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Abstract

Peer-to-peer and peer-to-X open a new world of transactions in the electricity sector. This world is characterised by the active involvement of new players, both small in size and non-professional in nature, and by new combinations of the activities carried out behind and in front of the meter. Peer-to-peer refers to transactions in which both the seller and the buyer are small in size and non-professional, whereas peer-to-X refers to transactions where only the seller is small and non-professional while the buyer is a different type of actor. Observations from the world of practice reveal the existence of multiple forms of peer-to-peer and peer-to-X transactions. The first part of this contribution illustrates those variants, by providing a sample of concrete implementation cases coming from liberalised electricity systems. The review shows the importance of three components that are essential to the functioning of this new world of transactions and which are discussed in the second part of the contribution. They are: a) the transaction loop, as small players cannot sell or buy from other peers so easily; b) the pricing mechanism, as existing wholesale and retail markets exert pressure on incentives for activating peers; and c) the delivery loop, as peers must deliver via existing grids and system operators, except when trading entirely within private networks.

Keywords

peer-to-peer electricity trading; electricity markets; digital platforms; energy communities; regulatory sandboxes.

Introduction*

Peer-to-peer and peer-to-X open up a new world of transactions in the electricity sector. We have already seen business-to-business (B2B) with the wholesale markets opening around 1990 and business-to-consumer (B2C) with the retail markets opening around 2000 (Glachant et al., 2021). This third new world of electricity transactions has not yet been fully explored.[1] However, two key features of these new transactions are notable. First, a particular set of players are involved. They are both small in size and non-professional. This is why we call them 'peers.' This is a striking novelty because the electricity industry has traditionally been dominated by the opposite: big and fully professional players. The other novelty is equally striking: the involvement of 'behind-the-meter' activities and various combinations of them with 'in-front-of-the-meter' activities (Sioshansi, 2020a). This is novel because electricity grids and markets are deeply regulated in front of the meter and necessarily much less or not at all behind the meter. With new activities and new players involved we are indeed facing a new world of electricity transactions.

This new world involves multiple variants because its two characteristic transactional features can address several objects (for example, energy, flexibility and storage) in different arrangements. This is investigated in more detail in the first part of this paper, in which we distinguish three forms of 'peer-to-peer' transactions and four forms of 'peer-to-X' transactions. 'Peer-to-peer' transactions are ones in which the 'peers' are both buyers and sellers and 'peer-to-X' transactions are those in which the 'peers' are only sellers, the buyers not being other peers. This review of the variety of new transactions feeds into the second part of the paper, which deals with the key components of this new transactional world. The many types of transactions suggest that three components are key to the functioning of this new world: a) the transaction loop, as so small players cannot sell or buy from other peers so easily; b) the pricing mechanism, as existing B2B and B2C markets exert pressure on incentives for activating peers; and c) the delivery loop, as peers have to deliver via existing grids and system operators, except when they manage their own mini-grids.

PART I: What's new in these new transactions in electricity?

The electricity sector is facing the emergence of new types of transactions that we call peer-to-peer (P2P) and peer-to-X (P2X). Both types present many variants. P2P refers to transactions in which the seller and the buyer are peers: they are both small in size and are non-professional players in the electricity market. This is typically the case of households and small non-energy businesses like hotels and farms. On the other hand, P2X refers to transactions in which only the seller is small in size and non-professional while the buyer is something different. It can be a traditional player in the electricity system such as a classical energy supplier or a regulated distribution company. Alternatively, it can be one of the new emerging professional entities active in electricity such as an independent aggregator or a platform (Schittekatte et al., 2021a; Morris et al., 2020). The variants also differ in terms of the object addressed (such as electricity, flexibility or storage) in the transactional arrangement.

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[1] See Sioshansi (2019) and Burger et al. (2020) for early explorations of this new world.

I.1 Peer-to-Peer transactions

Peer-to-peer transactions are becoming a new norm in the electricity sector since consumers started to invest 'behind the meter' in their own generation assets and were allowed to inject their electricity surplus into the public grid to which they were connected. The growing preference of some consumers for green or locally produced electricity also contributed to the increasing interest in P2P transactions in electricity (Sousa et al., 2019; Brown et al., 2019; IRENA, 2020; Hackbarth and Löbbe, 2020). At least three forms of P2P transactions are currently being implemented around the world: peer-to-peer in sandboxes, peer-to-peer within platforms and peer-to-peer in communities. The next section investigates their characteristics with examples from the real world.

Peer-to-peer in sandboxes

P2P transactions can take place in sandboxes. A sandbox is a closed space normally of limited size such as a building or a neighbourhood where some of the rules that usually apply to generation, transmission, distribution and supply of electricity are temporarily suspended. Firms, research institutions and regulators establishing a sandbox define which rules to replace and the alternative arrangements and business models to test in these delimited experimental spaces (Schittekatte et al., 2021b). The peers may decide whether to enrol in the sandbox or not, but they normally cannot control its framing.

This is the case of the frequently cited P2P electricity trading trial in Brooklyn (New York) (Mengelkamp et al., 2018). Brooklyn Microgrid (BMG), a benefit company owned by the software firm LO3 Energy, is cooperating with the local utility Consolidated Edison to enable 40 prosumers and 200 consumers to sell and buy the electricity they produce on their premises at a price they are free to set for a period of 12 months (Maloney, 2019; Sharma, 2019). Brooklyn Microgrid is going to install new devices measuring electricity flows but is expected to integrate its own billing in the regular bills managed by the regulated company Consolidated Edison.

Limited freedom to choose the rules of the game also characterised the peers involved in Quartierstrom, a P2P electricity trading trial that took place in Walenstadt (Switzerland) with the support of the Swiss Federal Office of Energy in 2019 (Ableitner et al., 2019; Meeuw et al., 2020; Ableitner et al., 2020). This sandbox involved 35 households and two small businesses located in the same neighbourhood, most of which were already endowed with home solar PV and batteries. During the trial, the peers had the possibility of trading their individual surplus generation at the local level. They could express their willingness to offer or buy local electricity by setting their profile on an online application. Based on this information and the injections and withdrawals of electricity measured at the peers' premises with a dedicated smart meter, a double auction allocated local generation to local consumption every 15 minutes (a private blockchain was used to implement the auction mechanism transparently and securely). Any excess or deficit in local generation was managed by the integrated local utility WEW. A reduction in distribution charges for the locally traded electricity was applied to further incentivise peers beyond environmental and social motivations.

A similar sandbox was conducted between late 2018 and early 2020 in Fremantle, a small town close to Perth (Western Australia), in the context of the RENeW Nexus Project sponsored by the Australian government (Green et al., 2020). In this case, 22 residential prosumers and 26 residential consumers living in the same area performed thousands of transactions concerning their surplus electricity production. Trade occurred on a blockchain-based platform developed by the software firm Power Ledger. An energy retailer, Synergy, provided the peers with consolidated electricity bills and was in charge of purchasing any excess local generation and of meeting any residual demand. Notably, the presence of high fixed daily charges discouraged to some extent the participation in the sandbox by local households (Wilkinson et al., 2020).

Peer-to-peer within platforms

P2P transactions can occur within a platform which provides an open space that multiple peers on both the production and the consumption sides can join. By leveraging network effects, a platform can establish a thriving two-sided market where peers can find counterparts with whom to exchange their goods or services (Einav et al., 2016; Parker et al., 2016). The platform can define to a greater or lesser extent what the peers can trade. However, it is subject to the limits and constraints imposed by the external world, in particular when the delivery of the product exchanged requires the use of physical infrastructure which is not under the control of the platform and possibly subject to public regulation (van Soest, 2018; Montero and Finger, 2021).

These characteristics of P2P transactions on a platform are shown by the two cases of Vandebron in the Netherlands and Bolt in Belgium. Vandebron is an electricity retailer that was established in the Netherlands in 2014. It has more than 180,000 customers but no generation assets since its business model is to provide an energy sharing platform where prosumers, mostly farmers and small businesses, can offer their excess production to consumers living in the Netherlands. Consumers joining the Vandebron platform can explore the personal webpages of more than 200 prosumers and small and non-professional electricity producers and select those from whom they want to get their electricity. They can also agree on the price at which to exchange electricity and the duration of the contract (from one to three years). Vandebron charges a monthly subscription fee and takes care of all the rest, including energy balancing and billing. A digital dashboard gathering information from regulated smart meters at the peers' premises allows all the platform users to access data on energy flows and transactions.[2]

Bolt does something similar in Belgium.[3] Although formally a retailer licensed in Flanders, Bolt basically provides a sharing platform where prosumers with a VAT number and a yearly production of at least 15 MWh can sell the electricity they inject into the public grid to consumers located in Belgium. Consumers can choose the peer from which they want to buy electricity. However, they cannot set the price at which the electricity is traded. The platform automatically settles exchanges at a price linked to the wholesale market in Belgium and charge a monthly subscription fee. Established in summer 2019, Bolt did not have difficulty in attracting prosumers and small electricity producers, but it is struggling to gain a sufficient number of consumers (Debruyne, 2019; Adriaen, 2021).

Peer-to-peer in communities

P2P transactions may take place within a community of peers too. Unlike platforms, which reduce transaction costs but do not alter the scale at which individual peers operate (Tirole, 2017), communities modify the operational size of their members. By enabling them to take decisions jointly and mobilise all the resources that they control individually in a coordinated manner, a community expands the scale at which each peer operates to that of the entire community (Ostrom, 2012). Although they are much bigger than a single peer, communities may still remain small compared to traditional players and preserve their non-professional

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[2] The information in this paragraph was taken from the Vandebron website: https://vandebron.nl/.

[3] The information in this paragraph was found on the Bolt website: https://www.boltenergie.be/nl/.

nature. As a result, in order to perform certain complex activities they may resort to external providers of professional services, which act as agents for the community.[4]

We can see this happening in the case of Partagélec in Brittany (France), where the municipality of Pénestin and the local energy syndicate Morbihan Energies involved a group of small businesses located in a production area in a joint initiative (Verde and Rossetto, 2020: 64-67). A 40-kW solar PV power plant was installed on the roof of a building owned by the municipality. The electricity produced by the plant first covers the consumption of the building. What remains is injected into the public grid and collectively shared among the 12 businesses involved. Any kWh injected that is not consumed in the same 30-minute interval by the community members is purchased by the renewable energy cooperative retailer Enercoop. The state-owned electricity distribution company Enedis, which operates the smart meters that measure the injections and withdrawals and the local distribution grid, provides the data to calculate the share of electricity self-consumed by each member of the community.

Communities may also operate at a broader geographical scale and make use of more sophisticated technologies. In the case of the Beehive Project, the social enterprise and community-owned energy company Enova Energy Community[5] is collecting the interest of up to 500 households and small businesses located anywhere in New South Wales (Australia) in order to create a virtual community, enabling every member to have access to solar energy via P2P electricity trading and a shared community battery (Lithgo Mercury, 2020).[6] People joining this community will be able to trade solar energy among themselves and with the community battery. Trading will be supported by Powertracer, a platform developed by the software company Enosi (Vorrath, 2020).[7] Using the data provided by the smart meters that any member of the community will have to be equipped with, Powertracer can match solar production with the energy use of any community member. The platform allows members to set their own trading preferences, automate the execution of transactions and settle them in the bills periodically issued by Enova (all community members will have to be Enova electricity customers). By installing a 1 MW, 2 MWh battery close to Newcastle, the community will be able to collectively store part of the surplus solar energy, operate better on the Australian wholesale electricity market and provide the local grid with ancillary services.

With the case of the 'hybrid' arrangement exemplified by the Beehive Project, which expands the activities managed by a community from behind the meter to in front of the meter, we arrive at the door of the second group of new transactions in electricity: 'peer-to-X.'

I.2 Peer-to-X transactions

Peer-to-X transactions have already grown in real life and will continue to grow because electricity consumers realise, or will soon realise, that their own production, consumption and storage devices can be mobilised to trade on traditional electricity markets, or on new markets derived from them (Sioshansi, 2020a; Sioshansi, 2020b). Peer-to-X is particularly fuelled by the deployment of individual storage units and the spread of a new type of 'consumption device and storage unit' on wheels: the electric vehicle (EV). When EVs are coupled with a garage storage unit and a rooftop PV panel, peers become fully equipped 'prosumagers' owning an entire local power system capable of doing many new things. At least four forms of P2X

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4 The external provider may be a specialised community. Some cases of communities providing specialised energy-related services to other community initiatives are described in REScoop.eu (2021).

5 https://www.enovaenergy.com.au/community-energy.

6 Updated information on the Beehive Project can be found on the Enova Energy dedicated webpage: https://www.enovaenergy.com.au/shared-community-battery.

7 Updated information on Enosi can be found on the company webpage: https://www.enosi.energy/.

transactions are currently being implemented around the world or are visible on the horizon: peer-to-system, peer-to-grid, EV as a coming wave of peer-to-grid and peer-to-system with an integrator. Below we review them with concrete examples.

Peer-to-System

P2X transactions can take the relatively simple form of peer-to-system. Owners of residential or commercial-scale PV panels benefitting from classical feed-in tariffs (FiT) can inject all the electricity they generate and do not consume into the grid to which they are connected. Another entity, usually the transmission system operator (TSO) or another company in charge of the matter, is responsible for collecting these electricity flows, integrating them into the power system and wholesale markets, and rewarding the prosumers. Prosumers entering into a peer-to-system transaction normally do not have any obligation in terms of time or the quantity they inject. They equally do not face any risk with regard to the level of remuneration they receive for the electricity they inject, which is usually stable for a period of a decade or more and sufficient to repay their initial investment in the generation asset.

FiTs and their variants, such as, for instance, net metering, are extremely peer-friendly. Households and small commercial electricity customers only have to invest a few thousand euros to buy and install the PV. This simplicity to a significant extent explains the massive deployment of solar PV in many countries in Europe and North America over the past 20 years (Ecofys, 2019). However, the phase-out of support measures for new installations makes the life of these peers somewhat more difficult as they have to leave this friendly ‘peer-to-system’ arrangement for another ‘peer-to-X’ arrangement (Brown et al., 2019).

Peer-to-Grid

Peers can trade with the grids to which they are connected. This type of transaction is more demanding since the object of the trade is not a generic injection of electricity into the grid but instead an injection with specific characteristics, for instance at a specific point in time. By modulating their net demand for electricity from the grid, small and non-professional consumers can offer something valuable to the professional actors participating in wholesale trading or to the entity in charge of the continuous and secure operation of the system. Depending on the identity of the counterpart, there are two different sub-forms. One is peer-to-grid in wholesale markets via aggregators; the other is peer-to-grid in local flexibility markets. Here we only consider the second.

These markets are new. Their purpose is to enable the local distribution system operator (DSO) to procure the ancillary services it needs to solve local congestion and other problems like voltage fluctuations, which are becoming more frequent due to the massive penetration of distributed generation and the electrification of end-uses like transport and heating. As well as the DSO, a software company may be involved to provide a digital platform on which to run the market. Peers can offer their flexibility on the platform, either individually or aggregated (Ofgem, 2019). Piclo Flex in Great Britain, Enera and NODES in Germany and GOPACS in the Netherlands are all examples of these emerging new markets where peers can trade with the grid at the local level and are facilitated in this by the direct involvement of the grid itself (Schittekatte and Meeus, 2020).

As we have seen in the case of the Beehive Project, communities can participate in these transactions too.

Electric vehicles – a coming wave of peer-to-grid

Millions of electric vehicles will be sold in the decade to 2030. In Europe, the European Commission expects 30 million EVs, which means that something around 1.5 TWh of storage capacity will be added to the electricity system in less than ten years. At the world level, it is expected that 116 million EVs might be driven by the same date (BNEF, 2020). Because of this gigantic potential size – only in the EU there are over 240 million passenger cars – the implications of EVs for the future of the electricity sector should not be underestimated.

If enrolled in smart charging schemes, EVs could be a flexible type of load, both over time and space, that can connect either in front of or behind the local utility's meter. EVs can be used by their owners to arbitrage the differences in electricity prices on wholesale markets and to offer ancillary services, both at the transmission and distribution level. Of course, they could also react to distribution charges and levies (Pearre and Ribberink, 2019; Sioshansi, 2020c). When connected to the distribution grid, EVs could adjust their charging rate in ways to ease local congestion and voltage issues (Bhagwat et al., 2019).

Peer-to-System with an integrator

A professional can specialise in linking peers with the energy system as an intermediary. The simplest form we met, more than ten years ago, was the aggregator. An aggregator only does the opposite of what a retailer does. Retailers adapt the products of wholesale markets to the actual size of retail consumption. Aggregators adapt the genuine consumption flexibility of peers, behind their meters, to the actual size and conditions of wholesale market offers. Each peer is obviously too small to enter these markets alone. However, when pooled by an aggregator, a minimum efficient scale can be achieved and a valuable product offered to a TSO, or to other market players active at the wholesale level (Glachant, 2019). Aggregators, both independent and within classical energy companies, already have significant experience in dealing with industrial and commercial electricity customers. More recently, they have been developing offers targeting the residential sector (Poplavskaya and de Vries, 2020).

However, peers can also trade with the whole system with the support of an energy asset manager acting as an 'integrator.' This professional party monitors and manages the assets of a peer in order to optimise their combined use and reduce the net cost of procuring 'last resort' energy from the grid. When endowed with assets such as solar PV, a domestic battery, flexible loads such as EV, electric heat pumps and water heaters, a peer owns a whole individual power system. This is why professional parties can offer integrated management solutions closely combining these assets to really maximise their local interactions and the value of their exchanges with the professional power markets and system. Indeed, by stacking different revenue sources and by managing the assets of a plurality of peers in an integrated way, the integrator can exploit its own technical and market expertise to create value for both itself and the prosumagers.

Early examples of this are Sonnen and the Octopus-Tesla Energy Plan. Sonnen is a German battery manufacturer which developed software to manage its customers' batteries in an integrated way. For a few years Sonnen has offered households the possibility of joining its collective scheme. Customers entering this scheme can virtually share the energy they generate with their own PV panels and the storage capacity of their Sonnen batteries. By managing these assets in an integrated way, Sonnen is able to reduce the cost of procuring electricity for its customers, who pay a flat tariff to consume up to a certain maximum amount of kWh in a year (Baak and Sioshansi, 2019).

The Octopus-Tesla Energy Plan is an offer available since 2020 to the owners of a Tesla Powerwall and a PV unit in Great Britain.[8] The customers purchasing this offer become part of Tesla's UK Virtual Power plant. Octopus, an asset-light retailer, ensures the procurement of 'last resort' electricity on the wholesale market, while Tesla's Autobidder ensures integrated management of all the customers' assets (Schittekatte et al., 2021b).

PART II: What are the key components of this new transactional world?

The many variants of transactions reviewed in Part I suggest that three components are key to the functioning of this new world: the transaction loop, as such small players cannot so easily sell to or buy from other peers; the pricing mechanism, as existing B2B and B2C markets exert pressure on the incentives for activating peers; and the delivery loop, as peers have to deliver via existing grids and system operation except when they manage their own mini-grid. We start our reasoning on each of these three components in a world of Peer-to-Peer, after which we introduce for each what we also learn from Peer-to-X.[9] We end by distinguishing four families of transactions with peers.

II-1 The Transaction Loop

Permitting small buyers and small sellers to trade their small units in the range of five euro cents per kWh but with strongly local characteristics – Oliver Williamson would have said "with notable asset specificities"[10] – requires an effective and precise transaction process. This is well beyond the capabilities and resources that each small non-professional agent can individually have or rationally acquire.

Digitalisation critically helps in this regard (Glachant and Rossetto, 2018; Rossetto and Reif, 2021). What is created for a local area can be reproduced somewhere else for other local areas because a robust digital application with adaptable parameters can easily be reproduced and spread. Of course, there are already families of apps that have demonstrated in other businesses that they can deal with multiple individual trading parties with no heavy central administration and hence no heavy costs: 'blockchains.' In fact, in the institutional economics of trade governance this mechanism to support trade is called a 'third party.' Small electricity players cannot individually build the 'digital transaction loop' that they need to be able to trade. Furthermore, the 'third party' also has to make its living from the trade services delivered to the individual small players. Two sets of business plans have to work together: those of the third parties and those of the non-professional individuals trading.

Such small players cannot individually take the initiative to build a full 'transaction loop,' the loop needed to make their small-to-small trade work. However, they can join together to act jointly. It can be a traditional cooperative or it can be a proper 'energy community,' as European Law has allowed since the adoption of the 'Clean Energy Package' (European 'energy communities' could also be assemblies of multiple flat owners in a single multilevel building or maybe the multiple renters of these flats – the 'net-zero consumption building' norm is opening multiple futures). Again, because of the particular rules governing cooperatives and energy communities, one can welcome both of them as forms of governance implementing the decisions of the individuals who are their 'principals.' Cooperatives and energy communities can also regroup in alliances to reach an operational size large enough to create their own

[8] Detailed information on the plan is available at https://octopus.energy/tesla-energy-plan-faq/.

[9] We expand there the reasoning started in Glachant (2020).

[10] Williamson (1985).

apps or blockchains. Alternatively, they can remain small and benefit from the applications and blockchains developed by external providers.

We can now add another layer to this reasoning. The providers of ready-to-use 'transaction loops' for cooperatives and communities can also set up their own P2P businesses, either to make additional money or to test other variants of pricing, searching, matching, settling and dispute resolution than the ones their existing 'principals' prefer. Some of these innovative providers are real 'start-ups.' They do not make much money from their billing but they build an operating unit to sell later to a bigger player, be it an energy incumbent or a new entrant.

We then end up with incumbents with pockets large enough to launch their own 'digital transaction loops,' which does not mean that this is a sound business model for each of them. New entrants too can be large enough in size, like the many European oil and gas companies willing to diversify into the electricity sector (Equinor, Total, BP, Shell…) but the same reservation applies regarding the accuracy of the P2P business model for such players. This is why, finally, the landscape for peer 'transaction loop' building, ownership and day-to-day management still looks very open and is moving fast.

II-2 The Pricing Mechanism

A pricing mechanism has to be adapted to these typically very small quantities of goods and to their intermittent delivery by the seller when the product traded is electricity from a renewable source. The typical unit size of the good on the sellers' side is a few kWh with a notional reference price of a few euro cents (on average 10 kWh are worth €0.5 euro in organised European wholesale markets). The supply is intermittent by nature (as it is renewable energy) and is also subject to another type of variability: the seller's own self-consumption. The pricing mechanism has to adapt to all these particularities of the supply while taking into account the varying value that buyers attribute to electricity at different times of the day, week or year, because all the buyers also have their own referenced traditional supplier guaranteeing their security of supply. Investment in storage can mitigate the intermittency of the generation but it increases the cost of supplying and requires more sophisticated pricing for the seller to maximise the temporal revenue stream allocation permitted by storage.

The few experiments that have been run have also shown that prosumer-sellers do not have a uniform elasticity to the prices offered. Some prosumer-sellers have a very low price elasticity. Others have a higher price elasticity but with significant elasticity thresholds governed by 'preference for self-generation and self-consumption,' which storage can mitigate, but only partially. On the buyers' side, some have pure 'price reactions' like classical rational consumers but others also react to the local nature of the supply, up to the individual identity of the supplier (Hahnel et al., 2020). Defining the best 'pricing mechanisms' for P2P trade in renewable energy is still an open field for experiment and research. Some may think that the wholesale power market already sends all the fine granular price signals needed, but this is forgetting that PV electricity is very local, meeting very local peaks in generation or in consumption, with very local system balancing conditions and grid congestion issues.

In P2X transactions, pricing is a much less complex issue because the buyer belongs to the traditional electricity world, or works very closely with and refers to the existing 'sequence of markets' pricing mechanisms to make P2X work. This is obvious in the aggregator case and the DSO case and it should be similar in the coming wave of peer-to-grid. In the most advanced form of P2X where an 'integrator,' being also a supplier of last resort, manages – on behalf of a prosumager – electric vehicle charging, its battery, a garage storage unit and the PV output, one finds full integration of a local 'home power system' in the general power system with a comprehensive stacking of all possible revenues obtained by the integrator and shared with the prosumagers.

II-3 The Delivery Loop

The ‘delivery loop’ is the last critical component without which P2P simply cannot work.

Of course, a community can be established within a private network, be it inside a multi-level building or a multi-building property or any other ambitious microgrid or minigrid. Therefore, a local ‘delivery loop’ can be duly conceived to closely work with the particular ‘transaction loop’ built by the community owner(s) or manager.

This strong community particularity does not exist, however, when a ‘transaction loop’ is intended to work among individuals connected to the ‘public access’ network. Public networks are regulated and function with rules set for the ‘B’ side of the electricity sector: the established generators and suppliers. They can easily deliver ‘B2B’ and ‘B2C’ trade but their basic rules are alien to the too many particularities characterising P2P transactions, which are all among peers.

The famous ‘Brooklyn Microgrid’ (BMG) mentioned earlier was launched at the end of 2015 and intended to create a new private direct current grid to bypass the established alternating current network owned and operated by the local distribution company, but it never did. After implementing a ‘proof of concept’ between two neighbours in 2016, BMG became a registered corporation cooperating with the utility to produce integrated bills for about 100 participants in a larger trial. Each of them needed a special Siemens metering and communication device embedded in a private blockchain. In 2019 BMG then applied for a ‘regulatory sandbox’ to start with 200 consumers and 40 prosumers in 2020. This world-famous case illustrates two key issues faced by P2P when entering ‘public access’ networks.

First, there is a settlement issue. This fully originates in the previous component, the ‘transaction loop.’ It is possible to install private meters on top of the publicly regulated ones, as BMG did, which fully synchronise injections from small sellers and withdrawals by small buyers (using a proxy for the grid losses). However, this will not work well if the regulated public metering system automatically bills any flow, be it between these small sellers and buyers, with its own ‘B2C’ regulated rules while ignoring any direct trade originated from a non-registered trading party. It would be technically doable to trace official ‘public’ bills and to reconcile them with the private unofficial billing but this might increase the transaction costs among small parties beyond any reasonable limit.

The second issue is typical of ‘delivery loops’: local grids have their own constraints on injections and withdrawals and particularly with PV, which most of the time is added to a distribution network not conceived to host injections. Not knowing the state of the local grid and not grasping how the local grid secures flows, balances load and manages congestion would create significant uncertainty about the actual delivery of the P2P privately contracted goods. Such ‘Russian roulette’ would deter the establishment of confident long-term relations between the peers buying and the peers selling. P2P trade is, in fact, very genuinely subject to veto by the regulated grid when there is no private ‘delivery loop’ working. On ‘public access’ electricity networks, there is no Amazon owning its private ‘delivery loop’ fully managed by the owner of its proprietary ‘transaction loop’ twin.

This duality between two fundamental pillars, transaction and delivery, both of which are necessary for ‘pure’ P2P to take off, can significantly reduce when a public access network voluntarily opens to peers who are sellers so as to be their monopsony buyer. ‘Peers-to-grid’ is a deep simplification of peer trading where both the transaction loop and the price mechanism are conceived and managed by the traditional regulated delivery loop. This form of ‘peers-to-X’ is already well known in the advanced world of flexibility procurement, where grids can launch their own subsidiaries or rely on ‘third-party’ platforms implementing it as a ‘delegated service.’

II-4 Four families of transactions with peers

We have just seen that three components are critical for the functioning of any trade with peers, and that each of these three components has its own options. This is why different forms of transactions with peers co-exist. In Part I of this article, we illustrated seven forms of transactions involving peers that are visible in current or emerging electricity markets. They can be reduced essentially to four different families of transactions: two for P2P and two for P2X. In fact, peer-to-peer in sandboxes represents only a very limited exception to ordinary rules applied to electricity networks and markets, while peer-to-system is losing relevance due to the phase-out of FiTs and net-metering schemes. Finally, electric vehicles represent a very relevant novelty for the electricity sector, but the transactions involving them can be assimilated to one of the other families of P2X.

1. 'Pure' Peer-to-Peer with a Third Party

The first family is that of 'pure' P2P trade. As we know that peers are too small to create their own 'transaction loops' and their own 'pricing mechanisms,' this 'pure' P2P trade in practice requires a third party offering peers a transaction loop as a service. If the third party conceives its business as a kind of two-sided market, it can grow by attracting new users as long as the definition of the products sold and their pricing mechanism are attractive enough for enough peers.

2. Peer-to-Peer within a Community

The second family is no longer a 'pure' P2P because individuals regroup to escape the consequences of being too small and non-professional. At a certain size, a group can build its own transaction loop or get one from an external 'transaction loop provider,' which becomes the agent of the community. At a larger size a community can invest in all 'behind-the-meter' directions (PV panels, EV charging stations, heat pumps, solar heater, storage and other advanced features like heating and cooling control devices). At this size, the community can also negotiate with all the traditional players in the power sector (notably the 'delivery loop') and combine its 'behind-the-meter' activities with regular 'in-front-of-the-meter' activities. The communities are therefore hybrid forms able to encapsulate both P2P and P2X transactions.

3. Peer-to-Grid

The third family is peer-to-grid, which actually means that it is the grid itself, being the regular delivery loop, which buys from the peers, offering them access to its own proprietary transaction loop and pricing mechanism. Peer-to-grid is a case of full integration of the three components of trading with peers, a full integration of the peers' trade activity organised by the monopsony buyer.

4. Peer-to-System with Integrator

The fourth and last family of peer transactions is another case of full integration of the peer by a traditional player in the power sector. This time, the integrator is a supplier extending its role to comprehensive energy management for prosumagers. The supplier acts both as supplier of last resort and as manager of the assets of the prosumagers (the PV panel output, the home storage unit, the EV charging station and the battery, etc.). By combining the potential of all these assets with the price signals coming from the many electricity markets, the integrator can maximise the revenues by 'stacking' them and share this added value with the prosumagers. As we noticed earlier that the 'within community' family was a hybrid form, this 'with integrator' family is also a hybrid form. It is because the same supplier can offer integrated services to well-equipped prosumagers while also managing a naked peer trade platform as a third party, or even operating a community transaction loop as the 'agent' of the community.

Conclusion

There can be no doubt that a new world has been born for electricity transactions. It is a world combining new players which are of a consumption unit size and non-professional, and new products originated from behind the meter. With these two dimensions to deal with, these new transactions are still looking heterogeneous and have not yet crystallised into regular forms of business models and governance. This is mainly because they are demanding a sophisticated frame to work (a transaction loop, a price mechanism and a delivery loop). These transactions therefore seem very sensitive to many constraints and to the actual behaviour of strongly positioned decision-makers like regulators, grid operators and market operators. However, step by step, peer-to-peer and peer-to-X transactions are getting a more favourable 'political economy' regime in the power systems where prosumers are numerous.

As we have seen, four families of transactions with 'peers' can already be identified as operational forms able to manage the particularities of these new transactions. This suggests both that the future of this new world of transactions is still widely open and that this world can only grow. People who saw the birth of electricity wholesale markets in the 1990s and of electricity retail markets in the 2000s remember the diversity and heterogeneity of those new forms of trade at their start. The variety of forms in new transactions and the uncertainty about their evolution in the future should not surprise. It could even become true that the 'business-to-business' and the 'business-to-consumer' worlds will learn how to create a 'peers-to-business' type of integration as the peer-dominant business model.

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