*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
CSU	Central storage unit
D-LFM	Daily local flexibility 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
LFM	Local flexibility market
H-LFM	Hourly local flexibility 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 deliverable specifies the market concept that will be implemented in EMPOWER. The specifications are made at business level, but contains sufficient technical detail to create a firm basis for further development and implementation in work package 5. The market and trade model is saturated with the business concepts developed in WP2 and draws on the explorative effort that was conducted in the tasks T6.1, T6.2 and not least task T6.3. The concept presented is a network market for trade in energy, flexibility and related services and products. This market concept will be enabled by the ICT platform to be developed in the project and for which this deliverable has been produced. Integration of the three parts of the market is specified at two levels. One is the management level and one is on contract level. Combined contracts that include energy, flexibility and service related elements represent the highest form of integration. This also cater for contracts with a fixed prices over a longer period to generate foresight and stability for the community members. The SESP takes the main responsibility for managing the deviances during the contract period, but may also design contracts that encourage community members to actively take measures to share this responsibility. The system that is going to be developed will be designed so that it allows different types of contracts to be traded with different user groups. System adaptability is strongly emphasized by this approach.

The trade incentives discussed in D6.3 are brought forward. It is argued how these incentives can be structured in the EMPOWER system to achieve the goals defined for the project. The two most important are:

- to create a local market economy whereby investment in distributed and renewable energy is encouraged
- to ensure that, as local generation capacity increases, specific measures driven by standard market mechanisms can be introduced to contain that increase to the benefit of all. This implies systematic use of end-user flexibility.

The trade is organized within a community which is rooted in a physical neighborhood, but where interactions happen through the EMPOWER system. Community membership is voluntary and therefore the community, the SESP and the market concept must be competitive and demonstrate economic sustainability, Efforts are made to explain how.

Among the forms of trade discussed in deliverable 6.2 and D6.3 two basic forms have been chosen and recommended for further implementation. One is a simple over-the-counter sale whereby the SESP is responsible for defining the contract templates and the buying and selling price. The SESP functions as a broker of such contracts. When competition within a community increases auctions may replace the over-the-counter trade. For this a price scan auction has been proposed. This is call auction where trade in contracts is non-continuous. The transition from over-the-counter sale to this type of auction is quite small. This should make the system more robust and scalable.

Cross-market operations are specified. These are operations where the SESP uses external resources or its own repositories to manage mismatches between what is produced locally and what is consumed locally. When a local market has unobstructed access to the central market it is specified how energy form the central market can fulfill such a compensating role. This requires synchronization between the SESPs internal and external operations. Specifications on how this must be accomplished are given. The challenge is amplified if the local market is going to support the DSO with flexibility too.

Interactions between important system objects are specified and key functions have been defined. The idea on trade agents and controllers have been expanded on since D6.3 and based on tests a recommendation for a zero-intelligence type of agent is made and specified. It is also defined how this type of agent can be made more intelligent.

Various parts of these specifications have been along with D6.3 have been exposed to a selection of external and internal reviewers to generate important feedback and a shared understanding. This also includes potential users of the system. The aggregated feedback has been incorporated.

2 Task description

The purpose of Task T6.4 is to create a sound basis for system implementation. Based on former activities the necessary specifications for implementation, deployment and maintenance of the market place and trading will be developed. The result of this will be included in the SESP platform. These specifications should constitute the technical basis for implementation of the market and trading concept developed in the project and all the interfaces capturing the communication between the management/trading level and the parts that optimize use of resources and control the physical flow of communication, energy and money.

3 Introduction

This deliverable synthesizes the results produced previously in the project, primarily work package 2 (WP2) and work package 6 (WP6). It offers a set of functional specifications for the EMPOWER platform, including use cases, stemming from deliverables such as D2.1, D2.2, D3.2, D6.1, D6.2 and D6.3. The present specifications should be sufficient to develop a proper platform design that can facilitate an incremental system development with sufficient potential for customization. The latter being of great importance since the EMPOWER platform should be accommodated with different communities in different countries and run under different regulatory regimes. As the EMPOWER project developed, the boundary between task T6.3 and task T6.4 became blurred. There were several reasons for that. Better chronological match between WP2, WP5, WP6 and WP7 was required. A pure water flow development strategy proved less useful. Multiple iterations were required. Secondly, detailed analyses were sometimes needed to cater for some of the more overall developments that constituted part of the conceptual effort in task T6.3. Consequently, elements that were originally intended for this deliverable were advanced and included with the D6.3 to create a more holistic perspective.

The work in T2.2 also had an impact, but was concluded almost in parallel. The platform business model prototypes described in deliverable D2.2 offer tentative ways for hosting the type of network markets and trade described in D6.3. A market and trade concept without a viable business model at its heart limits itself at best to academic evaluation. Together with the different trade options explored in task T6.3 and presented in the deliverable stemming from this task a wide array of options for implementation and testing emerges. Each combination of market design, trade concept and business model constitute a hypothesis that should be potentially proved in the pilot demonstrations organized in work package 7 (WP7). For obvious reasons the number of experimental concepts that can be tested in these pilots are not unlimited. Henceforth, a screening must be done prior to this. This deliverable synthesizes different ideas from different deliverables and promotes a suite of hypothetical solutions to be accommodated in the design of the EMPOWER platform. In doing so references to deliverable D7.1 will be made. This describes the potential infrastructure, communities and hardware that will be available for testing in the different pilot areas in Norway, Germany and Malta. This has influenced the screening and recommendations made in this deliverable. It also explains in part why all the theoretical alternatives presented in D6.3 and D2.2 cannot be pursued within the project. Still the approach chosen and the specifications presented here have some important general implications. First of all it requires an EMPOWER system and a SESP role that can demonstrate suppleness. This suggests a system design whereby specifics are treated as first order data, while all the procedural elements cater for functional features of a more general character. As an example we propose a system built around a limited set of contract templates that can support different forms or variations of trade. Each template will be associated with a specific set of operations. The alternative would be to customize all features to a set of specific contracts. This would yield less latitude for customization and little experimental flexibility.

Although the full suite of theoretical concepts and hypotheses produced so far may not be possible to accommodate in full the choices made in task T6.4 should be sufficiently representative to create a learning effect that reaches beyond the experiments conducted in the pilots. This should yield increased impact and fuel exploitation related efforts in work package 8 (WP8). At the same time concerns related to future exploitation have also been reciprocated in this deliverable. It has become evident over the last decade that a successful platform for network markets must be designed to facilitate the introduction and growth of such a platform. Designers must bear in mind not only what the platform is supposed to do, but how it is going to capture the attention and application of potential users, turning recipients into supplies and vice versa in self-propelled growth process. Based on the investigation of multiple successful and unsuccessful efforts Parket et al. (2016) offer some basic principles for the design of a platform for network markets. We have adopted several of these principles. This has influenced some choices and recommendations presented here.

Feedback has been harvested from a selection of external and internal reviewers knowledgeable in trading, wholesale markets as well as retailing and ICT.A selection of tentative contracts that can potentially be traded with the system has also been exposed to end-users. The aggregated feedback has helped to simplify and eliminate inconsistencies.

4 The local market overview

This section provides a general overview of the local market. Most of the details have been presented in D6.3 and this section synthesizes the concepts in a nutshell before describing the technical specifications for the software development.

A local market (LM) is an electricity trading platform to sell and buy electricity, flexibility and other services in the neighbourhood. The LM is divided into three sub-markets: Energy LM, Flexibility LM and Other services LM. In order to run these markets, local traders need a system for sharing information and scheduling actions. The Smart Energy Service Provider (SESP) is the organizer and manager of the local market place. The SESP is also a market maker. This implies that the SESP take actions to increase market interactions and to ensure increased liquidity. To facilitate engagement and interactions the SESP provides an ICT platform. This platform supports what has been defined as a network market.

The traders in the LM are recruited from the neighbourhood and constitute an energy community organized by the SESP. The traders in the market place are called community members. LM and the community is physically delineated by the Point of Common Coupling (PoCC). Community membership is voluntary. The SESP and the governing body of the community can also decide on certain rules and requirements that must be satisfied before membership can be granted.

In the local network market, traders need to hook into the system provided by the SESP. This implies a suite of software and hardware entities to support their interaction in the different part of the market. Such ICT support is also required to follow up contracts that are endorsed and allow the SESP to physically monitor and control entities that mak fulfilment of the various contracts possible.

4.1 Local market objectives

4.1.1 The basic ambition

The ambition of the EMPOWER project has been formulated as:

"Develop and verify a local market place and innovative business models, including operational methods to encourage micro-generation and active participation of prosumers to exploit the flexibility that this creates, for the benefit of all connected to the local grid."

From this the *primary* objectives of the EMPOWER have been defined. The EMPOWER local market has been conceived to:

1. Support a business model whereby locally produced energy is primarily targeted local consumers.
    a. Offer a competitive market place on commercial terms
    b. Facilitate local trade
2. Promote the installation of distributed renewable generators.
    a. This will be achieved by creating an attractive and competitive market place that forges incentives to buy energy from local, renewable resources.
    b. To cater for, on commercial terms, increased investement in ddistrinuted renewable resources.
2. Ensure that the increase in local production is compliant with the capacities of the local infrastructure and external supply
    a. Operate in accordance with governing regulations and the capacities of the local infrastructure at any time
    b. Cater for power curtailment services based on the flexibility of community members through market incentives
3. Support trade in end-user flexibility for the benefit of the DSO and the DSOs operations
    a. The DSO represents an important local player in the flexibility part of the LM
    b. If the grid bottlenecks are under control and SESP members provide the needed flexibility for smooth grid operation, grid upgrades can be postponed and grid costs are reduced.

In addition to these objectives the SESP and the LM players can also support, as a secondary option, power system balancing in wholesale markets.

c. Thanks to the communication and control systems, SESP can offer the community flexibility to TSO for profitable operations

The last ambition has been discussed in detail in deliverable D6.3 and constitute only an option once the primary objectives specified above are met.

4.1.2 Defining the overall task

4.1.2.1 <u>The hybrid market</u>

The common reason for becoming a member is the business model supporting the LM. To be economically sustainable the LM must offer benefits to both consumers, prosumers and suppliers that are competitive. To be competitive on energy price alone in an environment or region where prices are already low can be very difficult. Therefore the LM includes elements for trade that carry additional value for community members. That is why the LM encompasses both services/products as well as opportunities for trade in end-user flexibility. Even when the margins are so low that it becomes very hard to make any monetary gains on energy trade alone the EMPOWER market place will still be attractive. since exchanges in services, products and flexibility will secure the necessary revenues and a sound bottom line for all involved. These ideas were developed in D6.1, D2.1, D6.2 and D6.3. The relative strengths of the different markets are illustrated in Figure 1. Consolidation of the three should increase the total attractiveness for all involved.

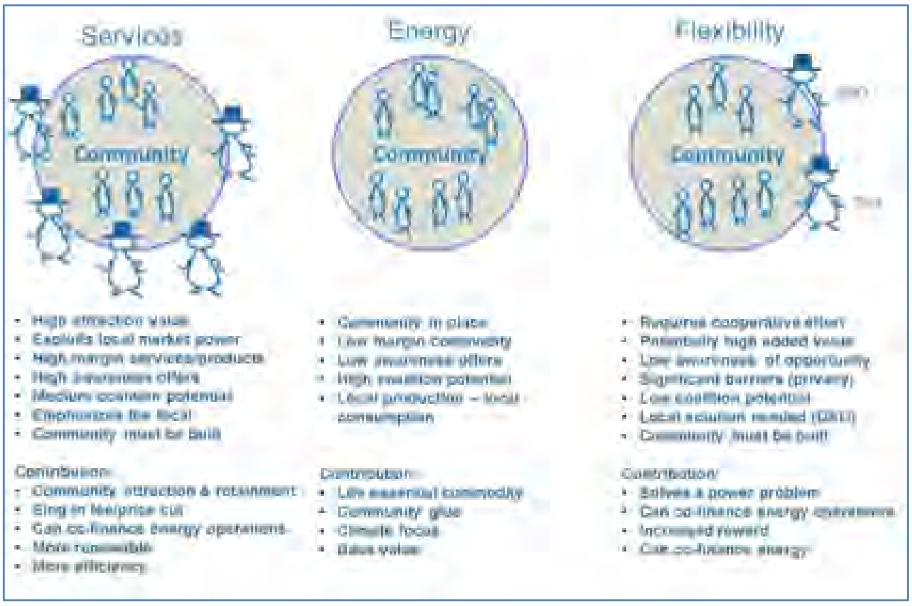

Figure 1 The relative strength of the three market in EMPOWER and how they complement each other and make community membership and trading attractive for prosumers and consumers alike. Characters with hats symbolize professional suppliers.

Even if energy trade alone will produce marginal yields for those involved it constitutes a powerful enablement of the two others. In turn these two will produce the necessary gains for all involved to make the LM competitive and the SESP operation economically viable. The three markets may be integrated in different ways. The most complete integration would be on a contract level whereby contracts encompassing energy, services/products and flexibility elements are traded in one and the same operation.

4.1.2.2 Accomplishing the objectives

The SESP must accomplish two main tasks. It must encourage and facilitate local trade and facilitate the best possible match between supply and demand on commercial terms. It must always compensate for non-conformances and mismatches between expected supply and demand during operation. As specified above a prerequisite for the market design and market activities specified is to create a LM that is faithful to the business model specified for EMPOWER. This business ambition can further be translated into an objective function for the benefit of the implementation:

Maximize: Vp

Here Vp refers to a *contracted volume* of renewable energy supplied by local members. Maximization involves expansion in production capacity through recruitment of community members that are willing to sell their production locally as well as increase unit performance. The business model established specifies that the renewable energy produced should be consumed within the local community too. Hence there will be a set of contracts traded that establishes a balance between demand and supply within the community.

$$Vp = Vc \quad (1)$$

Here Vp refers to the aggregated volume of contracted sales. Vc refers to the aggregated volume of contracted consumption that prefers locally produced energy. A market balance has been achieved. But it may not define a physical balance, neither short term or in the longer term. In fact, it may not be possible to do so because there exists a shortage of supply capacity. Part of the demand must be covered by imports from another neighborhood or the central market. This set of contracts will be referred to as $\lambda(\varepsilon)^-$ and specifies the contracted import of energy across the community boundary to cover the demand that local supply may not be able to cover. $\lambda(\varepsilon)^+$ suggests the opposite. Here a net export is contracted. This happens when there local production capacity cannot be sold within the community. ε symbolizes that actual flow of electricity that will pass across the boundary and that will eventually be billed. For a contract period T it is important that the following relationship exists:

$$Vp + Vc + \lambda(\varepsilon) = 0 \quad (2)$$

However, this relationship and the objective function is subject to certain conditions and constraints that must be observed:

4.1.2.3 The competitive condition

Let the p1($\lambda(\varepsilon)^-$) the cost of the import at any time where p1 represents the price in the central market including commissions and other costs associated with the import. Similarly p2(Vc) represents the cost of the locally produced energy. For producers a similar assessment can be made. Let p3($\lambda(\varepsilon)^+$) represent the gain when energy is exported. p3 is a net unit price from where costs such as commissions, tariffs etc. have been deducted. Yet, if locally produced energy is sold locally the gain can be expressed p4(Vp). For the local market to be attractive for the consumer the following must apply:

Price alone condition, buy: $p2 < p1$ (3)

Added value condition: val(p2,a) > val(p1)

The added vakue a is generated in combination with the service and flexibility market and the attractiveness of the community altogether. An equivalent set of conditions can be defined for the producer.

Price alone condition, sell: $p4 > p3$ (4)

Added value condition: val(p4,a) > val(p3)

We consider here the situation p2 = p4 (typically a common clearing price in a market) as a special case. “Buying low and selling high” in LM would imply that $p4 – p2 > 0$, which means a net gain for the SESP and the community as a whole.This could be in the form of a commission added to the clearing price or incorporated in the basic price of any bilateral contract.

If price alone is the sole competitive element, the difference between p1 and p3 represents the competitive latitude for the local market. In a low price market this difference, p1-p3, approaches 0. Consequently both p2 and p1 will be placed under pressure and the following can be the case:

p1 ~ p3 ~ p2 ~ p4

In order to create a strong business case under such circumstances EMPOWER needs to resort to the added value alternative to make a difference. But it may also introduce cross subsidies in order to create a distinct price difference. Consequently the price for consumers must be lowered compared to the price p1 and the price for producers must be ramped up compared to price, p3. This can be expressed:

$$p2 = p1 - \alpha 1 \quad (5)$$

$$p4 = p3 + \alpha 2 \quad (6)$$

$\alpha 1 + \alpha 2$ represents the subsidy and represents a cost for SESP as a market maker. This cost must be covered by revenues generated in the flexibility market and/or in the service market. Cross subsidies can be a strong instrument to ramp up community recruitment fast and has been applied for multiple network markets over the past decade[1]. But it imposes certain limits due to its cost.

Anyway, if the competitive condition is observed more people are likely to join the community and begin to trade locally, But in the meantime the condition(1) imposes a limit. This limit must find its way into the contracts as consumption may not be fully covered by local resources and vice versa. Similarly negotiation for $\lambda(\varepsilon)$ is required. Hence the SESP will also operate as an aggregator/retailer. As $\lambda(\varepsilon)$ should be less attractive than the contracts traded locally increased internal competition will arise. So will the increase in capacities. More important, the exchange of contracts, as part of the internal trade, need to be compliant with a fixed volume of internally produced energy. A recommended way of doing this is that each contract refers to a number of standard blocks of locally produced energy. Trade will then be focused on how many blocks to buy or sell. A simple quota system could be introduced too if necessary. It would also be possible to introduce a secondary form of trade that enables holders of a contract to sell blocks if needs or capacities change during the course of time.

4.1.2.4 Contract compliance and matching

Ep(T) and Ec(T) refer to the physical and metered production and consumption respectively within LM at the end of the contract period T.

[1] See deliverable D6.3

$$Ep(T) + Ec(T) - \varepsilon = 0 \qquad (7)$$

As this is no longer a single price system care must be taken that contracts are observed. Otherwise billing and remuneration will be unjust. Consequently Ep(T) = Vp(T) and Ec(T) = Vc(T). For a single consumer who holds a contract the part of his energy consumption that is supplied locally is honored with the price p2. If his metered consumption during time T exceeds what has been purchased locally the part, which is not covered by the local contract will be billed according to the price that the SESP purchases elsewhere. Since this will be higher it makes sense for the consumer to be as compliant with the original contract as possible. This should generate a strong incentive for measures to control energy consumption. The consumer himself can introduce energy efficiency measures to control consumption across T. Instruments such as energy displays and controllers that turn appliances off or down when no use is detected (i.e. automated on/off switches, dimmers and simple timers). Lower set points for thermostats can also be easily included as part of such endeavor. We prefer to call this energy efficiency initiative for $\Delta c(T)$. In the EMPOWER world the consumer may also choose to outsource the whole task for better results. Consolidation of all appliances under such regime can be enabled. Similar incentives could stem from this to purchase online diagnosis, healing and repair to make sure that problems do not impose greater losses. The same goes for suppliers. “Added value elements” are thus introduced, in addition to the price incentive.

4.1.2.5 The power or load constraint

Due to the fact that consumption and production can be inconstant the community may see periods of high influx of foreign energy within a certain contract period. In other periods locally produced surplus will flow across the boundary. During such period it is important not to violate the constraint:

$$\varepsilon min(t) < \varepsilon(t) < \varepsilon\ max(t) \qquad (8)$$

If t = T the inequalities above suggest a general capacity problem, but if t << T it should be considered a flexibility issue. But if contracts include aspects of flexibility, they could help the SESP to achieve its means to manage the physical balance, which is needed and to help observe the limits defined by (8). Moreover the DSO could capitalize on this flexibility too. End-user does not need to dedicate flexibility to a particular purpose. If temporarily there is a potential violation of ε max(t) the SESP may encourage more consumption i.e. charging of batteries and electric vehicles (EV), thermal charging of heated floor s and boilers. In the opposite case consumption could be reduced and batteries discharged in a similar way. This can be incorporated in the general energy contract. Price and non-monetary incentives should be used to have sellers and buyers endorse such a contract. The trading system must be able to handle this. There are multiple ways of combining flexibility with the basic energy contracts. Several of these were explored in D6.3. Different prices for different periods or hours during the day can be introduced to achieve the desired ends instead of an average price for the whole period. Separate flexibility contracts can be introduced. However, in D6.3 it was argued that it would be better to associate the value of flexibility in relation to the energy price. It is therefore recommended as a first option here. Yet, there might be circumstances or regimes where this produces disadvantages or is impossible to do. The task would then be to operate with a base price for energy and produce incremental prices for flexibility. This could be defined according to the device controlled, per kWh/h reduced or by the hour. This is illustrated below:

Player	Base price	Base incentive	Control of device 1	Control of device 2
Buyer	P	-3%	-5%	-3%
Seller	P	+5%	+2%	+2%

The base prices are settled in the LM as over-the-counter process or by means of an auction. Extra incentives are introduced by cross subsidies or similar if necessary. This is the contribution from the SESP itself. Devices could be a heat pump, heated floor, an EV charger or more. With this contract the SESP reserves the right to disconnect one or two devices under conditions that will be specified.

Player	Base price	Base incentive	500W	1000W
Buyer	P	-3%	-5%	-3%
Seller	P	+5%	+2%	+2%

This contract is similar to the one above. However, it makes the buyer or the seller to decide what to relinquish at any time.

Player	Base price	Base incentive	Hours 23:00 -06:00	Hours 6:00 – 23:00
Buyer	P	-3%	-5%	-3%
Seller	P	+5%	3%+	0%

This specifies a specific price for different periods of the day. The design of such a contract template stems directly from the two drivers. The cost or gain associated with λ(ε) and the physical constraints associated with ε.

4.1.2.6 <u>Mutual reinforcement</u>

Mutual reinforcement is the inherent strength of a network market. The consolidation of the three parts will generate demands and offers that will drive demand and supply in another. This will in turn recruit more attention and engagement which in turn reinforces demand and supply among different players (Fig. 2).

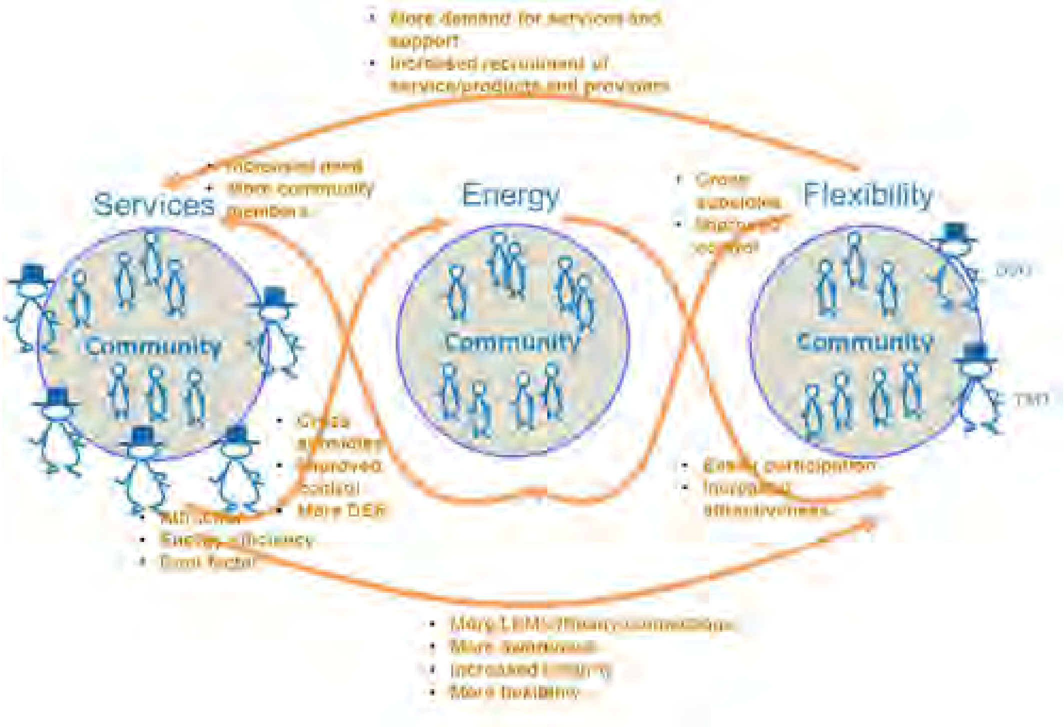

Figure 2 The mutual reinforcement of the three parts of the EMPOWER market

One example could illustrate this. Where there is a deficit of renewable generation in an area strong price incentives can be generated for consumers to buy local energy and for prosumers/suppliers to sell its surplus locally. Despite the potential cost at start-up this motion is likely to encourage more production capacity. More local consumers are likely to turn prosumers. This would attract suppliers of PV panels and other generation equipment. This causes more revenues within the community in terms of market access fees and price-cuts. This in turn will increase the need for more maintenance and diagnostic services. The contract compliance incentive is likely to boost investment in more energy efficiency measures and instruments such as a Local Energy Management System (LEMS). Increased dividends in the service/product markets increase the means to stimulate further growth in the energy market and increase the ability and means to invest in control measures. Variable production and concerns raised by the DSO may in turn increase the attractiveness and value of flexibility services. Incentives for increased local production may be curbed, but focus on the need for more controllers and improved storage capacity will increase both on the home side and as part of the SESP's tactical operations. As the optimal balance between energy produced locally (Ep) and local consumption is achieved (Es) the system is likely to maintain a stable operation where very specific incentives like cross subsidies are reduced. At the same time benefits from trade in flexibility and services like maintenance, diagnostic services etc. will increase.

4.2 Participants' roles

The main participants are the SESP, DSO and SESP members: consumers, producers and prosumers.

The SESP roles are listed as follows:

- Local market operator - organize energy exchanges, schedule local resources and operate trading platform.
- Retailer and aggregator - represent community members in the wholesale market
- Balance responsible party – This is an option introduced to ensure that all energy purchased in the wholesale market is consumed by the community and all energy sold must be produced by the community. This balance must be constant during all periods, otherwise SESP has to pay deviation penalties.
- Risk manager - manage all risks such as energy deviations, technical failures and so on.

The DSO roles are listed as follows:

- Plan grid upgrades and control grid operation
- Supervise SESP operations and authorize SESP schedules for the following periods. The DSO is the responsible for cooperating with the SESP.

- Request flexibility services from SESP to operate the grid within the limits.

The SESP members' roles are listed as follows:

- To fulfil the contracts established
- To install a local controller capable to receive and apply control signals from the SESP cloud
- To provide the needed information about the flexible resources.

4.3 Contracts

The SESP issues all contracts and offers a broking, clearing and settlement service. There are no direct negotiations between traders. Since the SESP represents the community there is no peer-to-peer interaction, but a peer-community-peer interaction, similar to several other network markets (Parker 2016)[2]. This was described in deliverable D6.3. This concept alleviates the burden on each trader, supports pool oriented energy exchanges and provides the SESP with essential information pertinent to future and past assessments.

there are no contracts without the SESP because it needs all the available information. The contracts are between:

- SESP-DSO: This contract defines the information shared, message exchanges, responsibilities of each partner and the rewards for each service provided by SESP
- SESP-Consumer: This contract defines the energy consumption price, flexibility subscription and activation prices, and penalties for failures to meet contractual obligations.
- SESP-Producer: This contract defines the price for the electricity supplied to the grid and the compensation for the energy curtailed.

4.4 Wholesale-Local market operations

The overall operation equation:

$$E_P(t) + E_C(t) + \varepsilon(t) = 0,$$

[2] Parker, G.g., Van Alstyne, M.W, Choudray, S.P. Platform Revolution, Norton 2016

Can be expanded. $E_P(t)$ and $E_C(t)$ are the forecasted local energy production and consumption for the time period t and $\varepsilon(t)$ is the energy imbalance in the community during time period *t.* Decomposing the imbalance variable into different imbalance sources, we have:

$$\varepsilon(t) = E_\delta(t) + E_{WM}^{DA}(t) + E_{WM}^{BM}(t) + E_{STO}(t) + E_{FL}(t) - E_{DSO}(t) + E_{dev}(t),$$

where, $E_\delta(t)$ is the forecasting deviation, $E_{DSO}(t)$ is the DSO request and $E_{dev}(t)$ is the energy deviated . The decision variables are:

- $E_{WM}^{DA}(t)$: Energy committed in the Day-ahead market
- $E_{WM}^{BM}(t)$: Energy committed in the Balancing market
- $E_{STO}(t)$: Energy from/to the storage systems
- $E_{FL}(t)$: Energy from/to the flexible loads

The SESP could have problems to maintain the balance between local consumption and generation during all periods, even with batteries. Therefore, SESP needs to operate in wholesale markets during those periods to buy or sell the community energy deficit or surplus. This is referred to as cross market operations because the SESP operates simultaneously both in the local community as well as in wholesale markets. The Energy and Flexibility LMs have their parallels in the wholesale market. The day-ahead market is the equivalent to the Energy LM, and the intra-day and balancing markets are the equivalent to the Flexibility LM as it is shown in Figure 3. Other services LM is not necessarily related to physical energy delivery, therefore they do not interact with wholesale markets.

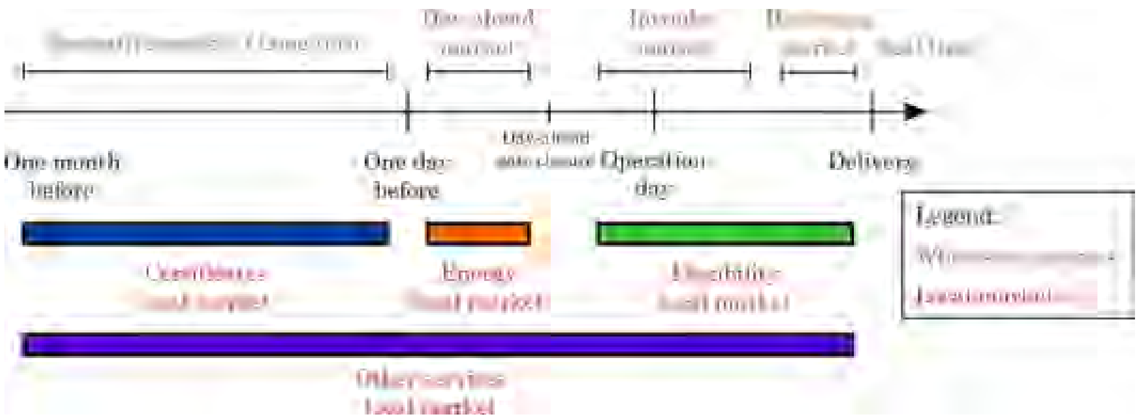

Figure 3: Wholesale-Local markets with parallel execution times

Finally, the Certificates LM also happens during the derivative market but they are not homologous because certificates do not specify the physical delivery time. The Certificates LM is a specific case of Other services LM.

Local markets have three modes of coexistence with the wholesale market as shown in Figure 2:

- Normal operation: Local market offers more value (V) than the central market.
- Constrained operation: The distribution grid is constrained with limited transmission capacity.
- Island mode: The supply from main grid is lost and LM supplies power to the critical loads from the battery if there is not enough local generation.

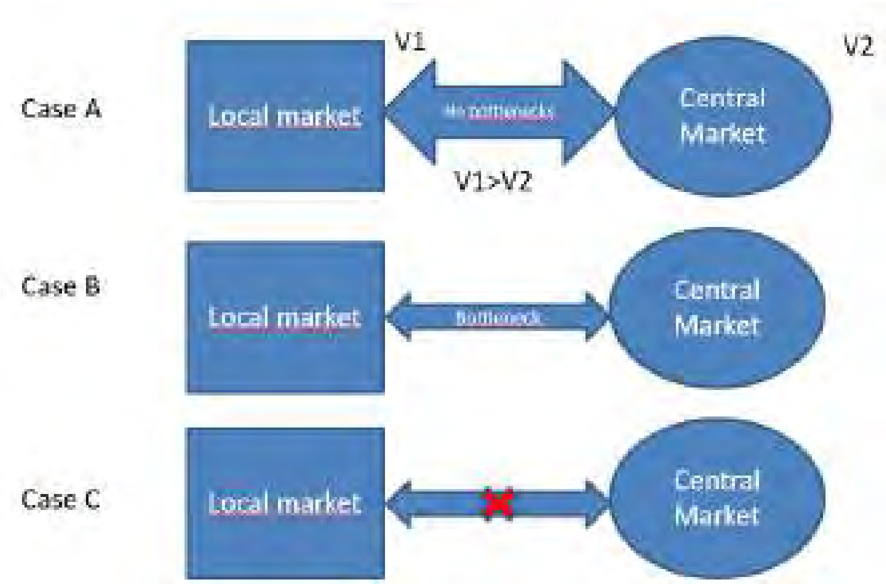

Figure 4: Wholesale-Local market relation modes

Moreover, the SESP has three states of operation:

1. Local market supervision: Related to the supervision role
2. Trading in wholesale markets: Buy or sell community energy deficit or surplus.
3. Emergency: When the DSO has an emergency request or the island mode is on. This mode implies that the energy operations are under SESP control.

4.5 Timeline

As presented in D6.3, the timeline for cross market operations and the interactions between various participants is described in Figure 5.

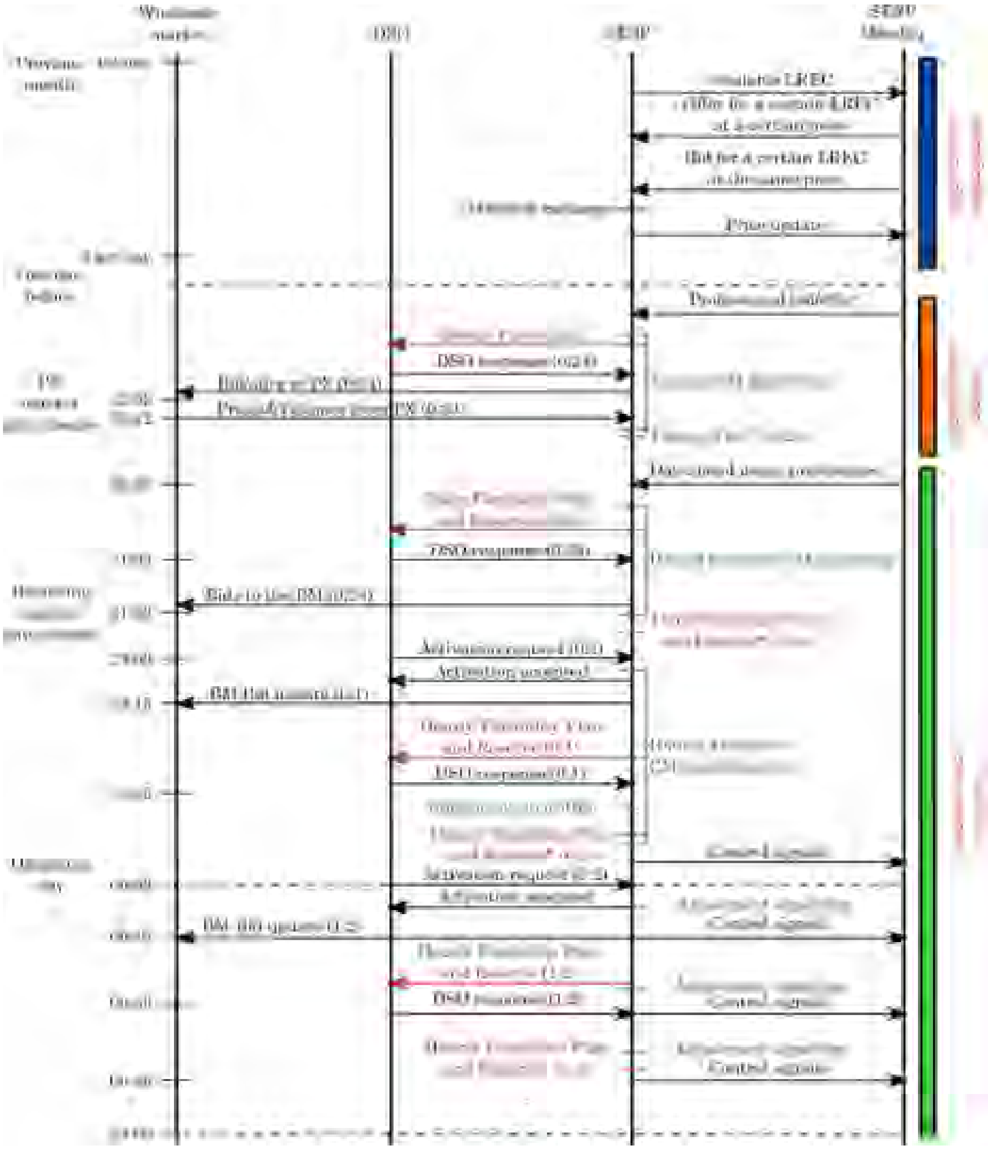

Figure 5: Local market time line

5 The EMPOWER platform

5.1 Overall description

The EMPOWER platform must facilitate all processes associated with creating an on-line community of consumers, prosumers and service providers. The overall life-cycle process for a of a member of this community consists of distinct steps:

- Recruitment
- Preparation
- Commissioning

- Engagement
- Exchanges
- Retainment

The EMPOWER platform should support all 6. Each major step can be broken down into lesser ones. The three first steps were illustrated in deliverable D6.3 (see figure 6) and shows the process until a member has been fully equipped to take part in all types of trade. This includes endorsement of the membership and commissioning of all technical equipment connected to the control cloud of the SESP. The community member will have access to all facilities that the community can offer and can involve himself according to the rules of the community and his own preferences.

Figure 6: The components of EMPOWER Platform

Engagement involves intriguing and involving the member so that he or she becomes an ardent and frequent user. Moreover, the network market concept and the community depend on a shared enthusiasm that recruits more users, that turns consumers into prosumers and ordinary households into a high-value flexibility asset. This requires a significant degree of "customer relationship management" typical for community platforms of this kind. Specifically, it requires a fair mix between push and pull techniques to keep members updated, interested and active. At the same time, it is important to shield the users from the nitty-gritty details that are always required, but only for specific purposes. Common system operations must be simple and intuitive. More specific and rarely used features must be hidden from the primary surface, but simple to find. The use of agents is an example whereby the user can be alleviated from the specific details of a trading process. The three first steps specified here require special considerations and the user surface must be carefully designed to make things as simple as possible. Multiple references pertaining to design simplicity for the purposes described here can be found on the web. A valuable reference of a more general character can be found in Maeda (Maeda 2006)[3].

“Exchanges” relate to processes that involve all kinds of trade and the exchange of tangibles in any form that the community can offer. The market place will consist of different departments customized for the community and the regulatory regime which the trade must adhere to. This also includes trade floor design, trading processes, order book design, settlement, billing and account management.

“Retainment” relates to diverse aspects and is closely associated with the initial steps. Facilitating the user in different ways to make him happy is pivotal. However, it suggests creating strings that make the user want to stay attached to the system and preserve his membership. In deliverable D6.2, references were made to how shopping clubs facilitate their members. Design wise there is much to be gained by studying how online games do this. Bonus opportunities, recruitment rewards and special offers rank among features that are especially important for this purpose and that have been discussed earlier in D6.2. The inactive and possibly discouraged user needs specific attention. Discouragement can be contagious and needs to be treated fast if it cannot be avoided. If an unhappy user shares his or her frustrations, it may influence other people’s involvement and the community may start to peel off. Once recruitment is reversed it may be hard to stop (Parker 2016).

A conceptual description to highlight the proposed business concept associated with a network market platform was offered in deliverable D2.1 (see figure 7). Since then developments in WP2 and WP6 have been quite loyal to this concept. From a functional perspective we will specify the inventory of such a platform. For obvious reasons most attention will be placed on the market and trade aspects. However, it is important to understand that the remaining platform aspects should help to funnel attention towards use, preferable exchanges of the type that is offered by the platform and the SESP. This should help to increase trade volumes and market liquidity, keep competitive initiatives at bay and increase cross-market power. At the same time it should cater for all aspects of the life-cycle process discussed above.

[3] Maeda 2006. Maeda, J. The laws of simplicity, MIT Press, 2006.

Figure 7: Entry point for the EMPOWER platform as proposed by WP2

5.2 The basic user oriented features of the platform

The set of basic user oriented features are specified in Table 1 below.

Table 1: Basic user oriented features of the EMPOWER platform

Main departments	**Description**	**Example(s)**
Special offers	Front page space that provide special offers	Discounts on special items, reduced energy prices, customized one-of-a-kind service etc.
News	News channel that offers pertinent news about the neighborhood, the local utility, the market etc. Can be supported by Twitter or Facebook	Today's trade volume reached €10.000 John Smith is a new member of the community. His house is equipped with a Steca 7kWp PV system
My EMPOWER	Personal log-in controlled channel and space that provides access to personal assets. See separate Table 2	Similar to personal spaces offered by banks, frequent flyer programs etc.
Community channel	Open community focused channel and space that let members share information, images etc. and discuss issues, status and opportunities. Can be supported by Facebook. It is an important channel for the SESP to listen in on.	"Hi folks, I just invested in the new flexible PV panels. They are definitely not inferior to my fixed rig. They provide a better yield in the morning than I expected. Flex PV Inc. has a special offer on these right now." "I am not happy with the batteries that I bought. They don't yield more than 40%. What can I do to improve this?"
Community status	Dials, bar charts and curves showing the performance of the community as a whole. Comparison with other communities should be catered for.	• Energy trade volume of the day, past week and month. • Exports and imports • The local energy mix of the trade • The green energy mix of the trade
Advertisements	Paid advertisements showing promoted services, apps or other offers entered by	"Energy saving services from EnerSave. More surplus to sell"

	different kinds of sellers.	"Special offer on PV panel insurance. Just for this community.Zurich Inc" "Snow cleaning improves PV performance when you really need it. The Snowman"
Services, products and app departments	Contains multiple offers organized in various departments (if there are many). Note that this could include "over the counter contracts" for flexibility contracts, combined energy products and pure energy sale and purchase too. See also Table 3.	https://www.amazon.com/gp/site-directory/ref=nav_shopall_btn/168-0160550-5901162 http://www.ebay.com/ http://m.finn.no/
Trading department	Contains different trading floors supported by call auctions. See also Table 4.	Energy auctions, Flexibility auctions, Other services auctions, Auctions for combined contracts (combos)

The department for personal and household specific data of the platform can be organized in ways which are very typical for web and smart phone platforms in general. The proposed set of features accommodated by this department is listed in Table 2.

Table 2: Person and household specific user features

My EMPOWER	**Description**	**Example(s)**
Personal benefit status	A continuously updated text on personal achievements and encouragement	Over the past one month, you have saved 20% on your electricity bills, you have earned 10 green certificates and 30% of your consumption came from local and green sources.
Membership profile	Describes the current personal data about the user	Name, Address, Age, Membership number
Bonus account	Current status of accumulated rewards	Rewards, Likes, Membership level, Expected annual bonus
Membership status (can be shared)	Graphic information on achievements. Absolute and relative performance Can be embedded with Facebook and harvest Likes.	Total production and sale, Improved efficiency and effectiveness, Number of times activated in flexibility regime, Membership level, Volume of local and green energy purchased, Volume of green energy sold locally
Trading account	Current and historic settlements	Credit and debit
Current contracts	Folder with the valid contracts	Flexibility, Service, Energy, Combos
Historic contracts	Folder with historic contracts	Same as above
Trade history (can be shared)	Extracts from Order book	Answer queries like: What did I do between 21/8 and 10/11?
Devices connected	The total number of devices connected and operating on the system installed with the household	Boiler, Heater, Heated floor
Devices controlled by the SESP	The number of devices that are or can be controlled by the SESP or others	Boiler 2000 watt, average load profile Heater 1: 3000 watt, average load profile
Device schedule	Specifies the hours that allow or inhibit operation on a device according to contract	Boiler: Everyday between 6 and 12 Washing machine: All week except Tuesday and Thursday between 18 and 23 hrs and Saturday between 12:00 and 14:00 Heater: Not less than 16 degrees

Personal agent	The specifications controlling the user's personal software agent	• Name, Type, Algorithm choice, Bid increments, Monitoring specifications, Base strategy

Services and products is a day-to-day attractor for the household and should appear at least in two ways. The most prominent is a direct presentation of offers as they are listed in Table 3 below. A subset of this might also appear directly on the front page. Finally, it may be reached through the service trade department.

Table 3: Services, products and apps department

Services, products & apps departments	**Description**	**Example(s)**
Energy efficiency and effectiveness	Offers related to reduction of consumption, more consumption oriented production, increased production etc.	Energy displays and presentation software for monitoring energy use, Solar maps and wind calculators, Online diagnosis systems, Big Data calculators, CO2 calculators
Solar support	Offers related to acquisition and operation of solar panels	Purchase and rent of panels, Snow cleaning, Online diagnosis systems, Inverters, Mounting accessories, Guide books, Voltage controllers, Batteries, Maintenance, Installation, Online diagnosis systems
Wind support	Offers related to acquisition and operation of wind turbines	Purchase and rent of wind turbines, Maintenance, Guide book, Installation, Online diagnosis systems, Storage
Bio support	Offers related to acquisition and operation of bio fueled generators, CHPs, fuel cells	Purchase and rent, Fuel, Maintenance, Guide books, Installation, Online diagnosis systems
Storage	Offers related to energy to vaulting or asset management	Batteries, Banking services, Flexibility management, Energy back-up
Monitoring and control	Offers on devices and systems for control	Timer, PID controllers, Cloud control services, Diagnosis, Maintenance, Communication accessories & services, Maintenance and repair
Contract support and management	Offers related to improved trade and contract management	SW agents and agent accessories, Optimization software & services
Energy trade support	Offers associated specifically with energy trade	SW agents and agent accessories, Optimization software & services, Storage
Flexibility sale support	Offers associated specifically with energy trade	SW agents and agent accessories, Optimization software & services, Storage, Demand side management, Remote controlled dimmers, switches
Combined offers support	Offers associated with combined contracts	SW agents and agent accessories, Optimization software & services, Storage
Insurance	Offers that reduce liabilities and increase safety for people and equipment	Waivers, Liability insurance, Security measures for equipment and people
Financing	Offers related to financial support, billing and transaction management of different kinds	American express, Pay Pal, Bank loan, Financial advice, Payment solutions, Billing management, Invoice management

The trade department lies at the heart of the system and will be elaborated on in subsequent sections. The source of the features listed and further described elsewhere is taken from the D6.3 mainly. As D6.3 painted the overall picture of the integrated trading concept and emphasized the need for adaptability and growth friendly concept that could support a network market platform D6.4 will specify strictly the features that should be prioritized and pursued in further developments. The claims, which are made here remain mere hypotheses until they are proven in the pilots. Consequently, we have also strived to substantiate our claims so that comparison with empirical data harvested later in the project can be made easy. Table 4 specifies the main sections of the trading departments. Each of them will be highlighted in more detail.

Table 4: Trading departments

Trading department	**Description**	**Example(s)**
Energy	This consist of two parts: Over the counter purchase and sale for local energy contracts. A room that hosts a call auction trading floor.	Simple energy trade, Exchange of classified energy contracts (local, green, general), Exchange of energy contracts with flexibility clauses
Flexibility	This consists of two parts: Over the counter purchase and sale flexibility contracts. An auction room supporting a reverse English auction.	Supply/Demand-response contracts for grid support purposes, Supply/Demand-response contracts for other purposes Exchange of storage related contracts
Services	This consists of two parts: Over the counter purchase, which takes the user to the “Services, products and apps departments” and an auction room where services and apps can be auctioned by means of an simple English auction	• Bidding for special offers
Customized	This consists of an exchange of customized energy products and combos specified in D6.3	• Exchange of energy security combo

6 The trading platform: In-community operations

The following describes the market operations that takes place within the EMPOWER community. In spite of the fact that different trade options are possible for the purpose defined and evaluated for the EMPOWER market we have settled on a set of concepts that can be intermixed in a seamless way in order to allow adaption and flexibility with respect to growth and expansion of the community. After scanning different options, we have found that two principal concepts will suffice for most of the trade that will take place in EMPOWER:

1. Simple over-the-counter (OTC) trade carried out at specific intervals
2. Call auctions (Price scan and English)

For smaller communities and in the early development of a community, competition will be low and the need to engage and build trust is most important. For this purpose, we advocate longer term bilateral contracts for buy/sell over the counter (see Figure 8). A different price can be offered to sellers and buyers. It is further proposed that contracts are made valid for the same period. This implies that for a specific period the same type of contracts will be valid. Standardization is important. This is to avoid conflicts within the community. Contracts may be renewed or replaced by a new set at a specific point in time. A surge in trade is likely to happen around the time for renewal. This is depicted here. But it does not mean that such contracts can be sold within a term.

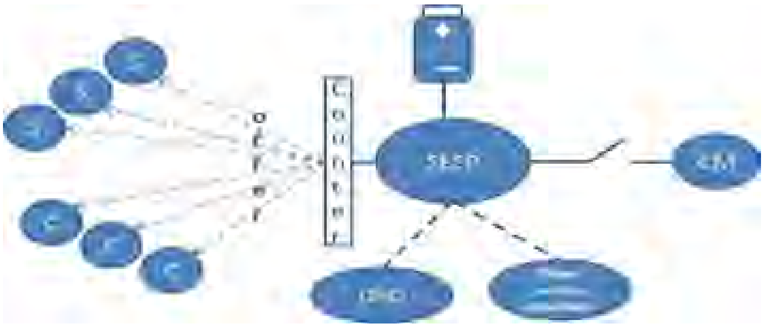

Figure 8: OTC trade: SESP offers specific contracts to consumers (c) and suppliers (s) directly.

Figure 9: Price-scan auction: A type of call auction where the auctioneer calls out prices and buyers/sellers respond by accepting or dismissing the call. In a more advanced version, bidders/askers will also nominate a volume for sale or for purchase.

When competition increases auction may be the best instrument. In fact, auctions can be used to increase competition. Hence it may be used interchangeable with regular over-the-counter sales. The idea then would be to create some very specific offers of limited volume that stand out. After significant evaluation a price scan auction is recommended for most of the trade in a competitive environment (see Figure). Price scan auctions belong to a type of call auctions. It is strongly related to the classic English auction. Consequently it is a form of non-continuous trade. It distinguishes itself from the more common call based double-auction used in many energy markets today by letting the auctioneer call out a tentative price for buy and sell and await a response to that before trying a new price. This means that seller and bidders will only have to consider what volume they want to buy instead of assessing a whole range of price volume considerations by themselves. The price scan alternative takes advantage of the fact that there may exist a very strong price signal from beyond. It also fits seamlessly with over-the-counter trades and can be introduced temporarily too to augment this if surge problems on the demand and supply side occurs. It also has some attractive technical features. It can easily be reduced to a single-sided English auction. Communications with end-user's and trade agents alike become simpler as these only have to respond with a single signal to the price given, expressed in terms of the volume they wish to trade. In most cases today this implies that the seller or buyer will simply make one decision, namely "take it or leave it". For a given price call they are either all in or all out. However, in the future there may be more home side controls. The households may also operate significant storage facilities. Consequently they will also have a better choice with respect to what volume of energy to choose.

A price scan auction clears the market when the best balance between demand and supply (Ep and Ed) has been achieved. The auction is semi-transparent. The call price is always visible. However, the state of the order book will remain hidden throughout the auction. Essentially the market clears with one price. However, in EMPOWER the SESP may signal an upward or downward increment for bids and asks. These increments will always be related to the basic call price.

6.1 Trade in energy

This part describes the trade in basic energy and energy trade supplemented with flexibility and services.

6.1.1 Over the counter fixed price energy trade

In a small community and in a community where competition is low over the counter operations are believed to be a more suitable form of trade. Then direct dialog and encouragement is more suited. OTC is described below.

6.1.1.1 Abstract

OTC is suitable fort trade in energy and combos including energy, services and flexibility. Pure service trade among community members which can be organized by the SESP can also apply this form of trade. Once the SESP market has evaluated its resources (balancing/flexibility resources) and determined the market situation and price signals from competing entities it prepares an offer, one for the buying side of the community and one for the selling side. A standard template for long term contracts are prepared. Digitally this is presented as a vector to be filled in. A selling price (Ps) is offered and a buying price (Pb) is offered. Depending on the situation the SESP will make the first offer to one side first. Which side first depends on the situation. In the general case it is better to start with the side which suffer a deficit with respect to fulfilling the local needs on the other side.

For this purpose, access to net consumption and production profiles is essential. This could mean that that the price offers are split in two or more. Example: Ps(night), Ps(day) and Pb(night), Pb(day). The price differentiation can be higher if other factors such as flexibility and services are included.

6.1.1.2 Sequence diagrams

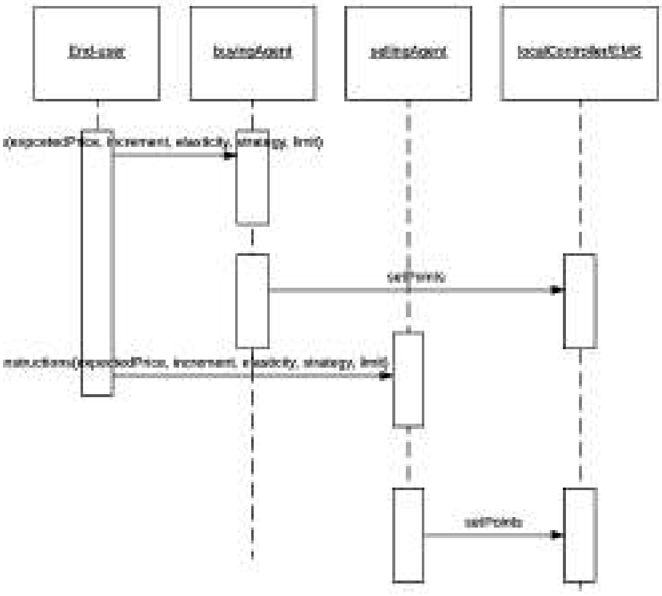

Figure 10: Setting up agents

- Buying Agent: Personal agent in the cloud that manages the procurement on behalf of its owner.
- Selling Agent: Personal agent in the cloud that manages the sale on behalf of its owner.

In cases where trade is made in terms of contracts that are valid for a long time the need for agents decreases. The end-user might want to take an active part in an occasional trade. However, the agent may never be made quite obsolete. The agents can be more informed than the user and can thus provide important decision support. In such a case the decision making is not automated as shown in the following diagrams. The agent and the end-user will operate together. In the following this might be thought of as user and agent sitting together.

However, when trade happens more frequently the importance of the agent increases fast. Even with monthly trades agents would significantly alleviate the end-user. In such a case the agents are directly involved with the trade floor and order book. This involvement is used as default. In Figure 11, an example of a set up function is given. It specifies the end-user's idea of the final clearing price. It further defines the limits and strategies and trade increments, if any, that the autonomous agent is instructed to follow. The diagram also shows how the trade agent passes on set points to any local controller once trade is done. The set-up of agents is explained in the section about agents.

6.1.1.3 Classes/Functions

- SESP Market: Has the overall control of the trade
- Trading floor: Part of the SESP Market class. Manages the trade.
- OrderBook: Part of the SESP Market class and strongly connected to the Trade floor. Maintains status of sale and purchase at all times.
- SESP control: Represents the internal resources that the SESP must rely on, especially metering values, prognoses etc.
- Buying Agent: Personal agent in the cloud that manages the procurement on behalf of its owner.
- Selling Agent: Personal agent in the cloud that manages the sale on behalf of its owner.
- Timer: A clock

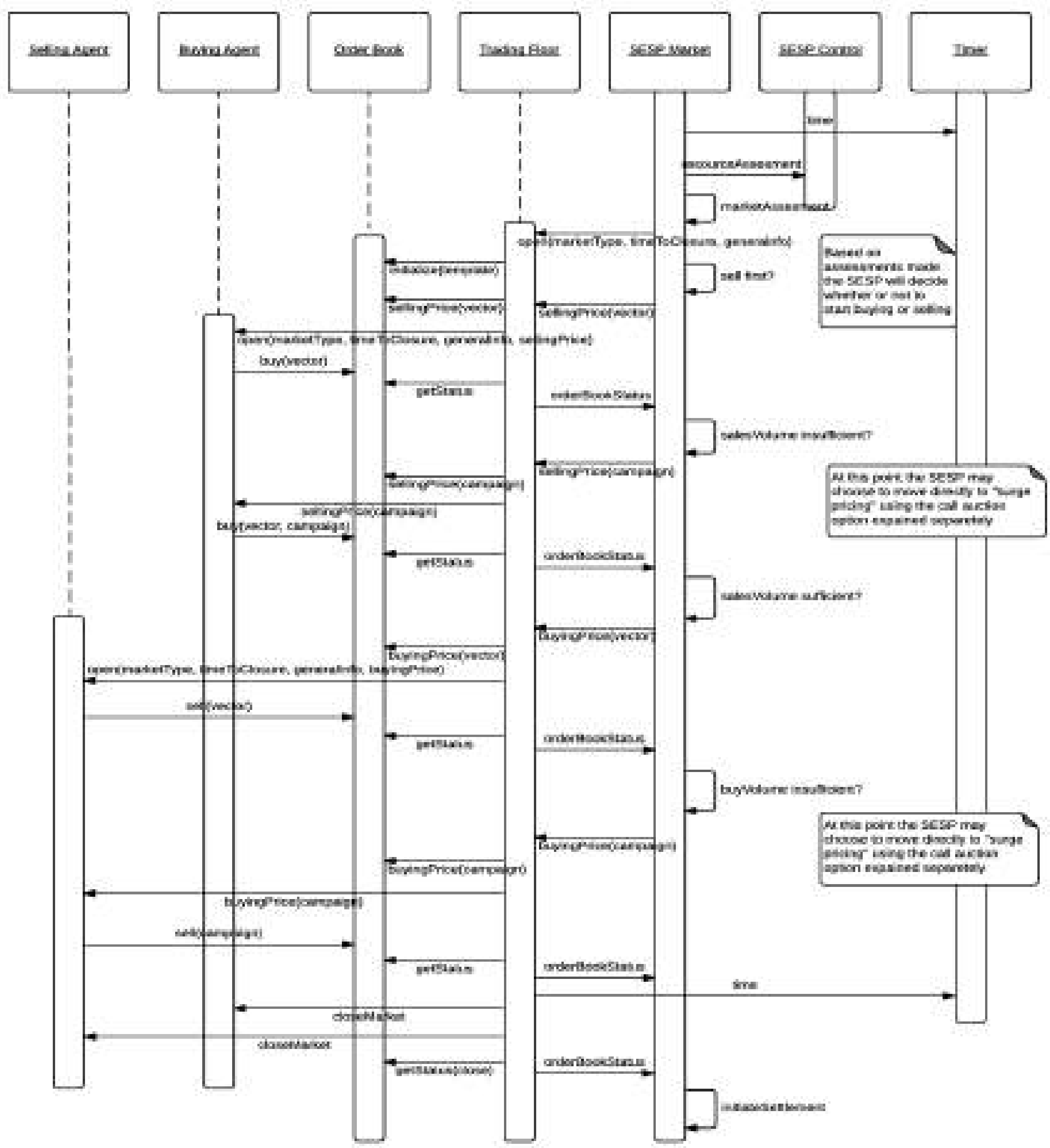

Figure 11: An example set up function

6.1.1.4 Functions

Class/object	Method/function	Description
SESP market	resourceAssessment	Internal function: On a time trigger evaluation of resources available required to support trade are made. This is to assure the best possible match between local supply and local demand (see detailed description below). Resource assessment is also required in order to determine opening prices called by the SESP.
	marketAssessment	Evaluates price signals from the central market or neighboring communities. Combined with the resource assessment this

		determines call price.
	specifyMarket	Internal function: determines what type of market and trade form is selected and specifies trade intervals and time to market closure. Associated information is passed on to trading agents.
	Sell first?	Sell first is a test whether or not to present an offer to the selling side before the buying side. The default rule is that the side with a comparative deficit will be given an offer first.
	orderBookStatus	Gathers current status about asks and bids
	salesVolume insufficient? & buyVolume insufficient?	The SESP makes an evaluation if the volumes sold or bought meets expectations and needs.
	InitiateSettlement	Validates received contract and issues final contract
Timer	time	Provides current date and time
SESP Control	resourceAssessment	Provides historic and current resource data for the SESP Market
Trading floor (Part of SESP Market)	open(marketType, timeToClosure, information, selling price)	Opens a flag that allows trading and which initiates the order book. Timer doing the countdown before market closure is set and pertinent information about the trade is posted.
	sellingPrice(vector)	This posts the selling price(s). This function carries a feature vector. In its simplest form it can be simply one price. In the more advanced cases it might include a series of prices indicating the value of flexibility, associated combos etc. (see detailed description of this below). If the SESP is unhappy with the response the price might be changed and a new attempt initiated. This is called a campaign.
	buyingPrice(vector)	This posts the buying price(s) for sellers of energy. This function carries a feature vector. In its simplest form it can be simply one price. In the more advanced cases it might include a series of prices indicating the value of flexibility, associated combos etc. (see detailed description of this below). If the SESP is unhappy with the response the price might be changed and a new attempt initiated. This is called a campaign.
	orderBookStatus	Internal function: Retrieves the order book and passes it to SESP market.

	buy(vector)	This is a buyer endorsed contract accepting the selling price offered by the SESP for a certain volume that might be specified for certain hours per week. buyl(campaign) = buy(vector) but may contain additional aspects.
	sell(vector)	This is a seller endorsed contract accepting the buying price offered by the SESP for a certain volume that might be specified for certain hours per week. Sell(campaign) = sell(vector) but may contain additional aspects.
	getStatus	Internal function: Requests the status from the Order Book.
	closeMarket	Internal function that passes on the latest order book to SESP Market and emits close signal to all traders.
OrderBook	initialize(template)	Receives the list structure that will keep the buy and sell orders and associated information passed on by the Trading floor. The template may be a vector, matrix or structured list.
	sellingPrice(vector) & buyingPrice(vector)	This is posted with the Order Book for continuous monitoring (also through a GUI). A variant of this is applied for campaigns.
	getStatus	Passes on the content of the Order Book template to the Trading Floor and reinitializes.
	buy(vector)	Posts the request from the buyer and the contract on the order book and passes it on.
	sell(vector)	Posts the request from the seller and the contract on the order book and passes it on.
Buying Agent/Selling Agent	open(marketType, timeToClosure, generalInfo, price offered)	Activates the agent which, based on its personal instruction set and policy, evaluates the call and possibly the activity in the order book.
	assessOptions	Internal function: That evaluates price(s) and market against its own resources, policies, limits and options and prepares a bid or decides to abstain (see details below)
	buy(vector)	Nominates a volume for purchase according to template issued and as a response to price(s) offered. The vector may also respond with specifications of committed flexibility or services (see details below) Similar for campaigns.
	sell(vector)	Nominates a volume for sale according to the template issued

		and as a response to price(s) offered. The vector may also respond with specifications of committed flexibility or services (see details below). Similar for campaigns.
	Contract	This is a copy of the contract endorsed by both the SESP and the community member. The buyer and seller will be billed and enumerated respectively according to this.
	closeMarket	Terminates trading activity.

6.1.1.5 More elaborate functions

6.1.1.6 resourceAssessment

This pertains to the SESP Market function resourceAssesment. Sound forecasts are essential. Prospective local demand and supply for the contract period T are treated as stochastic variables *Ec* and *Ep* with mean $\overline{Ec}$ and Ep and variance Var(Ep) and Var(Ep) respectively. Both Ec and Ep are aggregate value depending on community members needs and preferences for the period T.

On an individual consumer and supplier level we are faced with similar stochastic variables as a function of time, $E_{c,d}(t)$ and $E_{p,s}(t)$. The distribution governing these variables may not be uniform and not lend themselves to a standard distribution. The mean across the contract period T can be expressed as $\bar{E}_{c,d} = \sum_{t=0}^{T}\sum_{v} VE_{c,d}(t) * E(t))$ and $\bar{E}_{p,s} = \sum_{t=0}^{T}\sum_{v} E_{p,s}(t) * fp(E_{p,s}(t))$ where *fp* and *fc* are the distribution for the individual demand and supply respectively. The variance follows accordingly, i.e., $Var\left(E_{c,d}\right) = \sum_{t=0}^{T}\sum_{v} E_{c,d}^{2}(t) * fc(E_{c,d}^{2}(t)) - (\bar{E}_{c,d})^{2}$.

By aggregating across all consumers C in the community, expected energy demand can be calculated:

$$\overline{Ed} = \sum_{t=0}^{T}\sum_{d=1}^{D}\sum_{v} E_{c,d}(t) * fc(E_{c,d}(t))$$

A similar expression can be specified for the aggregate supply of all producers in the community.

$$\overline{Es} = \sum_{t=0}^{T}\sum_{s=1}^{S}\sum_{v} E_{p,s}(t) * fp(E_{p,s}(t))$$

The aggregate function would approach a Gaussian distribution according to the least square theorem if statistical independence can be assumed. As pointed out in D6.3

this may not be true and must be tested for each community. In case of strong covariance, a distribution based on empirical records need to be tested.

What is most interesting is to estimate how local demand meets local supply and vice versa for an upcoming contract period:

$Ed + Es$ +ε= 0,

where, ε is the aggregate uncertainty related to the estimated demand and supply. This is dependent on the variance. Given a normal distribution and 100% confidence interval, additional demand needed can be expressed as ε = 3.9 * $\sqrt{var(Ed + Es)}$. The error ε is then converted into a specification for capacity reserves in the form of batteries, demand-response measures, procurement in the central market and similar. What is most optimal relates to what compensating resources are available are available and the marginal cost of each. By organizing the means required to cover ε with 100% confidence in the most affordable way would be to organize the various resources in order of merit whereby the means with the lowest marginal costs are applied first. One important approach in this context would be to adjust the OTC or call price for purchase and/or sale in order to restrain or increase engagement.

6.1.1.7 marketAssessment

This function decides the call price. This the function that makes the SESP a market maker. It uses the resourceAssessment and the estimated ε to determine the cost to match supply and demand. It can also mobilize its cross subsidy scheme here. The market assessment is essential in this context and will also require good predictions.

6.1.1.8 Contracts and data types

Example	Specification	Example
Name of buyer	string	Peter Gabriel
Date of endorsement	date	Feb 12, 2016
Date of initiation	date	March1, 2016
Date of termination	date	April 1, 2016
Energy profile [kWh]	calendar	Calendar (click here)
Preferences 1 (renewable/indifferent)	string	Renewable
Preferences 2 (local/indifferent)	string	Local
Preferences (self-controlled/not-controlled)	string	Self controlled
Price (E-cent/kWh) Hours 6:00 – 22:00	number	3 E-cent
Price (E-cent/kWh) Hours 22:00 – 02:00	number	7 E-cent

Figure 12: Proposed contract where it is possible to specify several options such as volume, a profile, preference for renewable and local and whether or not the buyer will take the responsibility for ensuring compatibility with the contracts specified or leave that to the SESP.It also stipulates a different price during night hours.

Figure 12 displays a tentative contract that can traded within the community. Several options have been include for illustration. These were thoroughly discussed in deliverable D6.3. The contract takes into consideration that the buyer (in this case) does have a Home Automation System (HAS) with an EMS module and a storage facility. The household’s consumption can be better regulated and this can be reflected in the contract. This type of contract constitute a simple data structure in the EMPOWER system whereby all aspects of the contract are elements of a vector.

#(Name, DateEndor, DateInit, DateTerm, ProfileRef, Renew, Local, SelfCon, price1, price2)

This vector matches the type of contract depicted in Figure 12. The vector can be expanded or contracted according to will. In the simplest case, this is what is needed:

#(Name, DateEndor, DateInit, DateTerm, price)

This simply specifies a price of 3 €-cents and the rest is up to the SESP to manage alone. No further obligations are placed on the shoulders of the buyer. In fact, this contract is identical to the many existing contracts today and does not take into account the possibilities offered by smart grids or home automation systems (HAS).

However, as a uniform data structure the system should be able to handle such differences without major revisions. The change in contract implies less for the tarde than for whatever control the SESP shall execute during the course of the contract.

A similar structure is shown for a seller. This implies a similar vector to th one described above.

#(Name, DateEndor, DateInit, DateTerm, Commit, Solar, Local, SelfCon, priceDay) reflecting a contract structure as shown in Figure 13.

Example	[illegible]	Example
Name of seller	string	Anne Jones
Date of endorsement	date	Feb 12, 2016
Date of initiation	date	March 1, 2016
Date of termination	date	April 1, 2016
Volume committed (kWh)	number	820 kWh
Energy profile (kWh)	Reference	http://clientbase/2433335
Type	string	Solar
Type	string	Local
Preferences (self/ controlled/not-controlled)	string	Self controlled
Price (€-cent/kWh) Hours 6:00 – 22:00	number	[illegible]

Figure 13: A seller's contract with similar options to that shown for the consumer above. SESP Market module will be able to use the information to execute proper brokering.

6.1.2 Call auction based energy trade by price scanning (CATPC)

6.1.2.1 Abstract

This trade concept is pertinent for pure energy trade and energy trade with flexibility and services. As explained in D6.3 the call auction by price scanning (CATPC) offers suppleness for trade in multiple products including pure energy and combos of such. It constitutes a very simple step upwards from fixed price “over-the counter sale”.

6.1.2.2 Sequence diagram

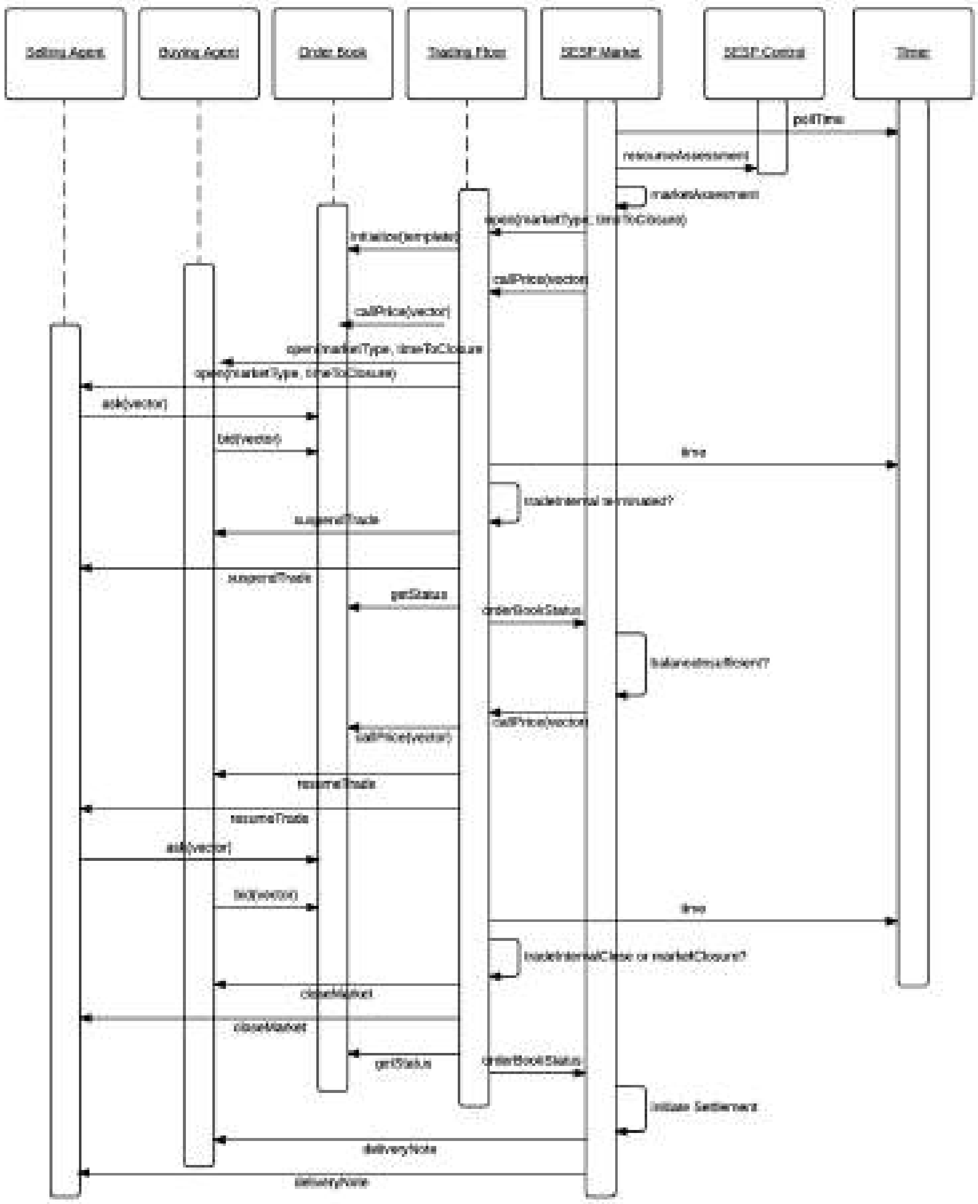

Figure 14: Call auction based energy trade by price scanning (CATPC)

In fact this type of call auction could be applied if OTC trade grows stale and surge pricing is considered. Consequently, OTC and CATPC can be used intermixed depending on temporary changes resulting in unexpected shifts between local demand and local supply, unexpected trade volume increases or decreases and development in general engagement.

6.1.2.3 Classes/objects

- SESP Market: Has the overall control of the trade
- Trading floor: Part of the SESP Market class. Manages the trade.

- OrderBook: Part of the SESP Market class and strongly connected to the Trade floor. Maintains status of sale and purchase at all times.
- SESP control: Represents the internal resources that the SESP must rely on, especially metering values, prognoses etc.
- Buying Agent: Personal agent in the cloud that manages the procurement on behalf of its owner.
- Selling Agent: Personal agent in the cloud that manages the sale on behalf of its owner.
- Timer: A clock

6.1.2.4 Functions

Class/object	Method/function	Description
SESP market	resourceAssessment	Internal function: On a time trigger evaluation of resources available required to support the trade are made. This is to assure the best possible match between local supply and local demand (see detailed description below). Resource assessment is also required in order to determine opening prices called by the SESP.
	marketAssessment	Evaluates price signals from the central market or neighboring communities. Combined with the resource assessment this will determine call prices.
	specifyMarket	Internal function: determines what type of market and trade form is selected and specifies trade intervls and time to market closure. Associated information is passed on to trading agents.
	orderBookStatus	Gathers current status about asks and bids
	balanceInsufficient?	This is a test that evaluates to true or false. The test evaluates status against initial resource and price assessment. If match between supply and demand is considered insufficient a new call price is prepared and emitted.
	clearMarket	Internal function: Match between demand and response is considered satisfactory. Market is cleared with latest call price. Settlement can begin.
	initiateSettlement	This initiates endorsement of contracts made. It updates accounts and caters for future metering and billing.
Timer	time	Provides current date and time

SESP Control	resourceAssessment	Provides historic and current resource data for the SESP Market
Trading floor (Part of SESP Market)	open(marketType, timeToClosure, information)	Opens a flag that allows trading and which initiates the order book. Timer doing the countdown before market closure is set and pertinent information about the trade is posted.
	callPrice(vector)	This posts the call price(s) for the call auction to begin. This function carries a feature vector. In its simplest form it can be simply one price. In the more advanced cases it might include a series of prices indicating the value of flexibility, associated combos etc. (see detailed description of this below)
	tradeIntervalTerminated	Based on the state of the trade or/and on the time elapsed trade might need to be suspended to evaluate status and consider a different call price.
	orderBookStatus(book)	Internal function: Retrieves the order book and passes it to SESP market.
	tradeIntervalClose?	A test that evaluates to True or False. Terminates the trade to evaluate status of bids and asks. Used to evaluate match between demand and supply before defining a new call price.
	marketClosure?	A test that evaluates to True or False. Terminates the market. If a good match has been found or time is up, the market closes.
	closeMarket	Internal function that passes on the latest order book to SESP Market and emits close signal to all traders.
OrderBook	initialize(template)	Receives the list structure that will keep the buy and sell orders and associated information passed on by the Trading floor. The template may be a vector, matrix or structured list.
	getStatus	Passes on the content of the template to the Trading Floor and reinitializes.
	bid(vector)	Receives a buy order with its specifications and enters them into the Order Book. Aggregated demand is updated.
	ask(vector)	Receives a sales order with its specifications and enters them into the Order Book. Aggregated supply is updated.
	callPrice(vector)	Posts the price call from SESP Market
Buying Agent/Selling	open(marketType, timeToClosure)	Activates the agent which, based on its personal instruction set and policy, evaluates the call and possibly the activity in the order

Agent		book.
	assessOptions	Internal function: That evaluates call price(s) and market against its own resources and options and prepares a bid or decides to abstain (see details below)
	bid(vector)	Nominates a volume for purchase according to the template issued as a response to the call price. The vector may also respond with specifications of committed flexibility or services (see details below)
	ask(vector)	Nominates a volume for saleaccording to the template issued as a response to the call price. The vector may also respond with specifications of committed flexibility or services (see details below)
	suspendTrade	Puts activity on hold until a resume notice is given
	resumeTrade	Reactivates the agent
	closeMarket	Terminates activity

6.1.2.5 More elaborate functions

6.1.2.6 resourceAssessment

See description in section 6.1.1.4

6.1.2.7 marketAssessment

See description in section 6.1.1.4

6.1.2.8 assessOptions

See description in section 6.1.1.4

6.1.2.9 callPrice(vector)

The call price may use a simple vector consisting of a single value, namely the energy price. It may also be a feature vector that consists of multiple options or additions for which the buyer or the seller might tick off. Examples of such have been shown above. This was also described in deliverable D6.3. Here are a few examples.

- No options, one price: #(price)
- No options, two price call (buy and sell): #(sellPrice, buyPrice)

- No options, subsidized (cross) can be a three price call: #(basePrice, sellPrice, buyPrice). The two latter are specified in terms of the first. Market is cleared on the base price. The sellPrice and the buyPrice are expressed in terms of increments (mark-ups and discounts) from the base price and simply informs about the additional benefits obtained if settlement is achieved.
- Three options, three prices: #(basePrice, greenPrice, localPrice). Market is cleared on the base price. greenPrice and localPrice are defined as increments related to this.
- Multiple options, multiple prices (combos): #(basePrice, greenPrice, 500Wflex, servicePrice, rewards). greenPrice, flexibility (500Wflex) and servicePrice are all defined as increments in terms of base price. Reward represents additional information that informs traders that taking part in this auction will inevitably lead to increased bonus in terms of reward points. This is explained more in detail later.

6.1.2.10 bid(vector) and ask(Vector)

This returns a vector compatible with the vector passed on through the call from the SESP. The vector returned would provide information on the order volumes for sale or for purchase in addition to additions and prerequisites that follow the offer. Examples that correspond to the call vector posted above:

- ask[Vp]
- bid[undefined volume]
- ask[Vp, green]
- bid[Vc, green, local]
- ask[Vp, green, service, rewards]
- bid[Vc, green, service, 500Wflex, rewards]

6.1.2.11 Contracts and data types

Similar to the ones shown in 6.1.1.7.

6.2 Pure flexibility trade

Before any interaction is initiated with the community members the SESP must negotiate a solution with the DSO. It is recommended that the SESP offers a standardized set of contracts to be discussed and customized. These standard contracts must reflect the type of controller, devices and appliances, which it controls. Before the interaction with the DSO takes place.the SESP must establish a firm knowledge of the current and prospective portfolio of flexibility providers. It is also recommended that tests are performed to determine vulnerability in the communication system and similar to avoid potential liabilities that could jeopardize the service offered to the DSO. A business level sequence diagram illustrates this in Figure15.

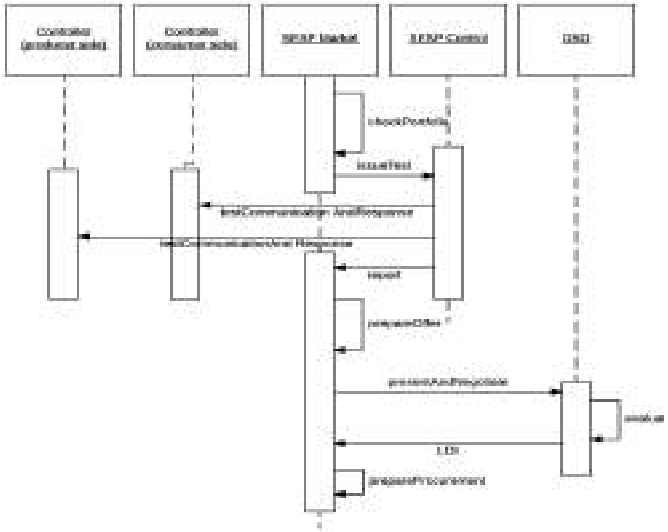

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Figure 15: Sequence diagram showing interaction with the DSO on a business level. The result is a letter of intent (LOI) specifying contract and conditional conditions on volume and hours that must be confirmed before final contract can be made.

It is further advised that the SESP evaluates own flexibility resources and determine the load situation in the neighbourhood and across the Point of Common Coupling (PoCC). It is of great importance that the SESP establishes the best possible idea of the energy and load footprint that non-members within the same area produces. The goal in this phase is to sign a detailed letter of intent (LOI) that the SESP can use as a reference when he turns around to purchase flexibility within the community. Ideally the obligations in the LOI can be met directly without further negotiations and the LOI is then turned into a bilateral contract with the DSO.

6.2.1 Over the counter fixed price flexibility trade

6.2.1.1 Abstract

This follows the same pattern as described for OTC trade in energy. The only exception is that it is not double sided. In this situation the SESP is only interested in buying flexibility on behalf of the DSO in order to get best possible fit with the specifications in the LOI.

6.2.1.2 Sequence diagram

Figure 16 follows the basic patter for OTC energy specified in 6.1.1.

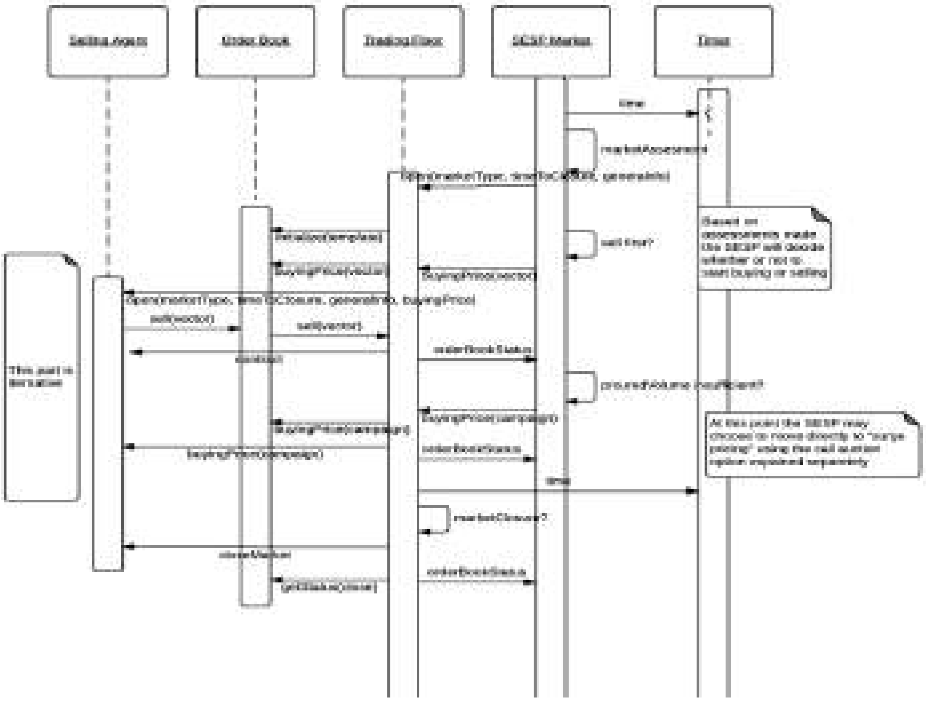


Figure 16: Over the counter trade in local flexibility

6.2.1.3 Functions

See analog specifications for energy sale 6.1.1.4.

6.2.1.4 Contracts and data structures

Three types of standard contracts have been considered so far in the EMPOWER project. They can serve as archetypes. There could be multiple variations to these. These archetypes are: Scheduled flexibility, Instant activation/Emergency activation and Feed-in ceiling.

- All contracts are defined as options with a reservation fee and an activation fee. The latter is only exercised if a household device is disconnected according to contract. Scheduled flexibility can be anticipated and planned for more extensively than an instant activation. Consequently, it is more directed towards load shaping and improved utilization of improved capacity than peak shaving. It can also be used as an instant for voltage improvement in weak grids. Because of this such a contract can be easily incorporated in an energy contract too. Some examples of the SESP's contract with the DSO and a community member respectively are shown below. The associated data structures use vectors as before and can be specified as shown in Figure 17:

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

Figure 17: Contract for scheduled flexibility signed by the SESP and the DSO.

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

Figure 18: An example of a back-to-back contract offered for scheduled flexibility signed with community members based on the contract with DSO shown in Figure 17.

#(strikeP, actP nameDSO, scheduled, endorseDate, initDate, termDate autoRenew, maxLoad, activations, days, interval1, interval2, maxActivation, tolerance, general information)

#(strikeP, actP1, actP2, nameHolder, scheduled, endorseDate, initDate, termDate autoRenew, maxLoad ,activations, device, minTemp, maxTemp, onTrigger, offTrigger, days, interval1, interval2, maxActivation, tolerance, general information)

Instant activation or Instant Cut, requires that the DSO can emit a signal and by this demand instant response. In addition to this basic requirement a contract of this nature may include more specific items that specifies remuneration, tolerance and specific devices to be disconnected. Multiple variations of this may be defined. A Instant Cut contract is likely to produce a higher activation and reservation fee than any form of scheduled flexibility. The associated data structure in the system could look like this for the DSO and the community member respectively:

#(strikeP, actP1, actP2, nameDSO, scheduled, endorseDate, initDate, termDate autoRenew, maxLoad, activations, days, interval, maxActivatio, tolerance, general information)

#(strikeP, actP1, actP2, nameHolder, scheduled, endorseDate, initDate, termDate autoRenew, maxLoad ,activations, devices, minTemp, maxTemp, onTrigger, offtrigger, days, interval1, interval2, maxActivation, tolerance, general information)

Attribute	Specification	Example
Name of DSO	string	Fredrikstad Energi Nett
Type	string	Instant cut
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	25
Days of activations	Calendar days	Monday, Tuesday, Wednesday, Thursday, Friday
On-trigger	DSO signal	DSO signal
Off-trigger	DSO signal	DSO signal
Max allowed activation time	Number of hours	3
Tolerance	Percentage deviation of requested load shedding per activation	+/- 2%
Strike price	NOK exempt VAT	70.000
Activation fee working days	NOK exempt VAT	9000
Activation fee weekends	NOK exempt VAT	15000
Non-conformance clause	text	See small print

Figure 19: Instant Cut - contract between the DSO and SESP that assures instant peak shaving.

Attributes	Specification	Example
Name of contract holder	string	Tom Jones
Type	string	instant cut
Date of endorsement	date	Feb. 16, 2016
Date of initiation	date	Feb 17, 2016
Date of termination	date	[illegible] 2016
Contract renewal type	(automated | by negotiation)	Automated
Max load per activation	number	1.5kW
Max number of activations in period	number	[illegible]
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)	13C
Max ramp-up temperature	Max temperature if room needs to be thermally charged prior to [illegible]	20C
Days of activations	Calendar days	Monday, Tuesday, Wednesday, Thursday, Friday
On-trigger	DSO signal	DSO signal
Off-trigger	DSO signal	DSO signal
Max allowed activation time	Number of hours	2,5
Tolerance	Percentage deviation of requested load shedding per activation	+/- 1%
Strike price	NOK exempt VAT	130
Activation fee working days	NOK exempt VAT	[illegible]
Activation fee weekends	NOK exempt VAT	120
Non-conformance clause	text	[illegible]

Figure 20: Instant Cut - contract between the SESP and the community member that reflects the one established with the DSO above.

The SESP offers a price for the control of a boiler, a heated floor or similar. More likely in the future is that a certain flexibility volume is asked for e.g. 500W. Then it is up to the home side EMS and the schedule defined by the end-user which appliance to disconnect. This concept has been illustrated in Figure 21.

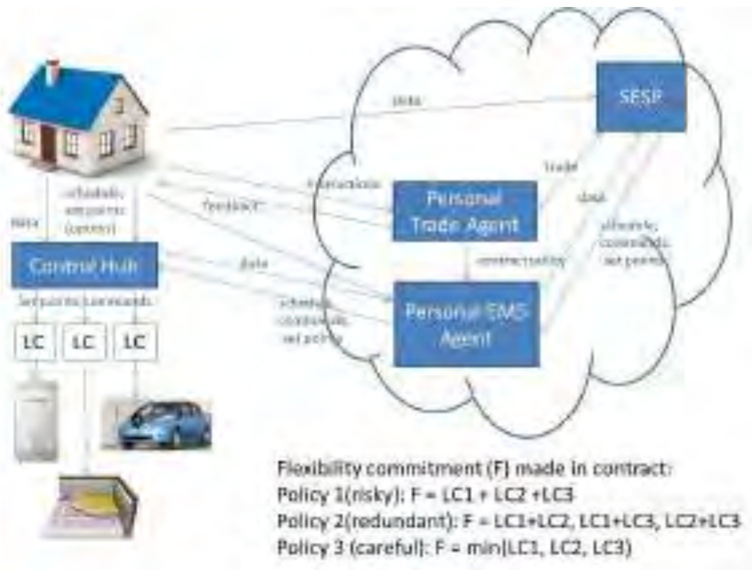


Figure 21: Local control hub receives signals from SESP control and according to its own policy decides which load to suspend according to the call and the contract signed. It is important that SESP considers the total available flexibility against the flexibility specified in the contract.

By comparing the overall flexibility with the commitment made in the contract the SESP may act proactively to reduce risks and increase resilience and robustness of the D_R system. Feed-in ceiling allows the DSO to activate a specific ceiling for energy fed into the distribution net. This can be expressed in the form of periodic energy volume or as a ceiling expressed in terms of kW over a period much shorter than the hour. An example illustrating this as vectors are shown below:

#(strikeP, actP1, nameDSO, endorseDate, initDate, termDate autoRenew, maxLoad, activations, days, interval, ceiling, tolerance, general information)

#(strikeP, actP1, nameHolder, endorseDate, initDate, termDate autoRenew, maxLoad, activations, days, interval, ceiling, tolerance, general information)

6.2.2 Flexibility auction

6.2.2.1 Abstract

The type of flexibility contracts procured from community members allow itself well to auctions provided that there is potentially some degree of competition. The most obvious form of auction when the SESP turns around is to apply the same type of call auction approach as described for pure energy trade. In its simplest form that would imply a simple, English auction. However, it will be a reversed English auction as it will address sellers, not buyers. Once one party is exempt form the price scan auction described earlier it technically turns into an English auction at once. Hence the same technical base can be used to support all types of auctions. It also establishes a smooth link from OTC operations, price scan to an English auction. That allows for rather seamless transitions and increased adaptability of the EMPOWER system.

Figure 22: English auction (reversed) where the DSO would rather seek the lowest offer rather than the highest from the sellers.

The proposed solution makes the auction in flexibility highly compatible with the ones proposed for trade in energy. The market in this diagram clears with one common price. This must be tested, but is believed to be perceives as fairer than operating with different prices for the same end-user service within a single neighbourhood. A prerequisite for this auction to work is that it is partially blind (only the call price is known). None of the traders will know the quota that is in play. Hence the traders will never know when the SESP will conclude the auction. The risk of not producing an offer early may lead to failure to win a contract completely. This concept should therefore honour those traders that are quick. They will be rewarded for their agility of the competition is fierce and the market clears at a higher price later.

6.2.2.2 Classes/objects

- SESP Market: Has the overall control of the trade
- Trading floor: Part of the SESP Market class. Manages the trade.
- OrderBook: Part of the SESP Market class and strongly connected to the Trade floor. Maintains status of sale and purchase at all times.
- Selling Agent: Personal agent in the cloud that manages the sale on behalf of its owner.
- Timer: A clock

6.2.2.3 Sequence diagram

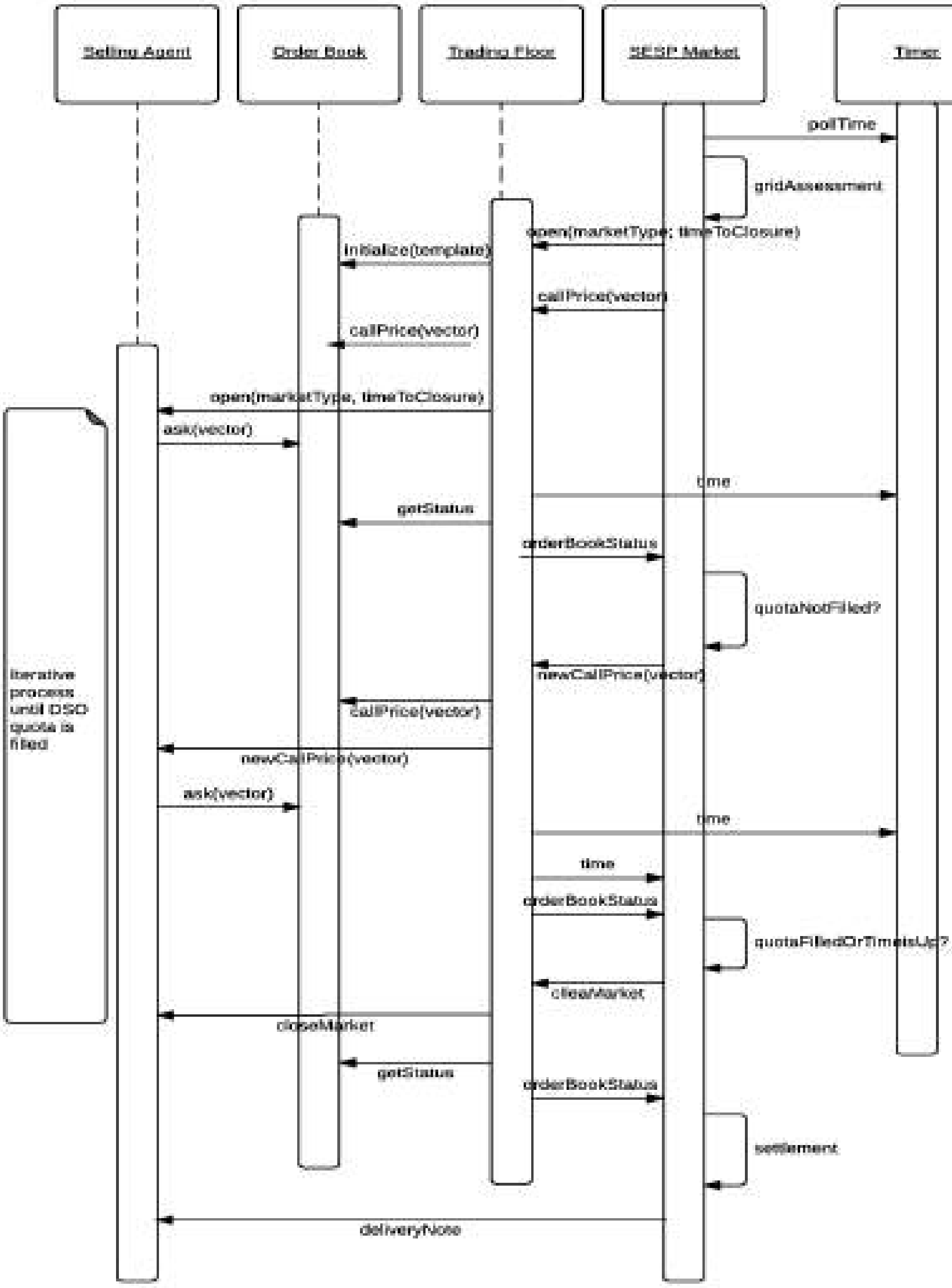


Figure 23: Flexibility auction. The price scan option is used rather than a call auction whereby the end-user or agent should propose its own flexibility volume and selling price.

6.2.2.4 Functions

Class/object	Method/function	Description
SESP market	resourceAssessment	Internal function: On a time trigger evaluation of resources available required to support the trade are made. This is to assure the best possible match between local supply and local

		demand (see detailed description below). Resource assessment is also required in order to determine opening prices called by the SESP.
	marketAssessment	Evaluates price signals from the central market or neighboring communities. Combined with the resource assessment this will determine call prices.
	specifyMarket	Internal function: determines what type of market and trade form is selected and specifies trade intervls and time to market closure. Associated information is passed on to trading agents.
	Sell first?	Sell first is a test whether or not to present an offer to the selling side before the buying side. The default rule is that the side with a comparative deficit will be given an offer first.
	orderBookStatus	Gathers current status about asks and bids
	salesVolume insufficient? & buyVolume insufficient?	The SESP makes an evaluation if the volumes sold or bought meets expecations and needs.
	InitiateSettlement	Validates received contract and issue final contract
Timer	time	Provides current date and time
SESP Control	resourceAssessment	Provides historic and current resource data for the SESP Market
Trading floor (Part of SESP Market)	open(marketType, timeToClosure, information, selling price)	Opens a flag that allows trading and which initiates the order book. Timer doing the countdown before market closure is set and pertinent information about the trade is posted.
	sellingPrice(vector)	This posts the selling price(s). This function carries a feature vector. In its simplest form it can be simply one price. In the more advanced cases it might include a series of prices indicating the value of flexibility, associated combos etc. (see detailed description of this below). If the SESP is unhappy with the response the price might be changed and a new attempt initiated. This is called a campaign.
	orderBookStatus	Internal function: Retrieves the order book and passes it to SESP market.
	sell(vector)	This is a seller endorsed contract accepting the buying price offered by the SESP for a certain volume that might be

		specified for certain hours per week. Sell(campaign) = sell(vector) but may contain additional aspects.
	getStatus	Internal function: Requests the status from the Order Book.
	closeMarket	Internal function that passes on the latest order book to SESP Market and emits close signal to all traders.
OrderBook	initialize(template)	Receives the list structure that will keep the buy and sell orders and associated information passed on by the Trading floor. The template may be a vector, matrix or structured list.
	sellingPrice(vector)	This is posted with the Order Book for continuous monitoring (also through a GUI). A variant of this is applied for campaigns.
	getStatus	Passes on the content of the Order Book template to the Trading Floor and reinitializes.
	sell(vector)	Posts the request from the seller and the contract on the order book and passes it on.
Buying Agent/Selling Agent	open(marketType, timeToClosure, generalInfo, price offered)	Activates the agent which, based on its personal instruction set and policy, evaluates the call and possibly the activity in the order book.
	assessOptions	Internal function: That evaluates price(s) and market against its own resources, policies, limits and options and prepares a bid or decides to abstain (see details below)
	buy(vector)	Nominates a volume for purchase according to the template issued and as a response to the price(s) offered. The vector may also respond with specifications of committed flexibility or services (see details below) Similar for campaigns.
	sell(vector)	Nominates a volume for sale according to the template issued and as a response to the price(s) offered. The vector may also respond with specifications of committed flexibility or services (see details below). Similar for campaigns.
	contract	This is a copy of the contract endorsed by both the SESP and the community member. The buyer and seller will be billed and enumerated respectively according to this.
	closeMarket	Terminates trading activity.

6.2.2.5 Contracts and data structures

See section 6.2.1.3

6.3 Trade in services and products

This section specifies trade in energy related services and products. One could foresee two types:

1. Apps that can be downloaded and activated within the digital environment
2. Services that cannot be downloaded, but activated through an online booking system.

Some services can be purchased and activated by means of the personal agent that is connected to a controller and other services that monitor the state of affairs. The trade agent might automatically invoke repair services, snow removal, diagnostic services etc.

6.3.1 Over-the-counter trade

6.3.1.1 Abstract

For this trade over-the-counter trade will be most common. However, as pointed out in D6.2 and D6.1 a shopping club might rally increased involvement through auctions too.

Two types of service/product providers can be engaged: The Digital and the Non-Digital. The former provides downloadable apps as services.

6.3.1.2 Sequence diagram: Non-digital provider

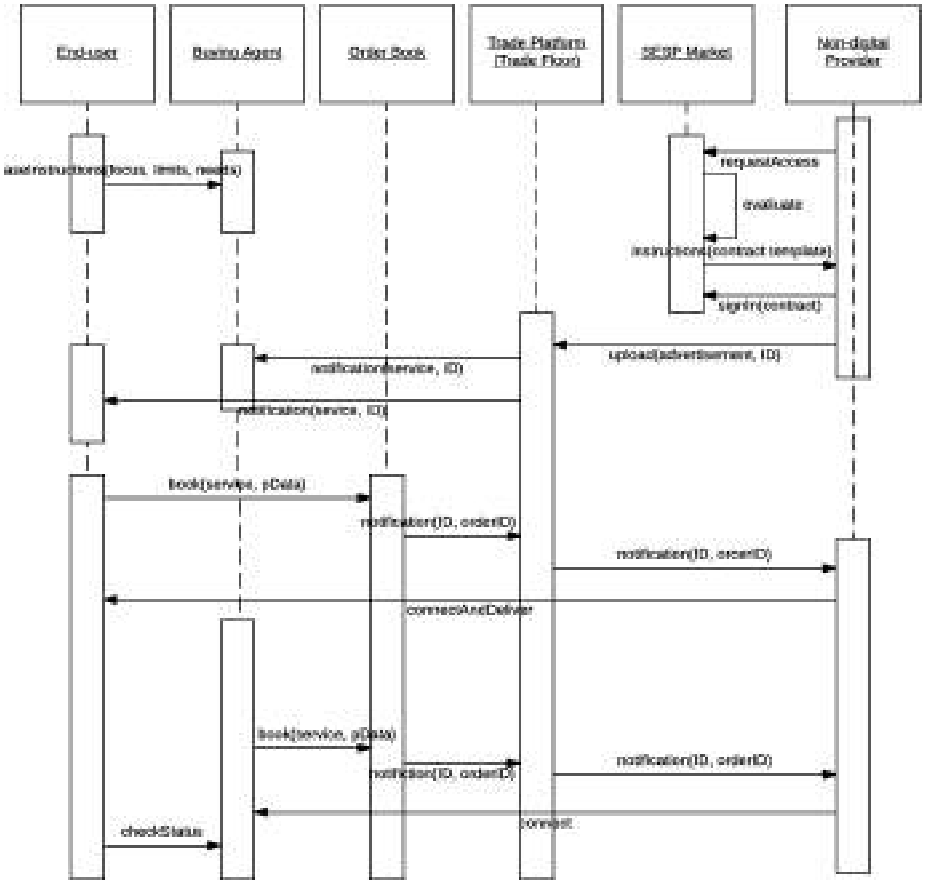


Figure 24: Trade in products and services that cannot be delivered across the electricity or the computer network

6.3.1.3 Sequence diagram: Digital provider

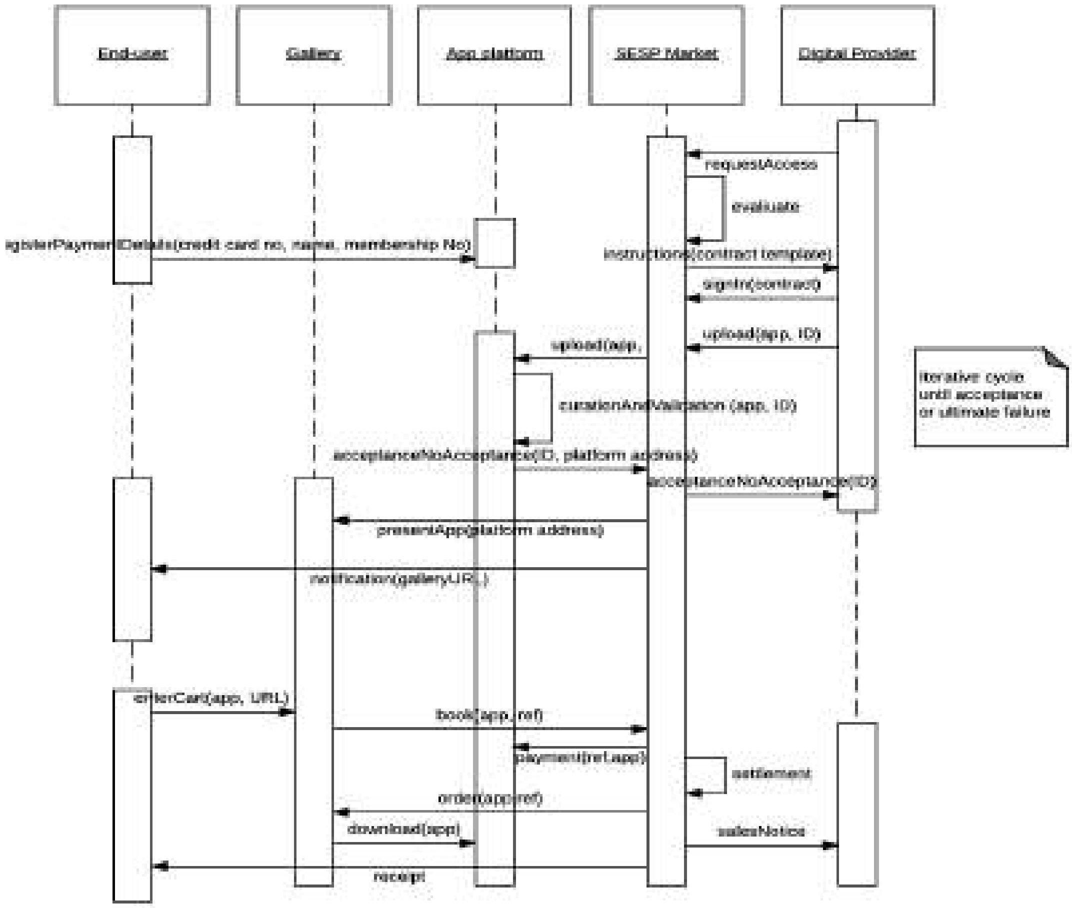


Figure 25: Trade in products and services that can be delivered as an app and activated or downloaded from the cloud.

6.3.1.4 Objects/Classes

- SESP Market: Handles requests and recruitment of service providers. Manages settlement and communication between provider and the app platform.
- App Platform: This might be a standard entity like Google Play or a customized entity entirely under the control of the SESP Market.
- Gallery: Is an online catalogue promoting all the offers (including the ones that the SESP offers the community) that the community member can enjoy. All offers are associated with a code, a photo, a reference link and the possibility to be transferred to a shopping cart.
- Trade Platform (Trade Floor): Could be a super class or sub class of Trade Floor. It could also incorporate functions highlighted under the App Platform object if developers wish to customize an app platform for the purpose. The Trade Platform will be fully controlled by the SESP market.

- Order Book: A subclass of the general concept of an Order Book. Manages orders and provides status/notifications about procurement/sales.
- Buying Agent: Operates on behalf of an owner. Useful for immediate response operations related to issues that may suddenly arise. Operates under customized policy rules.

6.3.1.5 Functions

Class/object	Method/function	Description
SESP Market	requestAccess	A provider makes contact and wants to become a service/app member of the community and upload an asset to the service gallery hosted by SESP. The request must include name, organization number, address etc. Also the reason why the request is made should be included. Input can be done by means of a form on a GUI.
	evaluate	By means of certain policy rules the request is processed. This is likely to be a semi-manual job in the beginning.
	instructions(contract template)	Internal function: A set of information, partly customized for the purpose specified in the provider's request is passed on together with a contract template to be filled in by the provider.
	signIn(contract)	The contract is endorsed and the provider is given a code/ID that can be used to for future work.
	upload(app, ID)	The digital entity e.g. an app, is uploaded to the app platform via SESP market. This simply implies that a standard platform like Google Play can be used and that the SESP Market offers an entry point for this platform. In the case of an independent app platform the platform might be more integrated and the upload operation to SESP takes the digital entity straight onto the platform.
	acceptanceNoAcceptance	Internal function: The result of the validation/curation process managed by the digital platform is passed on to the provider to fix errors, weaknesses or other problems.
	payment(ref, app)	Internal function: A standard platform may require up-front payment. In such a case the SESP Market may have to pay up prior to settling the accounts of the community member and provider.
	book(app, ref)	endorses
	settlement	Accounts are settled and due notifications issued.

	receipt	Internal function: A receipt (or invoice) is issued and sent to the user
	salesNotice	Internal function: The Digital Provider receives a notification that a sale has been done.
Trade platform (floor)	upload(advertisement, ID)	Same as above, but uploads an advertisement for a non-digital service or product. This function issues a notification to potential buyers.
	notification(ID, orderID)	Issues a purchase notification to the Non-Digital Provider. This is a structured form that can be digitally treated.
App platform	registerPaymentDetails(credit card no, name, membership No.)	A standard platform may request registration of payment details prior to any purchase. A customized platform can handle the payment by means of the regular settlement used of other kinds of trade.
	upload(app, ID)	The app is uploaded for test according to standard procedures.
	curationAndValidation	The new entry is subjected to tests and classification according to standard curation and validation rules. It may be rejected, accepted, or given pending acceptance if errors or weaknesses are fixed.
	presentApp(platform address)	Internal function: If entry is approved, information about it is passed on to gallery with a link to the download center.
	notification(galleryURL).	Internal function: A message is formulated and passed on to community members as a push based promotion service. The message contains a link to the gallery where the new service or product is described.
	download(app)	The app can be downloaded to a local machine.
Gallery	presentApp(platform address)	The SESP home pages presents a gallery of services and products where all entries are displayed with product/service details as well as a photo and price. The entry has a hyper link to the download site.
	enterCart (app, URL)	The user will make a choice and enter it into a digital cart for later settlement. The cart will contain a specification of the selection (typically with a reference number) and the URL that points to the gallery slot where it was picked up.
	order(app, ref)	Gallery receives a signal that settlement has been conducted and that correctly referenced app is ready to download.
	download(app)	a confirming signal is passed on to the app platform. This initiates the download procedure.

OrderBook	book(service,pData)	Receives a purchase order with reference to the advertised service using a service code. With this follows contact and personal data from the procurer. After a brief curation and approval the order is passed on as a notification for further processing.
Buying Agent	baseInstructions(focus, limits, needs)	This function receives instructions from its user. It will then sniff out services that can be useful with very short notice. Such services could be the need for instant maintenance, error fixing when problems are discovered. Policies that govern the behavior of the agent are included as rules.
	connect	Responds to the service owner with the nature of the call and the tasks that need to be resolved.
	checkStatus	Provides the agent owner with a log

6.3.1.6 Contract templates and data structures

This can typically be on the form:

#(price, specification, reference, nameOfHolder, linkToDownloadArea, general information)

#(price, specification, reference, nameOfHolder, linkToDownloadArea, general information, timeToDelivery)

6.3.2 Service/product auctions

6.3.2.1 Abstract

This depicts a regular English auction for trade in services and products. Hence this form of trade is technically compliant with the call auction approach explained earlier. Two types of bidders can be found, a human and an agent instructed by a human.

6.3.2.2 Sequence diagram

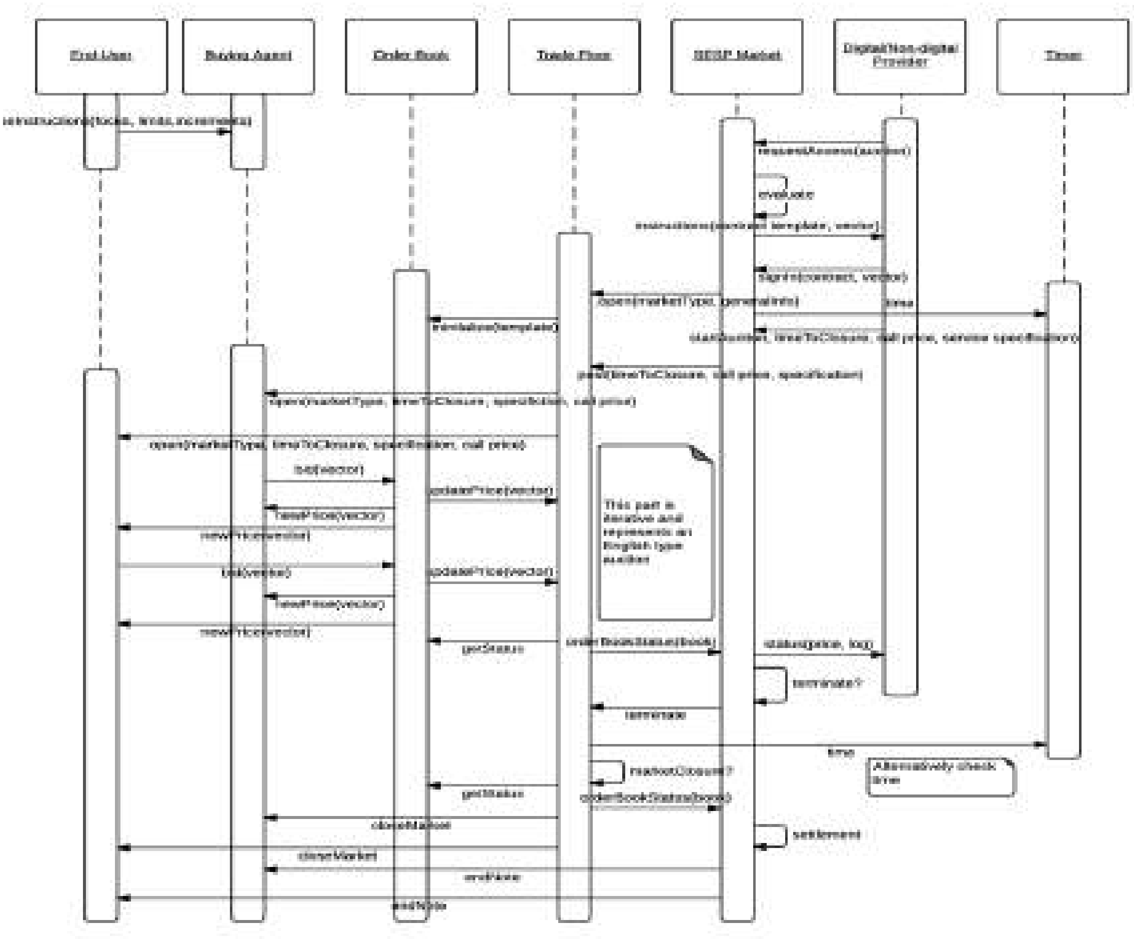


Figure 26: Service and product auctions

6.3.2.3 Classes/objects

- SESP Market: Handles requests and recruitment of service providers. It controls the initiation and termination of the auction. It manages settlement and communication between provider and the
- Trade Floor: Owned by SESP Market. Monitors the action and the bids.
- Order Book: Owned by SESP market and Trade Floor. It records bid activity and updates the highest price at all times and conveys this to the other roles involved in the trade.
- Buying Agent: The agent operates on behalf of a user and makes incremental bids in compliance with bid policy defined by the end-user. End-users may, however, take direct part in the auction.
- Timer. A clock

6.3.2.4 Functions

Class/object	Method/function	Description
SESP Market	requestAccess	A provider makes contact and wants to become a service/app member of the community and upload an asset to the service gallery hosted by the SESP. The request must include name, organization number, address etc. Also the reason why the request is made should be included here. Input can be done by means of a form on a GUI.
	evaluate	By means of certain policy rules the request is processed. This is likely to be a semi-manual job in the beginning.
	instructions(contract template)	Internal function: A set of information, partly customized for the purpose specified in the provider's request is passed on together with a contract template to be filled in by the provider.
	signIn(contract)	The contract is endorsed and the provider is given a code/ID that can be used to for future work.
	Open(marketType, generalInfo)	Internal function: Opens a flag that initiates the order book.
	startAuction(timeToClosure, call price, service specification)	Initiate an Englsih auction with the specifications given by the service provider and call price. The clock starts to run.
	orderBookStatus(book)	Evaluates the status of the auction and notifies the provider
	initiateSettlement	This initiates endorsement of contracts made. It updates accounts and caters for future metering and billing.
	Terminate?	Based on the status the provider might wish to terminate the trade before scheduled closure. In such a case this must be part of the general info posted initially. For agents to capture this info of this character must be in the form of flags or tokens.
Trading Floor	open(marketType, timeToClosure, information)	Opens a flag that allows trading and which initiates the order book. Timer doing the countdown before market closure is set and pertinent information about the trade is posted.

	post(timeToClosure, call price, specification)	Makes available specifications of the trade, time to closure and the call price set by the service provider.
	updatePrice(vector)	Records the new, highest bid price and notifies particpants of this.
	marketClosure?	Based on the time the trading floor will close if trade duration is up.
	terminate	Terminates the auction on command
OrderBook	initialize(template)	Receives the list structure that will keep the buy orders and associated information passed on by the Trading floor. The template may be a vector, matrix or structured list.
	bid(vector)	Receives a buy order with its specifications and enters them into the Order Book. Aggregated demand is updated.
	getStatus	Passes on the content of the template to the Trading Floor and reinitializes.
	newPrice(vector)	Internal function:
Buying Agent (& End-User)	baseInstructions(focus, limits, increments)	Specifications entered by the end user that specifies specific or default bid policies.
	open(marketType, timeToClosure, specification, call price)	Receives and processes message that the market is an English auction type (in contrast to others), that the trade will last for a specific duration
	bid(vector)	Internal function: Evaluates the highest price in the auction and decides whether or not to bid higher. This is determined by the limit and increments specified by the user.
	newPrice(vector)	Receives the leading price of the auction
	closeMarket	Terminates trade activity
	endNote	Bid winders receceive anda nd note and status of the settlement and delivery

6.3.2.5 Contract templates

- Same as for 6.3.1.6

6.4 Trade in combined products

Deliverable D6.3 explained the potential of combined products (combos) and how they can be traded. In this document different combos have already been presented. Selling combos over the counter creates no problem, but the mechanisms for auctions of such products should be understood. Here is an example of a vector in play at a given call.

Selling	Basic	K_δ= 500W	K_δ= 1000W	Diagnosis & repair
Price	2	-0,4	-0 ,8	+0,2

The vector illustrates a contract whereby the SESP calls for a price of 2 eurocents. Assuming that the other options are not selected the 2 eurocent will be what the buyer pays or the seller achieves if the market clears with this price. As such it fits the auction that has been prescribed earlier.

However, assume that the buyer ticks off one or more of the other options in the vector the received bill will be different. If he chooses the service offered the price to be paid will be 2,2. If he can offer 1000W flexibility for demand-response purposes that the SESP requests (must be specified as general information in the contract and posted on the trade floor display) the price will be 2+0,2-0,8 = 2,6. The prices of each option are based on the base price. The base price makes it possible to compare offers and clear the market accordingly. In a price scan auction every call will adjust at least the base price. However, this type of auction can also use the additional offers in order to attract more buyers and seller to come forward with offers of energy volumes to sell or to buy. Based on the resources that the SESP has available a combo like this can encourage more liquidity and engagement. Flexibility is related to the price. Naturally the conditions for the use of the flexibility or service options should be posted and made transparent prior to the trade[4]. When the market clears the base price is used. The additional choices made works like trailering elements.

[4] Which would resemble the type of contracts already discussed

6.5 When someone fails to make a bid or an ask

A default contract will be offered to those that do not take part in the trade. This will be a standard contract that generates no reward points or any other benefits such as a discount. The default contract will basically reflect the average offer that the market beyond can offer. This also implies that the benefits offered and the added value competed for must be highly competitive. .If the market clears with unmatched volumes, partial orders will be managed. The part that falls outside will be treated as a bid or ask that was never made. This is to stimulate early interaction and reduce the risk of potential gaming.

6.6 Setting up selling and buying agents

6.6.1 Autonomous or semi-autonomous

Different approaches to agent based trading was discussed in deliverable D6.2. A number of methods reported in the literature has been investigated and reported on since the inception of the EMPOWER idea. The basic idea behind the use of agents in most cases is usually to alleviate the user and let the agent take care of the more complex set of details. Based on this type of literature we also offered an hypothesis that zero-intelligence agents could suffice in EMPOWER since it is often proven that the market design and the trading rules defined will be adequate to create the necessary market efficiency. Since EMPOWER is not dealing with very hard lined self-interest traders, but a community, the zero-intelligence alternative seems a relevant test for our purpose. However, more sophisticated methods can be applied on top of the simple ones to improve individual performance, if necessary. It is also a question whether or not the agents should be fully autonomous. Autonomy means that the agents make decisions on trade and control alone. Agents can also provide decision support and leave the end-user in charge of the final decision. Consequently, a trading agent could be accommodated within a user app for that particular purpose. This semi-automated approach could have on/off options so the degree between full autonomy or passive support could be adjusted. This is not uncommon with many auction systems today. When trading frequency goes up the demand for more autonomy goes up as it otherwise would require excessive attention from the trader himself/herself. However, the agent concept has been tested in earnest with regular consumers and prosumers in order to harvest early feedback. Long term stability is a priority for those asked. Trading itself feels foreign for many too, especially with “no hands on the wheel”. It seems a good approach to introduce a function where there is a gliding transition from decision support to full autonomy.

6.6.2 Simple input

To set-up an agent and specify the requirements for a trading mission should be very simple. In its simplest form only two variables are required. Specification of volume may not be an option in the trade. If controls to regulate consumption or production are missing the agent will only accept or not accept an offer. Consequently, the agent should be initiated with a price that seems permissible, but not necessary the best possible. Next an upper (purchase) or lower limit (sale) should be defined so that the agent under no circumstances violates this, but challenges the user.

A more sophisticated version would in addition require specification of price increments defining what to do if a request for local energy or sale of such cannot be achieved for a specific call price. This price series defines a subjective specification of the probability that a bid or ask will be made for a given call. The same function can also be used to express how much will be sold or purchased if control measures allows other strategies than “all-in” or “all-out”.

Finally, the most sophisticated agent concepts would require that the end-user either specifies a policy or choose among a selection of such that are made available to him or her. Policies are rules of tactics that can be implemented.

6.6.3 A logistic simulator

A logistic simulator uses a logistic probability distribution as the principal decision making instrument. It is commonly used to determine the decision based on analogue input. The cumulative distribution function represents a sigmoid curve (see figure 27) that arbitrate between action/no action. This function is expressed as:

$$\frac{1}{1+e^{\frac{p-\mu}{s}}},$$

where p is the price considered and μ is the permissible price based on a subjective evaluation (fixed) of its own needs or assets. In its simplest form, factor s represents a simple policy and can be a constant throughout the whole trading process. The factor s defines the steepness of the sigmoid curve. It therefore provides a simple model for elasticity, namely the will to negotiate. The more linear, the more willingness the agent has to seek a solution. The s factor therefore introduces a variable that can be applied to seek equilibrium, alleviating the market making burden on the SESP. Hence the factor s can be associated with very simple policy rules. The user may use such rules to either increase or reduce s arbitrary or incrementally to ensure a sale or a buy.

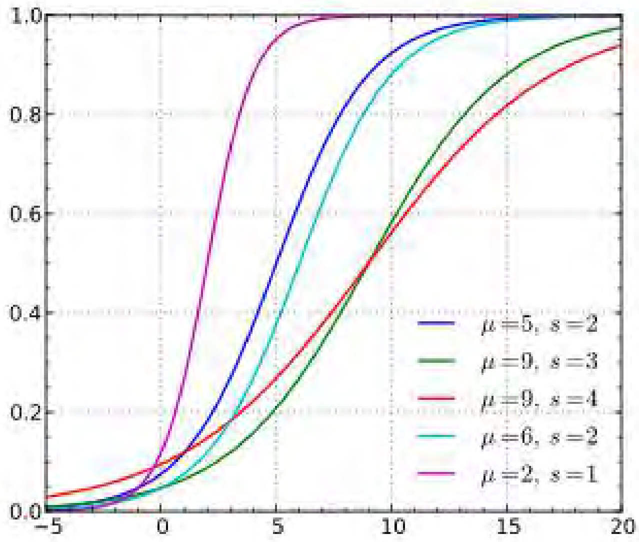


Figure 27: The logistic cumulative distribution function determines the probability between action or no action.

The negotiation is driven by a Bernoulli process whereby a random number is picked. This defines the probability and consequently the price which is acceptable at that instance or not. The comparison with call price decides the action (offer) or no action.

Assume that the following input has been defined by a consumer. The values are kept at the user side and is of course shielded.

Variable	Input value
Permissible price (μ)	30
S	2
Upper limit	55

A similar input has been entered by a prosumer:

Variable	Input value
Permissible price (μ)	45
S	3
Lower limit	35

From this it can be seen that the buyer hopes to get a low price, while the buyer hopes to get a much higher price. The seller is also more willing to negotiate. The factor S is higher than the buyer's.

Price call (SESP)	Seller's response	Buyer's response	Result
25	Abstain	Buy	New call
30	Abstain	Abstain	New call
35	Sell	Buy	Settle
40	Sell	Abstain	New call

There is a 17% chance that the selling agent will sell for 35, while a price of 55 would yield a definite sell signal. The buyer will procure with 22% certainty at price 35, but a price of 20 would yield an absolute decision to buy.

With controllable production and consumption it would be possible to associate a potential call price with a given volume that can be nominated for exchange. With a clearing price 0f 35 and given the specifications given by the buyer and the seller below the traded volume would be 0,5.

Price	25	30	35	40
Volume sale	0,1	0,3	0,6	1
Volume buy	0,8	0,7	0,5	0,3

If the traders take the trouble specifying a price distribution like this it could be used directly and the logistic probability function would be superfluous. However, there are reasons to believe that as people grow accustomed to the concept their empirical distribution would assume something similar to a logistic function. In the simple case this would imply:

Price	25	30	35	40
Volume sale	A	A	S	S
Volume buy	B	B	B	A

6.6.4 Agents that learn

At the outset an agent can start off without any knowledge of the market or prices at all. It essentially flips a coin (Bernoulli) and notices what happens. Later it can use the historic record to build a strategy which uses a set of weighted probabilities. There exists no up front distribution function. The result is stored in the memory of the agent. As an agent will not know what other agents are doing, (neither buyers or sellers) it simply responds to the signals emitted from the SESP. It can use two signals, the price signal (p1) emitted by the central market and the price call made by the SESP (p2). Diff = (p1 – p2/p1). A historic record could then be produced that looks like this for a seller.

Diff	-0,3	-0,2	-0,1	0	0,1	0,2	0,3
Historic frequency	1	3	7	5	9	8	4
Probability of action	0,02	0,1	0,18	0,13	0,23	0,21	0,11

A seller wild be more interested in the positive price difference, while a buyer would appreciate a negative price difference. A greedy policy would make the agent choose the highest risk adjusted reward. The most likely bid would be for +,02. The buyer is likely to be most satisfied with the -0,1 alternative. The strength of the different alternatives can be reduced by means of a learning factor α. Agents may shift policies and the historic value might decrease. Hence a decay factor, ρ, should be introduced. ρ could be set to 1/n where n is the number of steps since a specific alternative k (Diff) happened. Hence *preference for alternative k*, $\dot{\eta}_k = \frac{(pdiffk \quad 'diffk)\alpha}{\sum_{i\,alternatives}(p_i \ *diffi)\ \alpha}$

Learning is defined as $\dot{\eta}_{i\ new} = \dot{\eta}_i * \rho + \Delta\dot{\eta}_i$ for all alternatives. The increase for the chosen alternative is $\Delta\ \dot{\eta}_i$ = Diff.*/38, otherwise it is 0.

The concept above can further be expanded if the simple methods do not suffice. The Diff can be seen as states during a negotiation. This means that in addition to the frequency of each state defined as Diff above it is interesting to address what the next move will be if a call is unfavourable. As auctions are considered structured negotiation, a price scan option would represent a set of transitions from one state to another. This lends itself to a basic Q-learning method. Again the input from the user will be very limited. Again it all starts out with a Bernoulli lottery. However, in order to capture learning the following can be defined for the gain Q:

$$Q_{t+1}\left(diff_{t},action_t\right) < -(1-\alpha)Q_t\left(diff_{t},action_t\right) + \alpha\left(R\left(diff_{t},action_t\right) + \omega * maxQ_t\left(diff,action\right)\right)$$

$diff_{t,}$ represents the state defined by the SESP at time t (price call) and the action at this time represent a buy or a sell depending on the trading role. α is the learning rate and ω is a discount rate that reduces the impact of the last move.R is the immediate reward for a given state provided an action in the form of a successful bid or ask, which can be expressed by a positive or negative digit. Again the distribution related to state action pairs are developed by the agent itself based on the successes it has with its policy. Even if other agents chnages their strategy and this creates an impact on the strategy of the SESP the agent will be able to adjust to this.

7 The trading platform: Cross market operations

When local supply is not balanced with local demand, SESP is responsible for buying or selling energy deficit/surplus in wholesale markets. If this happens in the local energy market, it is called Energy cross market (CM). Moreover, if the SESP community wants to participate in the flexibility markets, SESP can aggregate the local resources to sell/buy flexibility services in the wholesale markets. Then the local flexibility market is named Flexibility CM. The cross-market operations include the local operations between SESP and the wholesale markets.

7.1.1 Energy cross market trading operations

7.1.1.1 Overview/Abstract

This section describes the Energy CM market operations for defining the Energy Plan.

Actors:

- SESP retailer: automatic agent to represent the potential energy to buy/sell electricity from/to the day-ahead market for every hour. SESP forecasts the day-ahead market price. The energy settled by this agent in the Energy CM will be bid in the day-ahead market.
- Non-prof members: automatic agent to buy/sell electricity for non-professional SESP members. SESP forecasts their consumption/generation and their bids/offers are settled at their contract prices. The consumption and generation prices will be the same for all non-professional members according to their

contracts. Bids/offers energy volumes are aggregated by grid zone. This agent bids for the following loads and devices at zone level:

  - Base load
  - EVs defined in the subscription flexibility contracts previously
  - Water boilers and heaters defined in the subscription flexibility contracts
  - Local generation

- Professional agents: professional SESP members' automatic agents to bid in the Energy CM defining their specific consumption (P) and price (λ) for every hour (t).
- Trading floor: database of bids and offers.
- Order book: database of energy settled by each agent
- SESP control: Agent in charge of receiving the Energy Plan

7.1.1.2 Timeline

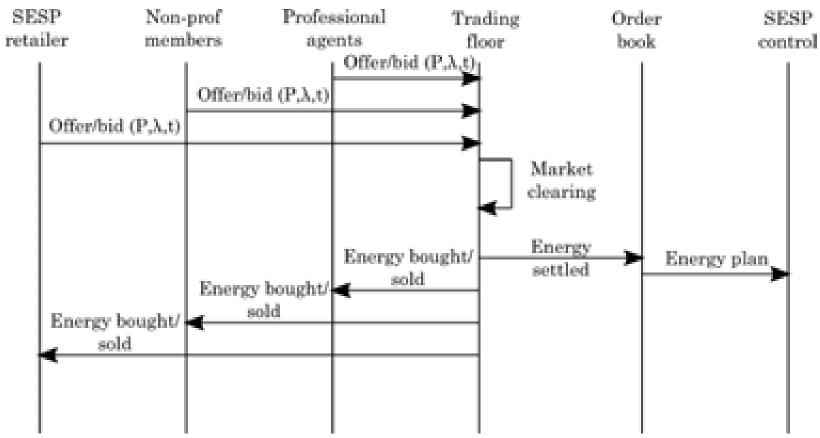


Figure 28: Energy trading timeline

7.1.1.3 Functions

These functions are executed during every local energy market.

Table 5: Energy trading functions

Function	Description
Offer/Bid	SESP as a retailer, professional and non-professional members' agents prepare the bids and offers for the energy cross market with the following information. For every period (t), power (P) [kW] and price (λ) [EUR/kWh or NOK/kWh]. This information comes from activation flexibility contracts.
Market clearing	Once the market session is closed, the clearing algorithm creates the merit

	order curves based on seller and buyer agents' offers. The clearing algorithm maximize the social welfare considering local constraints like EV requirements, maximum power, user requirements, flexibility status, and others. This market does not define the energy price, only schedules the local resources and establish the bids to be sent to day-ahead market.
Energy bought/sold	Automatic trading agents receive the energy settlement during the Energy CM. The energy bought/sold by the SESP retailer will be bid in the day-ahead market.
Energy settled	Power (P) and price (λ) settled in the Energy CM by each agent.
Energy plan	Power (P) and price (λ) by each zone

7.1.2 Flexibility cross market trading operations

7.1.2.1 Overview/Abstract

This section describes the local flexibility market operations for up and down-regulation creating the Daily and Hourly Flexibility Plans and Reserves (DFPR and HFPR).

Actors:

- Seller agent: automatic agent. It is program is based on activation flexibility contracts. Every SESP member with flexible assets and subscription contracts has its seller agent acting on behalf of them.
- Buyer agent: automatic agent programed by the SESP when it needs a certain volume of flexibility at a certain price.
- SESP control: automatic agent in charge of receiving the control signals and sending through the communication platform.

7.1.2.2 Timeline

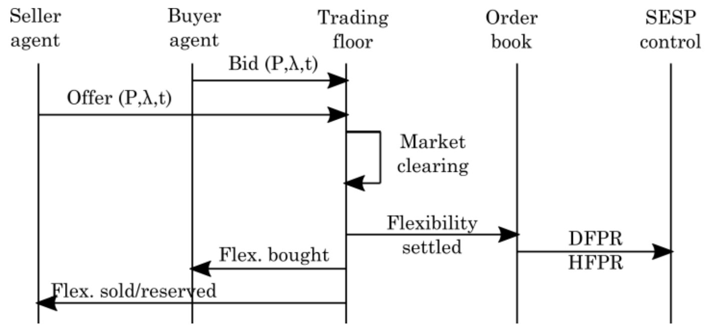


Figure 29: Flexibility trading timeline

7.1.2.3 Functions

This list of functions is executed every Daily-LFM and Hourly-LFM to settle local flexible assets.

Table 6: Flexibility trading functions

Function	Description
Offer/Bid	Buyer/Seller agents prepares the bids and offers for the flexibility cross market with the following information. For every period (t) Power (P) [kW], price (λ) [EUR/kWh or NOK/kWh]. This information comes from activation flexibility contracts.
Market clearing	Once the market session is closed, the clearing algorithm creates the merit order offers curve based on seller agents' offers. The Buyer agent, mainly the SESP as aggregator, asks for a certain power (P) at a certain price (λ). The clearing algorithm maximize the social welfare considering local constraints like EV requirements, maximum power, user requirements, flexibility status, and others. All flexibility sellers receive the same price. If there is not enough flexibility the SESP will obtain the available flexibility. If there is more flexibility than required, the most cheaper offers will be settled according to the merit order curve. If the flexibility offers are more expensive than the flexibility bid, the flexible resources will not be executed.
Flexibility settled	The flexibility settled is sent to the order book to be reported
DFPR/HFPR	The stored in the order book is transferred to the SESP control as the Daily/Hourly flexibility plan and reserve
Flexibility bought	Buyer agent receives a note about the flexibility settled in the LFM
Flexibility sold and reserved	Seller agents receive a note with the flexibility settled and reserved

8 Implementation cases

Different SESP companies could apply different Local Markets models according to their business perspective and the user involvement. This work package has presented all potential possibilities about different LM features. Moreover, this section analyses one single case and it develops all features related to the LM operation in the daily basis.

The LM model to be implemented is the Local Flexibility Market (LFM) for DSO requests. This model allows to execute control algorithms to satisfy DSO needs.

This section exposes a simple case as an example step by step to explain this FLM model. This example has a community with 8 households and 4 of them have 3.1 kW of PV panels in their rooftops.

The LFM for DSO requests is divided in three algorithms: Daily-LFM, Hourly-LFM and adjustment algorithm. The Daily LFM operates the LM considering the whole day and it is executed once per day. Later on, the Hourly-LFM adjust following hour operation dividing this hour in quarters and refreshing the consumption, generation forecast and flexibility status. Finally, the adjustment algorithm allows to manage emergency DSO requests at any moment. Figure 30 shows the LFM time-line and interactions between DSO and SESP.

Figure 30: LFM time-line and DSO-SESP interactions

DSO supervises the SESP operations and sends activation requests one hour ahead. As figure 31 emphasises, SESP sends Daily and Hourly Flexibility Plan and Reserve (DFPR and HFPR respectively) and the DSO confirms if they are feasible or not.

Following sections expose the Daily and Hourly LFM for DSO requests.

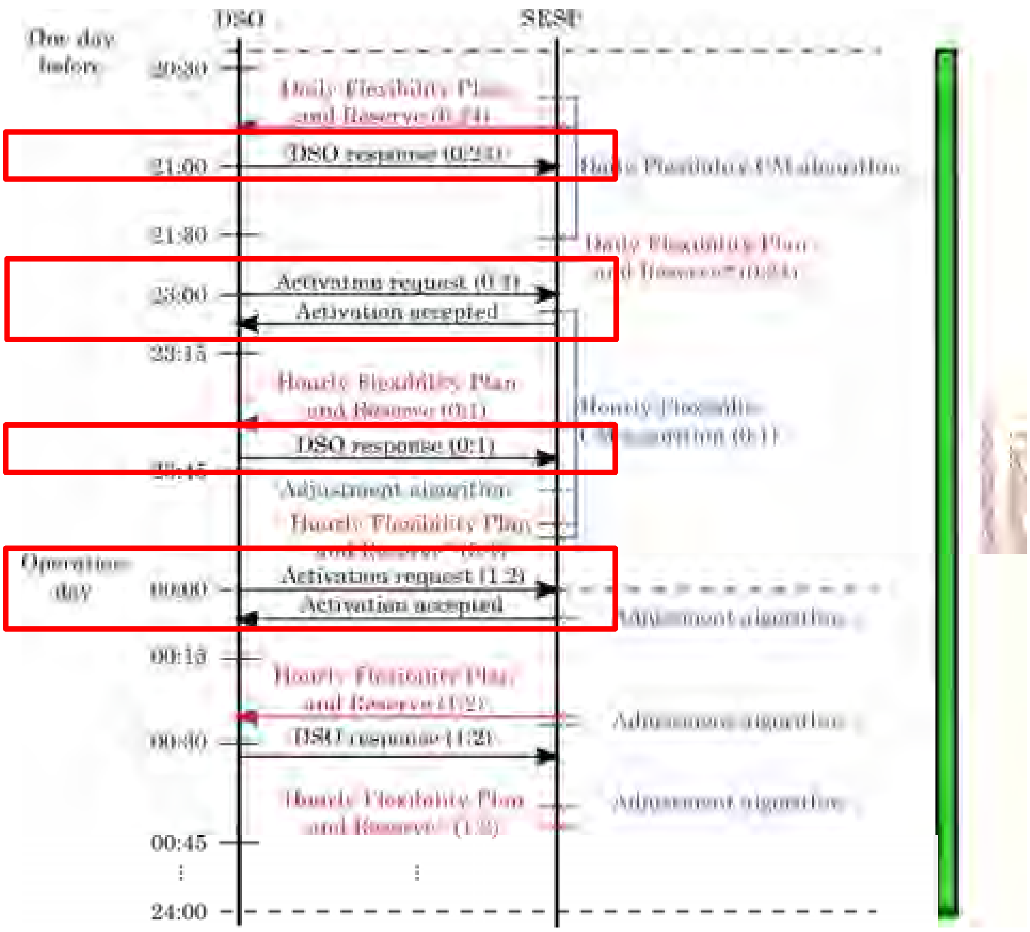


Figure 31: DSO-SESP interactions for supervision LM operation

8.1 Daily-LFM for DSO requests

One day before the operation at 20:30 SESP starts the Daily-LFM and before 21:00 it has to create the DFPR for the following day. As figure 32 shows, SESP executes forecasting functions to create the DFPR, collects the flexibility contracts and estimates the flexibility assets status.

As D6.3 exposed, forecasting functions are related to the following day and defines the community consumption and generation hour by hour as it is shown in figure 33.

Figure 32: Daily-LFM algorithm and functions

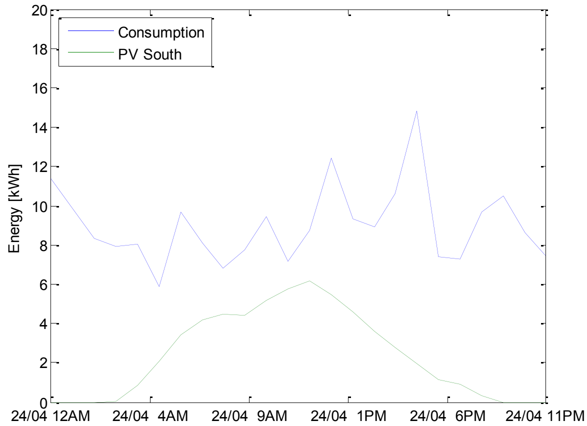


Figure 33: Community consumption and generation forecast for the following day predicted in the Daily-LFM algorithm

Table 7 shows the community flexibility contract parameters according to the D6.3 and D5.2. Every community member has three flexible assets: Heat pump (HP), water heater (WH) and electric vehicle (EV). All control types are ON/OFF and all loads are active.

Based on their contracts and their current consumption, figure 34 shows the available flexibility for every hour. In this case the community only has up-regulation capability disconnecting loads.

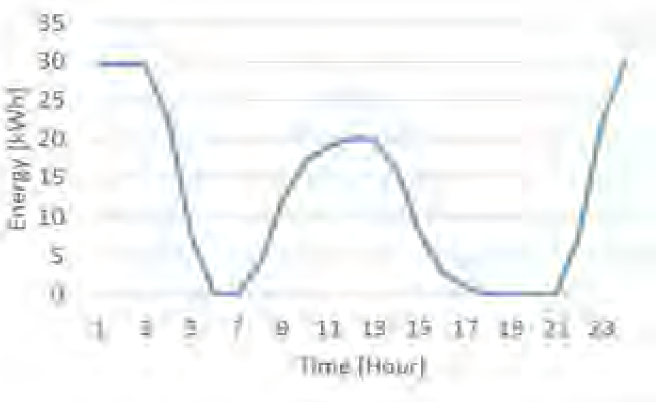


Figure 34: Up-regulation flexibility available

Table 7: Community flexibility contracts

Name of contract party	M123	M123	M123	M125	M125	M125	M127	M127	M127	M128	M128	M128	M130	M130	M130	M131	M131	M131	M132	M132	M132	M136	M136	M136
Resource ID	1	2	3	4	5	6	7	8	9	10	11	12	13	14	15	16	17	18	19	20	21	22	23	24
Status	Active	Active	Active	Active	Active	Active	Active	Active	Active	Active	Active	Active	Active	Active	Active	Active	Active	Active	Active	Active	Active	Active	Active	Active
Type	HP	WH	EV	HP	WH	EV	HP	WH	EV	HP	WH	EV	HP	WH	EV	HP	WH	EV	HP	WH	EV	HP	WH	EV
Control type	ON/OFF	ON/OFF	ON/OFF	ON/OFF	ON/OFF	ON/OFF	ON/OFF	ON/OFF	ON/OFF	ON/OFF	ON/OFF	ON/OFF	ON/OFF	ON/OFF	ON/OFF	ON/OFF	ON/OFF	ON/OFF	ON/OFF	ON/OFF	ON/OFF	ON/OFF	ON/OFF	ON/OFF
Metered	yes	yes	yes	yes	yes	yes	yes	yes	yes	yes	yes	yes	yes	yes	yes	yes	yes	yes	yes	yes	yes	yes	yes	yes
Max power per activation [kWh/time slot]	2	0.5	3.7	2	0.5	3.7	2	0.5	3.7	2	0.5	3.7	2	0.5	3.7	2	0.5	3.7	2	0.5	3.7	2	0.5	3.7
Max numver of activations per time interval	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1
Permitted interval start	8	10	22	7	9	21	9	11	23	8	10	22	8	10	22	7	9	21	9	11	23	8	10	22
Permitted interval end	14	16	4	13	15	3	15	17	5	14	16	4	14	16	4	13	15	3	15	17	5	14	16	4
Max allowed activation time [hours]	unlimited	unlimited	unlimited	unlimited	unlimited	unlimited	unlimited	unlimited	unlimited	unlimited	unlimited	unlimited	unlimited	unlimited	unlimited	unlimited	unlimited	unlimited	unlimited	unlimited	unlimited	unlimited	unlimited	unlimited
Minimum time between two activation																								
Reservation fee	50	50	50	50	50	50	50	50	50	50	50	50	50	50	50	50	50	50	50	50	50	50	50	50
Activation fee workdays	1	1	0.5	2	1	1	0.4	0.5	0.6	0.8	1.2	1.1	3	2	4	1.5	2.5	3.5	1	1	3	1.7	2.3	0.9
Activation fee non-workdays																								
Minimum normal temperature																								
Maximum normal temperature																								
Maximum temperature																								
Minimum temperature																								

Based on this information, SESP sends the DFPR to the DSO as it is shown in figure 35. This information allows DSO to check if the SESP has scheduled many flexible loads (e.g. EVs) during certain periods and the DSO does not know that.

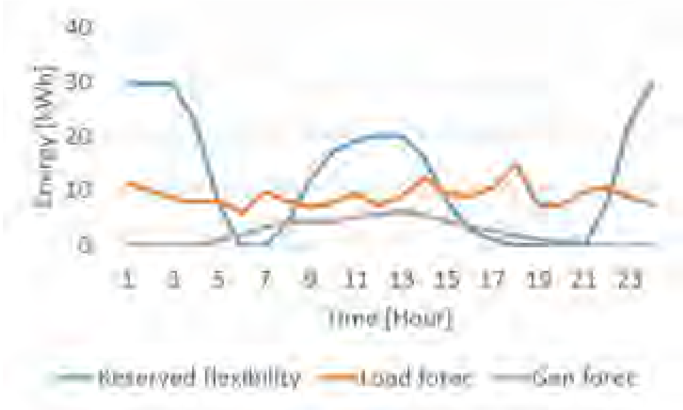


Figure 35: Daily Flexibility Plan and Reserve

Once the DSO receives the DFPR and checks the distribution operation, the DSO sends a response with the flexibility request for the following day. Figure 36 shows the DSO response for the example case.

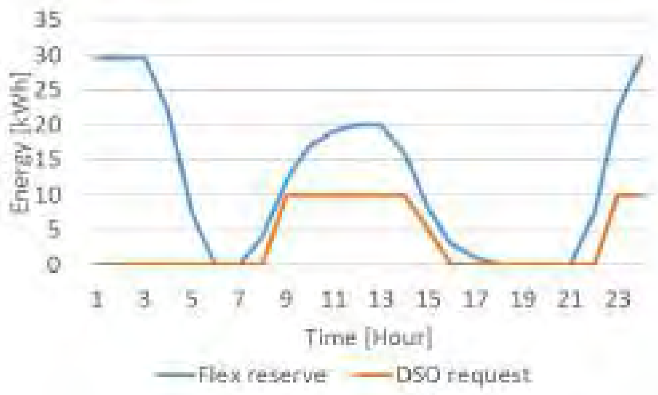


Figure 36: DSO request compared to the Flexibility reserve

Once SESP receives the DSO request, it has to determine who is going to supply flexibility services at the minimum cost. SESP decides this based on the activation fee of each flexibility contract previously settled, looking for the cheapest offers and checking their technical feasibility. Figure 37 shows the flexibility offers from community members without considering the period of each offer.

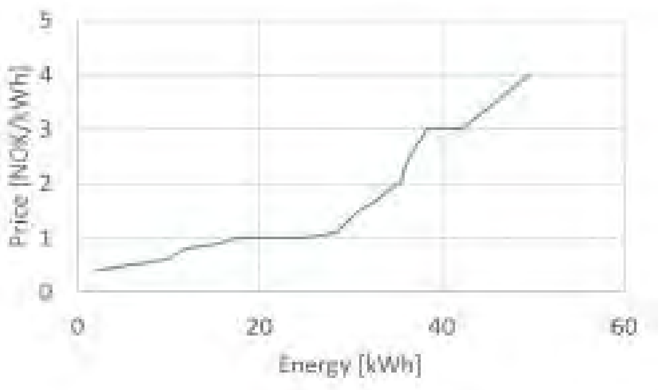


Figure 37: Flexibility offers sorted from the cheapest to the most expensive

Once the SESP has executed the LFM optimization algorithm to minimize the operation cost, it sends the control signals for the whole day. The LFM optimization algorithm result is defined as DFPR and Table 8 shows the DFPR* of the example case. The asterisk means that this plan includes the DSO response. Red figures represent the reserved flexibility but not scheduled.

8.2 Hourly-LFM for DSO requests

Once it is the 23rd hour of the day before operation, the DSO can send a new control signal and SESP activates the Hourly-LFM to allocate this new DSO requests. As figure 38 shows, the SESP sends the Hourly Flexibility Plan and Reserve to DSO and it can response if some correction is needed.

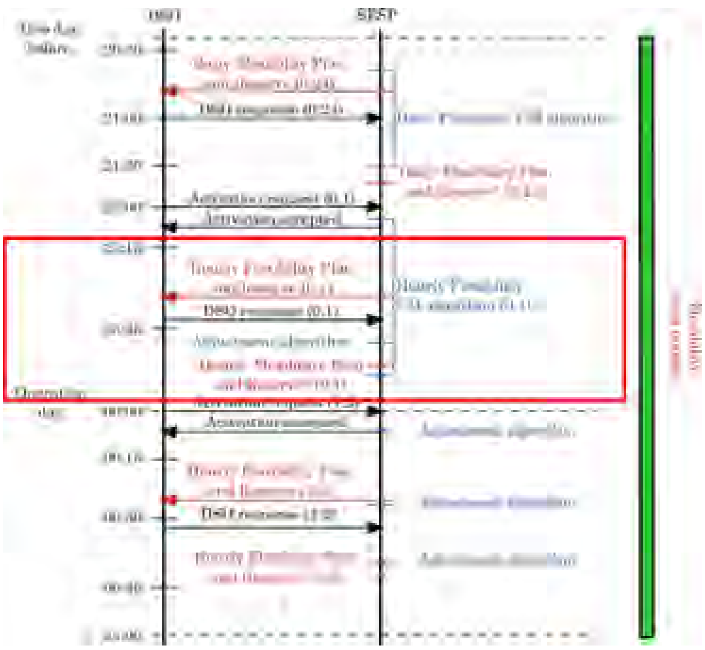


Figure 38: LFM interactions focused on the Hourly-LFM algorithm

Table 8: Daily Flexibility Plan and Reserve

Control signals after the LFM optimization algorithm	1	2	3	4	5	6	7	8	9	10	11	12	13	14	15	16	17	18	19	20	21	22	23	24
ID Resource																								
7										2	2	2	2	2	2									
3	0	0	0	0																			3.7	3.7
8												0.5	0.5	0.5	0.5									
9																								3.7
10									2	2	2	2	2	2										
24	0	0	0	0																			3.7	3.7
1									2	2	2	2	2	2										
2											0.5	0.5	0.5	0.5	0.5	0								
5										0.5	0.5	0.5	0.5	0.5	0.5									
6	0	0	0																			0	3.7	0
19										2	2	2	2	2	0									
20												0.5	0.5	0.5	0.5	0	0							
12																								
11																								
16										2	0	0	0											
22									2	0	0	0	0											
4								0	2	0	0	0	0											
14											0.5	0	0	0	0.5	0								
23																								
17										0	0.5	0	0	0	0.5									
13									2	0	0	0	0	0										
21																								
18																								
15																								
Total	0	0	0	0	0	0	0	0	10	10.5	10	10	10	10	5	0	0	0	0	0	0	0	11.1	11.1

The Hourly-LFM algorithm is the same as the Daily-LFM but it includes the DFPR* previously settled as it is shown in figure 39.

Figure 40: Hourly-LFM algorithm

In the example case, the DSO does not request any additional curtailment at 10:00 and the SESP refreshes its consumption and generation foresight. Figure 40 shows the real values and the new foresights for the period 12 (between 11:00 and 12:00). Periods after the 12th are not forecasted for the moment. In this step, SESP foresighted more consumption and less generation, and sends this information to the DSO. This information is titled Hourly Flexibility Plan and Reserve (HFPR) and contains the following expected consumption, generation and flexibility available.

Previously during the Daily-LFM, DSO requested 10 kWh for period 12 and the Flexibility Reserve still has 10 kWh more. The DSO response requested 15 kWh instead of 10 kWh to compensate the new expected demand and lower generation.

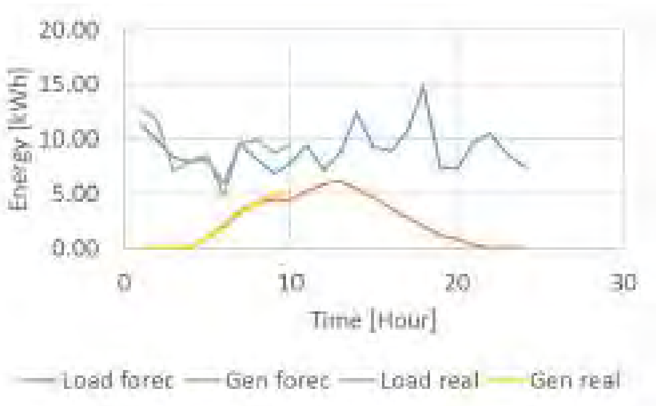
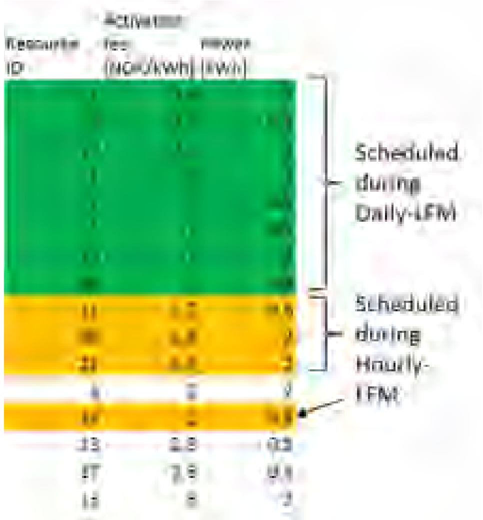


Figure 40: Community status comparing the daily foresight and the real values

Based on this request, SESP executes the LFM optimization algorithm to schedule the following hour divided by quarters considering the contract and technical constraints. Table 9 shows the scheduled resources during the Daily-LFM and Hourly-LFM.

Table 9: Flexibility resources scheduled for period 12



The corresponding merit order curve is shown in figure 41. Quarterly data is homogeneously distributed from hourly data.

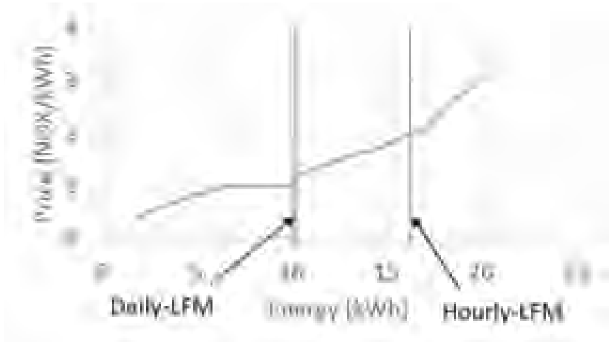


Figure 41: Merit order curve for period 12

Finally, the HFPR specifies who will provide the flexibility service and SESP sends the control signals to them as it is shown in Table 10.

Table 10: Hourly Flexibility Plan and Reserve for every flexible resource

Resource ID	HFPR	Resource ID	HFPR
7	ON	11	ON
8	ON	16	ON
10	ON	22	ON
1	ON	4	OFF
2	ON	14	ON
5	ON	23	OFF
19	ON	17	OFF
20	ON	13	OFF

9 Conclusions

In task T6.4, we have embarked upon finalizing a local market design suited for implementation at the pilot sites. The local market overview chapter provides a base platform for all types of market operations (local, central, cross) in three distinct modes (normal, constrained, islanded) with various players (DSO, prosumers, producers, consumers, storage owners). Based on the resource and regulation constraints at each pilot site, different SESPs can pick and choose various aspects of the market design presented in this document to be implemented at the pilots. This document provides in-depth technical specifications at the functional level for the software development that will go into the ICT platform for SESP control and market cloud management. A detailed description of the EMPOWER platform together with its technical and user-oriented features are provided. Platform layout guidelines together with user interaction features have been recommended for enriched user experience. The trading platform has been presented for energy, flexibility and services trade and the details of the contract templates between SESP and various market players have been outlined for each type of trade. The functional features of trading mechanisms have been sketched out as sequence diagrams separately for in-community and cross market operations. In community market operations have been presented in both over the counter and auction formats. Depending upon the size of the local market, SESP can choose to implement one format over another. Specifications and recommendations have been made for simple, yet autonomous (or semi-autonomous) zero intelligence trading agents that operate on behalf of the SESP members. Energy and flexibility cross market operations have been provided in a nutshell by extracting and building up on core elements from D6.3. Detailed interactions with the central market together with the timeline for managing various SESP functions have been provided. Two separate implementation use cases, namely, Daily-LFM for DSO requests and Hourly-LFM for DSO requests have been outlined along with the timeline of their operations. The specifications provided in this document should be sufficient enough to develop a fully functional, user-oriented SESP cloud-based ICT platform.