EMPOWER
A network market approach for local energy trade

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***Abstract*—This paper describes the local market for trade in energy, flexibility and energy related services developed in the ongoing H2020 project, EMPOWER. It is based on a network market approach. The establishment of a local community of prosumers and consumers, inspired by Internet communities, energy cooperatives and online shopping clubs, is central to the idea. At the heart of the community the Smart Energy Service Provider (SESP) can be found. The principal entities and operations associated with the local market concept developed are explained. Some early field results described.**

***Index Terms*—local energy trade, network market design, smart grids, renewable energy, energy communities**

I. WHY LOCAL ENERGY MARKETS?

The EMPOWER[1] project has identified multiple reasons for why local markets should be considered. These include:

- The advent of potent Smart Grid technologies
- A steady increase in Distributed Renewable Energy Resources (DER)
- Increasing loads due to the green shift
- Current state of the retail and whole sale market
- The lack of focus on what energy users really want
- Increased proficiency among people in new ICT (Information and Communication Technologies)

Smart grid technologies offer more control and transparency into the distribution grid. Information sharing is an immediate benefit. Continued government focus on climate issues and emission goals, along with a steady price decrease on small-scale generators and panels have created a surge for local production situated at the leaf nodes of the distribution grid. *Prosumers* have emerged. In some places excess surplus from these has become a reason for concern. The traditional electricity system was never designed for a bidirectional feed. Voltage issues, congestions problems are two of the issues many utilities are faced with. Government programs for non-fossil heating have been introduced too, and electric vehicles have since long made their entry into many European driveways and city traffic. Because of such developments power loads concentrated in short periods are increasing and tend to threaten grid capacity. Solving problems like these as close to their source is often a good strategy. This recommends that issues related to the increase in DER and loads, stemming from the end-user side, should be dealt with locally. A market approach seems pertinent in this context.

A critical look at how most end-users are served and what value for money they are offered is also pertinent. When the incumbent utility defines quality of supply it typically relates to aspects such as voltage control and resilience defined by the regulatory bodies. But it is questionable whether this concept of quality fully matches the expectations of the end-users that pay the bills. A significant body of research places emphasis on an *energy experience* where comfort, convenience, cleanliness [1] and even coziness [2] govern decisions about energy use. Security and safety in its broadest sense underpin all this i.e. environmental safety (outlook for our children), economic security, security of property and more. Energy as a commodity is insufficient. Additional aspects need to be prepared to meet the actual demand and create *perceived added value*.

Current, centralized energy markets seek settlements on partial equilibriums and tend to disregard externalities that push costs on a third party. Local markets can better seek a general equilibrium i.e. for both energy and flexibility. We argue that negative and positive externalities with a local impact can better be incorporated by means of local markets.

When addressing both present and future end-user needs it should be recognized that a new generation of more technology proficient people are emerging. ICT technologies such as social media and smart phones have made people more self-serving and insightful in many ways. The advent of Internet of Things and the influx of Home Automation

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Systems (HAS) are creating a new platform for energy management that suggest more active users and a less centralized energy management concept.

All of the items listed above are arguments that provide a rationale for studying the potential of local markets. More specifically the EMPOWER project asks, *how can we increase the local DER capacity while avoiding the negative effects that it may cause? How can end-user flexibility be leveraged and produce a commercial effect?* In one sense it is maximization problem that tries to accelerate increase in DER capacity and the "green shift process", but within the constraints set by the existing electricity system. A network market approach has been chosen to address this.

II. A LOCAL ENERGY MARKET – THE EMPOWER DEFINITION

In the context of EMPOWER a local market is rooted in a residential area or similar and based on a micro-market [3] concept that includes prosumers and consumers as well as storage facilities within such a community. Different forms of smart grid enabled services connect these and other players in this marketplace. Basic energy trade between people located in the same neighborhood constitute an essential part, but is not limited to this. The local market in EMPOWER also treats end-user flexibility and associated services and products as tradeable assets. In the following we will use the term *service* to include products too. The local market can be technically delineated by the point of common coupling (PoCC) e.g. a secondary substation. This type of demarcation and the natural neighborhood aspect give rise to a community of energy users that share some fundamental interests. A local market thus employs market rules in a medium voltage (MV) and low voltage (LV) scale. Multiple local markets may connect in different ways to constitute a structure of several small energy units, each with significant provisions for local generation. The local generation may not cover in full the consumers' demands within the micro-market. Hence a local market is typically characterized by periodic surplus and deficit that demand interaction with its surroundings. The local market is not the equivalent of a micro-grid, though the design and efficiency of a system of micro-markets could benefit significantly from micro-grid technologies.

The definition offered here postulates that a local market distinguishes itself from the central wholesale electricity market specifically with its more holistic approach to create the type of energy experience suggested above. The EMPOWER local market is thus characterized by de-commoditization of energy sales at the distribution level.

III. OTHER INITIATIVES

A limited, but increasing number of research initiatives on local energy markets have been reported in the literature over the past few years. A review of some important ones can be found in [4]. Industrial initiatives claiming to support local trade have also emerged recently. Examples of such are [5], [6]. Research initiatives have typically focused on energy trade alone using software agents as instruments for continuous trade [7],[8]. In their own way they show how high frequency trade can be accommodated by means of multi-agent systems (MAS). However, few of these have been tested from a business point of view. User orientation has also been largely ignored. Energy trade in light of congestion issues have mostly been excluded too. An exception is Vytilingum [7] who have also incorporated measures for resolving capacity limitations across micro-market nodes.

Operators like Energinet.dk [9] have solicited the possibility of a flexibility market to manage both the temporary surge in demand as well as the variable production caused by PV panels and wind. The iPower initiative [10] has also pioneered the design of a general flexibility market.

Combined contracts (combos) encompassing more than energy as part of the trade has been explored by others too. Its importance has become more pronounced, especially in low price energy markets [11]. In the ongoing project the application of cooperative game theoretic solution concepts to sharing renewable energy have been studied too. Literature such as the ones by Street et al. [12] led us to understand the importance of a community approach in EMPOWER.

IV. METHOD OF APPROACH

The development of the EMPOWER concept is based on an extended body of former research and reported experiences from industrial initiatives both within and beyond the energy domain. A review of the most important literature has been documented. The emergence of microgrids created a foothold for the idea of a local energy market. However, it was established early that a local market approach offers value even if there exists an unobstructed connection to the central market. A general study of local versus more centralized and global business concepts were also performed. The basic question asked was whether a local approach offers the type of perceived added value that we were looking for. We found that emotional aspects related to local brands and local communities supported empirical market studies that was conducted earlier [13]. Local patriotism and sentiments that associates with local institutions can have profound effects on consumers' choices. Much support for the claim that local marketplaces can be competitive can be found in sources like [14] too. There are aspects of added value associated with both "green energy" and "the local". We solicited end-user input that supported this based on previous surveys and field tests. Meetings with prosumers and consumers produced direct insight on how people in different communities are thinking. Moreover, we asked the question why the idea of energy cooperatives have been rejuvenated? Part of the answer was found in literature such as [15],[16]. Extracting information from multiple web pages revealed that there is a gap between what incumbent energy companies offer and what many people want. What

then does energy users actually value and what make them apprehensive about energy use, generation and market participation? More answers were found in scientific papers such as [1],[2]. Acceptance criteria and taboos were extracted and documented.

Incentives that cause growth in local energy generation and DER was studied. The German market offers an interesting case in point [17]. Government subsidies and long term contracts have caused an indisputable rise in DER capacity.

To determine the competitive latitude for local markets different added value drivers and non-monetary reward mechanisms were addressed. Cooperative game theory offered a lead. Descriptions of online shopping clubs and different incentive programs such as frequent flyer programs [4] provided important insights that we used to form the concept presented here.

The impact of recent and emerging network markets [18] cannot be underestimated. ICT based trading systems like AirBnB [19], Uber [20] and Lyft [21] all inspired the conceptual market development in EMPOWER. Well-known brands like Google, YouTube and Facebook [18] are all examples of systems that offer a market platform for asynchronous exchange of assets. The participating parties can engage for free. The cost of operation is covered entirely by third parties who buy advertisement spots and pay for pertinent data. Buyers and sellers use recognition tokens (i.e. likes) only as the common currency.

The goal forward is to verify the viability of the EMPOWER concept in three different European regions, in Norway, Germany and Malta.

V. THE EMPOWER MARKET AND BUSINESS CONCEPT

The market design and the associated business model in EMPOWER is for the most part inseparable. We will describe the concept developed in terms of a set of key elements.

1. The Smart Energy Service Provider (SESP)
2. The community idea
3. The network market idea
4. The hybrid market idea
5. Trade and contracts
6. Market reinforcement
7. Scalability

A. The Smart Energy Service Provider

The Smart Energy Service Provider (SESP) is a pivotal entity in the EMPOWER concept. It is a stack of roles and was first introduced in an earlier paper [22]. The different roles can be separated or consolidated according to the regulator regime and market opportunities that characterize the realm of its existence. The principle idea is that the SESP *manages the local market* and *provides an arena for local trade*. Unless the SESP is situated in a neighborhood separated or partly isolated from the central market it must also extend its operation towards other local markets and/or the central market. Thus the SESP takes the position of an *aggregator*. This emphasizes the fact that local markets can co-exist along with the established whole-sale market and its regular players (see Figure 1). A local market, which enjoys an unconstrained channel to the central market have few technical responsibilities. Those rests with the ordinary players e.g. DSO and TSO. It is much less of a concern of the SESP. An exception are the cases where the SESP takes on the responsibility for demand-response programs on behalf of the DSO or use end-user flexibility to achieve commercial ends in the balancing market. The SESP also occupies an important role as a *market maker*. This means that the SESP may play an active role in the market to assure liquidity and increased participation. This can be especially important in the early phase of a local market or when the number of active traders is low.

B. The community idea

The EMPOWER local market is situated in a neighborhood. This constitutes a *natural community* where shared assets such as the grid, roads, feeds and sub-stations are typically found. The community idea in EMPOWER has been leveraged and formalized along the lines of *energy cooperatives,* however with a commercial flavor inspired by *shopping clubs* and *social media*. Formal membership is voluntary, but meant to provide a string of benefits for the individual member and the whole community. This implicates some powerful business drivers that could help to attract and contain residents and others in the neighborhood. The EMPOWER community also offers a concentrated and homogenous market segment for professional service providers. By paying a sign-on fee and offer discounts and other benefits to community member the professional suppliers of services and goods can be given special favors that save sales and marketing costs. Thus the community can be viewed as a coalition that can gain more than one member alone. The neighborhood is a potent coalition. Neighbors share grid connections and other infrastructure, which they all are dependent on. A degree of cooperation will already exist. Seen from the local DSO, a neighborhood based community is also a coalition that can help to overcome congestions and capacity issues arising from excess demand or supply. By leveraging this coalition's aggregated flexibility, capacity issues can be circumvented. However, quantifying and sharing the benefits of cooperation amongst all players in the local market in a fair and stable manner is a non-trivial problem of great interest. The community idea thus pertains to cooperative game theory. In fact, we see our definition of a community as a *grand coalition*. Community rules have been introduced to avoid sub-coalitions and to assure efficiency as well as a reasonable and feasible payoff for all members. To survive, the community must assure *imputation* too. This means that active community participation should generate more value for the individual than the individual can achieve alone.

C. The network market idea

The community forms a natural *network market* provided that the right incentives for trade and exchange are established. This has been extensively explained in [22] - [23]. Many new trade concepts on the Internet pertain to the network market concept. A network market prospers on *demand economies of scale* in contrast to the more common *supply economies of scale* [18]. A network market needs a connected platform to work. Hence, a network market is closely related to what has been termed a *platform based business model*. The concept is well known from systems like Uber and AirBnB. EMPOWER has adopted a similar approach. Management of the market may be seen as an act of network orchestration which aims to generate *positive network effects* in the form of exchanges of energy, end-user flexibility and services. Two types of networks effects are pursued in EMPOWER, interactions between people on the "same side of the table" and cross-effects based on a more traditional customer-supplier relationship. The idea is to generate amplified outcomes of all activities in the hybrid market.

D. The hybrid market idea

EMPOWER attempts to exploit the differences between the three markets to achieve this. The differences have been shown in Table I and explained below.

Attraction effect: Refers to the enticement and engagement that the different offers in the three markets can produce. Trade in the service part is characterized by items that have pronounced design and multiple quality features. Accessibility and immediateness (both mentally and physically) are also important quality measures.

Awareness effect: Associated with the former, but is not the same. It relates to the knowledge of a given product iti is distinguished from others.

Branding potential: Branding is associated with the former two, but it relates to the aggregated "energy experience" more than energy itself. This experience builds on the attributes of what and how it is offered to satisfy customers.

TABLE I THE HYBRID MARKET: KEY CHARACTERISTICS

Characteristics	Services	Energy	Flexibility
Attraction potential	High	Moderate	Low
Branding potential	High	Low	Moderate
Awareness potential	High	Low	Low
Profit potential	High	Low -Moderate	Moderate-High
Naturally local	Often	Rarely	Typical
Cohering potential	Moderate	High	Low
Community oriented	Rarely	Typical	Necessary

Profit potential: The profit margins in energy in the Nordic electricity market is currently very low. It is a little better in other parts of Europe. But still low when compared to the margins that can be obtained with more tangible goods.

Naturally local: Does the market have natural local sourcing and has it been developed as such? A functional flexibility market that serves the local DSO is inherently local.

Natural community: This implies assemblies of people that share a particular environment or facility which unites them in some way or another.

Cohering potential: Related to the one above. This implies the ability to leverage and organize coalitions of individuals and allow the community concept to prosper. An energy cooperative is a case in point.

E. Trade and contracts

Where there exists an open channel between the local and central market the local market will always be a *price taker*. This is a challenge that needs to be overcome if local trade is going to take place. In fact, the cost of buying electric energy in the central market should not yield a better deal than trading within the local market. How big the required difference needs to be depends on the state of the grid and the state of local production. A market approach regulates this through demand and supply. Similarly, the benefits achieved for selling locally should be perceived more attractive than selling it through an aggregator. This is not necessarily a price issue, but a utility related problem of which price setting is just one element. The aggregated utility offered by the traditional market, as seen from the end-user, relates to quality of supply, tariffs, taxes and price. The local market can include much more into the utility function.

In EMPOWER we have introduced long term energy contracts as the most important instrument for capacity increase. The contracts traded resemble financial instruments such as forwards and options. End-user flexibility is meant to cater for short term variations for multiple reasons. End-user flexibility can be self-imposed to accurately honor a long-term contract or SESP imposed in order satisfy a contractual agreement entered with the DSO. However, it may also relate to a community mandate given to the SESP in order to seek opportunities in the central spot or balancing market. Contracts related to participation in a SESP or DSO initiated flexibility regime takes the form of options and have two prices, a strike price and an activation fee.

Some deviations might be treated by means of insourced services. A local storage service offered by an external provider is one example. As presumed earlier it is possible to combine such elements into combined contracts where energy, flexibility and services are included. The following illustrates the basic principles for simple and combined offers and contracts. Consider the following typical trading example. Assume *Ask(S,p1,V1)* is seller's S offer of volume V1 for sales price, p1. *Bid(B,p2,V2)* is buyer B's offer, where buying price is p2 for a volume V2. After negotiation we get *Settlement(S,B,p,V),* which is the result of negotiations and becomes the final contract. Assume then the following:

$$Ask(S,p1,V1,\Delta p+, A1),\ Bid(B,p2,V2,\Delta p-, A2) \rightarrow Settlement\ (S,B,p,V,\ \Delta p+,\ \Delta p-,A1,\ A2)$$

This relates to a combo and is an extension of the example above. But the settlement is hinged on a standard set of conditions (Ai) that pertains to community rules. One

condition could refer to additional needs e.g. guarantees, payment services offered by third parties. In return the community provides some additional payoff *„Δp+/-* which tops the clearing price. A1 and A2 could refer to flexibility too. The *Δp+/-* would then relate to the value of that flexibility. This could reflect the value of "self control" or whatever arrangement has been made with the local DSO. A combined contract like this is not unusual in other domains e.g. aviation. A low-fare airline ticket gives little flexibility. The expensive ticket entitles the passenger to rebook at his own will. The price difference between the two tickets can largely be attributed to flexibility.

If A1 and A2 are *nil* and a mark-up, *Δp+* and discount, *Δp-*, are still valid we have a perfect case of subsidization. However, in EMPOWER subsidies of this nature are not government funded. The cost gap related to *(Δp+*V)-(Δp-*V)* is covered by network effects related to sales in other goods. If the revenues and profits generated through sales done between community members and third parties, the SESP has a means to cover the subsidizing cost. If the *Δp+/-* can help to stimulate increased and profitable sales in more DERs, which the SESP controls directly or indirectly, reinforcement has been achieved. Table II provides an overview of different types of contracts. An added value (*Δp+/-*) and payoff indicator is associated with each. *Xi > Vi* implies that payoff as a member (*Xi*) of community *N* will be higher than pure individual involvement (*Vi*).

TABLE II CONTRACT TYPES AND ADDED VALUE/UTILITY AND OBLIGATIONS

Contract type	Δp+/-	Feasible payoff	Added obligation (A)
Regular	0	Xi = Vi, i∈N	None
Boosted	0, but with non-monetary rewards	Xi >= Vi, i∈N	None
Cross-subsidy	>0	Xi >= Vi, i∈N	None
Flexibility combo	>0	Xi >= Vi, i∈N	Flexibility = ΔV+/-
Service combo	>0	Xi >= Vi, i∈N	Service = λ+/-
Flex & service combo	>0	Xi >= Vi, i∈N	ΔV U λ

EMPOWER supports different forms of trade depending on the maturity of the local market. To kick-start the local market, a simple over-the-counter trade has been introduced using cross-subsidized contracts. This suggests a form of asynchronous trade that pools demand before the supply side is served (or vice versa). As market engagement increases it is anticipated that the SESP can step back and take the more passive role of a broker. Then the SESP will provide standard templates that traders will use. Clearing can be based on full or partial matches. In this state the likelihood of competing offers will rise too. This opens for auctions. We have chosen a call auction type called *price scan auction* [24]. The SESP call out a buying price and a selling price. In return, traders offer a volume for that price. If the aggregated match between demand and supply is poor a new price will be called. When a good match is established the auction terminates.

To optimize the benefits for itself and the community the SESP may also operate in the central day-ahead, intraday and balancing market. Periodic deficits must be covered. Surplus that cannot be retained within the community needs to be exported. Obviously the EMPOWER concept resides on the

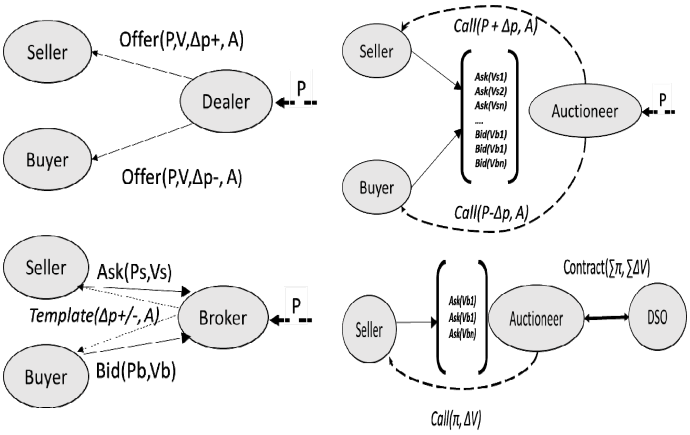

Figure 1 Trade concepts (counter clockwise). i. SESP as regular dealer and continuous over the counter trade. ii. SESP as broker controlling peer-to-peer deal making and issuing the contract templates. iv. SESP as auctioneer for price scan auction v. Reverse English auction for trade in end-user flexibility. P is the price signal from the local market.

idea that locally produced energy yields more added value and therefore the first choice of community members.

Empower allows trade in pure flexibility, if needed. A reversed *English auction* has been designed for this (Fig.1). Technically it is a one sided price scan auction. Simple software agents handle the more routine like aspects of the trade on behalf of the end-user. These agents can operate both as decision makers and as decision support. They have been introduced to boost trade and alleviate the regular user.

F. Market reinforcement

Fig.2 indicates how activity in one part of the hybrid market should accelerate and amplify activity in another. For instance, with simple cross-subsidies, consumers should be tempted to cross the line and become prosumers too. Existing prosumers should be encouraged to invest in more generation capacity, batteries and control gadgets. Demand for diagnostic services to secure persistent generation and management type of services are also likely. This in turn should pave the way for demand-response programs offered by the DSO and SESP. More flexibility related activities yield more revenues. More product and service sales increase revenues and benefit for all. Then, more community members and more third party suppliers of services are recruited.

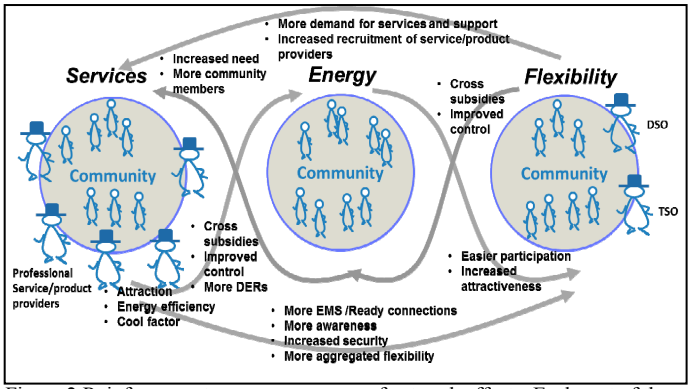

Figure 2 Reinforcement as a consequence of network effects. Each part of the hybrid market amplifies activities and revenue streams in the others.

effects that could yield increased benefits, lower prices and additional capacity increase. As traction increases all parties in the network should benefit.

G. Scalability

While maintaining local focus, the concept is scalable. Different SESPs can be syndicated under global control (like market systems such as Uber and AirBnB). The approach chosen applies directly to a particular type of expansion strategy for network markets called the *micromarket* strategy. Facebook applied this after its inception in order to expand in the shadows of established social systems at the time.

VI. EARLY FIELD TESTS

TABLE III EARLY RESULTS FROM NORWAY

No. of established energy neighborhoods – zone level	4
No. of new members	60
No. of volunteers – super users	>10
Type of user delivered support/services	Apps, videos, janitor services, system support etc.
No. of external suppliers requesting access	15+
Community batteries delivered and installed	1
Increase in PV sales	60%
Increase in local DER capacity	100%
Increase in sales of monitoring gadgets	60%
Competitors	2

The EMPOWER concept has just recently been introduced in one region (Hvaler, Norway). The SESP is a retailer converted to the idea. Over the counter trade with cross-subsidized type of contracts has been catered for. It is too early to conclude anything, but positive network effects are stirring (see Table III). After its inception, several volunteers came forward and a lot of media buzz was generated. As anticipated, this stirred the interest of suppliers who wish to seize an early opportunity. Quite rapidly too, the community multiplied 3 times and members started to post videos, offer system support and janitor services to their neighbors to recruit more local prosumers. A street level battery has been installed by a principal supplier that offers storage services. Local PV capacity has started to increase. Interestingly the sales of energy monitoring gadgets have doubled. The local consumers are becoming increasingly active. Two competitors have come forward and picked up part of the idea. This should indicate the type of business potential that we are seeking. Currently we are monitoring developments carefully to expose both strengths and weaknesses before more sophisticated forms of trade and contracts are introduced.

VII. CONCLUSION

The experimental local market concept in the EMPOWER project has been presented. It is based on a network market approach known from other domains. The idea is to organize communities harbored around a trading platform and an entity that we have coined the SESP. Community membership and participation in the local market should generate more benefits than regular, stand-alone activity. Early results from the first test site indicate that network effects are taking place.

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