A BUSINESS CASE FOR A LOCAL COMMUNITY ELECTRICTY MARKET

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ABSTRACT

In this article we try to identify real time economic signals that could drive a local community electricity market. Two pilot projects one in Germany and Italy will try to demonstrate the working of such a market with the purpose of fostering investments into local solar energy and storage. Members of the community should be able to exchange electricity while relying on the electricity retailer as an alternative to locally produced electricity.
In order to make a business case for the local market, one needs to answer the question of what are the local prices based on since the market is coupled to the wholesale market. Also, why would one community member be ready to pay more than another to the same local producer?

We describe the drivers behind the local market. These come mainly from three different sources; avoided network losses, reduced network capacity and a reduced tax burden on the locally produced electricity.

The article argues that excluding taxes, there are short and long term benefits to be gained from active demand side participation. The short term benefits are related to network energy losses and represent at most a few percent of the retail cost of electricity. Long term savings are due to investment deferral and have a very slow dynamic due to the length of the network component lifetime. An optimistic estimate of both types of savings is provided. The article concludes that the economic case for the local market is rather weak, but it could change due to a number of technological and economic trends.

INTRODUCTION: DEMAND RESPONSE AND DISCERNIBLE TRENDS

In 2013 the EU FP7 funded research project CoSSMic was initiated. The idea behind it was to establish a local electricity market where members of a neighbourhood can participate as electricity consumers and/or suppliers. This local electricity exchange would hopefully stimulate the neighbourhood to invest into flexible demand, solar energy and storage and improve its carbon footprint by gradually reducing the exchange with the transmission grid.

Without abundant storage, a flexible demand is essential to the functioning of the local market. Given the level of electricity prices, price volatility and household electricity consumption, however, the economic case for demand response in Europe is still weak. Also, unlike in the US system, where outages cause economic damages in the order of 1% of GDP [1], system reliability in Europe is relatively very high. On a national scale the countries that develop the technologies first, can join the race and benefit from job creation [2], but the case at the household level is yet to be made.

The few tens of euros per year that can usually be saved through demand response programs are too small to justify either thousand euro investments into enabling technology or significantly alter consumer behaviour. But a few emerging trends could soon change this:

- Renewable energy support is gradually being phased out, providing a high incentive for small PV (photovoltaic) producers to change their consumption and use their own energy;
- Falling costs of PV, battery and electric vehicles; the levelized cost of electricity from PV has reached grid parity in many European countries. Battery systems seem set to become a viable option to increase self-consumption of PV electricity.
- Together with battery costs, electric vehicle costs will also continue to drop. Electric vehicles offer further possibilities for flexibility as well as considerably increasing total consumption.
- Intelligent devices and intelligent buildings; after years of initially very high technology costs, simple commercially available smart home systems are reaching costs in the order of a few hundred euros.
- Peak capacity based network tariffs; as more and more consumers produce their own electricity, network operators will switch to charging higher, peak capacity based tariffs and lower energy based tariffs. This will provide a stronger incentive for peak reduction.
- Crowd-funding and cooperatives; renewable energy is a popular sector for crowd-funded projects. These can strengthen the sense of community and offer cost savings in a very capital intensive sector, since small investors demand lower returns than bigger ones.
- Self-sufficient buildings and neighbourhoods with network as back-up supply; these trends could make microgrids, where community members can share local energy resources and reduce their use of the network an increasingly more attractive option.

This article looks at the economic case for a local electricity market. It first describes a model of a local market and the economic reasoning behind the bidding into the local market. It then provides an estimate of the potential economic benefits of flexible demand that is necessary for the market to work. The second section therefore focuses on the network costs to explain how price signals for the local market can be derived from network cost savings. The benefits stemming from the variable electricity prices are at this point dealt with only superficially. They are considered in the next section where the pricing mechanism for the local electricity market is described.

PRICING MODEL FOR THE COMMUNITY MARKET

During the entire project two kinds of price settings will be investigated:

Case 1: Variable network charge and variable energy tariffs for a local electricity market.
Case 2: Fixed peak power based network charges and variable energy tariffs for a cooperative community. The community schedules its consumption in a way that minimizes day-ahead market costs and participates in the intraday and balancing markets.

This article focuses on the first case. It describes a pricing mechanism that could be used to stimulate the electricity exchange between members of a community at the distribution level. The second case will be investigated at a later point in the project and tested in the trials in two pilot projects, one in Konstanz, Germany, and the other in Caserta, Italy.

So how can the price be established if we have a local electricity market where consumers and generators can bid and exchange electricity? Two consumers bidding for the electricity locally would want to pay less than they pay to their supplier (we assume that they are given the choice whether they want to buy from the supplier or locally). The price that their supplier charges them can be higher than a local price for a number of reasons. For example, by buying locally they can avoid a part of the network losses, avoid paying some taxes and levies, or avoid high spot market prices. Table 1 lists the possible sources of savings when a transaction between a local generator and consumer occurs.

The question remains why would two consumers bid different prices into the market? One reason is that they can be charged different prices by their suppliers. Another reason is that depending on where they are located with respect to the generator, network losses can be higher or lower.

Level	Source of savings
State	Avoided value added tax Avoided electricity tax Avoided renewable energy levies Avoided public space tax
Supply	Variable prices
Transmission	Peak reduction Energy balancing Reduced energy losses
Distribution	Peak reduction Reduced energy losses

Table 1: Possible sources of savings in electricity cost for consumers

To illustrate this fact Figure 1 depicts a simplified grid diagram. The grid is divided into high voltage, which is part of the transmission system, and the medium and the low voltage that constitute the distribution system. The figure shows a generator and two consumers. Generator can be a consumer whose solar installation produces more than she is currently consuming.

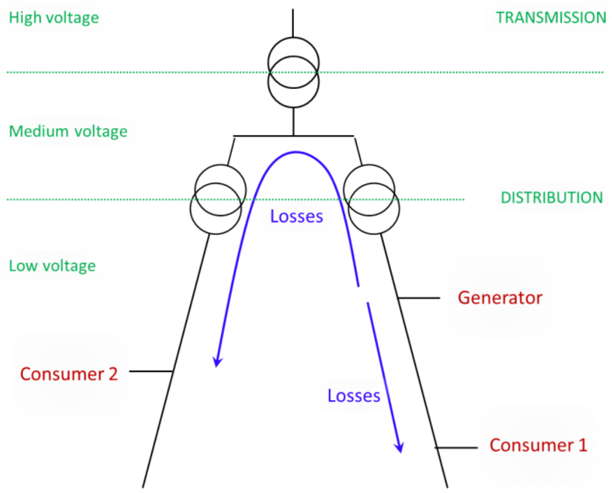

Figure 1: Electricity grid diagram with a generator and two consumers

Consumer 1 and Consumer 2 can be consumers with a solar installation whose consumption exceeds the electricity production or consumers without a solar installation. Generator and Consumer 1 are connected to the same low voltage line, which means that the electricity losses between them are very low. Also, if by exchanging energy they manage to reduce their combined load permanently, the network capacity can be reduced. Consumer 2 is also located at the low voltage level but connected to a different low voltage transformer.

Generator is selling her electricity to the best buyer. This can be the state with the feed in tariff, the spot market with possibly a feed in premium, Consumer 1 or Consumer 2. The two consumers can purchase the electricity from Generator or their supplier. If they purchase it from Generator they avoid the transmission network charges and a part of the distribution charges since the electricity is only transmitted locally. Below are the three participants' alternatives, which are then summarized in Table 2.

Generator; she is currently not charged for network use of the PV plant. She just pays the connection charges and in future possibly the network capacity tariff corresponding to the peak production. Table 2 indicates this situation with "/" in both "energy charge" and "taxes" columns.

So the first alternative for Generator is to sell the electricity at whatever arrangement she may have, feed-in tariff, spot market with or without the feed-in premium.

The second alternative is to sell the electricity to Consumer 1 receiving Bid 1. The third alternative is selling to Consumer 2, receiving Bid 2.

Consumer 1; Purchasing the electricity from the supplier implies paying for the energy cost at market rates, the transmission system and distribution system energy charges and the full taxes.

Buying the electricity from Generator, Consumer 1 avoids the transmission energy charge as well as most of the distribution system charge. Being located on the same low voltage line as Generator, distribution system losses will be minimal.

Consumer 2; the two alternatives are the same as for Consumer 1. However, Consumer 2 is connected to a different low voltage transformer and drawing the electricity from Generator will have considerably greater losses, twice the low voltage line losses, twice the low voltage transformer losses and medium line losses (Figure 2).

How will the price be established? Generator receives a feed-in tariff or a market price (RES price in Figure 2) that is lower than the price Consumer 1 and 2 pay. Both Consumer 1 and Consumer 2 can acquire their electricity from their respective suppliers. Their electricity price includes the energy costs, transmission and distribution charges and taxes (column "Retail price" in Figure 2). Opting to buy electricity from Generator means that they can avoid paying the transmission charges, a part of the distribution charge due to the avoided losses, and a part of the taxes that would otherwise be imposed on the retail price of electricity (column "Local market" in Figure 2).

Their bid has to be higher than what generator would receive outside the local market. The price in the local market will therefore lay somewhere between what Generator would receive from the state or spot market and what the Consumer 1 or Consumer 2 would pay to the supplier (the dotted black line in Figure 2).

Participant	Alternative	Electricity price		
		Cost of energy	Energy charge / loss compensation	Taxes
Generator	Market Consumer 1 Consumer 2	RES rate Bid 1 Bid 2	/ / /	/ / /
Consumer 1	Supplier Generator	Supplier rate Bid 1	Full TSO + DSO DSO losses minimal	Full Reduced
Consumer 2	Supplier Generator	Supplier rate Bid 2	Full TSO + DSO DSO losses	Full Reduced

Table 2: Local market participants' alternatives

Just how much will they actually bid? Consumer 1 has lower distribution losses and corresponding charges as Consumer 2 since he is located on the same low voltage line as Generator. The net benefit is greater if Consumer 1 purchases the electricity from Generator. If only economics plays a role in both consumers' bids, Consumer 1 will consequently be able to offer a higher bid than Consumer 2.

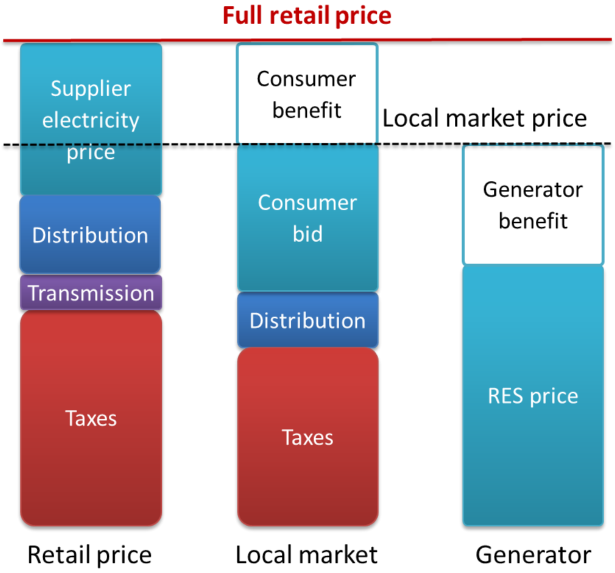

Figure 2: Consumer and Generator benefit and the formation of price bids on the local market.

ELECTRICITY COST BREAKDOWN AND THE BENEFITS OF FLEXIBLE DEMAND

The following is an estimate of the benefits of flexible demand. It is not a rigorous cost analysis but rather a very optimistic estimate. The conclusion being that even a very optimistic estimate doesn't seem to imply the necessary economic incentives for flexible demand. The data for the network cost composition is taken from

Finland, since corresponding German sources couldn't be found. The savings are capacity related and energy loss related. The capacity component is high in Finland. For the energy losses we take an even higher estimate than the Finish.

Energy cost composition

To estimate the benefit and understand the potential sources of savings we first look at the electricity cost composition. Figure 3 shows the typical retail electricity price composition for a German household in 2013 [3].

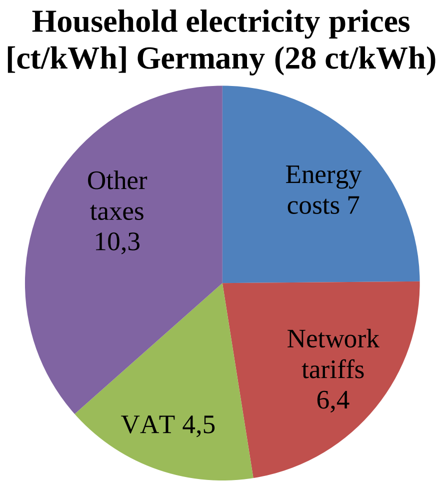

Figure 3: Retail electricity price composition for a German household in 2013 [3].

Energy and network costs constitute each close to one quarter of the total cost of electricity. Wholesale electricity prices usually vary between 30 EUR/MWh and 45 EUR/MWh. By shifting its load, a typical household with a yearly consumption of 4.000 kWh could therefore save in the order of 0.5 ct./kWh or 20 EUR per year.

The remaining 50% of the cost in Figure 3 is the value added tax and other duties such as the levy to finance the PV feed-in tariffs and CHP support etc. Under favorable regulation some of these charges can be avoided when consuming one's own or locally produced electricity. Since network costs play a significant role in the proposed community market mechanism the entire next subsection is dedicated to these.

Distribution network costs

The distribution network tariff must cover the different types of costs that distribution system operators (DSOs) incur. Metering and administrative costs are roughly proportional to the number of customers, energy losses are volume dependent, investment costs are capacity dependent and so forth. Costs can be broken down into five categories [4]:

- **Capital costs;** related to investments in the infrastructure that includes overhead lines and underground cables, substations and substation components, control centers, ICT, metering systems. They also include capital depreciation and interest.
- **Operation and maintenance;** Operation including system services. The cost is proportional to the capital costs and to the length of the lines, the rated power and voltage levels.
- **Procurement of network losses;** network losses constitute approximately 5-15% of total cost (the major share of them happen in the distribution). Depending on the country network losses are responsibility of either DSOs and TSOs or suppliers.
- **Customer service;** include metering service, invoicing and other administrative and commercial costs, cost of meters and ICT systems, as well as O&M costs. These costs are related to the number and not so much the consumption of the customer.
- **Overhead costs;** Corporate costs that are not directly related to network O&M.

Figure 4 shows the cost composition of a DSO [5]. The values are representative of Finland, but shouldn't deviate significantly from other systems. Capital costs constitute the major part of all DSO costs. They are proportional to capacity and can only be influenced in the long term. We look at them in the subsection after the short and medium term costs savings.

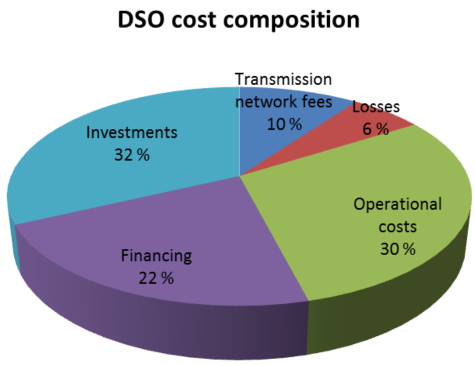

Figure 4: Typical cost composition of a distribution system operator. [5].

Network losses are in the order of 10% of the total cost – 6% in Finland but we are looking for an optimistic estimate. A smaller share of losses occurs in the transmission system and will not be dealt with. Distribution losses can be influenced in the short term and are analysed in the next subsection.

Short and medium term cost savings

Distribution system losses range between 5% and 15%. They are relatively high for lower loads where transformer core magnetization losses (no-load losses) dominate, somewhat lower for medium loads as line and transformer winding losses increase, and high for high loads as resistance losses (proportional to square of current) pick up. This means that if consumer behavior can be influenced in such a way that the network is operated with lower peaks and higher valleys, resistance losses can be reduced (the transformer no-load losses cannot).

Let us assume that through lower peaks losses could be reduced by an optimistic 1/5 from 10% to 8%. If a household consuming 4.000 kWh pays 6 ct./kWh in network costs of which, 0,6 ct./kWh correspond to network losses, the potential savings would amount to 4.8 EUR per year.

Long term

Lower peaks will result in lower required rating of transformers, lines and other network components. Lower rated transformers have lower no-load losses. Reducing the peaks can therefore reduce these losses in the long term. However, lower rated components will, on the other hand result in higher load losses. Long term savings stem from lower rated components and related capital and operational costs. To obtain an upper estimate for the long term savings, let us assume that the capacity related costs represent 80% of total DSO cost – in Figure 4 capacity related costs are represented by "Investments", "Financing" and a great part of the "Operational costs". These 80% consist of investment, financing and a part of the operational costs. Reducing the peak by 20% or 1/5 the average household can save 16% (16% = 80% x 1/5) of the total network costs. At 6 ct./kWh network charge and a consumption of 4.000 kWh this amounts to 38.4 EUR per year.

With regard to the above, two remarks need to be made. First, network components have lifetimes of 30-40 years and the savings from deferred investment will accrue only gradually. Once the peak reduction has been achieved, the savings will therefore only gradually approach the above value of 38.4 EUR.

Second, reducing a household's peak consumption by 1 kW does not mean that the total network capacity is reduced by 1 kW. Not all household peaks coincide at the same moment and the total network peak is not simply a sum of all consumers' peaks.

Incentives

How can the above estimates for network costs savings be translated into real time market signals suitable for the CoSSMic local market? Total savings for the 4.000 kWh household were 43.4 EUR per year, 4.8 EUR for the avoided 2 percentage points of network losses and 38.4 EUR for lower capital and operation costs due to a 20% peak reduction. This amount could be used to offer real time incentives of for example 3 ct./kWh to shift 145 kWh or 3.6% of the household's total electricity consumption to before or after peak hours.

CONCLUSION

The pricing model proposed in this article describes a mechanism that could drive a local electricity market for a local community. It assumes that members can choose whether they wish to buy electricity from their supplier or from a member of a CoSSMic community. The benefit that drives the local electricity market is derived from a reduced tax burden, reduced network losses resulting from this local transaction and long term capacity savings. The first source, the reduced tax burden, is potentially the biggest, but depends on the regulation. The second one depends on the DSO being able to estimate network losses in real time and provide a corresponding billing regime. Network losses can provide real time signals to the market. These signals are, however, marginal. The last source of benefit is related to the long term investment deferral. The benefits of reduced peaks accrue over the long term, but time of use network tariffs can translate these benefits into real time signals. All benefits are in any case rather low. But as has been mentioned in the introduction, current technological trends will increase these benefits and drive the cost of the enabling technology very low.

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