International Renewable Energy Agency

PEER-TO-PEER ELECTRICITY TRADING

INNOVATION LANDSCAPE BRIEF

IRENA
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ABOUT IRENA

The International Renewable Energy Agency (IRENA) is an intergovernmental organisation that supports countries in their transition to a sustainable energy future and serves as the principal platform for international co-operation, a centre of excellence, and a repository of policy, technology, resource and financial knowledge on renewable energy. IRENA promotes the widespread adoption and sustainable use of all forms of renewable energy, including bioenergy, geothermal, hydropower, ocean, solar and wind energy in the pursuit of sustainable development, energy access, energy security and low-carbon economic growth and prosperity. **www.irena.org**

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1 BENEFITS

Peer-to-peer (P2P) electricity trading empowers prosumers and consumers, leading to increased renewable energy deployment and flexibility in the grid. P2P platforms also aid in balancing and congestion management and providing ancillary services.

Peer-to-peer electricity trading

- **Higher renewable power deployment and flexibility**
- **Balancing and congestion management**
- **Ancillary services**

2 KEY ENABLING FACTORS

- Distributed renewable energy resources
- Digitalisation
- Conducive regulatory framework

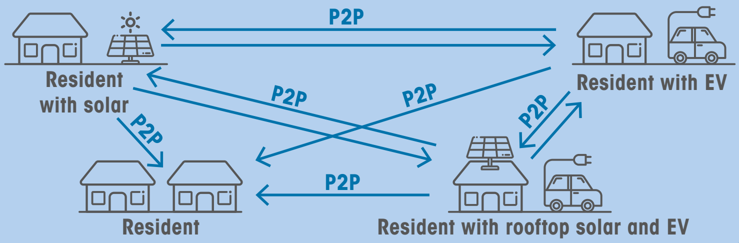
3 SNAPSHOT

➜ Australia, Bangladesh, Colombia, Germany, Japan, Malaysia, the Netherlands, the UK, the US and others have started trial P2P schemes.

➜ Many pilot projects used blockchain technology.

What is P2P electricity trading?

The P2P model creates an online marketplace where prosumers and consumers can trade electricity, without an intermediary, at their agreed price.



PEER-TO-PEER TRADING

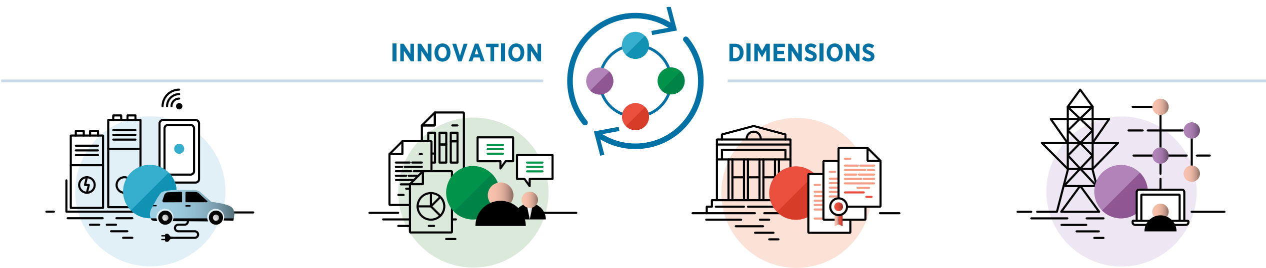
Trading based on P2P models makes renewable energy more accessible, **empowers consumers** and allows them to make better use of their energy resources.

ABOUT THIS BRIEF

This brief forms part of the IRENA project "Innovation landscape for a renewable-powered future", which maps the relevant innovations, identifies the synergies and formulates solutions for integrating high shares of variable renewable energy (VRE) into power systems.

The synthesis report, "*Innovation landscape for a renewable-powered future: Solutions to integrate variable renewables*" (IRENA, 2019a), illustrates the need for synergies between different innovations to create actual solutions. Solutions to drive the uptake of solar and wind power span four broad dimensions of innovation: enabling technologies, business models, market design and system operation.

Along with the synthesis report, the project includes a series of briefs, each covering one of 30 key innovations identified across those four dimensions. The 30 innovations are listed in the figure below.



ENABLING TECHNOLOGIES

1 Utility scale batteries
2 Behind-the-meter batteries

3 Electric-vehicle smart charging
4 Renewable power-to-heat
5 Renewable power-to-hydrogen

6 Internet of Things
7 Artificial intelligence and big data
8 Blockchain

9 Renewable mini-grids
10 Supergrids

11 Flexibility in conventional power plants

BUSINESS MODELS

12 Aggregators
13 Peer-to-peer electricity trading
14 Energy-as-a-service

15 Community-ownership models
16 Pay-as-you-go models

MARKET DESIGN

17 Increasing time granularity in electricity markets
18 Increasing space granularity in electricity markets
19 Innovative ancillary services
20 Re-designing capacity markets
21 Regional markets

22 Time-of-use tariffs
23 Market integration of distributed energy resources
24 Net billing schemes

SYSTEM OPERATION

25 Future role of distribution system operators
26 Co-operation between transmission and distribution system operators

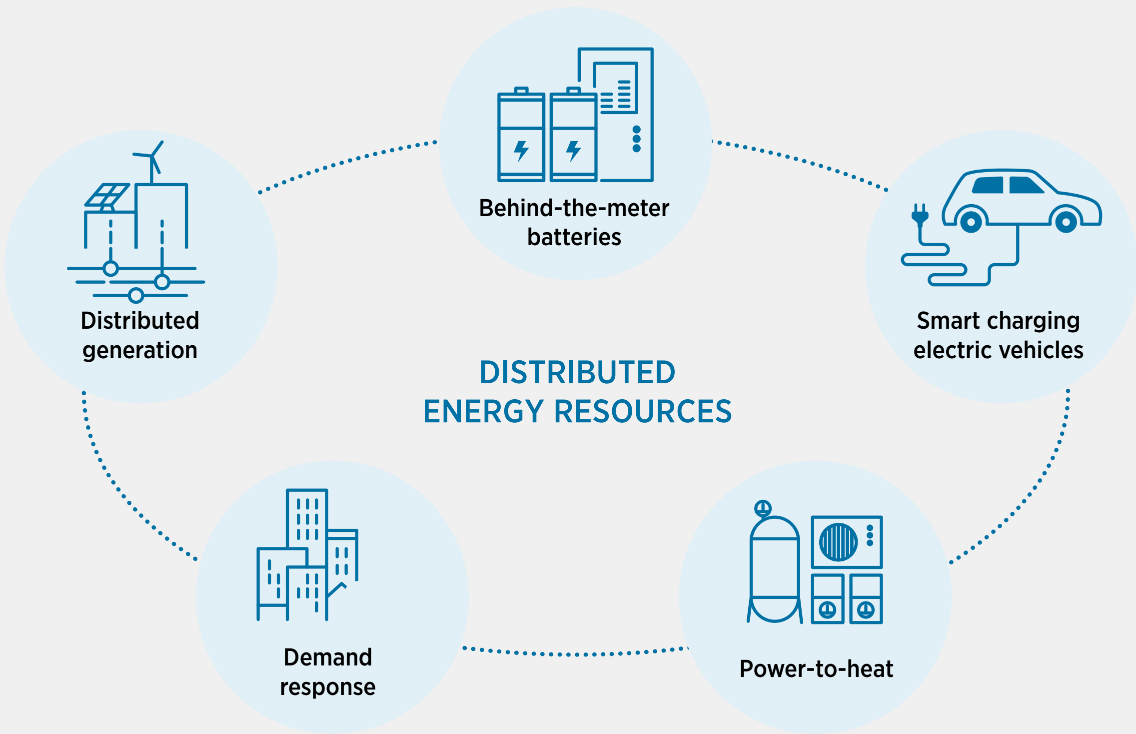
27 Advanced forecasting of variable renewable power generation
28 Innovative operation of pumped hydropower storage

29 Virtual power lines
30 Dynamic line rating

This brief provides an overview of the peer-to-peer (P2P) electricity trading business model that emerged as a platform-based scheme in view of increasing the integration of distributed energy resources into power systems. Distributed energy resources allow previously "passive" consumers (from the system operators' point of view) to become "active" consumers, often called prosumers because they both consume and produce electricity.

With P2P electricity trading, prosumers can share the benefits of generating electricity with the communities that they belong to, further encouraging the consumption and deployment of distributed renewable generation. The brief focuses on how the P2P business model can both contribute to power sector needs, while also empowering consumers.

Distributed energy resources (DERs) are small or medium-sized resources, directly connected to the distribution network (EC, 2015). They include distributed generation, energy storage (small-scale batteries) and controllable loads, such as electric vehicles (EVs), heat pumps or demand response.



The brief is structured as follows:

I Description

II Contribution to power sector transformation

III Key factors to enable deployment

IV Current status and examples of ongoing initiatives

V Implementation requirements: Checklist

I. DESCRIPTION

Peer-to-peer (P2P) electricity trading is a business model, based on an interconnected platform, that serves as an online marketplace where consumers and producers "meet" to trade electricity directly, without the need for an intermediary. P2P electricity trading is also known as the "Uber" or "Airbnb" of energy, as it is a platform that allows local distributed energy generators to sell their electricity at the desired price to consumers willing to pay that price.

This electricity is usually transacted between users (buyers/sellers) of the platform that also become members of the platform, for example by paying a pre-determined monthly subscription fee. Just like an open market economy, suppliers seek the highest possible price, keeping their costs and profit in consideration, and consumers choose the lowest price possible based on their needs and preferences. Where the supply and demand offers – that is, the sell and buy bids – are matching, a trade occurs.

The common practice with traditional power supply is that consumers purchase electricity from utilities or retailers through fixed tariffs or time-of-use tariffs.

In contrast, prosumers (who produce as well as consume) or "self-consumers"[1] sell excessive electricity back to the grid at a "buy-back rate", as shown in Figure 1 (Liu *et al.*, 2019). However, consumer tariffs for electricity supply are generally much higher than the buy-back rates that prosumers can obtain from selling electricity to the utility. Also, these consumer tariffs do not account for the other benefits that this renewable generation brings to the power system.

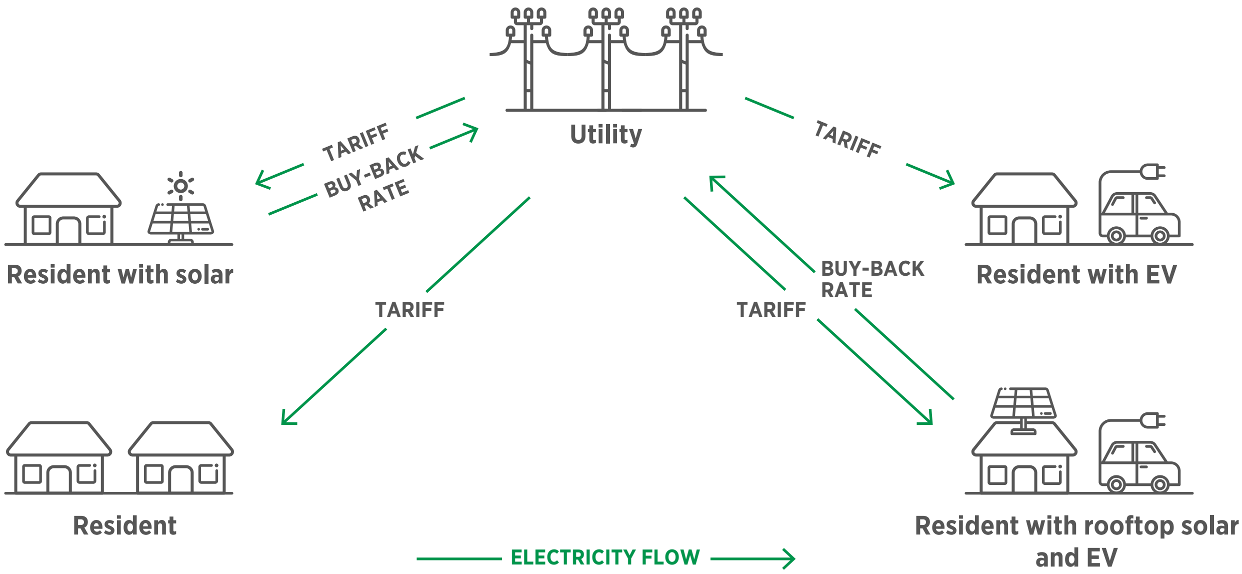
For example, while a prosumer can charge an EV using a rooftop solar plant, the prosumer's neighbour would obtain electricity to charge his or her EV from a distant centralised power plant. If, however, the vehicle is charged from a solar power plant located in the neighbourhood, the prosumer with solar installation would receive a "buy-back rate" for the electricity injected into the grid. However, this would not take into account the reductions in transmission losses and congestion that this distributed generation provides for the network. Around 41.1% of the typical electricity cost goes towards managing and maintaining the poles and wires that deliver power from generators to the premises of customers (Auroraenergy, 2020). Part of these costs could be saved in a P2P model.

1 *In the European context, a "renewables self-consumer" is defined as "a final customer operating within its premises located within confined boundaries [..] who generates renewable electricity for its own consumption, and who may store or sell self-generated renewable electricity, provided that, for a nonhousehold renewables self-consumer, those activities do not constitute its primary commercial or professional activity" (Directive (EU) 2018/2011 of 11 December 2018 on the promotion on the use of energy from renewable sources).*

The P2P electricity trading model was born as a consequence of the increasing deployment of distributed energy resources connected to distribution networks, and the intention to provide more incentives to promote further deployment of these resources. In P2P electricity trading, prosumers are allowed to switch their roles between buyers and sellers to either purchase or sell electricity.

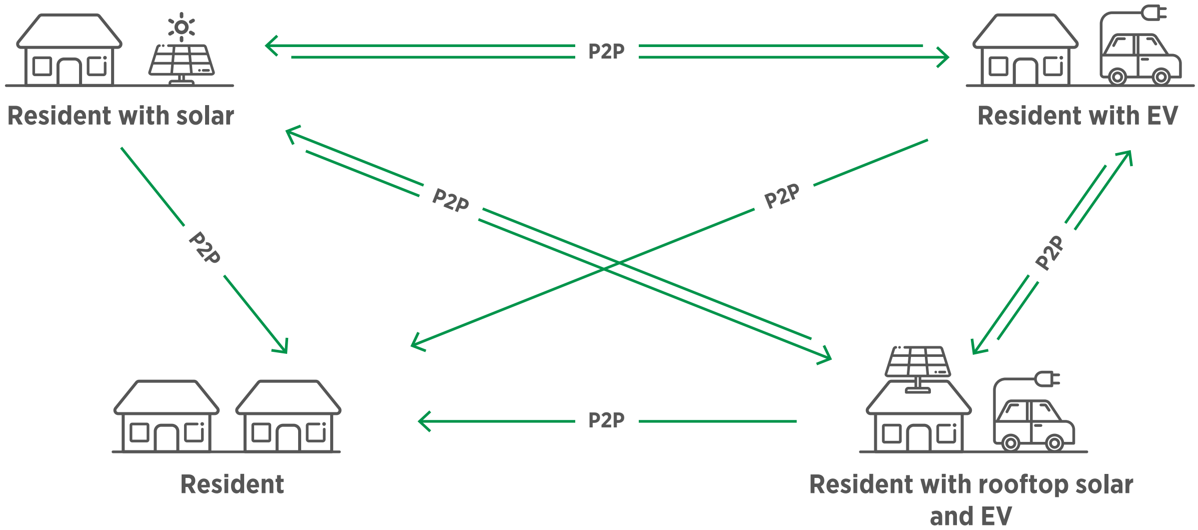
In addition, they are able to directly trade electricity with other consumers to achieve a win-win by seeking a better outcome compared to the relatively high tariffs and the relatively low buy-back rates. In this way, buyers can save costs while sellers can make a profit (Liu *et al.*, 2019). Figure 2 illustrates the structure of the P2P trading model.

Figure 1 Traditional trading model of residential consumers and prosumers with utilities



Source: Adapted from Liu *et al.*, 2019

Figure 2 Structure of P2P electricity trading model



Source: Liu *et al.*, 2019

Note: The direction of the arrow indicates the accounting and transactions flow directions.

A P2P trading model can be established among neighbours within a local community, as well as on a larger scale, among various communities. Figure 3(a) shows P2P electricity trading among individual neighbours on a small scale, which is done either on the distribution grid or via a "mini-grid" set-up. Figure 3(b) shows a group of small communities or mini-grids forming a bigger group that trades electricity among themselves. This is enabled by interconnected networks owned by distributed system operators. Like any P2P trading scheme, the size and number of participants are important. Therefore, such platforms are viable only when there are enough participants willing to trade electricity with each other.

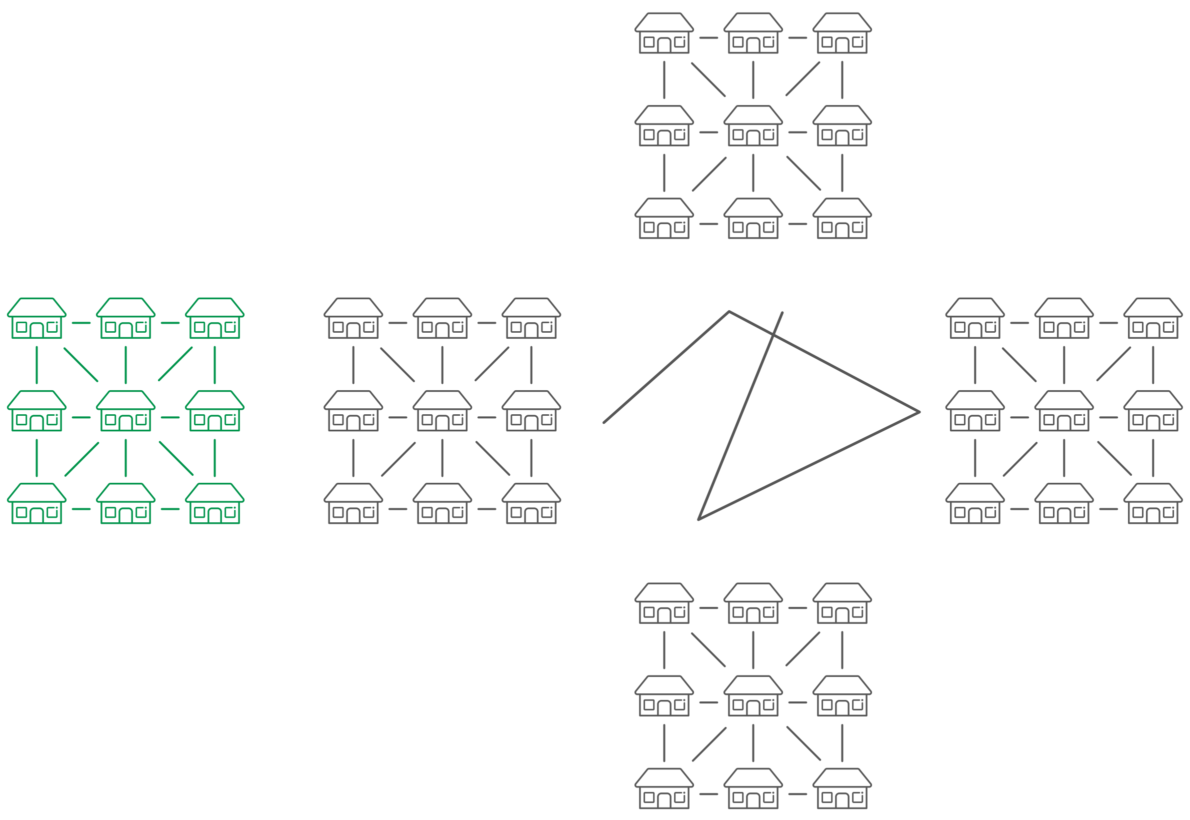
If the P2P platform (market) operator is organising trading among subscribers that are part of the main distribution system (rather than an isolated mini-grid), then it will need to interact with system operators and the electricity market.

This is because:

- power flow between the participants will affect the local distribution network;
- the local distribution network needs to be operated, maintained and remunerated accordingly; and
- it will need to buy/sell excess demand/generation upstream.

If the P2P platform operates based on an isolated mini-grid (and therefore has to fulfil the system operator role), then the operator needs to ensure that supply and demand are balanced at all times and at fast time scales to maintain grid stability.

Figure 3 P2P electricity trading concept



(3A)

Electricity trading among neighbours within a community

(3B)

Electricity trading among communities within a region

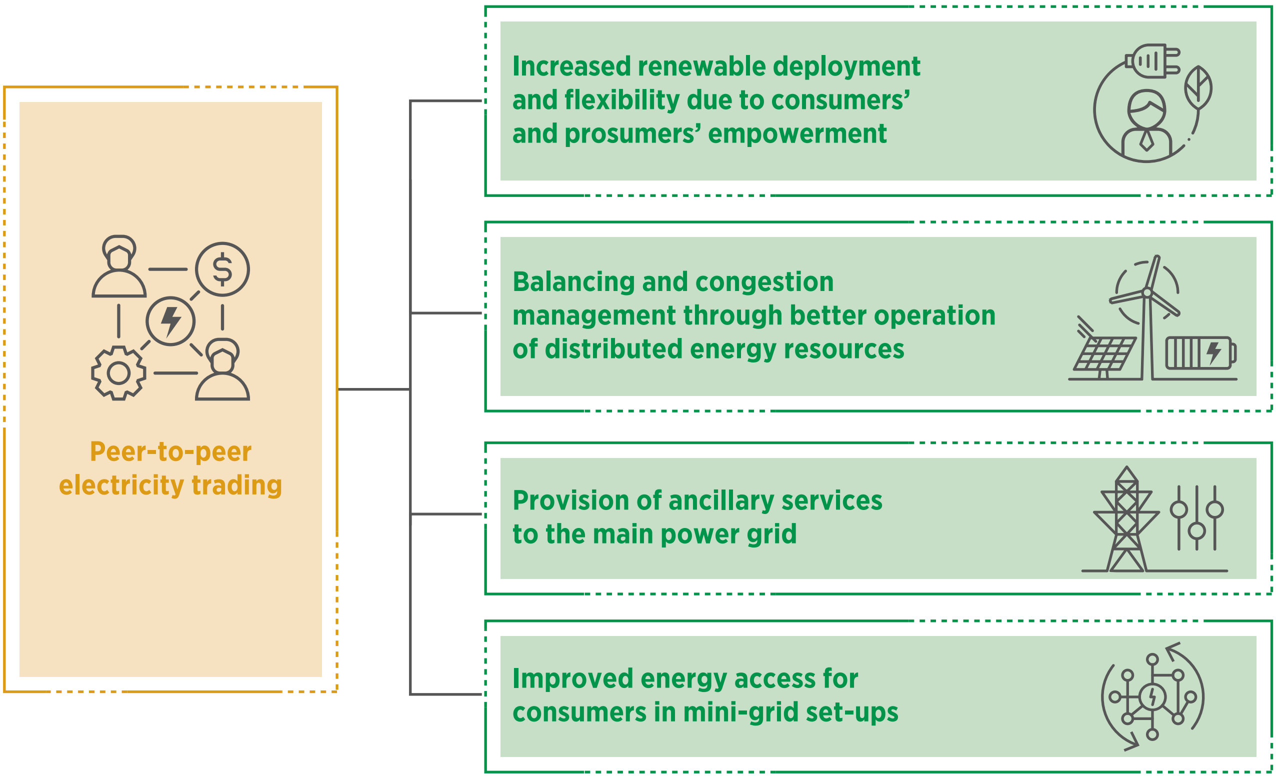
Source: Adapted from Park and Yong, 2017

II. CONTRIBUTION TO POWER SECTOR TRANSFORMATION

The P2P electricity trading model makes renewable energy more accessible, empowering consumers while making better use of their distributed energy resources. It also keeps the community resilient to outages in emergencies, and it can improve the energy access in some cases.

The main power grid can benefit from decentralised P2P electricity trading platforms as well. Figure 4 summarises the key benefits of P2P electricity trading for power sector transformation.

Figure 4 Key contributions of P2P electricity trading to power sector transformation



Consumer and prosumer empowerment boosting renewables and flexibility

P2P trading platforms offer a marketplace for prosumers to trade the renewable energy generated at a better price, encouraging the deployment of distributed generation. Similarly, P2P trading allows the consumers to have control over their electricity consumption and its price, increasing flexibility in the system.

Moreover, P2P trading allows participants to support their local communities by enabling them to consume renewable power and earn more from their distributed generation, with or without storage systems. At the same time consumers without renewable generation capacity can benefit directly from local renewable generation through P2P electricity trading.

For example, in 2019 London's Global University (UCL) and EIA University in Colombia set up a P2P pilot project in Medellin, Colombia called the Transactive Energy Colombia Initiative. In Medellin, many energy users, especially those living in high-rise buildings, are not able to generate their own electricity. The main idea is that P2P trading will allow these users to buy electricity from other people around the city based on different attributes, such as renewable shares, generation infrastructure, and location.

This creation of social value around energy is a key point of this project (UCL, 2019).

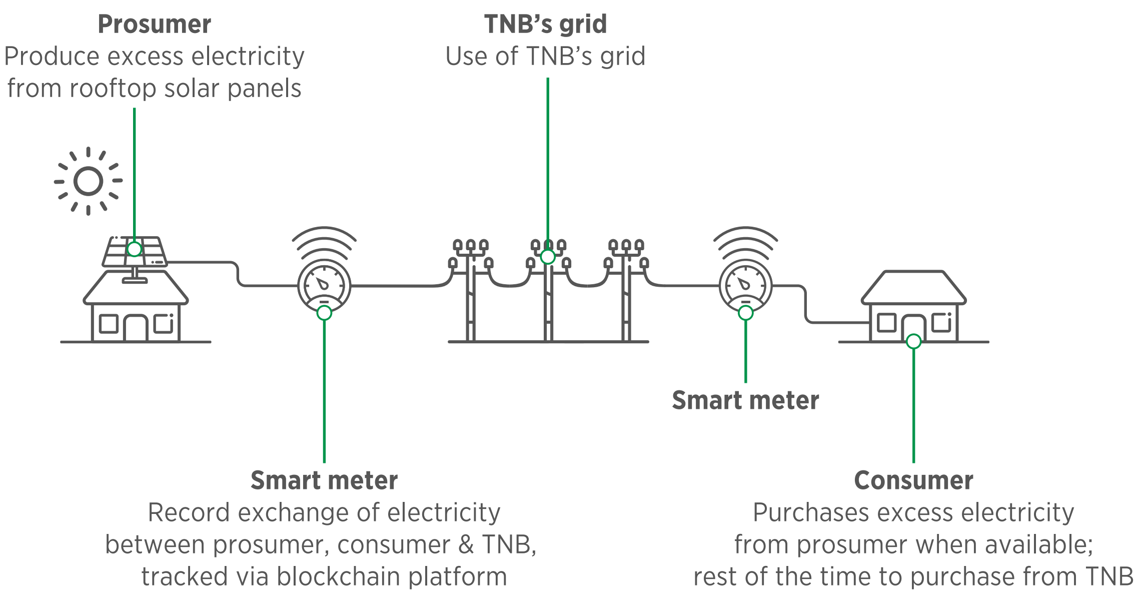
The P2P pilot will group 14 residential users with different income levels in Medellin, each of them independently connected to the distribution network. Low-income users will have solar panels installed on their rooftops and will trade electricity with high-income consumers and prosumers (UCL, 2019).

Balancing and congestion management through better operation of distributed energy resources

P2P trading platforms enable better management of decentralised generators by matching local electricity demand and supply at all times. Along with the higher local consumption of variable renewable energy, P2P electricity trading can help reduce investments related to the generation capacity and transmission infrastructure needed to meet peak demand.

For example, the Sustainable Energy Development Authority in Malaysia is piloting a P2P electricity trading project, launched in November 2019. Prosumers can trade electricity with consumers or sell their excess solar photovoltaic electricity to the utility Tenaga Nasional Berhad (TNB). Exchanges are tracked via a blockchain platform. The concept is illustrated in Figure 5

Figure 5 Concept of P2P electricity trading project in Malaysia



Source: SEDA, 2019

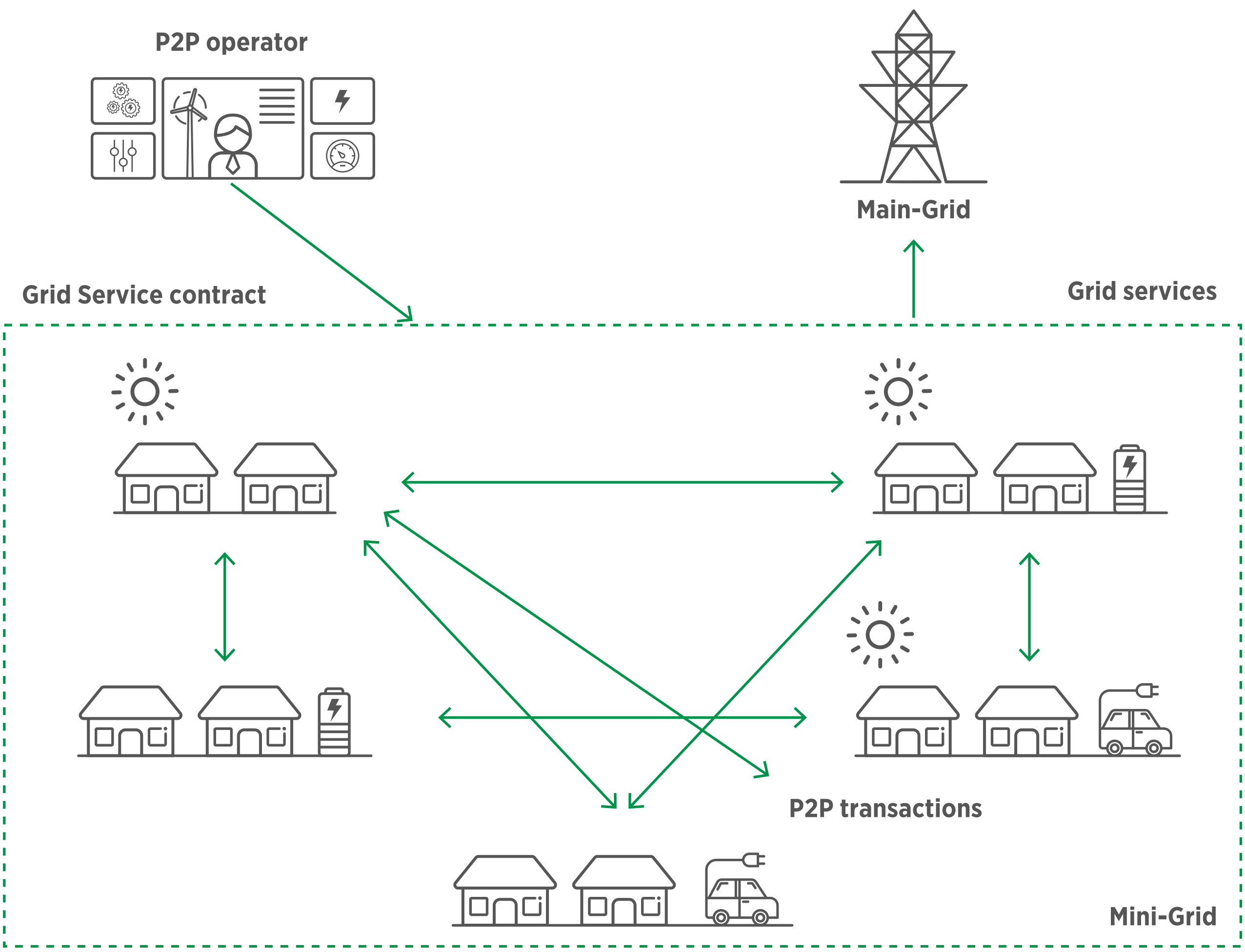
Preliminary findings of the pilot project show that P2P electricity trading helps to balance local generation and demand and has the potential to enable large penetration of renewable electricity in the grid. If carried out at distribution level, P2P trading can reduce peak demand and grid congestion in the main grid. With P2P trading available, the amount of electricity sold back to the grid is very small compared to the amount of electricity traded in the community (SEDA, 2019). This illustrates the better use of distributed energy resources inside the community through P2P energy trading.

Provision of ancillary services to the main power grid

In a mini-grid set-up, apart from enabling P2P transactions, the P2P platform operator can also enable peers to provide ancillary services to the main grid. In addition, the P2P electricity trading platform can serve as a virtual power plant (VPP). Formed by self-organised consumers, such VPPs provide services to the main grid. (For more on how this works, see *Innovation Landscape brief: Renewable mini-grids* [IRENA, 2019b], and for more about VPPs, see Innovation *Landscape brief: Aggregators* [IRENA, 2019c].) Figure 6 illustrates the concept.

For example, Piclo, the P2P electricity trading company formerly known as Open Utility, has signed up five of the six distribution system operators in the United Kingdom (UK) to its flexibility marketplace. The Piclo Flex platform allows distribution system operators to identify flexibility options to meet their distribution system needs in each specific location of the grid. Part of a trial funded by the UK government, this marks a stage in the transition of distribution system operators from passive to active managers of their networks. The marketplace gives them the chance to relieve constraints without having to resort to costly grid reinforcements.

Figure 6 P2P operation in a mini-grid context



Source: Adopted from Morstyan *et al.*, 2018

Improved energy access for consumers in mini-grid set-ups

In the context of an isolated mini-grid, P2P trading could improve the energy access and the reliability of local electricity generating sources. In such mini-grids, users are generally supplied electricity through solar home systems, which often cannot store the electricity surplus. By enabling P2P trading and connecting several solar home systems to each other as well as with other homes without electricity supply, energy access of consumers can be improved. Extra generation from solar home systems can serve another consumer in exchange for remuneration.

SOLshare, a Bangladesh-based company, piloted the P2P electricity trading network for rural households with and without solar home systems in Shariatpur, Bangladesh. The trading network interconnects households via a low-voltage direct current grid and controls power flows through bi-directional metering integrated with an information and communications technology (ICT) back-end that handles payment, customer service and remote monitoring. Each SOLshare meter enables the user to buy and sell renewable electricity with neighbouring consumers (households, businesses and rural industries). People in rural Bangladesh are now earning additional income by selling their surplus electricity, and at the same time new users have gained electricity access for the first time (UNFCCC, 2020).

Potential impact on power sector transformation

P2P trading can greatly reduce overall operation costs of the power system and ultimately reducing consumers' electricity bills. Consumers can save in various ways. On the one hand, prosumers can monetise the excess production of renewable energy. On the other hand, consumers without generation capacity can benefit from low-cost local renewable energy supply. Examples where P2P trading have resulted in cost savings are:

- Power Ledger, an Australian P2P trading platform, has **saved** an average of **USD 424 (AUD 700) per year for its energy consumers** on annual electricity bills and helped solar rooftop system owners double the savings they normally get from their solar plants (Kabessa, 2017).

- The New York-based energy start-up Drift, a P2P trading platform, has helped **consumers save 10% of their electricity costs** compared to Con Edison, a local utility in the New York area (CNBC, 2017). To drive down the cost for these consumers, Drift relies on blockchain technology and algorithms to source and trade power.

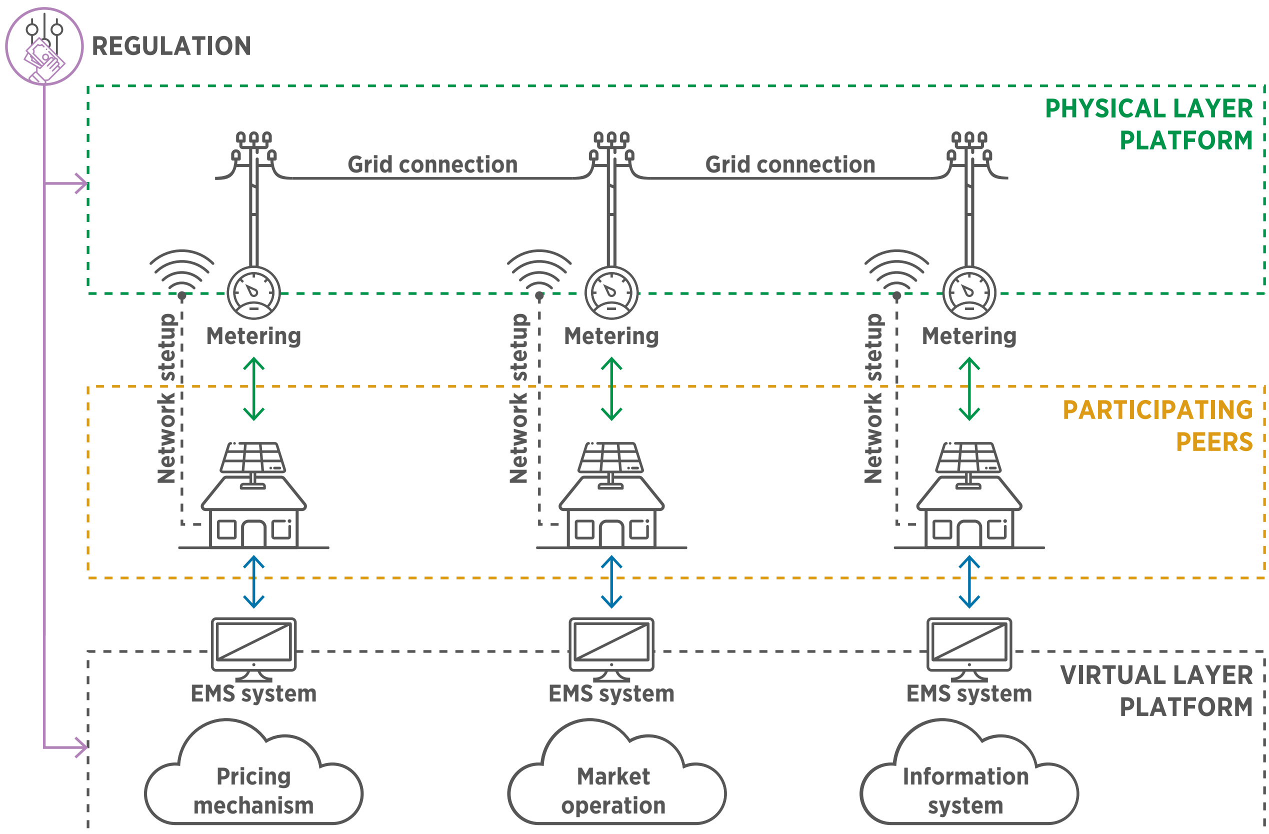
III. KEY FACTORS TO ENABLE DEPLOYMENT

The key success factors for P2P electricity trading platforms are the reliability of the platform, good customer service, the availability of a conducive regulatory framework and a reliable grid.

Digitalisation

In addition to the physical layer of P2P electricity trading for which a network is needed (*e.g.*, mini-grids, micro-grids, distribution network, etc.), another layer that is needed for this business model to be implemented is a virtual (*i.e.*, digital) layer (Figure 7). An energy management system (EMS) is an integral part of it.

Figure 7 Illustration of the physical and virtual layer platforms of a P2P electricity network



Source: Tushar, 2020

P2P trading is facilitated by platforms where a large number of peers can interact. Data from both producers and consumers need to be collected and analysed to check the reliability of the power system. Smart meters, broadband communication infrastructure, network remote control and automation systems (network digitalisation) are thus fundamental enablers of platform-based business models, such as the P2P electricity trading model (see the *Innovation Landscape briefs: Internet of Things* [IRENA, 2019d] and *Artificial Intelligence and big data* [IRENA, 2019e]).

The P2P trading platform can work efficiently with the help of distributed ledger technologies, of which the most prominent type is blockchain. Blockchain technology can help reduce the transaction costs for electricity trading among prosumers in a P2P trading scheme (see the *Innovation Landscape brief: Blockchain* [IRENA, 2019f]).

For example, the P2P blockchain developer LO3 Energy operates the Brooklyn Microgrid, which augments the traditional energy grid, letting participants tap into community resources to generate, store, consume (*i.e.*, buy and sell) energy at the local distribution level. Another example of P2P trading using blockchain technology is the Power Ledger platform in Australia, which records the generation and consumption of all peers in real time. The P2P project piloted in Malaysia is built on the Power Ledger platform, which is also running trials in Australia, Japan, Thailand and the United States (US) (Ledger Insights, 2019).

Conducive regulatory framework

To reap the benefits of P2P electricity trading, regulators would need to ensure a level playing field for platform-based businesses vis-à-vis traditional utilities and retailers. in one major development in this area, the European Commission defined for the first time P2P trading of renewable energy in EU Directive 2018/2001 of 11 December 2018 on the promotion of the use of energy from renewable sources, (part of the so-called Clean Energy Package of legislation). In the Directive, P2P is defined as "the sale of renewable energy between market participants by means of a contract with pre-determined conditions governing the automated execution and settlement of the transaction, either directly between market participants or indirectly through a certified third-party market participant, such as an aggregator. The right to conduct peer-to-peer trading shall be without prejudice to the rights and obligations of the parties involved as final customers, producers, suppliers or aggregators." (EC, 2018). The directive must be transposed into national law by all EU member countries.

The European Commission defined further criteria indicating that renewable energy consumers shall be entitled to P2P trading without being subject to disproportionate or non-discriminatory (network) charges, fees, levies, taxes and procedures, including the case in which renewables self-consumers are located in the same building, including multi-apartment blocks. However, a distinction is to be made between "individual renewables self-consumers" and "jointly acting renewables self-consumers" (Art. 21(4) of Directive (EU) 2018/2001).

Moreover, in the US, P2P trading is possible only through microgrids, without using the main grid infrastructure (ARENA, 2017). Despite isolated microgrid experiments such as the one running on an LO3 Energy blockchain in Brooklyn, New York, not many P2P projects have been implemented in the country given the limitations in the regulatory framework (Deign, 2019).

IV. CURRENT STATUS AND EXAMPLES OF ONGOING INITIATIVES

Several companies have set out to test and start commercialising P2P electricity trading in recent years. Some innovators focus on the creation of the platforms, while others target local ICT systems for mini-grids.

Pilot schemes have started in many developed and developing countries, including Australia, Bangladesh, Colombia, European countries, Japan, Malaysia, the United States and others. Table 2 provides a brief overview of some of these projects.

Table 1 Key facts about EaaS business model development

P2P trading platform	Country	Details
Brooklyn Microgrid	United States	Brooklyn Microgrid is a community energy market within a microgrid. Under the platform, members can buy and sell energy from each other with smart contracts based on blockchain (Mengelkamp *et al.*, 2018).
Centrica plc	United Kingdom	Centrica is a pilot project to develop a local energy market in Cornwall, UK by testing the use of flexible demand, generation, and storage, and rewarding consumers for being more flexible with their energy. The participants use the latest digital technologies to connect to a virtual marketplace that will allow them to sell their flexible energy capacity to both the grid and the wholesale energy market. Centrica is trialling the use of blockchain for this platform, using LO3's blockchain-powered energy trading platform (Centrica, 2018).
Lumenaza	Germany	Lumenaza's "utility-in-a-box" energy platform enables P2P energy sharing and communities on a local, regional and national level. The software connects producers of electricity with consumers, controls demand and supply (*e.g.*, by loading batteries) and includes balance group management, aggregation, billing and visualisation of energy flows. It allows energy communities to participate in electricity market design (Lumenaza, 2020).
Piclo	United Kingdom	Piclo by Open Utility (a platform) and Good Energy (a renewable energy power company) matches consumers and prosumers based on their preferences and locality, every 30 minutes. Customers are provided with consumption data visualisations, and generators are provided with control and visibility over who buys power from them. Good Energy balances the peaks and valleys in generation, provides contracts and meter data, and does the billing (Piclo, 2019).

P2P trading platform	Country	Details
SOLshare	Bangladesh	SOLshare installs small-scale mini-grids that connect local consumers and allow them to share electricity within the locality. Consumers who have a solar panel installed on their homes can supply surplus power to others who do not have access to electricity. By providing a mini-grid, a consistent power network is available across the locality (UNFCCC, 2020).
sonnenCommunity	Germany	sonnenCommunity allows sharing of self-produced renewable power by individual consumers who are using sonnen's batteries. This surplus energy is not fed into the grid, but into a virtual energy pool that supplies energy to other community members during times when they cannot produce. The electricity price is fixed at around USD 25 cents/kwh (EUR 23 cents/kWh). The monthly usage fee for the platform is EUR 20 (sonnen, 2019).
Transactive Energy Initiative	Colombia	The pilot project activities include the development of a P2P trading app, the elaboration of policy recommendations for Colombian policy makers and a roadmap for commercial scale-up (UCL, 2019).
Vandebron	Netherlands	The Vandebron platform allows consumers to buy power directly from prosumers, at the price set by prosumers. It behaves as an energy supplier that connects consumers, prosumers and generators and balances the wholesale markets. It also provide suppliers with generation forecasting information for their assets. The monthly usage fee of the platform is USD 12 (Vandebron, 2020).

V. IMPLEMENTATION REQUIREMENTS: CHECKLIST

TECHNICAL REQUIREMENTS

Hardware:

- Physical layer: Smart meters that can help monitor real-time power production, and smart grids, including mini-, micro- or nanogrids
- Virtual layer: ICT network to enable communication between participants, handle payments, monitoring; and EMS

Software:

- Platform for P2P electricity trading
- Advanced power demand and supply forecasting analysis
- Robust data analytics tool
- Algorithms for automated execution of P2P transactions or blockchain technology for reduced transaction costs

Communication protocol:

- Common interoperable protocol for co-ordination among system/network/market/platform operators, consumers and prosumers

POLICIES NEEDED

- Supportive policies encouraging decentralisation of power systems and better utilisation of existing grid infrastructure
- Encourage pilot programmes to work as a test bed, in regulatory sandboxes; and dissemination of results
- Improve the access to capital for platform developers

REGULATORY REQUIREMENTS

Retail market:

- Enable trade of power among prosumers and consumers without renewable generation capacities
- Establish regulations on data collection and access, as well as cybersecurity and privacy for platform owners/developers and platform members, i.e., peers
- Define clear roles and responsibilities of stakeholders involved in P2P
- Ensure that consumer rights are respected by stakeholders in P2P schemes
- Define market operation rules for the P2P schemes

Distribution network:

- Enable distribution system operator to procure flexibility from P2P platforms
- Define technical criteria for ancillary services needed
- Determine network charges when P2P trading is using the main grid

STAKEHOLDER ROLES AND RESPONSIBILITIES

Consumers, prosumers:

- Engage in P2P electricity trading
- Provide services to the power system, either individually or via retailer or aggregator

P2P platform/market operators:

- Develop and operate platforms for P2P trading with ICT companies
- Ensure that the platform is secure and trusted

ABBREVIATIONS

AUD	Australian dollar
EMS	energy management system
EU	European Union
EUR	Euro
EV	electric vehicle
ICT	information and communications technology
IRENA	International Renewable Energy Agency
IT	information technology
P2P	peer-to-peer
TNB	Tenaga Nasional Berhad
UK	United Kingdom
US	United States
USD	United States dollar
VPP	virtual power plant

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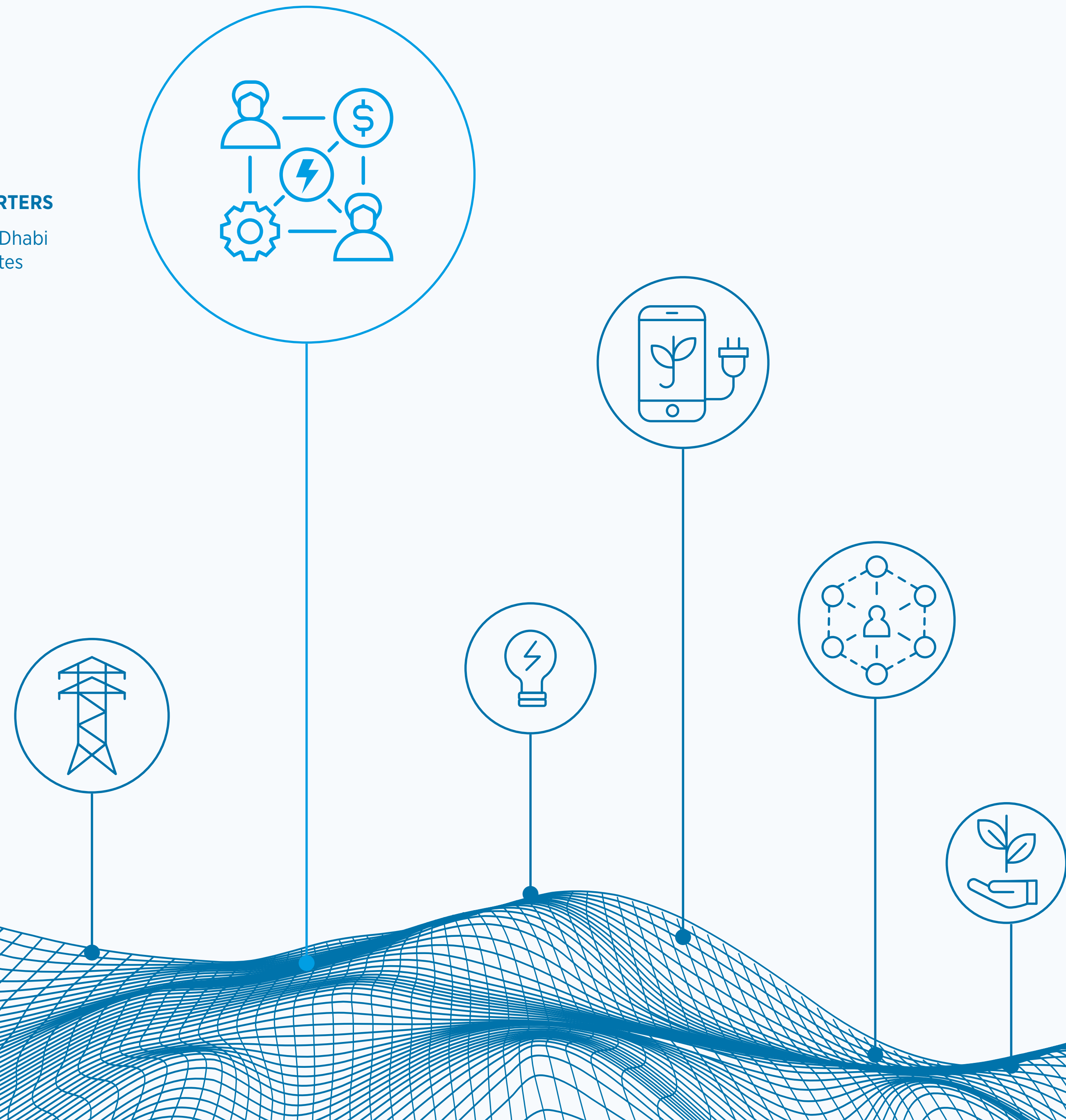

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