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Taking markets to all levels: Valuing flexibility to achieve market-based sector integration

A Siemens – EPEX SPOT paper

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Abstract

This paper proposes an integrated energy market concept – ranging from buildings to countries – by extending the role of the market to make full use of flexibility while facilitating sector integration, decarbonisation and supporting the grid.

Siemens technology opens up new opportunities for decentralized market players on EPEX SPOT markets.

Context

Decarbonisation, decentralisation, digitalisation and democratisation represent key developments in the energy sector, including the electricity market. These 4D trends are interdependent: digitalisation is one of the triggers to an efficient decentralised energy sector, which further supports decarbonisation, as well as the opportunity to tailor energy services to the need of consumers

The energy landscape is rapidly changing. Centralised assets are being replaced by smaller, more distributed energy resources (DERs). This challenges existing procedures and adds complexity to the system In Germany, the wind and solar net installed generation capacity has been multiplied by a factor of 5 since 2005, reaching 106 GW[1] in April 2019. Rapid urbanization, growing attention to sustainability, diversification of energy sources and the wider uptake of new available technology – Electric Vehicle (EV) charging, heat pumps, residential electricity production via rooftop Photo-Voltaic (PV) panels, domestic batteries and other smart devices – will not only contribute to change our lifestyle, but will also accelerate the decentralization trend, increasing the amount of capacity from decentralized assets activated independently from grid constraints.

The result is an increase of multilateral energy flows, both at transmission and distribution level that bring strain on the grid and can eventually exacerbate grid congestions. Already today, transmission system operators are

[1] To understand the potential of this increase, it is sufficient to think that Germany's peak consumption is 85GW.

obliged to take costly re-dispatching measures to compensate horizontal grid constraints – for example by cutting wind farms production in case of overload in a specific region – in line with the current regulatory approach of a cost-based congestion mechanism. In Germany alone these re-dispatching costs have reached over 1billionEuros per year[2].

This evolution triggers the development of new trading solutions – from building-level to the wholesale market – that can fully grasp the flexibility potential provided by decentralized assets. The advantages are manifold: the grid can operate more efficiently, asset owners can personalize services without having to worry about their EV being fully charged when they need it, and new actors can more actively interact and contribute to an innovative eco-system.

These solutions are most effective if they provide a consistent chain of offer and demand equilibriums, all the way from the transmission level to the distribution level, and even to investors and operators behind the meter. In order to both unlock their flexibility potential and grasp the best energy procurement means, decentralized assets cannot be isolated at their level, but should be treated as part of a larger structure, with several levels and interactions across these levels. These interactions can be achieved by combining EPEX SPOT's expertise as a market operator and Siemens' technology. Connecting the Building Energy Management Systems and optimization algorithms developed by Siemens to the Local Flexibility and wholesale markets operated by EPEX SPOT will enable the direct participation of decentralized assets to energy markets. **The present paper lays out such a chain of offer and demand mechanisms paving the way to these new trading solutions**. The chain has four levels for the usage and provision of flexibility:

- Level 1: behind the meter, typically within a site or a building;
- Level 2: local distribution area, typically within the area of a village, a city district or a small city;
- Level 3: regional distribution area encompassing larger cities (above 36kV);
- Level 4: national or even transnational areas (220kV and higher).

Introducing the different levels requires an in-depth analysis of the interaction between the levels. This paper first sheds light on how flexibility is defined for each level. Consequently, at all four levels, we then identify key interactions (with regards to prices and congestion) across the levels, and how they can benefit the whole electric system, from end-consumers to System Operators.

[2] ENTSO-E Transparency Platform

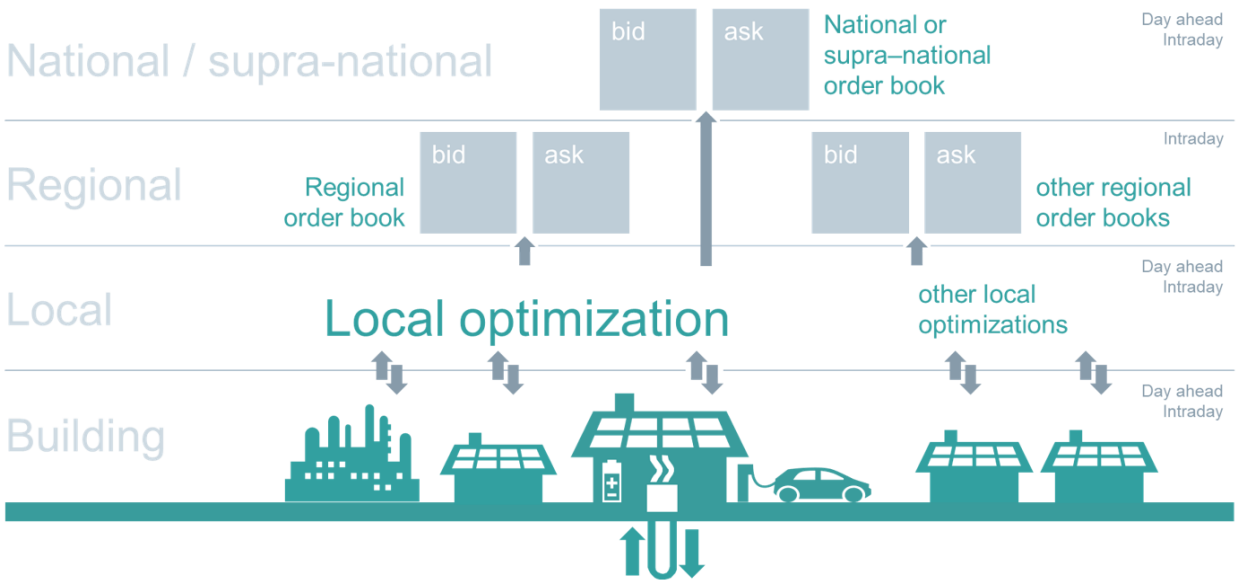

Figure 1: Concept of interaction levels

The definitions of flexibility

Level 1: Flexibility at site or on building level

Buildings are increasingly equipped with devices that allow to actively shape the building's consumption or generation pattern. Existing technology allows nowadays buildings to entirely self-supply their needs and even store power for future use. The devices making this possible are heat-pumps, EVs, domestic battery storages, combined heat-and-power engines, and any other flexible consumption enabled via smart devices such as smart fridges. Often these buildings are also equipped with rooftop PV panels. Heat pumps can provide flexibility via the thermal inertia of the building. EVs may proactively adapt their charging behavior to fluctuating power prices, provided that a defined minimum state of charge is achieved no later than at a time defined by the user. First pilot EVs are even able to charge and discharge in a smart way. Buildings are therefore the first testbed for sector integration.

Energy management systems for buildings combine one or several of these devices while considering PV forecast, as well as thermal and electrical load forecasts. Analyzing and integrating these forecasts with the generation assets at the building and intra-building level, along with the interaction of multiple devices, represent a challenging optimization problem. Several vendors have developed energy management systems for buildings that are able to solve this problem by automatically and remotely piloting the different energy devices.

Such building energy management systems drastically reduce the complexity for building operators and provide more transparency on how energy is used and therefore when flexibility is available. Applied in combination with technologies such as smart metering, smart devices, Artificial Intelligence, Machine Learning and blockchain,

building energy management systems also have the potential to lower the entry barrier for an active, automated and remote market participation of decentralized assets. **This means that energy trading becomes accessible and attractive even for individual buildings.**

Thus - in order to generate additional revenues for the owner - the building energy management system can interact with other such buildings to achieve local optimization on a marketplace. In order to do so, **the Building Energy Management System (BEMS) developed by Siemens automatically generates offers to other buildings or market participants expressing the willingness to buy, sell or to give access to flexibility**. These orders are then matched on level 2.

Interoperability of devices and harmonised data-sets will be key to allow to seize the opportunities provided at this level.

Level 2: Flexibility on local distribution area, e.g. a village, a city district or a small city

On a local level, several entities are good candidates for providing a local optimization service, for instance: the sales function of an electricity provider, the local distribution grid operator or a third party with a digital customer approach.

In a local optimization concept - as developed in the frame of the Pebbles project in the village of Wildpoldsried for instance[3] – the flexibility originating from buildings on level 1 can also be made available locally to other participants. To this end, market participants within the concerned distribution area offer the flexibility of their assets on the local optimization platform.

If for instance, a market participant does not fully use his own home battery storage, he may make any remaining capacity available to other parties in his surroundings by stating the following in his offer: "*the available kW, kWh, storage efficiency and a desired minimum price*". The operator of a local optimization mechanism will integrate this flexibility-offer in the overall optimization problem that he is solving. **Because of the limited size of the offer, as well as its time-constraints, trading on a local level would be much more efficient and practical than offering the same capacity on a regional level** (level 3).

The key role of the local optimization is:

- To aggregate the individual offers for supply and demand from level 1, netting with the application of optimization methods (peer-to-peer (P2P) trading of electricity);
- To interact with the regional flexibility market on level 3 to value global and aggregated flexibility (implicit electricity prices from optimization) or to the wholesale market on level 4 to value energy surpluses or extra needs. Flexibility and energy surpluses depend on the available net overload and therefore on the local preferences (consumption of green and local energy, price-sensitivity, etc.). For example, an energy

[3] https://pebbles-projekt.de/

community willing to be as energy self-sufficient as possible with a very low price-sensitivity, will very likely not have the same needs to value its flexibility or energy on the upper markets as an economy-driven industrial cluster, willing to react as much as possible to external price signals in order to maximize its monetary benefits.

Based on a first local matching, the local optimization operator can generate aggregated offer and demand curves for the local flexibility market (level 3) and/or the wholesale market (level 4), depending on available opportunities and local preferences. This means that **P2P trading at a local level is complementary with wholesale market trading,** as the decentralized market players benefits both from the marketing of their surplus and from a reliable, transparent price signal as provided by the wholesale market.

The local optimization operator submits these curves of local optimizations as offers to the regional orderbook on level 3, depending on the existence of grid constraints and the value he can get for the flexibility. The operator can also submit the offers directly to the level 4, depending on available opportunities on the market and local price-sensitiveness. Once the local optimization operator receives the execution confirmations from level 3 and/or level 4, he will execute a second local matching – this time incorporating the executions on level 3 and/or level 4. By doing so, the local optimization operator implicitly makes the local flexibility available to level 3, and to level 4. Within the boundaries of the available transmission capacities he also injects the liquidity of level 3 or 4 into level 2, providing additional liquidity and transparency to the market. EPEX SPOT's trading system is already fit to welcome these direct offers from the local optimization operator via Application Programming Interfaces (APIs), providing an automated interface for these interactions to levels 3 and 4.

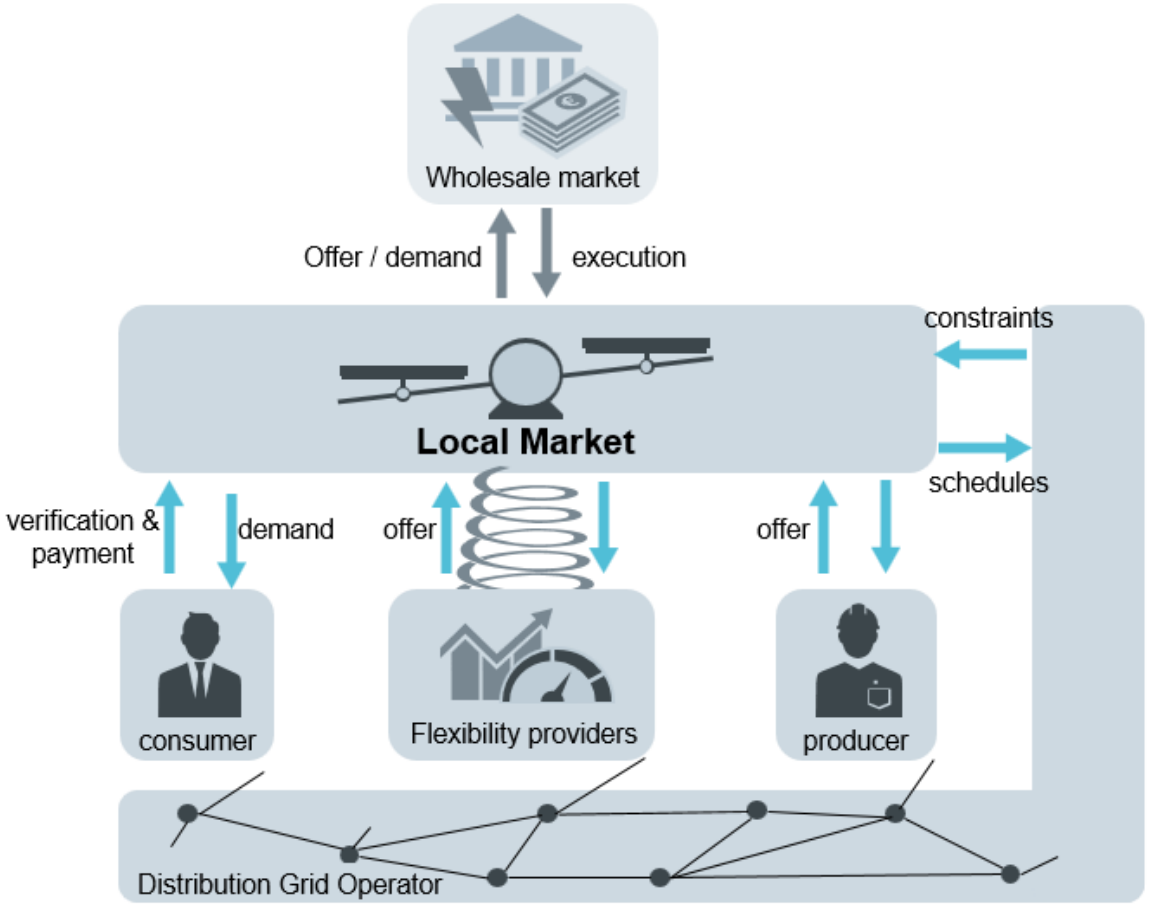

Figure 2: interaction between players on level 2

EPEX SPOT and Siemens are further studying the interfaces between their systems to ensure this direct and automated connection between level 2, levels 3 and 4, and to define the underlying conditions for these interactions to happen smoothly.

As this stage we assume that at level 2, excess flexibility for the regional market will be provided after all local demand and supply have been matched with the help of an optimization method, depending on local preferences. As such, the platform serves to automatically match supply and demand. This means that the platform provides a clearing price that consumers are willing to accept and that suppliers will meet the desired power demand. The (implicit) equilibrium power price at level 2 may de- or incentivize participants to place bids, if participants in the local market additionally monitor market prices from level 3 or even 4.

Placing bids incorporating higher levels largely depends on the possible trading opportunities on level 3 and level 4, calculated using the implicit price of level 2 (or the delta between them) stemming from the internal optimization rules given at this level (representing the willingness to pay or selling price of level 2) and possible existing prices and market conditions on the upper orderbooks on level 3 and/or 4 that can be used to build a market offer. The placement of bids also depends on the individual preferences of the local optimization model (price-sensitiveness,

priority given green/local energy, etc.). To properly accommodate these dependencies, the following conditions have to be fulfilled:

1) a priority rule requiring agents to first serve system stability when their flexibility is required before following their own optimization criteria;

2) a fully-fledged multilevel matching algorithm made within the optimization at level 2, that considers each level individually for optimal matching, across markets, and provides the possibility for decentralized assets to value their flexibility and energy on upper markets.

Additional flexibility can be provided for level 3 by the mechanisms described in this chapter on level 2. In doing so, different voltage levels can further cooperate, receiving the same flexibility offers and decentralized assets which are currently not considered in the existing cost-based redispatch mechanism (and cannot be considered as such due to their different values and opportunity costs compared to traditional assets). This will further enhance liquidity in the market as well as provide greater transparency. Of course, such market-based mechanisms will require strict market rules, as for any market, applicable to all market players, including decentralized ones. A so-called “regulatory sandbox” where actors can try out a new concept without yet having a dedicated set of regulations on a national or European level, as currently applied to Level 3 to properly test the feasibility should be envisaged.

Level 3: Flexibility on regional distribution area (with the use of a regional orderbook also called Local Flexibility Markets)

EPEX SPOT has developed the concept of Local Flexibility markets, providing a **complementary regional market run by a neutral and objective third party** and aiming at:

- Efficiently centralizing local flexibility offers;
- Allowing System Operators (SOs) to reliably and economically relieve physical congestions from the grid, with clear guidelines and communication protocols to increase and develop the cooperation between TSOs and DSOs;
- **And last but not least, creating a new economic space for flexibility providers to value their assets.**

Flexibility on regional distribution areas and market places are complementary to the wholesale Day-Ahead and Intraday markets (level 4) and to the balancing markets. Flexibility providers can bid their resources on both the wholesale market (level 4) and in a local flexibility orderbook (level 3), when certified by the relevant System Operator. At this level, voluntary market-based mechanisms are key to support the proper coordination of all market players including SOs and flexibility providers.

In general, on a given Local Flexibility Market, SOs are able to open "on-demand" regional orderbooks in the Intraday timeframe (from several hours until a few minutes before the flexibility is needed), depending on the congestions arising at a specific node of the electric grid. Matching of flexibility offers in each orderbook leads to the activation of certified resources at the underlying node. Activations are then further verified by the respective SO. These market-based mechanisms allow further coordination between SOs and flexibility providers, as well as among the different types of SOs. Indeed, a local flexibility market provides SOs with clear guidelines and communication protocols to increase and develop their interactions and cooperation, as SOs within a same geographical area are aware of each other's flexibility needs and of the level and location of flexibility that has been procured. Also, the platform being operated by a neutral and objective third-party ensures transparency, confidentiality and trust in the market. To guarantee low cost for the end consumer, SOs need to be able to procure flexibility in the most cost-efficient way. Therefore, a level playing field for all flexibility costs (redispatch, flexibility markets, curtailment etc.) needs to be created at national level[4].

As the Market Operator, EPEX SPOT is in charge of defining the market rules and product specifications, of the admission of market participants and of operating and monitoring the flexibility market in a transparent and neutral way.

Along with various project partners, EPEX SPOT is testing this concept in the Enera project in the windy North West of Germany, which has a significant wind production triggering frequent congestions and therefore high costs for SOs. Together with the partners in the enera project (incl. Avacon Netz, EWE NETZ and TenneT)[5] EPEX SPOT developed a clear and transparent market mechanism for flexibility providers who wish to participate in market-based congestion management as explained above. The enera market works as a "regulatory sandbox".. It has been put into production on February 4th 2019 for a two-year demonstration phase. Successive evolutions will be brought during this period, aiming at determining the best model and at making concrete suggestions for future regulatory evolutions to be implemented for the most efficient market.

Flexibility marketplaces work on a continuous mode, just as the Intraday market. Local Flexibility Markets including enera, run on the same system as the EPEX SPOT Intraday market[6] , meaning with the same possibility to directly connect decentralized market players from level 2 to this market. Connection to the trading system is made possible via an API through which automated messages can be sent to the trading system to automatically interact with the market, offering flexibility needs depending on pre-set trading criteria on the algorithm and according to the observed market conditions.

[4] At German level this could be done within the incentive regulation framework (Anreizregulierungsverordnung).
[5] https://www.epexspot.com/document/40266/190205_EPEX_EWE_ENERA_PressRelease_EN_clean.pdf
[6] M7, from Deutsche Börse AG

Local Flexibility markets are complementary to the wholesale and balancing markets. The traffic light concept below explains the interactions between the market and the grid for congestion management [7].

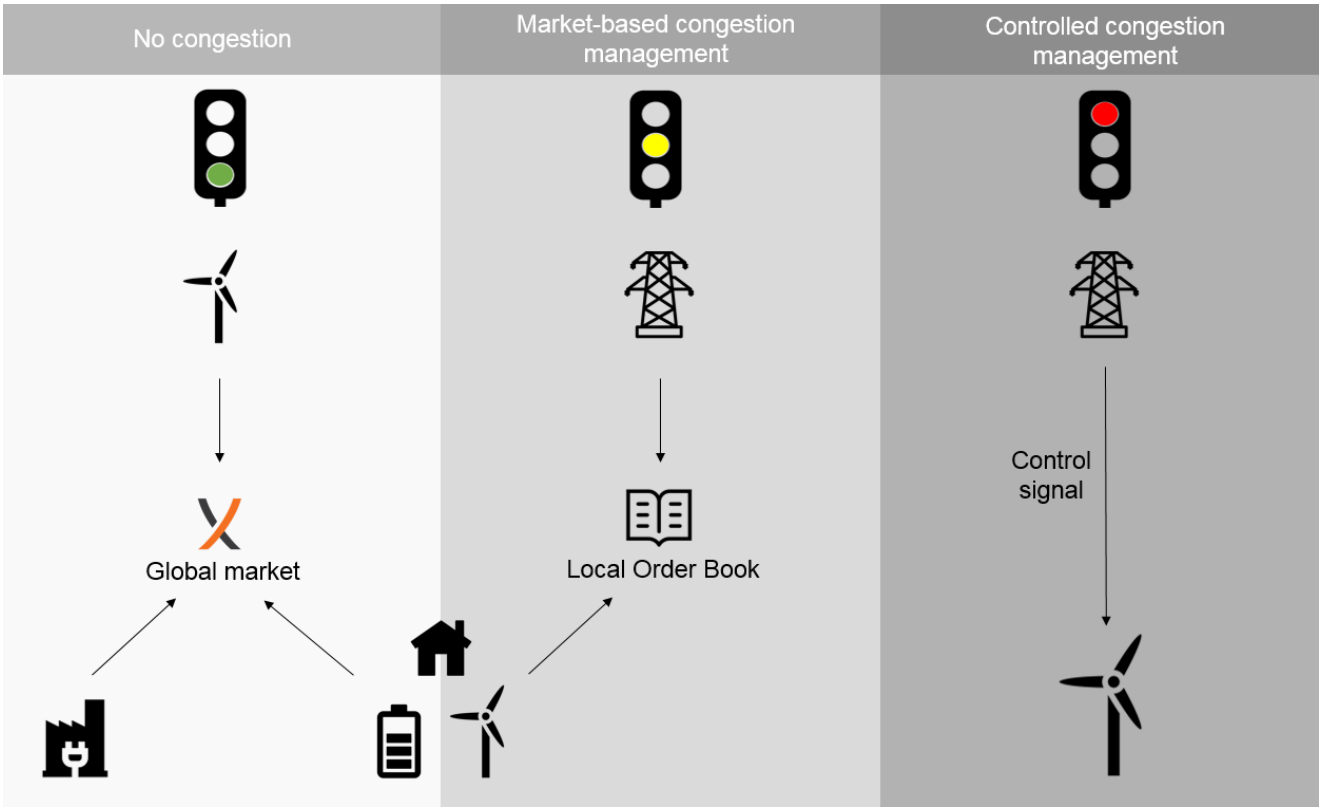

Figure 3: the traffic light concept.

In the green phase, no congestion occurs. Market participants can operate in the wholesale market matching their energy needs, supplying or selling the flexibility provided by their assets. This phase is covered today by the existing markets operated by EPEX SPOT.

In the yellow phase, the System Operators track some congestions occurring at some specific points of the grid. The idea implemented with EPEX SPOT's Local flexibility markets is that TSOs and DSOs concerned by these congestions can open orderbooks "on demand" for one or several nodes, where they can call for flexibility from certified assets, in order to alleviate the corresponding congestions. Flexibility providers can then decide to sell their flexibility on this Local Flexibility market. During this yellow phase, Siemens will conduct tests with microgrids in the area to determine the best economic conditions for decentralized market players, such as microgrids, to value their flexibility and play a transactive role in the formation of a democratic price signal for flexibility within a specific Local Flexibility Market.

[7] Source: enera project

In the red phase, congestions need to be urgently tackled by the corresponding System Operator, who will send direct control signals to the assets that will help alleviate the congestion.

Considering the interfaces between EPEX SPOT and Siemens, it means that, depending on the traffic light scenario, flexibility providers located at level 2 could even interact directly with the flexibility market (if available) or with the wholesale market, with a possibility for arbitrage between the two, depending on the optimizer's preferences (green energy, monetary value, etc.), covering both green and yellow phases.

Level 4: Flexibility on national or transnational level

EPEX SPOT operates power spot markets in Austria, Belgium, France, Germany, Great Britain, Luxembourg, the Netherlands and Switzerland. In all these markets EPEX SPOT's services cover both Day-Ahead auctions, coupled with other European countries, taking place every day at noon to trade the 24 hours of the next day, as well as Intraday continuous markets running on a 24/7 basis, also coupled with other European countries via the XBID system. The offer is completed with national and coupled Intraday auctions in several market areas. In Germany, for example, EPEX SPOT offers a successful daily national auction taking place at 3 PM within the Intraday timeframe, during which market participants can trade the 96 quarter of hours of the following day.

The Intraday markets provide an effective solution for integrating intermittent supply, enabling producers and consumers to balance their positions closer to real time and with the benefit of more accurate forecasts compared to the information available on the Day-Ahead timeframe. EPEX SPOT's Intraday markets are used by market participants to balance volume risk as a result of unexpected outages, forecast errors of demand or production (for intermittent assets such as wind turbines), rendered even more efficient with their small granularity products as well as trading close to delivery. In some countries including Germany and Austria, trading is authorized up to 5 minutes before delivery, providing a high level of flexibility for market participants. Also, 15-minute contracts are available on the Austrian, German, Belgian, Dutch and Swiss markets to further increase the level of flexibility for market participants, allowing them to handle intermittency and daily ramping effects of renewable production. All these measures contribute to a more balanced market. At the wholesale level, flexibility helps to balance the overall electricity system.

Aggregated energy surpluses stemming from level 2 (e.g. production or consumption surpluses) can be offered directly on the EPEX SPOT wholesale market in order to be valued at a transparent market price. As of today, the minimum threshold to access the EPEX SPOT market is 0.1 MW. To determine the conditions under which a microgrid would value its surpluses on the wholesale market, Siemens is currently testing the interaction between its BEMs and its local optimization algorithm with EPEX SPOT historical market prices. This will help microgrids to calculate their surpluses / extra needs and determine the best conditions to interact with the wholesale market.

Technically speaking, EPEX SPOT trading systems are already fit to welcome decentralized market players. EPEX SPOT's auctions (Day-Ahead and Intraday) run on the EPEX Trading System ETS. Intraday continuous

markets run on M7, a trading system developed by Deutsche Börse AG. Both trading systems can be automatically accessible via automated messages using the API connection, making the link easily implementable. Also, EPEX SPOT benefits from a 10-year experience as a market operator, running a safe and secure physical market for electricity buyers and sellers.

Conclusion

EPEX SPOT and Siemens believe that the decentralization of the electric system is a strength for the energy system when managed using the full potential provide by new technologies and markets. The decentralization of the electric system triggers variable offers on the market from intermittent production, which need to be completed and matched with a variable demand, in order to make new energy transactions possible. This implies the automated and direct interaction of flexibility stemming from decentralized assets with markets and transparent price signals. The interaction between a local optimization and upper market levels where decentralized market players can value their flexibility (on Local Flexibility markets) and their energy (on wholesale markets) allows a wider and transactive participation to the democratic formation of flexibility and energy prices, finally to the benefit of the end consumer.