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**Abstract**

While the share of fluctuating renewable energy resources is constantly increasing, the centralized, hierarchical organization of the current energy system cannot adequately accommodate such decentralized electricity generation. New ideas have been developed for improved integration, especially in the lead market Germany. One of these concepts is the microgrid, a grid within the grid. This paper presents a local reserve energy market, which can facilitate the operation and allow trading within the microgrid. Emphasis is put on the regulatory options and current market framework, mainly from a European and German perspective, which serve as a basis for implementing the local market.

Keywords: local reserve energy market, balance group, prosumer

JEL Classification: C91, D03, D44, D83

# 1 Introduction

With the goal and the reality of an increasing share of (distributed) renewable energy generation, many of the recent research efforts in the field concern possible ways of adequately integrating them into the existing energy system. Alternatively, it means adapting the existing system to the requirements of this type of energy. In both cases, the approaches can be manifold. They are not only influenced by political decisions on multiple levels (international, national, regional) and economic reasoning, but also by the latest developments in the areas of electrical and mechanical engineering (e.g. grids, transformers, and turbines), chemistry, geophysics, as well as the information and communication sciences (e.g. grid protocols, smart grids/meters). Above all, there are resourceful entrepreneurs, including big companies from all sectors (f.ex. telecommunications) and small start-ups, who constantly come up with fresh ideas and business models that shape the energy landscape.

There are two related solution concepts that have found particular attention, namely microgrids and virtual power plants (VPPs). A lot of technical issues concerning their installation have been examined. Some authors consider a multi-agent system that determines the timing and the extent of power sales or purchases "jointly", according to the parameters set by the system, i.e. the system is controlled by using a multi-agent approach. These agents have either similar or opposing interests, which are solved in negotiations (cf. Dimeas and Hatziargyriou, 2007). However, it is not clear what the negotiations look like and which rules they follow. One way to organize such negotiations is by introducing a market. For microgrids or VPP, it can be called a "local" market due to its scope. When being implemented in a microgrid, it can be limited geographically, while its application in a VPP would mean a limit in terms of the number of participants and/or technologies. The concepts of microgrids and VPP are closely related, because in both cases a target value for energy production needs to be defined. The main difference is that in a microgrid, this value is determined from an internal optimization, whereas for a VPP, it is given by the sales volume, which results from external processes. Especially in Europe, the idea of microgrids has been promoted by islands with decentralized generation equipment that do not have an external grid connection and, therefore, do not profit from grid balancing mechanisms. In this “islanding mode”, microgrids can thus sustain themselves, which has been recognized as being an advantageous feature also for areas connected to the general grid. In the case of grid disturbances, such as black-outs, a microgrid can encapsulate itself and remain stable (cf. Lasseter et al., 2002; Katiraei et al., 2005; Pecas Lopes et al., 2001, also for solutions that support such operation). Under normal conditions, it can operate as an open microgrid, i.e. interchanging as much electricity with the grid on the next higher level as desired. On the other hand, a VPP is the aggregation of a fleet of generation devices that are operated to behave like a (synthetic) single large power plant. The main difference is that a VPP is used to export electricity, for example for trading, i.e. produce electricity only for an external party. Assuming that sufficient generation capacity is available, a microgrid can, therefore, be transformed into a VPP by adjusting the target value.

This paper builds upon the idea of a microgrid which connects private households with and without electricity generation equipment and introduces a local reserve energy auction market, where such self-produced electricity can be traded. While there are studies that discuss the general concept of local markets (discussed in the next section), their implementation and the effects thereof have not been evaluated. This paper aims at filling the gap by shedding light on the regulatory background and the current market framework, while identifying important links and potentials for amendments. For achieving this purpose, Section 2 gives an overview of the relevant existing concepts in the literature. Section 3 summarizes the current regulatory framework in Germany and explains how it can be used for local markets. Section 4 discusses the current market environment and the properties of the envisaged local market. Section 5 analyzes the impacts of the introduction of a local market on the most important stakeholders, Section 6 concludes.

## 2 Perceived need for local energy markets

The need for local energy markets has previously been expressed in a number of articles. Hvleplund (2006) refers to the situation in Denmark, where wind turbines produce a lot of renewable, but fluctuating electricity. So far, during windy hours there was no other option than to sell the immense surplus electricity at low or even negative prices to actors in other countries. While depressing payoffs of wind-farm operators, it can reduce acceptance of further fluctuating renewable energy in the long-term, which is counterproductive in the strive for more green energy and for the achievement of the energy policy goals set by the European Commission for 2030, i.e., a 40% reduction in greenhouse gas emissions, a significant, but undefined, increase in energy efficiency, a 27% increase in renewable energy (European Commission, 2014; a discussion of the former 20-20-20 goals can be found e.g. in Vasconcelos, 2008). Therefore, Hvleplund suggests introducing a decentralized market system that mirrors the decentralized nature of energy production and consumption, as opposed to the current centralized market system that mirrors the conventional centralized production procedure. In a decentralized system, local generators and consumers should be able to trade directly and without barriers with each other, thereby solving the issues related to renewable power fluctuations immediately in their own market. The reduced impact on the grid system and possible delays in costly grid expansions are apparent.

Cardell (2007) even goes one step further. Her main objective is to enable the involvement of distributed resources in the power system. Changes in coordination and operations seem inevitable. Beyond recognizing the need for local markets, she proposes a price-based mechanism that could serve to coordinate the distributed power generation facilities. Her design is similar to the traditional load-based demand side management, where prices are used to trigger a response in load and thereby shave peak-load demand. These time-of-use tariffs have been discussed in the context of the possibilities that a smart meter can offer upon roll-out (Siderius et al., 2004; Siderius and Dijkstra, 2006). However, for balancing, extensive data acquisition and data processing is needed to calculate the price signals necessary to reach an energy supply-demand balance in an orchestrated way. The mechanism works via determining the market clearing price from the energy demand or the occurred difference to the balanced state and then sending it as a signal to the participating generators, which produce the required amount of energy accordingly.

Lund and Münster (2006) model the Danish market for the case of increased investments into wind power. They find that by embedding wind generators in a system of micro-CHP plants, boilers and heat pumps, the supportable share in total power generation can be significantly increased. Even more interestingly, using this system intelligently to balance supply and demand, profits can be raised, yielding a total rate of return for the system of several hundred percent in their study.

The above-mentioned studies show that local markets have been perceived as a necessary institution for a high share of distributed energy generation. However, their implementation in the context of current regulation has so far been missing. Therefore, the next section details how the current regulatory framework emerged and which parts can be employed for the introdcution of local markets.

# 3 Regulatory framework for local energy supply and use in Germany

The German and other European energy markets are highly regulated. Although energy market liberalization is also known as deregulation, this does not mean that the amount of regulations in the form of laws, acts, and rulings is really decreasing. In some areas, there is direct public involvement (such as the system usage fee), whereas in other areas, there is indirect involvement through legislative provisions (such as unbundling); in still other areas, the involvement is limited to the usual antitrust efforts that apply to all sectors equally. In the following, we shall discuss how the current situation has evolved and what possibilities for the future result from this.

## 3.1 Historical development and current situation

The energy market liberalization in 1998 was meant to be the first step towards an internal market in electricity, which was agreed upon in the EC directive 96/92/EC (European Parliament and Council, 1996). To enable the European market, the formerly regulated markets of each country first needed to introduce a competitive basis. One of the cornerstones to achieve this has been the unbundling of vertically integrated undertakings. This means that enterprises engaged in generation must not be involved in distribution or grid operation as well. Specifically, the directive requires that the management and accounting for these activities be separate (Articles 7 and 14). The goal of this separation is to support competition by ensuring non-discriminating network entry, i.e. use of the electricity grid. In Germany, the grid usage conditions are determined by individual negotiations.

These requirements entailed many changes for the German energy sector. Its foundation is the amendment of the German Energy Industry Law (Energiewirtschaftsgesetz EnWG, 1998, 2005)[1], a regulatory framework developed that is favorable for establishing local markets. The introduction of balance groups in 2001 by a working group of six associations aimed at enabling fair competition on the then recently liberalized electricity market has particularly supported this idea (BDI - Bundesverband der Deutschen Industrie e.V. et al., 2001). The concept of balance groups was transferred to the Electricity Grid Access Ordinance (Stromnetzzugangsverordnung StromNZV, 2005), which came into force in July 2005. The law states that within each control area, one or more grid users need to create balance groups. These can be utilities, industry, traders, and other entities. Each balance

[1] Please note that all laws are cited with the date they came into force. The dates they were agreed upon can be found in the bibliography.

group needs a balance group responsible party (BGRP) who takes care of balanced drain and injection of electrical current in every quarter of an hour. Grid operators on every voltage level are obligated to deliver all data concerning billing and possible reductions in imbalances immediately. The balance group is created by the transmission system operator (TSO) upon request from a BGRP. The balance groups can be established along one of the three contract modules referring to the grid, the end users, and trading.

The primary objective of the *grid module* is the introduction of grid balance groups for implementing federal regulation (StromNZV, 2005). These special balance groups are used for managing energy losses due to grid operation and for the transmission of energy that is fed in from renewable sources. The most important task in these balance groups is to capture deviations of actual consumption from forecast consumption with the help of standardized load profiles.

The *end-user module* regulates the distribution of energy. This way, the BGRP can distribute energy from his own power plants or contracted power plants to end users within the control area of the TSO. He can also import energy from other balance groups or abroad. Note that this is completely independent from the grid in the sense of the unbundling regulation and rather refers to the accounting purposes necessary for distribution.

The *trading module* enables trading with other balance groups domestically, abroad, and at the stock exchange.

Beyond the creation of balance groups, the TSO compensates any irregularities that may occur. These may, for example, be due to the usual stochastic imbalances of demand and supply irrespective of schedules or due to malfunctioning of power plants within a certain balance group. In order to prevent a black-out, the BGRP receives help from the TSO. Compensation takes the form of reserve energy, which is procured centrally via the reserve energy market. The need to implement such a central market stems from the coming into force of the second EnWG and the StromNZV in July 2005. With only few guidelines given in these laws, further regulation has been necessary and falls within the remit of the Federal Network Agency (*Bundesnetzagentur*). Hereby, Ruling Chamber 6 (*Beschlusskammer 6*) decides upon the details. An overview of the rulings that are relevant for balance groups or (local) reserve energy markets can be seen in Tables 1 and 2. These and all other rulings including their attachments can also be found on the website of the German Federal Network Agency (www.bundesnetzagentur.de).

The most important variables that have been determined are the timing and the procedure of the tendering process, including minimum bid sizes and increments, as well as the specifications about information to be published before and after the bidding. Besides the details of the market, associated issues concerning the forecasting methods, the usage of reserve energy, the data exchange between the individual parties, and the billing have also been sorted out. In particular, the average price of each measuring period is billed to the BGRP according to usage, which means that everyone pays the same price per kWh.

From the tables, one can also see the developments that have taken place in recent years. Although a common reserve energy market was already introduced in 2006, it took almost four more years before all TSOs actually procured their reserve energy via that market (see Table 2, BK6-08-111). Once this had been achieved, the prevailing market rules were adjusted to ease the bidding process, while keeping in mind the interdependence of the reserve energy markets with other energy markets, such as the intraday and the day-ahead market.

In a long process involving many stakeholders, the German Federal Network Agency has worked towards an improvement of the billing procedures for balance groups by determining in more detail who has to provide which data at what point in time. This has been a result of the on-going complaints especially from grid users who asked for more detailed and binding specifications concerning data exchange, deadlines, data formats, and contract-related regulations (see Table 1, BK6-07-002).

Since 2012, the balance groups and reserve energy markets seem to be working well and to remain free of major complaints. This is at least the conclusion one can draw when looking at the rulings. In fact, a remarkably large portion of the rulings in 2013 and 2014 concern problems with grid access, especially for offshore wind farms.

### 3.2 Identification of regulatory amendment possibilities

The aforementioned balance groups can be seen as the current administrative groundwork for local energy markets. The idea here is that a balanced group does not need the services of the TSO and thereby might be able to save money as well as help renewable energy technologies reach a wider diffusion. This also makes sense in terms of the cost of learning, as distributed resources are mainly locally operated. This means that operators, such as city utilities, are re-empowered and given a greater degree of self-determination.

Although one could argue that the local procurement of reserve energy does not comply with the unbundling regulation, it is actually an expansion of the procurement of compensation energy for grid losses, which all grid operators with more than 100,000 customers already need to organize for themselves (StromNZV, 2005, §10; BK6-08-006). From a legislative point of view, only utilities with a similar size should be required to establish a local market. This also means that the additional administrative burden can be well estimated, as experience with the operation of compensation energy markets has already been accumulated. However, we are not suggesting that only local utilities are eligible as local market operators. Other players, such as locally owned energy service companies, can serve the same purpose.

Recent studies have brought forward similar ideas. Corn et al. (2014), for example, suggest implementing an internal market in balance groups, where the BGRP can control producers and consumers of energy to keep his group in balance. For this purpose, the producers and consumers are assumed to submit flexible offers that cover a certain period of time during which the cheapest are called whenever necessary. A related concept is

**Table 1:** Rulings by the German Federal Network Agency in ascending order of their reference number: Part 1/2

| Reference no. | Date | Contents | Details |
|---|---|---|---|
| BK6-06-012 | 29-08-2006 | Determination of procurement rules for tertiary reserve energy | Common procurement on a daily basis; further details for the procedure: gate closure times, minimum bid sizes (15 MW) and increments (1 MW), settlement rules, time slices, and requirements for publication of information about forecasts, demand, and bidding results |
| BK6-06-065 | 31-08-2007 | Determination of procurement rules for primary reserve energy | Monthly procurement (dates to be determined for an entire year in advance), no time slices, minimum bid size (5 MW) and increments (1 MW), settlement rules, and requirements for publication of information about demand and bidding results |
| BK6-06-066 | 31-08-2007 | Determination of procurement rules for secondary reserve energy | Monthly procurement (dates to be determined for an entire year in advance), two time slices, minimum bid size (10 MW) and increments (1 MW), settlement rules, and requirements for publication of information about demand and bidding results |
| BK6-07-002 | 10-06-2009 | Determination of market rules for balance group clearance | Data exchange using EDIFACT, time series in MSCONS, consistent descriptions of business processes |
| BK6-08-006 | 21-10-2008 | Procurement of compensation energy for grid losses and approach for determining grid losses | Procurement once a year, bidding procedure for the long-term component (can be forecast), short-term component contracted after bidding procedure (pricing with a variable pay determined by the EEX and a fixed pay); alternatively, both components can be procured via the energy exchange |
| BK6-08-226 | 12-05-2009 | Regulation for balance groups according to the German Renewable Energy Act (EEG) | Rules for trading energy from renewables; procurement of EEG- reserve energy to overcome forecasting errors when there is insufficient liquidity on the energy exchange: monthly procurement of positive and negative reserve, minimum bid size of 15 MW, publication of all details of the transactions |

**Table 2:** Rulings by the German Federal Network Agency in ascending order of their reference number: Part 2/2

| Reference no. | Date | Contents | Details |
|---|---|---|---|
| BK6-08-111 | 16-03-2010 | Employment of reserve energy for secondary and tertiary control | Integration of the last TSO in the common reserve energy market, coordination to prevent using opposing reserve energy types in different zones, adjustment of the amount of required reserve energy to the joint needs, calling the winners of the joint bidding process according to the merit order of the energy prices |
| BK6-10-097 | 12-04-2011 | Determination of procurement rules and publication requirements for primary reserve energy | Common weekly procurement every Tuesday for the following week for all control areas (dates to be determined for an entire year in advance), no time slices, minimum bid size (1 MW) and increments (1 MW), pooling, settlement rules, and requirements for publication of information about demand and bidding results |
| BK6-10-098 | 12-04-2011 | Determination of procurement rules and publication requirements for secondary reserve energy | Common weekly procurement every Wednesday for the following week for all control areas (dates to be determined for an entire year in advance), two time slices, minimum bid size (5 MW) and increments (1 MW), pooling, settlement rules, and requirements for publication of information about demand and bidding results |
| BK6-10-099 | 18-10-2011 | Determination of procurement rules and publication requirements for tertiary reserve energy | Common daily procurement for the following day for all control areas (dates to be determined for an entire year in advance), gate closure times, time slices, minimum bid size (5 MW, with indivisible chunks of up to 25 MW) and increments (1 MW), pooling, settlement rules, and requirements for publication of information about demand and bidding results |
| BK6-06-013 | 29-06-2011 | Standard contract for balance groups | Avoidance of tedious negotiations with all individual balance group responsible parties; builds upon BK6-07-002 |
| BK6-12-024 | 25-10-2012 | Advancement of the billing system for the balance energy price | Specifications for the reBAP (balance energy price to be employed in all control areas), publication of calculations and billing details |

presented in Ridder et al. (2011), who analyze several business cases to better integrate decentralized energy. They also follow the idea of clustering consumers and producers who trade their demand and supply first among themselves and subsequently (if no match can be found) on a higher level market.

In Europe, the first practical steps in the direction of local markets have been taken by the government of the United Kingdom. The Department of Energy and Climate Change has launched the "Community Energy" strategy[2], which aims for communities to take on more responsibility in energy usage and procurement. There is a £15 million fund open for rural communities and a £10 million fund for non-rural communities. Energy projects can take many forms, such as the installation of equipment for renewable energy, building insulation, the use of smart technologies, and collective purchases of energy. But most importantly, this strategy is also meant to facilitate local trading of energy, supporting the ideas delivered in this paper.

# 4 Markets and other ways to keep the system balanced

The dilemma with electricity from renewables is that it is not always produced when needed. Photovoltaics provide electricity when it is sunny, meaning that other sources need to be tapped during evening and night hours. Wind turbines produce energy when it is windy – a weather condition which cannot reliably be predicted until one or two days ahead – and therefore without balancing mechanisms, are not useful as a main energy source. Altogether, the output of many renewable energy technologies depends on external conditions, which cannot be controlled for and, therefore, need compensation mechanisms.

[2] https://www.gov.uk/community-energy

## 4.1 Options to balance fluctuations

One possibility would be the extensive use of storage (IEA, 2014). Scenarios include load management at the generation site or within the grid, load shaving at the consumers' sites, as well as frequency control and integration of renewables. In the course of an enhanced diffusion of electric vehicles with large storage batteries, flexible storage could be handled in a distributed way and could offer an additional advantage of electric fleets (Raths et al., 2013). For stand-alone applications, however, due to the currently high investment costs for such batteries, only the employment as primary reserve energy is profitable, at least at the current price level for (reserve) energy (e.g. Ohler and Chartouni, 2007). Lund et al. (2012) even completely oppose the use of electrical storage due to economic reasons and rather promote the application of system solutions including several technologies that can adjust their production or consumption.

Hydropower would be an optimal option, but capacities in Germany are not sufficient for this purpose and it is uncertain in how far they can be extended, mainly in terms of geographical possibilities, but also in terms of social acceptance (cf. debates about "saving" the Rursee, North-Rhine Westphalia; rettet-den-rursee.de). However, a promising study has been conducted in the German federal state of Baden-Württemberg. While considering ecological, technical, and economic constraints, it has been found that the existing installed capacity of 68 MW can be extended by another 25 to 32 MW. On the one hand, this includes retrofitting existing plants and, on the other hand, building new plants at suitable sites (Heimerl et al., 2010). The main potential is, however, in small hydro power plants, which are also subsidized by the German Renewable Energy Act (EEG).

## 4.2 Market design of the general reserve energy market

Before examining the possible design of a local market, it is useful to understand how the superordinate reserve energy market works. While this section, for consistency with the preceding sections, only deals with the German design, it should be noted that all European markets have similar properties and that they all need to comply with the regulation put forward by the Union for the Co-ordination of Transmission of Electricity (2004), which is now administerd by the European Network of Transmission System Operators for Electricity (ENTSO-E).

The general reserve market uses a multi-unit auction design with discriminatory pricing. This means that in each separate auction, several units of the same (identical) good are procured and remunerated with varying prices. Each bidder submits a vector of bids, stating his willingness to supply a certain amount of energy at a certain price and at a certain time. Payment occurs according to the individual bid (pay-as-bid rule). The unique design in the German market is that two bids are submitted, one stating the energy price and one stating the capacity price. Winning bidders are determined according to a merit order rule. They are, thus, sorted in decreasing order of their capacity bids until the required amount of capacity is procured. Once their services are needed, they are called up in decreasing order of their energy bid. This bears some opportunity for strategic bidding, as a relatively low capacity bid combined with a high energy bid can bring income without the need to actually deliver, i.e. without incurring other costs than opportunity costs for withholding capacity. More information on this issue can be found on the joint website of the German TSOs (www.regelleistung.net).

Fortunately, the number of suppliers participating in the markets rose over time. As of July 2014, twenty suppliers completed the prequalification process for primary reserve, 27 for secondary reserve, and 38 for minute reserve. Note that the situation was much denser in the past, with evidence that the four big German players (E.ON, RWE, EnBW, and Vattenfall) were able to use their market power in the minute reserve market. Growitsch et al. (2010) found that these four dominate the market in all products (different time slots, positive and negative reserve) with a combined market share of 69% to 94%, respectively. The then only 24 fringe suppliers sharing a quarter of the revenues of the entire market had no means to exert market power. An indication for the abuse of their position could be found in the frequency with which the four big players gained higher revenues than the fringe players. Due to a change in the data policy, which prohibits the publication of information that can be used to trace back the identity of the bidders, there are no recent studies available on this issue.

A general criticism of the reserve energy market is that entry barriers are high, which induces low levels of liquidity in the markets. Before 2007, all TSOs procured their own reserve energy, each using a separate platform. This made the markets nontransparent and prone to collusion as well as other strategic behavior, for example resulting from different market closing times (cf. Swider and Weber, 2003). Although the situation has improved since then, the qualification procedure is still deemed to be complicated, taking too much time and therefore being very costly.

## 4.3 Properties of local energy markets

To date, the local energy market is a theoretical construct. Nevertheless, it has some definite characteristics that result from the specific technologies and their users. The predominant attribute is the involvement of households, i.e. end customers without much expertise in the field of energy or trading. Rules need to be very clear-cut and understandable to create something comparable to an "energy-eBay".

The participants can be described as "prosumers", i.e. a combination of producer and consumer. The term was coined by Toffler (1980), who predicts a sharp decrease in importance of the markets as we know them. A reason for this is that people are no longer willing to pay for products and services which they can easily produce themselves with or without guidance. Ritzer and Jurgenson (2010) claim that this is not a recent phenomenon, but had started to develop in the 1950s and 1960s with the rise of shopping malls and fast food restaurants. Here, the consumer is actively involved in the production process by taking over certain tasks, such as filling up his glass with a soft drink. This is, of course, a very early and different form of what we are observing today. Since the start of Web 2.0, prosumption has experienced a great spurt. Prosumers have become more independent from producers – who used to be required for the necessary infrastructure – and are beginning to see themselves on the same level.

Related concepts are discussed in Sauter and Watson (2007). They describe the activity of consumers also producing energy as “co-construction”, “co-production”, and “co-provision”. The latter term was also coined during the 1980s, when the American government had to sharply cut back fiscal spending. With an upcoming discussion about privatization, it became clear that several tasks and services that had formerly been carried out by governmental agencies now had to be delivered by individuals or groups of citizens in the sense of co-provision or co-production (Ferris, 1984; Mattson, 1986; Brudney, 1987). Humphreys and Grayson (2008) add “co-creation” to the list and argue that there is potential for a fundamental change in the economic organization, much along the lines of Toffler (1980), but with a more critical view on capitalism.

There are also technically-oriented definitions of the “prosumer”. Kanchev et al. (2011) describe a prosumer as a home application that produces power during some hours of the day and consumes power during others. The home application then consists of a number of individual entities, such as solar panels, storage systems, and controllable loads. While Karnouskos (2011) sees the residential prosumer as the most important stakeholder in a smart grid and related markets, he also points out the commercial prosumer. According to his definition, these are large facilities, such as factories, that both produce and consume energy. Once a local energy market is operational, these larger players can be allocated to one of the markets for collaboration.

The market envisaged here is defined by a possibly small number of participants, which can be expected to grow in the case of profitability, with a natural limit in the size of the balance group. This becomes even more prevalent if investment costs can be recouped quickly. However, it also depends on the development of household energy prices, as it is certainly not profitable to use the equipment for reserve energy only. The main use should remain the self-supply of energy for the individual household. Legislation and incentive programs can also have a great influence. They make investment more attractive by offering advantageous financing conditions and often direct remuneration. In 2009, the self-consumption rule was introduced to the German Renewable Energy Act (EEG, 2009, §33, 2). This made externally purchased energy non-competitive, and also rendered storage more attractive. Since 2012, this special compensation is no longer available, because grid parity of solar power has been reached, and PV owners would otherwise be paid to consume energy (EEG, 2012). In August 2014, the feed-in tariffs have been drastically cut back (EEG, 2014), such that one should start thinking about new ways to incentivize investments in distributed renewable energy generation. A local market that offers some remuneration for self-produced energy might be a suitable instrument. Beyond the financial incentive, the political support inherent in such a market (or any other support mechanism) enhances a positive attitude towards specific technologies, making their adoption more likely.

Entry barriers should be constructed to be low, especially when compared to the superordinate reserve energy market. This is given by short lines of communication, which ensure that the qualification procedure will take less time and be less complicated. In fact, the BGRP could develop standard procedures that are easy to check on a supra-regional basis. As reserve providers are thought to be mainly private households, short catalogs could mention technologies and manufacturers that are generally eligible for balancing. In some cases, additional power electronics might be needed to fulfill communication needs. This can be solved by providing an additional list of standard equipment that needs to be installed before market participation can be allowed. With the proceeding roll-out of smart meters, some of the information and communication needs can be readily provided with a minor software update. Additionally, a business case could develop for contracting or at least retailing equipment, especially when the BGRP is a utility having considerable experience in customer support and service.

Substitutes for the locally procured reserve energy are the reserves from the superordinate reserve energy market. As these are expected to be more expensive, they can be disregarded in the analysis. Should they become competitive, it might be of ecological interest to give priority to distributed resources by law. This could be done in an amendment to the existing law for feed-in of energy from renewable resources, which would then need to be expanded to reserve energy (on this issue, see Rosen and Madlener, 2013a). Although significant interdependencies can be expected to arise between the local reserve energy market (especially upon a wide-spread roll-out) and the superordinate reserve energy market, these impacts are not part of the current analysis. Their evaluation requires a joint model of the superordinate market and the local market, which is beyond the scope of this paper, as it also needs to incorporate strategic behavior and market positioning issues of energy companies. These companies do not play a significant role in the analysis of a suitable local market for household producers.

## 4.4 Auction design for a local market

In the superordinate reserve energy procurement auctions, bidders do not only bid with a certain amount of capacity, but also with two types of prices. These are used to remunerate the opportunity cost of reserving capacity on the one hand and, in the case of being called up, to remunerate the cost of producing energy on the other hand. In this case, the opportunity cost is just the cost of not selling energy somewhere else for sure (for example at the spot market) minus the cost of production plus the cost of keeping the plant on standby to be quickly operational when the reserve is actually needed.

A household has a similar cost structure except that it would not necessarily sell the energy on a different market, but might use it itself. The opportunity cost is thus determined by the availability of energy or the amount of discomfort a household might experience when giving up some of the energy that was meant to be used within the household. The second component differs with the technology in use, but also with its respective efficiency. For battery storage systems, this would be wear-out cost and, if connected to a distributed generation device in the same household, energy production cost from this device, and otherwise procurement cost of external energy to be stored. Beyond this, the battery can also be used for primary reserve, which is the most expensive reserve energy category. Considerable gains can, thus, be expected in this form of application.

A very important difference when trying to determine the efficient market outcome is that it is not necessary or required to find those units that incur the lowest generating costs, but to find those bidders to whom it is the least costly to provide energy at a certain point in time. The objective is, thus, not to save as much fuel as possible, but to support some level of comfort, which is valued very highly by consumers (cf. Siderius and Dijkstra, 2006). The ecological impact does not suffer from this, as all technologies in use are energy-efficient and/or renewable, and are to be supported by their additional use as reserve energy providers.

Furthermore, the technologies that can be and are applied in households have very unequal cost structures. It might, therefore, be useful to have separate auctions for each technology in order to foster fair competition. The downside is, of course, that the already low expected number of participants drops even further. However, if the bidding process is not adjusted to the individual technology, returns might not cover costs any longer, let alone give an appropriate profit premium. Comparing this to the current incentive scheme for solar panels, it can be expected to be well-received by households.

Also, the policy of information disclosure can have a significant impact on the efficiency and effectiveness of a market. For the local reserve energy market, a similar approach as for the grid loss energy market can be recommended. This issue is also further discussed in Rosen and Madlener (2013b).

# 5 Impact on parties involved

The introduction of local markets would have important consequences for several stakeholders. The main stakeholders are the government, private households, the TSOs, the distribution system operators (DSOs), and utilities or energy service companies.

The government plays a crucial role in establishing the market, determining its conditions, and mediating the interactions. If the market works fine, it might make sense to reduce the subsidies to rely more and more on competitive forces. However, it is necessary to always control for the financial reliability that consumers experience with the set-up. If this cannot be achieved with a pure market mechanisms, some form of intervention might be required.

In general, however, local energy markets are a way to empower consumers and to make household investments in distributed generation more attractive. Economic benefits should not be overstated, though. Selling reserve energy does not mean that great fortunes can be earned. It is only meant to support the maintenance of a device that has already been bought anyway and to make an investment in such a device more attractive upfront by offering different, additional uses.

For BGRPs, the biggest change would happen. Of course, it is much easier to have reserve energy procured by a third party. Nevertheless, there might be some real economic benefits in procuring it locally. So far, utilities and energy service companies were only able to offer contracting models for generation equipment, with which they could participate in the superordinate reserve energy markets. Also, even here application has been very limited and mainly been available for industrial consumers, such as hospitals[3]. This is because investment costs are still very high and each customer needs to undergo an individual application procedure. With a general framework and easy-to-use catalogs, as presented above, these costs can be significantly reduced.

Beyond their activities as BGRPs in their grid subsidiaries, for utilities also their traditional core business, the operation of district heating grids and heat supply as well as supply of electricity and gas are likely to be affected. This is due to the expected growth in diffusion of distributed generation, which implies extended home energy production. Their role as energy suppliers could be reduced to providing electricity for heat pumps and natural gas for combined heat and power generators only. Another traditional field of activity is customer support, service, and advice. As demand for assistance in finding the right combination of energy-saving measures and distributed generation possibilities or arrangements can be expected, this would also be an area of growth for utilities.

Focusing on the role as DSO only, they become decisive in local markets. As BGRPs, they gain from not calling on control energy from the superordinate market, which is expensive. Furthermore, they need to send the signal for starting production of reserve energy. The communication between the generation devices and the auctioning process could be done by the DSO himself or by an independent service company, subcontracted to the DSO, much like the way metering is done nowadays.

The responsibility and the trade volumes that are taken over by balance groups are at the same time subtracted from the superordinated reserve energy market. This means that TSOs lose part of their influence. When local markets are used to counterbalance wind power parks, as suggested by Lund and Münster (2006), grid expansions might be reduced, which further diminishes the role that TSOs play in the energy system.

[3] cf. Stadtwerke Düsseldorf, program for emergency power generation units "Notstrom effizient", more information on this can be found on their website: http://www.swd-ag.de/geschaeftskunden/contracting/contracting_produkte/minutenreserve.php

# 6 Conclusion

In this paper, we have discussed how the current regulatory framework can be used and extended to accomodate renewable, decentralized energy generation in local energy market settings. The most important concept hereby have been the balance groups. They can be used as the administrative entities for local markets where households and other small-scale prosumers trade their self-produced energy. To achieve this, an adequate auction market needs to be designed that takes into account the properties of both the technologies in use and the household-traders. It is therefore paramount that the market is easy to understand and easy to interact with to create some kind of "energy-eBay", where users enjoy bidding and selling their energy. With some simple amendments to current regulation, these local markets can be organized by the BGRPs. They can use these markets to procure their own control energy for balancing purposes. This not only reduces grid losses, but also helps to better integrate renewable, decentralized energy generation and thereby supports to achieve the ambitious energy policy goals for 2030 put forward by the EU.

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