CREATING A LOCAL ENERGY MARKET

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ABSTRACT

The local energy market concept in EMPOWER is introduced. It places emphasizes on a value oriented approach and not energy price alone. It is organized within a neighbourhood and supported by a platform based business model. The concept integrates trade in energy, end-user flexibility and energy related services and products. Example contracts are presented along with initial results related to recruitment and establishment of such markets.

INTRODUCTION

Can local energy markets cater for increased interest in distributed energy generation from renewable resources (DER)? Can the local market better deal with the negative issues associated with DER that many DSOs are currently faced with? How can people be engaged in order to take part in such a market? These are the most important research questions addressed by the still ongoing Horizon 2020 project named EMPOWER. Several European governments actively support investment in DER with different forms of incentives. DER can help to accelerate the transition to a fossil free energy reality. Many households, like in Germany, have followed suit. This has typically created situations and grid states for which the distribution system was never designed. Capacity threats and voltage problems in the local infrastructure, are but a few of the issues that must be dealt with. The main goal of the EMPOWER project is thus *to investigate how a local market can be designed to create incentives that boost investment in DER while at the same time create enticements for containing and balancing the renewable energy produced at the leaf needs of a distribution grid*. An early introduction to EMPOWER has been provided in [1]. A more substantial background on the project and details around the market and trade concept developed can be found online [2]. In this discourse we will attempt the first answers to the research questions put forward.

MAIN REQUIREMENTS

The EMPOWER project addresses each neighbourhood as a local market. In regions where DER is scarce the local market should encourage investments in such. When capacity increases and excessive surplus becomes default other measures need to be introduced. The local market is grounded on some simple principles. If more of the locally generated surplus can be consumed nearby a better physical balance can be achieved both locally and centrally. Excessive local demand can be contained by increasing the surplus. EMPOWER seeks the right incentives to achieve this through a market approach. An approach that must take both trade in energy as well as end-user flexibility into account.

In EMPOWER a third requirement has been added. The local market operation must be able to attract prosumers, small scale suppliers and consumers and be economically sustainable. This demands a viable business model that can ensure the creation, development and maintenance of such a market and engage its participants. Current energy prices and tariff structures in different countries may not be sufficiently favourable to support this. Moreover, a local flexibility market is not a well-established concept and may seem foreign to many ordinary house owners. Previous research has also shown that demand-response initiatives can be hard to "sell in", especially because of what is often perceived as a privacy intrusion problem [3]. Henceforth, a third market aspect was introduced where *services* and *products* serve an important role. They create high margin benefits that increase the attractiveness of the local market concept if coupled with other trade.

METHOD OF APPROACH

A smart grid approach underpins EMPOWER. Project initiatives that parallel the EMPOWER effort has been studied [2]. These include academic oriented approaches [4,5], as well as novel business activities such as [6] and [7]. Common to all is that they strive to find a way for local consumers to purchase energy from renewable sources in their neighbourhood. Different models of trade have been proposed to ensure proper interaction and settlement. Continuous double auctions or system brokered peer-to-peer contracts have been explored. EMPOWER sees a solution in a different way. It includes congestion problems and load issues as an integral part of the local energy market. The project has thus pursued a local market design that can be harboured in a microgrid as well as in an unconstrained part of the distribution grid. The latter represents the general case and is the most interesting. It must operate side by side with the central market or other local markets. However, understanding the "free flow case" also enables a solution for the isolated and semi-

constrained neighbourhood too. When no bottlenecks exist the local market will always be dominated by the central market. The local market for energy becomes a "*price taker*". Unless different tariffs, lower taxes and commissions favour selling and buying energy locally, price alone cannot justify a local market alternative. Other incentives must be mobilized and a *value oriented* approach must be adopted. This means less emphasis on energy as a commodity. A new "*energy experience*" must be created. The project has tried to identify attractive incentives to generate such an experience. This implies creating perceptions of *added value*. Figure 1 shows a list of strong and weak value boosters that have been addressed. Each of them can be combined to create an attractive, local energy offer.

Weak value boosters	Medium value boosters	High value boosters

• Green energy
• Local energy
• Lower commission
• Minor price differences on energy
	• Consumer membership
	  ◦ Influence
	  ◦ Recognition
	  ◦ Loyalty rewards
	  ◦ Shared faith and cooperation
	  ◦ Local and green energy
	• Capitalization on flexibility
		• Distinct price differences on energy
		• Add-on services and products
		  ◦ Discounts
		  ◦ Immediateness
		  ◦ Availability
		  ◦ Endorsement
		  ◦ Local
		  ◦ Complient
		• Bonuses
		• Smart capitalization on flexibility

Figure 1 Weak, medium and strong value boosters

To better understand such aspects we have explored why people dismiss regular offers from retailers and sign up for energy cooperatives [3]. The renewed interest in such cooperatives have surged over the past few years [2]. Joining a cooperative is motivated by incentives that are not particularly related to the energy domain. They are more universal. Some important incentives have been extracted and listed in Figure 2. Many of them pertain to non-monetary and emotional values that tend to go unrecognized, but can have a profound impact on people's preferences. Hence, EMPOWER has embraced the basic principles of an energy cooperative and introduced what we have called a *local energy trading community*. However, our investigation also established that several energy cooperatives lack a reasonable business focus and therefore a sustainable economic platform. Unpaid efforts and loosely defined organizational structures characterize several cooperatives [2]. This insight led us to study *shopping clubs*. Such clubs share some important characteristics with cooperatives in their engagement and containment of members. However, they are pinned on a commercial platform, which is organized around a market concept. Here members are primarily buyers. But some clubs encompass sellers too. The organization of the club leverages regular people's market power and creates an attractive target for suppliers of different kinds. All of these cater for an economic sustainability that many cooperatives lack. The ideas have been incorporated into the EMPOWER energy community. Finally, our research focused on the recent success of network markets [8] such as Uber, AirBnB and Lyft. It was established that the network market concept could

Typical reasons why individuals participate in energy cooperatives.

- It is voluntary
- It gives a sense of solidarity
- It yields social recognition
- It gives a sense of control over personal, «green future»
- It supports the notion that "together we are strong"
- It supports the idea that "Working together means achieving something together"
- It is a form of local, social welfare
- It nourishes local patriotism
- It leverages local market power
- It gives increased influence
- It offers co-ownership
- It offers an attractive form of cost sharing

Figure 2 Reasons why people join energy cooperatives

provide an interesting template for the local energy market that EMPOWER is pursuing. Web based shopping clubs and platform based business models supported by web browsers or smart phone apps also helped to form the EMPOWER concept. This also encompasses an online trade arena and a personal site (MyPage). The specifications include provisions for trade, settlement, measurement and control. Hardware that controls heaters, boilers and other appliances need to be managed. High resolution metering is required to enable remuneration and sound book-keeping according to contracts traded. Software agents are meant to alleviate end-users. The ICT specifications defined are comprehensive.

THE LOCAL MARKET IN EMPOWER

The EMPOWER market concept has been depicted in Figure 3. The hybrid market concept adopted provide more value for all participants than for one part alone. The different parts of the EMPOWER market can be more or less coupled. A fully integrated market would offer trade in contracts that combine energy, flexibility and services/products. The connection to the central market (or any other local market) is also illustrated. This emphasizes the free flow, but is also a necessity whenever local demand and supply does not match. Participation is voluntary unless the neighbourhood is situated within a micro-grid. A consumer or a prosumer that wishes to become a member of the local trading community will sign up in ways that are typical for shopping clubs. This is managed by an entity that we have called a *SESP (Smart Energy Service Provider)* [1]. The SESP may be owned or controlled by the community members, like a genuine cooperative, or it may be owned or operated by a DSO or a third party. The business models will differ accordingly. Consolidation of multiple local markets is possible, for instance by means of a *franchise system* or a *network market*, similar to that of AirBnB [9]. This offers

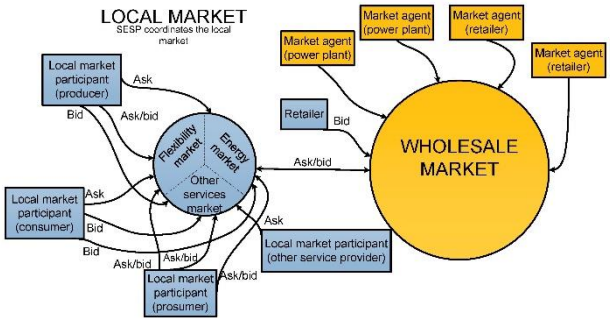

Figure 3 The hybrid, local market enabling trade in energy, end-user flexibility and energy related services and products.

scalability. Signing up with the community will yield immediate benefits such as discounts on services and products offered through the community. These benefits are provided with no other obligations. But it leverages local market power and attracts the interest of external suppliers who can reach a clear cut market segment directly. This caters for good offers that members of the community can enjoy. All members trade for free, while outsiders and professional parties pay a sign-on fee or yield a cut per transaction to the SESP. This revenue is fed back in full or in part to the community members depending on the business model. The SESP combines multiple roles that may be consolidated or split according to the regulatory regime under which it operates. It organizes the market and defines the rules of trade and the contract templates that will be used. It is also a market maker assuring sufficient activity and liquidity. The aggregator and retail roles can also be assigned to the SESP. This entails operations in the central market.

Price volatility and uncertainty may inhibit investments in DER. Stability and predictable pay-back alternatives are needed. Long term contracts based on government subsidies, like in Germany, is a case in point. It has been proven beyond all doubt that it has stimulated a capacity increase in DER. A proper question to be asked is whether this can be replicated without spending tax payers' money. Much of the answer can be found with the extra value boosters that can be combined and the organization of the community as a shopping club. To control and contain excessive surplus or large deficits that cause congestions or overload on local infrastructure similar mechanisms can be invoked. Demand-response, the use of storage and the use of price incentives can together, and in a collective form involving the full community, cater for this.

Local trade in EMPOWER can be peer-to-peer. In such a case the SESP operates merely as a broker or market provider. However, in order to build a local market from scratch, the SESP is believed to take a more active role (see Figure 4). For such purposes we have considered regular over-the-counter sales of bilateral contracts between the SESP and the community members. The SESP combines this role with a market maker role offering one price for the supply side and another price for the demand side. For a more mature local market with multiple members and higher competition we have proposed the use of a call auction, a form of non-continuous trade based on price scanning.

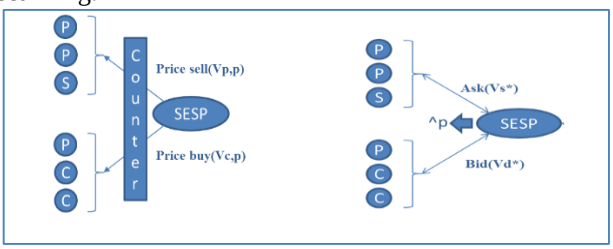

Figure 4 Left: Over-the-counter trade with bilateral contracts between the SESP and community members. Right: Price scan auction: The SESP acts as the auctioneer.

This still leaves some control with the SESP as it is in a position to interpret price signals from beyond and call out prices and offers that are competitive. This form of auction simplifies the task of the end-users and their trading agents. They will simply accept or reject a proposed price called by the SESP. The auction will terminate when the best possible balance between local demand and supply has been achieved.

TYPES OF CONTRACTS TRADED

Different contracts can be supported by the EMPOWER ICT system and traded. Two basic exemplars and a hybrid of these is presented here.

Cross-subsidized energy contract

The first contract to be described relates entirely to pure energy trade and constitutes possibly the simplest case that can be introduced in an unconstrained local market. In its basic form this contract can be issued in its entirety by the SESP and traded over the counter. Bilateral contracts between the SESP and local prosumers and a matching set of contracts with the local consumers are established. To enhance trade and increase trade volume this type of contract use cross-subsidies as a value driver. This means that local sellers are given a price mark-up and local buyers are honoured with a discount if they buy locally produced energy. Mark-ups and discounts can influence the settlement price directly, be offered as extra social recognition or be in the form of extra benefits expressed in some other currency, i.e. bonus points. For simplicity we address the added value provided by the SESP to local traders in monetary terms only. The following applies:

$$Cspot = Pspot + C1 \quad (1)$$
$$Ispot = Pspot - C2 \quad (2)$$

The external price signal is *Pspot* and specifies what other markets will pay or charge for energy. A unit cost *Cspot*

[€/kWh] or unit reward *Ispot* [€/kWh] defines the references for buyers and sellers respectively if they wish to deal in the external market. *C1* defines the regular cost for import and includes tariffs, taxes and commissions per kWh. *C2* defines similar types of cost for exports. If the SESP offers a local buying price, *Pbuy*, for all surplus that can be sold to local consumers under the condition that *Pbuy* > *Ispot*, prosumers and small scale suppliers should be attracted and encouraged to invest in more production capacity. A prerequisite for this is that local buyers prefer the renewable energy produced locally. The assumption is that this can be achieved if local buyers receive a benefit or discount so that *Psell* < *Cspot*. Obviously, if regulations will not except the local traders from regular taxes and tariffs, the cost gap incurred must be covered entirely by the SESP.

$$\text{Cost of trade} = (P_{buy} - P_{sell}) * V, \text{ where } V = \text{volume} \quad (3)$$

A neighbourhood with a low production capacity usually has fewer sellers than buyers. The mark-up for sellers should then be higher than the discount or benefits for the buyers. In the reverse case buyers should receive more. Strong enough incentives should turn consumers into prosumers and prosumers into bigger prosumers. This in turn should generate revenues from sales of PV panels, generators and associated services. A part of this revenue will secure the SESP a source of income that should cover the cost specified in Eq.3. The rest could be credited community members in the form of instant pay, annual bonuses or added discounts. One average price can be applied for the whole contract period. But prices can be different for different hours of the day and the week. Failure to meet contracted demand or supply for a specific hour could incur a penalty. With this type of trade and contract the SESP takes a significant risk. This risk can be mitigated if the SESP redefines its position and operates as a broker. Then peer-to-peer trade can be facilitated based on standard contract templates issued by the SESP. Each trader would then be responsible for negotiating a matching ask or bid. However, the contract template could still include a clause specifying a mark-up for the seller and discount for the buyer once settlement is reached.

Flexibility contract

Operation in the local flexibility market requires installation of controllers and storage devices such as batteries. The need for on-site devices and possibly technical support could be a barrier for participation. However, being part of a formal group, such as the SESP organized community, may lower the threshold for entry. Enjoying favourable energy contracts that stimulate more control on the home side could open up for general engagement in the flexibility part of the market too. Different needs for different areas should be anticipated. As pointed out in [1] the local DSO could benefit from the collective and orchestrated flexibility of a community where members are mutually dependent on each other.

Attribute	Specification	Example
Name of contract holder	String	Thomas Moore
Type	String	Scheduled
Date of endorsement	Date	Feb.16, 2016
Date of initiation	Date	Feb.17,2016
Date of termination	Date	Apr. 01, 2016
Contract renewal type	{automatic| negotiated}	automatic
Max load per activation [kW]	Number	1,5
Max number of activiations in period	Number	60
Device controlled	{boiler|heated floor|heat pump|heaters|battery}	Heated floor
Min temperature (C) (or max temperature for cooling)	{temp in room|boiler|not applicable}	15
Max ramp-up temperature (C)	Max temp if room or device needs to be thermally charged prior to disconnection	25
Days of activations	Calendar days	All weekdays
Permitted interval in morning	Hours	6:00 – 12:00
Permitted interval in evening	Hours	15:30 – 20:30
Max allowed activation time	Number of hours	2,5
Tolerance	% deviation tolerated	+/- 0,5
Strike price	Euros	11
Activation fee	Euros	4
Non-conformance clause	Text	See small print

Figure 5 An option for end-user flexibility specifying a strike price, activation fee and criteria for activation and deactivation.

Figure 5 shows an example of an end-user contract for routine load shaping. This was inspired by work presented in [10]. Similar contracts have also been defined for other needs, i.e., voltage control, instant load reduction. Such contracts resemble both forwards and options common in the financial market. It typically specifies when and for how long activation of flexibility can take place. Compensation will be in the form of a reservation fee (strike price) and an activation fee. The ratio between these two forms of compensation is still a subject for experimentation in EMPOWER. The strike price gives an instant reward and can be important for recruitment, while the activation fee is believed to yield increased loyalty when the need for more flexibility is needed. The strike price yields a nominal value as with any paper on the stock exchange. But it can also be auctioned for less or for more in the local market. Calls for other uses of flexibility can be constructed along the same lines. EMPOWER will allow contracts to be defined for each flexibility source e.g. boiler. However, as home automation systems (HAS) become commonplace a more universal contract should be offered. Instead of specifying a contract for a particular device a more general type can be designed. A simple request for peak reduction expressed in kW or kWh/h is generated. A home side software agent connected to the HAS will figure out how the request should be met and orchestrate the disconnection and reconnection of devices to produce a proper response.

A combo

A combination of the two contracts introduced above, is possible. Local energy prices can be used to balance surplus against consumption. Instead of creating specific flexibility contracts the agreement with the DSO can be translated into price boosts and discounts and included in the energy contracts instead [2]. The price mark-up for a

seller could be adjusted to the level of flexibility that he is ready to commit (surplus control or storage). Discounts for buyers could relate to their willingness to reduce loads on demand. The cost specified in Eq.3 could then be covered by means of the deal with the local DSO. Consequently, trade in *kW* and trade in *kWh* can be better linked. This principle has been borrowed from other domains whereby flexibility on the consumer side is coupled to the basic product or commodity traded. One example is the difference between an economy ticket and a full price ticket in aviation. The difference in price reflects the value of flexibility, which is typically offered with the full price ticket and not the other. It is further assumed that energy flexibility will be more moderately priced and more widely accepted in this way since it is coupled to the basic energy price. In situations where end-user flexibility [kW] is valued much higher than the price of energy the combo can also avoid speculative behaviour. The impetus to raise the set points for thermostats to achieve added flexibility is imminent if the value difference, *€/kW - €kWh*, is significant.

EARLY RESULTS

The neighbourhood market concept has recently been promoted in different ways and towards different stakeholders. A commercial entity has volunteered to adopt the SESP role for the different pilot sites in Norway, Germany and Malta. The concept has already been introduced to residents at Hvaler in Norway. A web based community platform has been created in earnest and different offers are being promoted along with the market related aspects. Every household has its own "My page" where they can monitor their consumption and production and energy exchanged. They can also follow the activities of the community. The basic energy contract described here and the trade community concept have been promoted in a regular commercial way through different channels. An important one has been general folk meetings in the neighbourhood where the first tests have been planned. The response has been very good and the introduction of the local market has created significant media buzz. This again has attracted suppliers of wind generators, batteries, PV panels, controllers for boilers and apps. The SESP has negotiated community benefits from all in the form of discounts up to 30%. Early prosumers upload homemade instruction videos to the community web to help other members. Knowledge sharing is taking place in different ways within the community. Currently 3 neighbourhood markets have been set up. Two more are underway. The SESP is also negotiating with the local DSO in order to go forward with a type of flexibility contract described in [1] and here. This has also lead to a cooperation between the SESP, the DSO, the community and a supplier who has recently installed a community battery. In the course of the process the SESP has split the community into lesser units organized around neighbourhood zones. Each zone shares a gateway that connects each member with the SESP and other members. Each household within a zone may request support from a trained super user within the neighbourhood. This is the person who also hosts the gateway. This person has volunteered to become a *local service prosumer* and *community facilitator*. This reduces overall costs for all and yield instant hands-on support. Sales of control gadgets and solar panels increases too. One recent meeting gathered almost 100 "would be" local prosumers. They all expressed interest in becoming a community member. More than 30% of the households present at this meeting are now getting involved. Since the inception of the first local market more than 10 new suppliers have come forward. Naturally, more evidence must be gathered before firm conclusions can be made, but so far instant engagement has been proven and DER capacity is on the rise.

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