25576	-1	-1	-1	0
55776	-1	-1	0	0
64312	0	-1	-1	0
12345	0	0	-2	-1
78442	0	0	-1	-1
Total	-5	-6	-6	-2

11.7.2 Local Deviation and a DSO request case

This section shows a case with a local deviation and a DSO request. For example, if the SESP detects a local deviation of 10 kWh of less consumption than expected in DFP during T3, and at the same time that DSO requests to reduce 20 kWh from DFP, SESP only has to reduce consumption by 10 kWh because both requests are in the same direction. However, if SESP detects 10 kWh of higher consumption compared to DFP, it needs to reduce consumption by 30 kWh. Following the example shown in Table 25, the DFP was expected to consume 200 kWh during T3 in zones 1 and 2. Here, DSO requests to reduce 20 kWh and the local deviation forecast is about 10 kWh more than expected. In order to avoid local grid problems, SESP applies control signals to reduce 30 kWh of consumption. Table 31 shows the HFP with local deviations and Table 32 shows the control signals sent to community batteries to supply the 10 kWh of consumption.

Table 31: Evolution of the Hourly Flexibility Plan after each Adjustment algorithm execution. In blue the energy measured in the community

Hourly	Quarter				
Flexibility plan	**1**	**2**	**3**	**4**	**Total**
Without DSO-FCM	62.5	47.5	52.5	47.5	210
Before Q1	55	40	45	40	180
Before Q2	56 (+1)	39	45	40	180
Before Q3	56	38(-1)	44	42	180
Before Q4	56	38	43(-1)	43	180
Real	56	38	43	43(0)	180

Table 32: Control signals sent to community storage units to compensate the local deviation

	Quarter			
Member ID	**1**	**2**	**3**	**4**
Community battery Z1	-1.25	-1.25	-1.25	-1.25
Community battery Z2	-1.25	-1.25	-1.25	-1.25

11.8 Functions

This section specifies the previously mentioned market functions needed to implement the local flexibility market.

- Demand and generation forecast for the Daily Flexibility CM: to know the expected consumption and production for the following day in one-hour periods based on time series and weather foresights.
- Demand and generation forecast (FCM): to know the expected consumption and production for the following hour in quarter hour periods based on time series and weather foresights.
- Refresh offers & bids: to update the offers and bids defined in the Energy CM based on the new consumption and generation foresights.
- Daily flexibility clearing algorithm: to re-schedule the flexible assets based on new foresights, the established contracts in the PX and the SESP members' energy needs.
- Determine state of flexible resources: to update the flexibility reserve based on the metered energy of flexible resources.
- Offer formulation for flexible resources (DSO-FCM): to create the offer including all flexible resources and their prices from each contract.
- Hourly Flexibility clearing algorithm: to clear the auction between the bids from the DSO or the local deviation with the flexible assets available. This function should include multiple periods in the optimization algorithm to schedule resources like EVs or batteries with time dependencies.
- Bid formulation for local deviations: to define the bid with the deviation energy and the deviation cost expected.
- Offer formulation for balancing markets: to define the offer with the flexible energy and the corresponding prices for each flexible asset.
- Balancing market forecast: to know if the power system is up- or down-regulated and the deviation cost

12 Reward Mechanisms

The reward mechanism in local energy and flexibility markets is designed to broadly serve the following purposes:

- Encourage members to increase their participation in local markets
- Reward top performing members
- Provide incentives for recruiting new members
- Increase awareness about the role of energy and flexibility in markets
- Resolve conflicts in auctions and trade
- Maintain enthusiasm and continuous engagement
- Foster a sense of cooperation and understanding

Members of the community enter into various types of contracts with the SESP for actively participating in local energy and flexibility markets. These contracts define the extent of participation and in turn the monetary benefits received by members. However, this mechanism does not reflect the entire dynamics of local markets such as cooperation within the community and various other soft factors influencing the market. Providing non-monetary benefits to community members based on their willingness, extent and frequency of participation combined with a measure of the quality and quantity of their contribution towards trading serves as an excellent mechanism for capturing the flavour of local markets. Such a non-monetary individual reward system can be compared and contrasted with frequent flyer programs of airlines, membership privileges in online forums, rankings in online trading such as e-bay, etc. The individual rewards for SESP members are normally based on a number of performance criteria in the local markets, which are evaluated by the SESP itself. The challenge for SESP is to design effective individual reward mechanism that provides its members with strong incentives for continued and extensive participation in local markets.

In addition to non-monetary rewards, if the SESP is a very strong community initiative driven by a sense of contribution and participation, the SESP could choose to share a part or whole of its profits among its cooperating members. This is due to the fact that the profits earned by the SESP are a direct result of the participation of its members and hence it is logical to assume that the community members would want to share the profits in a fair manner. The collective reward mechanism can be compared and contrasted with collective trade union agreements in labour markets, profit allocation between various government bodies for public facilities, team-based incentives in companies, points sharing in online multi-player games, etc. In this situation, the natural question that arises is how to share among individual community members, the benefits that were reaped together as a cooperative community in the local energy and flexibility markets? In order to answer this question, we must first quantify the individual and community worth of a member which can be used as a metric for dividing the joint benefits from cooperation. Moreover, the sharing mechanism must be perceived as fair by all community members and should provide an incentive for continued cooperation and participation in local markets. There is more than one way to reward the members of a group and each solution has a different fairness aspect associated with it.

Monetary rewards can take different technical forms. In WP6, we have emphasized the use of kick-backs in the form of periodic bonuses and direct price mark-ups or discounts on local energy. The latter provides an instant comparative effect. Members can immediately assess the benefit of membership in a single statement. It should be realized that in some regions, this may not be even practical or legal. Henceforth, two statements might be required. One would be a simple estimate of the cost of energy including tariffs and taxes. The actual bill will be passed on from the DSO or another authority. The other statement would specify the earnings in the form of kick-backs to be paid out by the SESP. In addition, this could include specification of bonus points, membership enhancements and special discount coupons.

In this chapter, we introduce the concepts behind various reward mechanisms and classify them broadly as proportional allocations and cooperative allocations. In proportional allocations, members are rewarded monetarily or non-monetarily, an amount that is directly proportional to some performance criteria. However, proportional allocation methods do not capture how well or crucial a member's contribution could be in a group that cooperates to achieve a certain goal. Cooperative allocations quantify the worth of a member to a group and the rewarding mechanism is based on solution concepts from cooperative game theory.

12.1 Proportional allocations

Rewards that are proportional to and based on some performance criteria or a metric of contribution of members are universally perceived as a fair allocation method. For example, in the local flexibility market, the reward for a participating member could be based on the number of appliances in the household that the member lets the SESP control. However, it is possible that some members of the community could argue that evaluating a member's contribution based on the number of appliances made available for SESP control is neither fair nor does it extensively reflect the nature of participation of members. Such scenarios could arise in situations where a particular member has offered very few appliances for SESP control, but during crucial times and therefore these appliances are likely to be used more in the flexibility market than ones of another member who has offered more appliances for control, but during times when the need for flexibility in the grid is minimal. Hence, a fair rewarding mechanism must capture all the intricate details of a member's contribution to the flexibility market and in order to accomplish this, the contract between the SESP and members serves as a good starting point. Though many different types of contracts could exist between the SESP and members, there are some basic building blocks common to most contracts that can be utilized in the rewarding process. An optimal reward mechanism must be a function of combination of the following parameters for each SESP member:

- The duration of the contract
- The number of appliances made available in the flexibility market
- The combined and individual rated power of the appliances
- The total power of appliances that may be available in the flexibility market
- The total time for which the appliances are made available in the flexibility market
- The total time for which the appliances are activated in the flexibility market
- The frequency of activations of the appliances
- The total amount of energy consumed in the flexibility market
- The peak to average ratio of the power consumption
- The criticality of the time during which the appliances are activated
- The percentage deviation of appliances from contracted power

Similarly, if the member happens to be a prosumer with solar panels, who has offered complete control of the production source to the SESP, the reward mechanism must include a combination of the following parameters:

- The peak power of the solar panel installation
- The total energy produced from the panels
- The criticality of the time during which the energy is produced

It is also obvious that the reward mechanism works both ways and hence any deviations (other than what is allowed for in the contract as tolerance limits) or non-fulfilment of contract terms should incur a penalty for the member. The penalty incurred will then be a function of the following parameters

- The amount of contracted power that was not delivered in the flexibility market
- The frequency of such non-fulfilments or non-compliance with contracts
- The criticality of the time during which the contracted power was unavailable

Both the reward and penalty functions must have some desirable properties such as real-valued, monotonicity, continuity and differentiability (for continuous time index), boundedness, etc. in order for the analysis to be mathematically tractable.

12.2 Cooperative Allocations

Cooperation is an instinctive and evolutionary trait in humans that results in mutual benefits for all persons involved irrespective of whether we are living in a hunter-gatherer society or a digital economy. Similarly, rational members participating in local markets also benefit from cooperative behaviour. The fundamental assumption and the foundation upon which cooperation is built is that cooperation results in greater benefits for the group and the individual as opposed to the sum of individual contributions of the members of the group. This also forms the basis for the SESP operations as the SESP derives value out of the local energy or flexibility market based on the collective strength of its members. Sharing the benefits of cooperation in a fair manner is a non-trivial problem that has been studied by economists for over a century. Cooperative game theory provides a mathematical framework for studying the formation of coalitions and allocation of payoffs. We introduce in this section, a formal definition of the terms used in the literature in order to understand the applicability of cooperative game theory to local energy and flexibility markets.

- Formally, a cooperative game (N,v) consists of N, the set of SESP members and v, the characteristic function that associates a value or worth with every non-empty subset of members. v can be thought of as the value created when the SESP members come together and interact in the local market. It is also the total payoff that is available for allocation among the SESP members.
- An allocation or payoff $x = (x_1, x_2, \dots, x_n)$ is a division of v(N), the overall value created, where x_i is the value received by member i in N.
- An allocation x is individually rational if $x_i \geq v(i)$ for every member in N, i.e., no rational member will have an incentive to cooperate if the allocation gives it lesser than what it can get by itself.
- An allocation x is efficient if $\Sigma x_i = v(N)$, i.e., all the value that is created is allocated.

- Marginal contribution m_i of a member is the amount by which the overall value created decreases if the member does not cooperate, i.e., $m_i = v(N) - v(N \backslash i)$.
- An individually rational and efficient allocation x satisfies the marginal contribution principle if $x_i \leq m_i$ for every member. The marginal contribution is the upper bound on the allocation or the maximum payoff that a member can expect in the grand coalition and is also referred to as the utopian payoff.
- The excess of a member is given by $e_i = v(i) - x_i$. The absolute value of the excess is the measure of the amount under and below its worth that a member obtains when payoff is allocated. In other words, the excess measures the member's dissatisfaction of the allocation.

Two fundamental questions arise at this point.

1. How to formulate the value or worth of member v(i) in the local market?
2. How to divide the overall value v(N) among all the members?

It is interesting to note that the first question is very closely related to the question raised in the previous section on how to capture the contribution of members in order to reward them. The reward function that was used to capture the contribution of members to the local market can also serve as the characteristic function in the cooperative game. Once the characteristic function is established in the cooperative game, the overall value created must be divided among the members in rationally efficient allocation. However, before proceeding to the various allocation solutions, it would be helpful to characterize the cooperative game in order to imbibe the finer aspects of cooperation and allocations.

- A game is non-negative if for each subset S of N, $v(S) \geq 0$. Non-negativity implies that a member or a coalition of members is not capable of generating negative worth assuming that there are no malicious members in the community.
- A game is monotonic if for subsets S, T of N such that S is a subset of T, $v(S) \leq v(T)$. Monotonicity is an extension of non-negativity property implying that addition of new members cannot reduce the worth of the coalition of existing members.
- A game is additive is for non-overlapping subsets S, T of N, $v(S \cup T) = v(S) + v(T)$. Additive games imply that the worth of any coalition is equal to the combined worth of the sub-coalitions.
- A game is superadditive if for all non-overlapping subsets S, T of N, $v(S \cup T) \geq v(S) + v(T)$. Since the whole is greater than the sum of its parts, superadditive games provide all members with an incentive to cooperate thereby ensuring the formation of a grand coalition.

Next, we introduce the various solution concepts in cooperative game theory that are used for dividing the overall value v(N) created by the coalition. A solution concept assigns at least one allocation or payoff x to the member of the coalition. Solution concepts may be a set of payoffs (set-valued) like the core or a singleton (one-point) like the Nucleolus, Shapley value and tau-value.

Given a cooperative game, an allocation x is said to be in the core of the game if it is individually rational and efficient: $x_i \geq v(i)$. An allocation x_i lies in the core if and only if it satisfies the marginal contribution principle: $x_i \leq m_i$. Therefore, $v(i) \leq x_i \leq m_i$. The core is a set of payoff profiles that satisfy a system of finite weak linear inequalities and hence is closed and convex provided the core is non-empty. The exact allocation in the core is arrived by means of bargaining between members. However, when there are many members in a game, it is a tedious process to solve for the system of inequalities and arrive at a singleton solution through bargaining. Hence, one point solutions such as Shapley value, tau-value and Nucleolus are employed to obtain a direct allocation without solving for the core.

The Shapley value is a solution concept that is defined as the expected marginal contribution of a member over all possible orderings of that member in the set of all members. This is because, the marginal contribution of a certain member in the market depends on the ordering of all members in the SESP and hence an average sense of contribution is used as a payoff to the member. The Shapley value is individually rational and efficient, but does not necessarily lie within the core.

The tau-value is a solution concept that can be thought of as a feasible value between the marginal contribution and the minimal right payoff. In other words, the tau-value is a compromise between utopia and disagreement. Tau-values are individually rational and efficient, but not necessarily in the core.

The nucleolus is a solution that minimizes all excesses in a non-increasing order. It can also be thought of as a min-max fairness solution. The definition of nucleolus is not standard, but the nucleolus always exists, is unique and lies in the core of the game if the core is non-empty.

12.3 Recommendations for SESP

A basic reward function that can serve as a starting point for the SESP operations is formulated as follows:

$$r_i = f(PAR_i, P_i, E_i, T)$$

where, r_i is the reward for member i, f is a reward function, PAR_i is the peak to average ratio of power consumption of the member, P_i is the total combined power of all appliances offered in the flexibility market, E_i is the total energy traded in the flexibility market and T is the time period. Reward function for a prosumer follows a similar line of reasoning. It is possible that other parameters will play an important role in determining the reward for the member depending upon the nature of their contract with the SESP. However, we relegate the task of formulating the exact function f, its characterization and properties to T6.4. This reward function forms the basis for more advanced formulations that capture even the minutest intricacies of a member's contributions.

Under the assumption that there are no malicious members, it is easy to see that individuals not belonging to the community have no considerable value either in the energy or flexibility market. Hence for all practical purposes, the value of non-members v(i) = 0. The value of a member can be calculated based on the reward formula and also serves as the characteristic function for the cooperative game. The reward function gives the member an estimate of its perceived contribution to the group and can be used to adjust its contribution according to circumstances prevailing in the local markets.

The cooperative game must be designed in such a way that the characteristic function is non-negative, monotonic and superadditive. Superadditivity ensures that the grand coalition will always form and thus guarantee the operation of SESP members as one unit. The resulting games must also be balanced in order to have stable allocations resulting in payoffs that provides every member with an incentive to cooperate. The overall value created by the SESP members v(N) can be measured in terms of the profits earned by the SESP in the local markets. The core of a balanced cooperative game is always non-empty and guarantees the existence of solutions that are stable, meaning no member has an incentive to leave the group. The one-point solution concept used to allocate profits could be based on either Shapley values or nucleolus. It is not guaranteed that the Shapley value will lie in the core of the game and hence, it might be helpful for the SESP to verify this analytically. While the Shapley value is fair in the average sense, the nucleolus is fair in the min-max sense and is always guaranteed to lie in the core. Complexity wise, the nucleolus can be computed efficiently in polynomial time.

13 Operational Risk Management and Optimization Issues

In this chapter, we outline the risks that are expected to challenge SESP operations and methods to overcome them. Some of the risks faced by the SESP have been mentioned in the passing in D6.2. Additionally, we also touch upon issues that the SESP might encounter in its operations while maximizing for profit or welfare, which are inherently related to the risks faced by the SESP. A profit maximizing SESP is highly likely to be risk loving while a welfare optimizing SESP is likely to be risk averse or neutral. Much of the risk taking abilities of the SESP depend in turn on its ability to gather prior information, reduce prediction and forecasting errors, anticipate customer behaviour, hedge and speculate in both local and centralized markets, negotiate strongly with DSO and TSO. Depending upon these factors, the SESP can choose between risk loving, risk neutral and risk averse strategies for its operations. It must be mentioned that the in the local market, no player other than the SESP is willing to take risks and the SESP acts as a risk absorber for all foreseen and unforeseen circumstances. However, some SESP members who have the freedom to estimate their energy production/consumption and draw up a contract accordingly with the SESP will be interested in risky trading. In such cases, neither the community nor the SESP is responsible for the resulting consequences and there might be a high penalty associated with such activities if it affects the SESP's operations. Being the sole risk absorber in the market, the SESP must optimize its various operations in such manner that risks are inter-absorbed or propagated through the operation chain resulting in risk attenuation at each step. For example, risks arising from conservative consumption forecasts in the day-ahead energy market can be easily smoothed in the flexibility market. However, if the flexibility assets cannot compensate for the forecast errors, the SESP must venture into the intra-day or real time balancing markets where the energy prices may be highly volatile. If the SESP has prior knowledge or is equipped to predict the direction of balancing markets, then conservative forecasting in the day-ahead energy market may be a strategy to mitigate risk. In the following table, we outline possible risks for the SESP in its market operations, associated consequences and mitigation strategies.

Operational Risks	Consequences	Mitigation Strategies
Forecasting errors in day-ahead energy market	Exposure to volatility in intra-day and balancing markets, increased local deviations/imbalances	Optimal use of flexibility assets including batteries, improved forecasting about balancing market direction

Intra-day over-estimation of consumption or under-estimation of production	Energy surplus resulting in local deviations/imbalances	Profit from participating in balancing market or charge batteries
Intra-day under-estimation of consumption or over-estimation of production	Energy deficit resulting in local deviations/imbalances	Activate flexibility assets or discharge batteries or pay penalty in balancing market
Large scale temperature fluctuations resulting in increased/decreased consumption/production	Large forecasting errors in consumption/production	Reserve adequate flexibility assets for managing unforeseen circumstances
Forecasting errors in estimating the state of flexibility resources	Unable to counter local deviations or unable to fulfill DSO/TSO request	Engage members for better feedback on state of appliances, conservative forecasting
Shortage of flexibility assets	Unable to counter local deviations or unable to fulfill DSO/TSO request	Recruit more members and increase flexibility asset portfolio
Underperforming flexibility assets	Unable to counter local deviations or unable to fulfill DSO/TSO request	Penalty for underperforming members
Malignant/gaming members	Unforeseen operational errors or compromised grid stability	Community strengthening by means of spreading awareness, assuring fair reward mechanism and fostering sense of responsibility
Dissatisfied members	Loss of flexibility portfolio and membership income	Adequate customer support, improve understanding of local market functioning
DSO request not fulfilled	Breach of contract, punishment by way of heavy penalty, tarnished reputation, serious doubts over SESP operational capability	Increase flexibility margin and reserve, recruit more members, conservative operation and forecast
Unable to cater to normal DSO request	Irrelevance in local market,	Diversify and improve flexibility portfolio, improve forecasting algorithm
Unable to cater to emergency DSO request	Missed chance for assuming a greater role in the distribution grid, lost profit	Diversify and improve flexibility portfolio, improve forecasting algorithm
TSO demand not fulfilled	Breach of contract, strict rules regarding continued operation in the balancing markets	Improve flexibility plan and prioritize assets
Other non-operational risks involving, hazards, safety, security, etc.	Operational hiccups, occasional bottlenecks in operation	Elaborate emergency risk management plan

SESP would like to optimize its planning and operations based on its goal of profit or welfare maximization. In either case, SESP decisions in the energy/flexibility local market are based on the outcomes of executed optimization algorithms. These algorithms deal with preparation of bids/offers in the wholesale energy market, adjustment of bids to TSO, creation of energy plan, creation of daily/hourly flexibility plans, estimation of daily/hourly flexibility reserves, activation of flexibility assets, allocation of rewards to members, etc. Some of the tasks are intricately related to SESP's operational risk management strategies. While the actual task of formulating optimization algorithms has been relegated to T-6.4, we provide some insights into the nature and motivation of the optimization processes. For example, while responding to a normal hour-ahead request from DSO for load curtailment of 50 kWh in a particular zone, SESP has 15 minutes to adjust its bids sent to TSO the night before. Bid adjustment is the result of an optimization process that takes into account the following inputs and constraints:

- Input - The total amount of estimated flexibility available from various flexibility assets for the next hour with respective tolerance margins
- Input – Costs of activating each flexibility asset
- Input - The estimated amount of flexibility required to cater for local deviations in energy consumption/production
- Input – Probabilistic estimate of TSO placing a request for the next hour
- Input – Estimate of income from catering to TSO request and loss of income from canceling TSO bid
- Input – Estimate of fine/penalty if TSO request is unfulfilled
- Constraints - Amount of flexibility required to cater to emergency requests from DSO, Total available power and traffic light status in the zone published by DSO

This optimization process determines if SESP should proceed with the bids placed with TSO the night before and if yes, the margin of adjustment of the volume. It must be noted here that the risk taking ability of SESP plays a crucial role in the extent of probabilistic estimation of TSO placing a request with SESP. A risk averse SESP is bound to make conservative estimates and play safe while a risk loving SESP weighs the income from balancing market more than the incurred penalty of not catering to the request. A detailed list of inputs and constraints for other optimization problems can be drawn out for SESP in a similar fashion. Some of the optimization problems will require SESP to quantify abstract concepts such as member dissatisfaction, compromised grid stability, increased community welfare, etc. Appropriate utility functions and preference relations have to be formulated by SESP to capture these notions.

14 Conclusions

The overall market design for EMPOWER was defined in Task 6.1 and outlined in Deliverable 6.1. The various theoretical and practical solutions for prosumer oriented trade was discussed in Task 6.2 and described in Deliverable 6.2. Following these tasks and deliverables, Task 6.3 has developed a trading concept for EMPOWER that has resulted in this Deliverable. We have provided a comprehensive report that delves into various design aspects of local markets. The report also extends its scope to certain implementation issues from Task 6.4. However, the extensive market design and related aspects proposed in this report stands out as pure hypotheses at this time. In line with common scientific principles, the applicability and viability of the proposed market design and trade will be tested by means of full-scale experiments at different pilot sites. Experiments will be formulated and concepts from local market design will be translated into use-cases in other work packages that constitute the framework for experimental work at pilot sites.

In this report, we have elaborately defined the trading concepts and principles resulting in local markets for energy, flexibility and services, their design, construction, structure, operations, functions, processes, interactions and some implementation aspects as well. The proposed trading platform and local markets are designed to be scalable, adaptable and customizable in order to suit the diverse conditions at pilot sites. Apart from the technical concepts developed for trading and market design, the report also touches upon issues related to business models, ICT implementation and member/community involvement and participation.

Local market operation rules, timelines and interactions between various players, stakeholders and central markets have been detailed separately for certificates, energy, flexibility and other services. The report delves into the intricacies of operating a local energy and flexibility market in conjunction with central energy markets and stipulates the rules for planning and operating such cross-market trading models. The trading concept has been developed keeping in mind both the connected and disconnected modes (with respect to central markets) of their operation. In particular, the interactions between SESP and DSO and SESP and members have been given special attention and form the contents of separate chapters. These interactions are based on various types of contracts that the DSO and members may enter into with the SESP. Though the trading model primarily recommends long-term contracts, different types of contracts have been formulated and analysed. The trading concept and model applies to multiple facets of energy and flexibility related trade and this report has studied most of the associated technical aspects including risk management and optimization issues required for SESP planning and operations.

The local energy markets for energy and flexibility relate very well and are consistent with the platform-based business models studied and developed in Work Package 2. Platform-based models for local energy and flexibility trading require active involvement consumers/prosumers at both the individual and community level. This report touches upon economic and financial incentives required to boost local energy and flexibility trade that support platform-based business models. Such business models thrive on rewarding actively participating/contributing members and thereby creating a membership hierarchy such as frequent flyer or shopping club programmes. This not only drives competition among members for further active participation in local markets, but also fosters a sense of cooperation while working towards a common goal for the community. Reward mechanisms together with a fair allocation of profit ensures that members are adequately compensated both in monetary and non-monetary terms for their participation and involvement. Moreover, the proposed trading model and market design have been developed keeping in mind the heavy ICT focus of the project.

In conclusion, the following key issues have been addresses in this report:

- A trading model concept has been developed together with a local market design for trading in energy, flexibility and other services.
- The market design, structure, functions, operations and processes have been formulated and discussed in great detail.
- The interactions between various market players, especially between SESP and DSO and SESP and members have been outlined and described.
- The community-based approach to trading in local energy and flexibility markets has been emphasized and both individual and collective reward mechanisms have been proposed for SESP members to compete and cooperate to achieve common goals for the community.
- The proposed trading model and market design fit well both within the platform-based business models and ICT platform for implementation.

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