Business Models

Business Models: Innovation Landscape

- Aggregators
- Peer-to-peer trading
- Energy-as-a-service
- Community ownership
- Pay-as-you-go models

IRENA
International Renewable Energy Agency

AGGREGATORS

INNOVATION LANDSCAPE BRIEF

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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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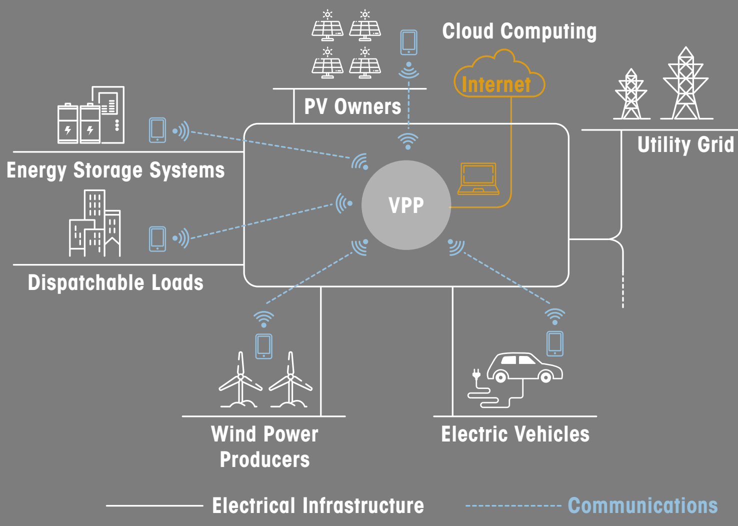
1 BENEFITS

Aggregators use a centralised IT system to remotely control the DERs and optimise their operation.

They can provide:

- ➜ Load shifting
- ➜ Balancing services to TSOs
- ➜ Local flexibility to DSOs



3 SNAPSHOT

- Global market value of USD 762 million in 2016, expected to reach USD 4 597 million in 2023
- World's Largest VPP is expected to connect DERs in 50,000 homes to meet 20 % of South Australia's daily power demand.
- Projects in Netherlands, Germany and Australia are aggregating behind the meter batteries to provide grid services.

2 KEY ENABLING FACTORS

- Smart meters & Communication Infrastructure
- Regulatory framework allowing participation of new market players
- Accurate data (weather forecast, load projections, wholesale prices)

WHAT ARE AGGREGATORS AND DERs?

Distributed energy resources (DERs) are small and medium-sized power resources connected to the distribution network.

Aggregators bundle DERs to engage as a single entity – a virtual power plant (VPP) – in power or service markets.

AGGREGATORS

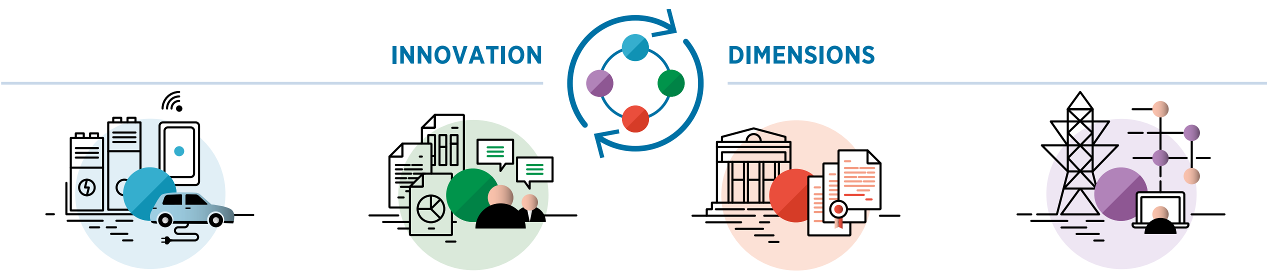
Increased digitalisation and smart metering have created new business models. **Aggregators are a new market player that can optimise the use of distributed energy resources.**

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, 2019), illustrates the need for synergies among 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 main 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

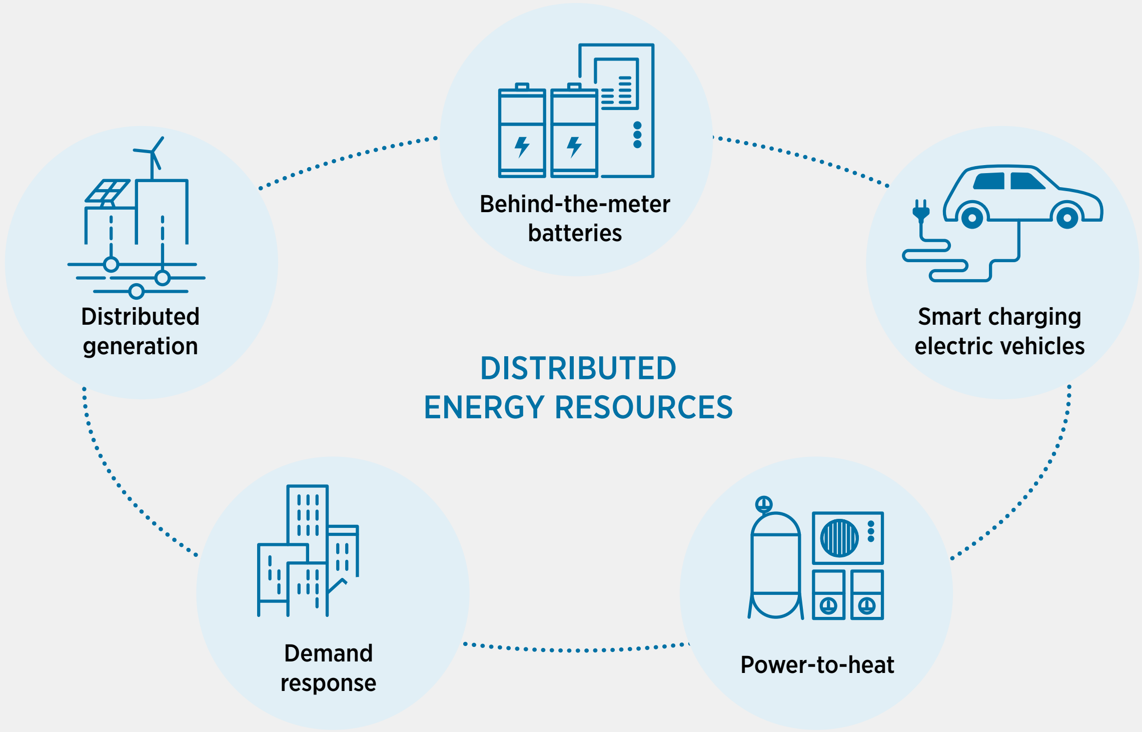
SYSTEM OPERATION

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

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



This brief provides an overview of an innovative business model: aggregators.

An aggregator can operate many distributed energy resources (DERs) together, creating a sizeable capacity similar to that of a conventional generator. This aggregation also can be called a "virtual power plant". Aggregators can then sell electricity or ancillary services via an electricity exchange, in the wholesale market, or through procurement by the system operator. The brief focuses on the various services that aggregators can provide to support power system transformation and the integration of VRE.

The brief is structured as follows:

I. DESCRIPTION

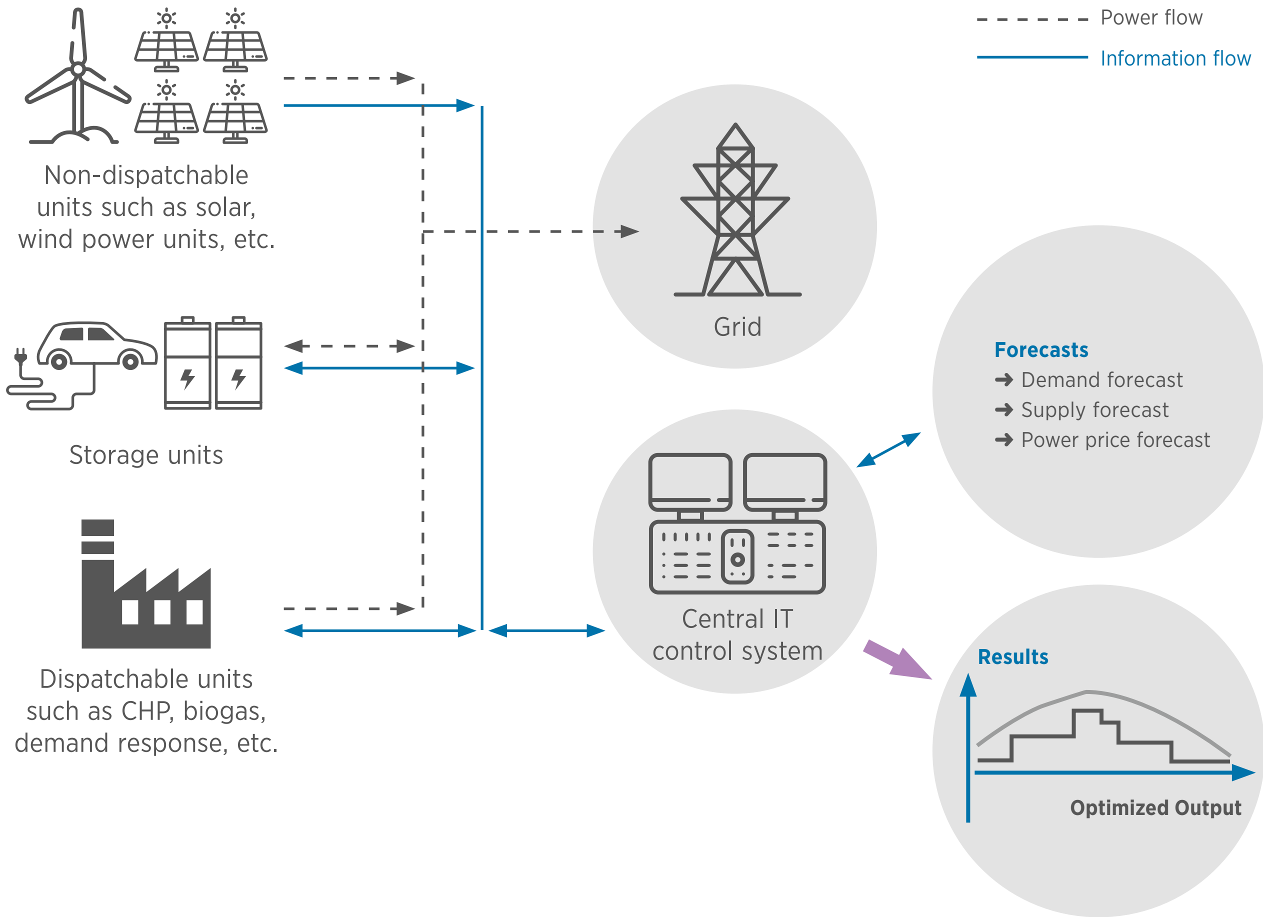
An aggregator is a grouping of agents in a power system (*i.e.*, consumers, producers, prosumers or any mix thereof) to act as a single entity when engaging in power system markets (both wholesale and retail) or selling services to the operator (MIT, 2016). In the context of this brief, an aggregator is a company that operates a virtual power plant (VPP), which is an aggregation of disperse DERs with the aim of enabling these small energy sources to provide services to the grid.

VPP operators aggregate DERs to behave like a traditional power plant with standard attributes such as minimum/maximum capacity, ramp-up, ramp-down, etc. and to participate in markets to sell electricity or ancillary services. The VPP is controlled by a central information technology (IT) system where data related to weather forecasts[1], electricity prices in wholesale markets, and the overall power supply and consumption trends are processed to optimise the operation of dispatchable DERs included in the VPP.

An aggregator can help in better integration of renewable energy resources by providing both demand- and supply-side flexibility services to the grid. Demand-side flexibility is provided by aggregating demand-response resources or energy storage units to act to grid requirements. Supply-side flexibility is provided by optimising power generation from flexible resources such as combined heat and power (CHP) plants, biogas plants, etc. and the use of energy storage units. Operation optimisation is done based on data on historical and forecasted data on demand, generation and prices. Figure 1 provides an overview of how an aggregator operates the distributed energy resources.

1 *Weather forecasts are used to predict power generation from non-dispatchable renewable energy resources such as solar and wind power.*

Figure 1 Overview of an aggregator



Note: A central IT control system or a decentralised energy management system (DEMS) sends an optimised schedule to the dispatchable distributed energy resources.

II. CONTRIBUTION TO POWER SECTOR TRANSFORMATION

By bundling DERs and creating VPPs, aggregators create a sizeable capacity that becomes eligible to participate in wholesale power markets. The aggregator can provide various grid services such as frequency regulation, operating reserve capacity, etc. by optimising a suitable portfolio of distributed energy resources. A VPP can include fast-response units such as super capacitors and batteries, along with CHP and biogas power plants and demand-response resources to provide different flexibility services (Ma et al., 2017).

The benefits that an aggregator can provide include:

Services to help operate the power system

- **Load shifting**: Aggregators can enable real-time shifting of commercial and industrial loads to provide demand-side management services to grid operators, based on price signals. A field trial conducted with the PowerMatcher[2] Suite in the Netherlands showed that peak demand can be reduced by 30 % to 35 % by managing heat systems (micro CHP and heat pumps) (TNO, 2016). This makes a business case for deferred investments in distribution and transmission grid infrastructure.

- **Balancing services**: Aggregators can use optimisation platforms to provide a range of ancillary services, increasing the system's flexibility to integrate VRE resources. Aggregators can mitigate the "ramps" caused by solar going down in the evening (*i. e.*, the neck of the duck in the duck curve) or any other variable generation output. In addition to providing ramping requirements, VPPs can be used to provide ancillary services. Next Kraftwerke, a VPP in Germany, has its power shifted up and down as often as 20 times a day. The power plant can be controlled in 15-minute increments based on current prices on the spot market. The transmission grid operators benefit from valuable control reserve. The power plant offers an average electric capacity of 1.2 megawatts (MW), while the installed capacity is nearly 4 MW. Inclusion of the power plant's added flexibility from storage plants can help compensate for fluctuations in wind and solar (Next Kraftwerke, *n.d.*).

- **Local flexibility**: Aggregators can provide flexibility at the distribution system operator level, if there is a regional/local market for flexibility in place.

Decreasing the marginal cost of power

In some cases, large power plants are used to supply electricity in order to meet a small quantity of demand, leading to a higher cost of power production. For example, for an increase in peak demand, an additional fossil fuel plant needs to be dispatched, increasing the system's marginal cost. Instead, an aggregator might be able to reduce the load and therefore decrease the marginal cost. Also, resources included in an aggregator can replace the peak power plant by dispatching the aggregated distributed generation technologies and charged batteries.

2 *PowerMatcher is a smart grid co-ordination mechanism developed by the Netherlands Organisation for Applied Scientific Research (TNO).*

Optimising investment in power system infrastructure

An aggregator can bundle and control the DERs to provide real-time operating reserve capacity that can participate in ancillary markets when needed. This can enhance the economic return for the owners of the distributed energy resources. Further, using existing distributed energy resources to provide reserve capacity services can help in avoiding investments in peak generating capacity. For example, in the US state of New Mexico, the Enbala VPP is being used to provide 20 MW to 25 MW of flexibility, mitigating the need for expensive traditional power generation resources. A VPP helps save on the cost of new capacity additions while generating additional revenues for already connected distributed energy resources (Next Kraftwerke, *n.d.*).

The US Energy Information Administration estimated the cost of building a new coal-fired power generation unit in the range of USD 2 934 to USD 6 599 per kW, depending on the technology used. The cost of building a gas-fired plant would range from USD 676 to USD 2 095 per kW.

Both of these options have significant environmental and stranded investment risks. Using already connected energy resources, through aggregators, can minimise the investment needed in additional capacity. Aggregators can provide financial benefits to owners of distributed energy resources by maintaining demand and supply balance at a cost of USD 70 to US 100 per kW (Enbala, *n.d.*).

By using aggregators to provide demand-side management and load shifting, investments in transmission and distribution grid reinforcements also could be minimised.

Potential impact on power sector transformation

In South Australia, aggregators can meet 20 % of daily power demand and provide 30 % savings on energy bills.

The South Australian government and Tesla are developing a network of 50 000 household solar PV units connected into an aggregator. This is expected to meet around 20 % of South Australia's average daily power demand (250 MW).

Additionally, the new power plant is expected to lower energy bills for participating households. The wholesale price is estimated to drop by around **USD 3 per MWh** for all customers **with each additional 50 MW of capacity** that is brought onto the system via the aggregator. The Australian VPP Tesla proposal could reduce the wholesale electricity price by around **USD 8/MWh**, or around **USD 90 million per year** across all South Australian customers, which means **30 %** of the total energy bill (Frontier Economics, 2018).

III. KEY FACTORS TO ENABLE DEPLOYMENT

Regulatory framework

A liberalised wholesale power market with no price caps (especially with spot markets in place) is essential for establishing aggregators. The main incentives for creating an aggregator are given by the difference between peak/off-peak pricing on wholesale markets or by signals from transmission system operators to deliver control reserve or other ancillary services.

The regulatory framework should enable aggregators to participate in the wholesale electricity market and also in the ancillary services market. For example, the New York Independent System Operator (NYISO) proposed aggregating DERs connected to the same bulk transmission node to ensure that these resources are compensated based on their locational and temporal value (NYISO, 2017). While NYISO has restricted aggregation of DERs to a specified geographical limit, other system operators can allow DER aggregation without geographical barriers.

Advanced metering infrastructure

Real-time data acquisition from DERs is necessary for the creation and operation of a VPP. This would require smart meters, broadband communication infrastructure, network remote control and automation systems (network digitalisation). Real-time communication between VPP operators and the connected DERs is needed. Network remote control and digitalisation help in improving network efficiency since the data gathered can be used to better forecast demand. Two-way communication network devices are essential.

Better generation forecasting

Advanced forecasting tools and techniques are essential to predict power generation from renewable energy and load forecast in the power system for deriving an optimised schedule of dispatchable DERs. Forecasts for distributed generation can be integrated with load forecasting to obtain net load forecasts, thus increasing the visibility of demand-side variations.

IV. CURRENT STATUS AND EXAMPLES OF ONGOING INITIATIVES

Some of the key indicators about aggregators have been captured in the table below, followed by examples of aggregators.

Table 1 Aggregators: Key indicators

Description	Value
Virtual power plant (VPP) global market value	USD 762 million in 2016; expected to reach USD 4 597 million in 2023 (compound annual growth rate of 25.9 % from 2017 to 2023) (Research and Markets, 2018)
Countries with established regulatory frameworks allowing VPP trading	Australia, Austria, Belgium, Germany, Denmark, France, Netherlands, UK, US, etc.
Services provided by aggregators	• Forecasting and trading of distributed energy resources • Optimised dispatching of distributed energy resources according to intraday pricing on spot markets • Delivery of ancillary services to transmission (and potentially distribution) system operators

VPP contributes to renewable energy integration and system stability in South Australia

Tesla proposed the development of a 250 MW virtual power plant to contribute to stabilising South Australia's electricity infrastructure and to improve the security and reliability of the grid in an area where nearly half of the electricity comes from wind farms. The initiative will start with a trial in 1 100 public housing units (Government of South Australia, 2017).

The technology involves four key components:

- Smart meters installed in every participating household to assist in controlling the rooftop solar and battery, and to measure the power flows;
- A network of rooftop solar PV systems installed on public housing (5 kW solar panel system);
- Battery storage installed on public housing in South Australia (5 kW/13.5 kWh Powerwall 2 Tesla battery); and
- A computer system to control the storage, use and transfer of renewable and battery-stored power between houses and the grid, to maximise the value for customers while delivering services to the grid when needed.

The impact of such a solution would be considerable in terms of renewable energy integration, with approximately 130 MW of added rooftop solar PV generation capacity and 130 MW/330 GWh of distributed, dispatchable battery storage. This approximately doubles if the roll-out is extended to a similar number of private customers.

In terms of the flexibility added to the system, the participation of 50 000 households in the programme would add 250 MW of peak capacity to the system or, alternatively, reduce the demand on the central grid by 250 MW, freeing the capacity to be supplied to other customers.

In terms of cost reduction, the wholesale price in South Australia is estimated to drop by around USD 3/MWh for all customers, with each additional 50 MW of capacity brought into the system that would not otherwise be operating. This suggests that if only the public housing customers participated in the arrangement, the Tesla proposal could reduce the wholesale price by around USD 6/MWh[3], or about USD 65 million per year, across all South Australian customers. The savings would be approximately double if the project could achieve its full scale of production of 250 MW. Moreover, the government has provided estimates showing that the project could lower the power bills of those who sign up by 30 % (Frontier Economics, 2018).

Other examples of aggregators

Table 2 Key features of leading aggregators

Aggregator	Country/Region	Key features
AGL	**Australia**	• AGL's VPP consists of a network of behind-the-meter batteries providing a range of benefits to the household, the retailer and the local network. The VPP aims to both cut consumer electricity costs and help maintain grid stability in South Australia (AGL, *n.d.*).
Eneco CrowdNett	**Netherlands**	• Founded in 2016, Eneco CrowdNett is a Dutch-based aggregator of home batteries and provides grid services through a network of behind-the-meter batteries owned by prosumers. • Consumers are provided batteries at a discount and receive an additional EUR 450 annually in exchange for access to 30 % of the battery capacity at any time during the day (Hanley, 2016).
Energy & meteo systems (emsys)	**Germany**	• Emsys supports power aggregators in efficient market integration of their power assets. • Emsys's offering in VPP includes: connection to distributed power plants through various interfaces, real-time data management, remote control of wind and PV (*e.g.*, to avoid negative spot market prices), generation forecast optimisation, energy scheduling, trading on the day-ahead and intraday spot markets, provision of balancing power by distributed power plants (primary, secondary and tertiary control), provision of balancing power by wind farms (tertiary control in Germany), demand-side management and balancing group management. • Emsys is one of the first aggregators to execute primary control using batteries in the German balancing power market.
Next Kraftwerke	**Europe**	• Next Kraftwerke is a network of multiple power-producing and power-consuming units of varied sizes distributed across Europe. • Next Kraftwerke forecasts the approximate production and consumption of energy on a real-time basis for the balancing group. It then transmits the schedule to the TSO on a daily basis and trades the forecasted volumes on the day-ahead market on the stock exchange. Deviations from the forecast are compensated through intraday trading. • Next Kraftwerke's VPP delivers ancillary services (primary reserve, secondary reserve, tertiary reserves) in seven European TSO zones and uses its algorithms to send optimised schedules to the networked units to benefit from peak pricing on wholesale markets. • The VPP consists of around 5 500 units amounting to over 4 500 MW (Next Kraftwerke, *n.d.*).
Stem	**United States**	• This California-based start-up with artificial intelligence technology focuses on behind-the-meter energy storage systems and VPPs. • It uses energy storage systems to reduce the cost of electricity for commercial consumers. The batteries are charged when the cost of electricity is low and discharged when the cost of electricity is high (typically during peak demand period). • Stem can use its software to reduce the net demand of its customers, thereby reducing the demand of the whole area when the existing supply system cannot supply in the local area (Stem, 2019).

3 *Converted from AED at the rate of 1 AED = 0.72 USA*

V. IMPLEMENTATION REQUIREMENTS: CHECKLIST

TECHNICAL REQUIREMENTS

Hardware:

- Controllable load and supply assets such as energy storage, electric vehicles and distributed generation
- Smart meters (to provide real-time power consumption and production), home gateways (energy boxes) and smart appliances for energy management, to enable VPP operation

Software:

- Aggregation software, algorithm to calculate the optimal operation of each unit
- Real-time communication between the aggregator and the hardware system
- Advanced demand and supply forecasting models/platforms for optimised scheduling of dispatchable distributed energy resources

Communication protocols:

- Common interoperable protocol for co-ordination among system operators, network operators and prosumers

REGULATORY REQUIREMENTS

Wholesale market:

- Participation of aggregators should be allowed in electricity wholesale markets and ancillary service markets
- Introduce regulations allowing decentralised sources to provide services to the central/local grids
- Clear price signals to guide the aggregators' operations
- Regulations to mandate implementation of smart meters and smart grid infrastructure

Distribution:

- Establishment of local markets for DSOs to procure services to avoid grid congestion and ensure grid stability
- Data collection, management and sharing rules for DSOs to ensure consumer privacy

Retail market:

- Regulators should define a standardised methodology for computing dynamic prices that can be adopted by retailers.
- Functioning retail markets could provide innovative products and pricing models for various customer needs. For example, in Finland innovative products are being introduced, and customers can opt to choose the product and pricing method best suited to their needs (such as hourly dynamic pricing, retailers buying excess solar photovoltaic generation as a marketbased solution, ToU tariffs, etc.).
- Regulation should set clear roles and responsibilities for market parties. Long-term foreseeable regulation is needed.
- Liberalised markets, as opposed to regulated markets, could facilitate the market entry

System operation:

- Defining rules for co-ordination between distribution and transmission system operators

STAKEHOLDER ROLES AND RESPONSIBILITIES

Aggregators:

- Provide grid-related services to DSOs, if a market is established
- Information exchange with DSOs related to capacity, location, type of DERs

Distribution system operators:

- Ensure a level-playing field for all flexibility providers
- Procure market-based flexibility services from aggregators
- Securely share consumer and grid-related data with third parties as per applicable data privacy and sharing norms
- Better forecasts for DER services based on past data or historical performance and weather forecasts

ABBREVIATIONS

AMI	Advanced metering infrastructure
BtM	Behind-the-meter
DEMS	Decentralised energy management system
DER	Distributed energy resource
DSO	Distribution system operator
EV	Electric vehicle
GW	Gigawatts-hour
IT	Information technology
kWh	Kilowatt-hour
TSO	Transmission system operator
VPP	Virtual power plant
VRE	Variable renewable energy

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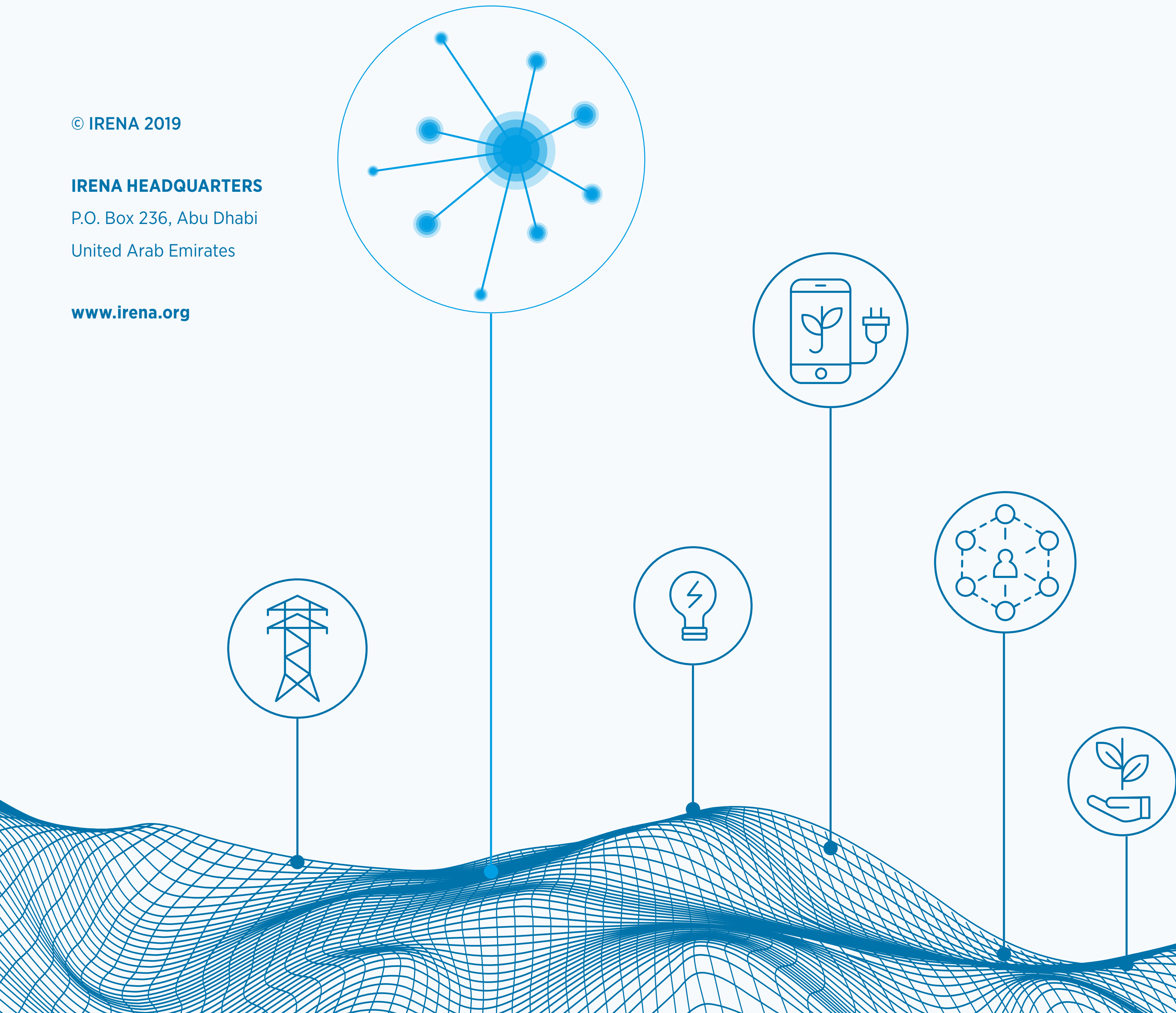

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PEER-TO-PEER ELECTRICITY TRADING

INNOVATION LANDSCAPE BRIEF

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DISCLAIMER

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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

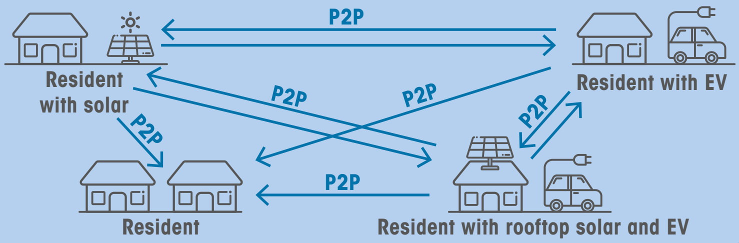
3 SNAPSHOT

➜ 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.

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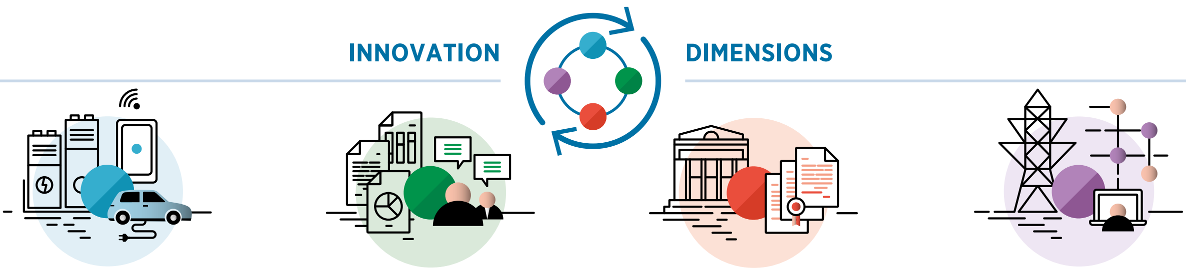

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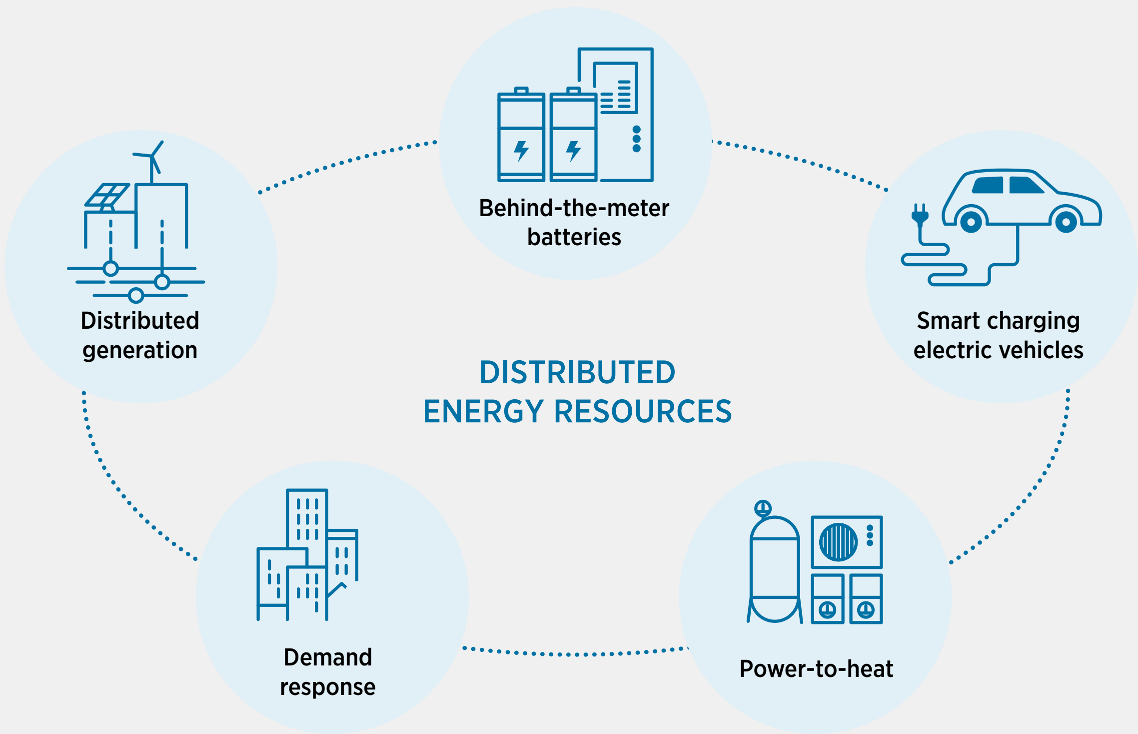
This brief provides an overview of the peer-to-peer (P2P) electricity trading business model that emerged as a platform-based scheme in view of increasing the integration of distributed energy resources into power systems. Distributed energy resources allow previously "passive" consumers (from the system 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

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.

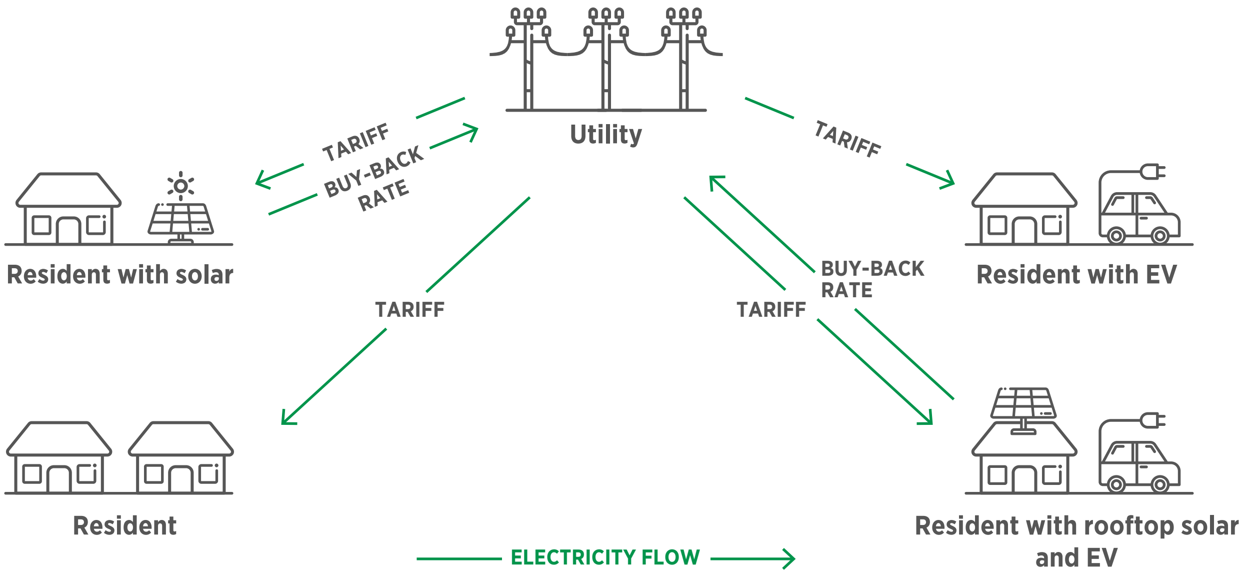
For example, while a prosumer can charge an EV using a rooftop solar plant, the prosumer's neighbour would obtain electricity to charge his or her EV from a distant centralised power plant. If, however, the vehicle is charged from a solar power plant located in the neighbourhood, the prosumer with solar 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.

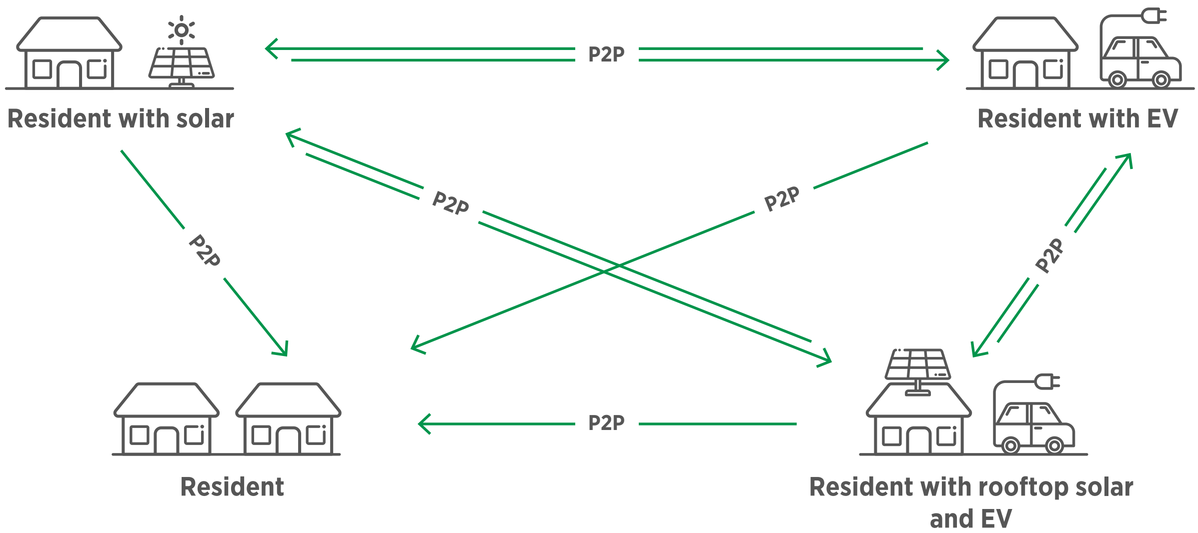
In addition, they are able to directly trade electricity with other consumers to achieve a win-win by seeking a better outcome compared to the relatively high tariffs and the relatively low buy-back rates. In this way, buyers can save costs while sellers can make a profit (Liu *et al.*, 2019). Figure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

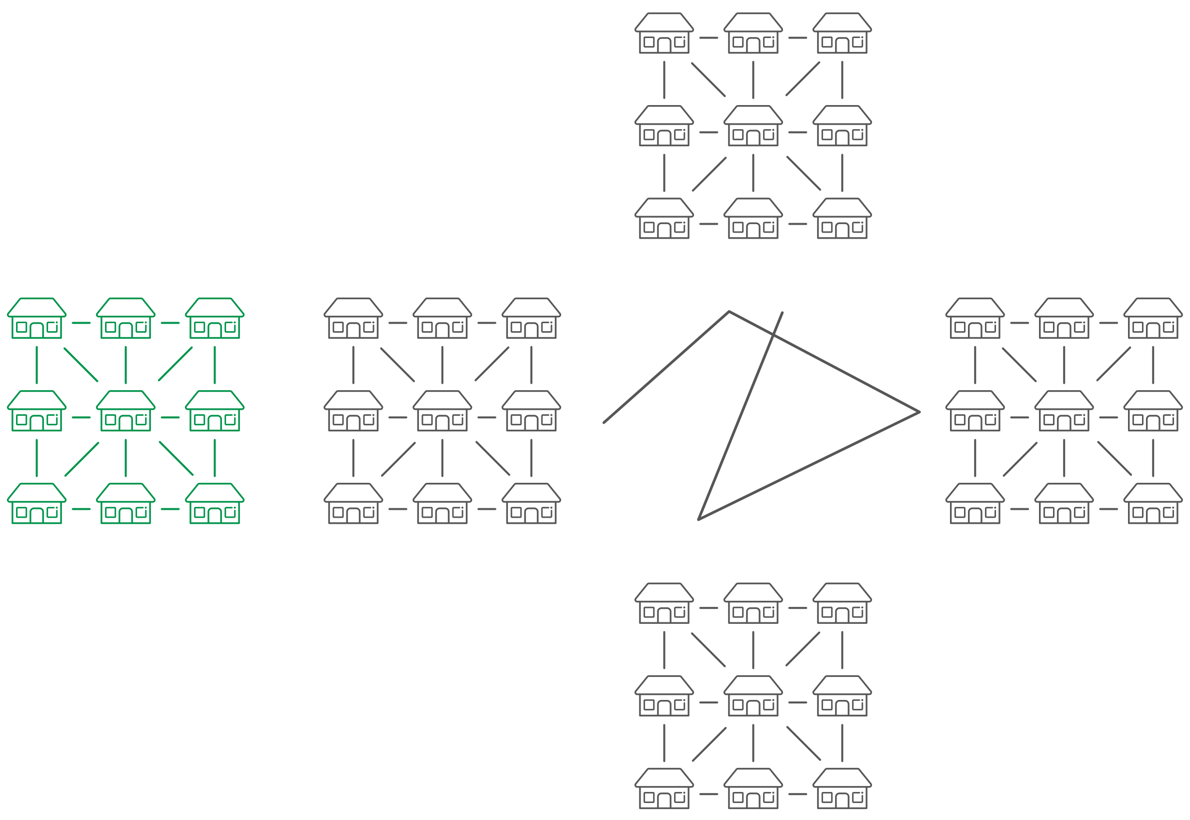
If the P2P platform (market) operator is organising trading among subscribers that are part of the main distribution system (rather than an isolated mini-grid), then it will need to interact with system operators and the electricity market.

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

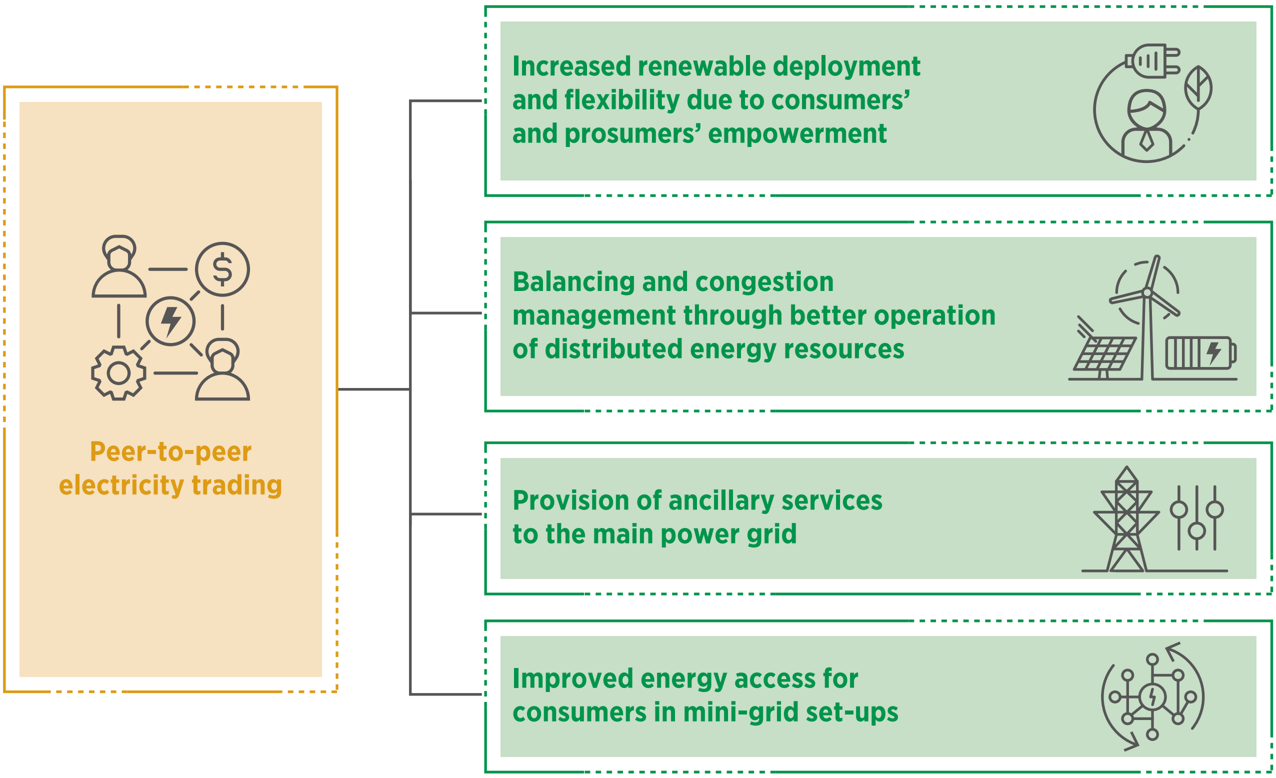
Source: Adapted from Park and Yong, 2017

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).

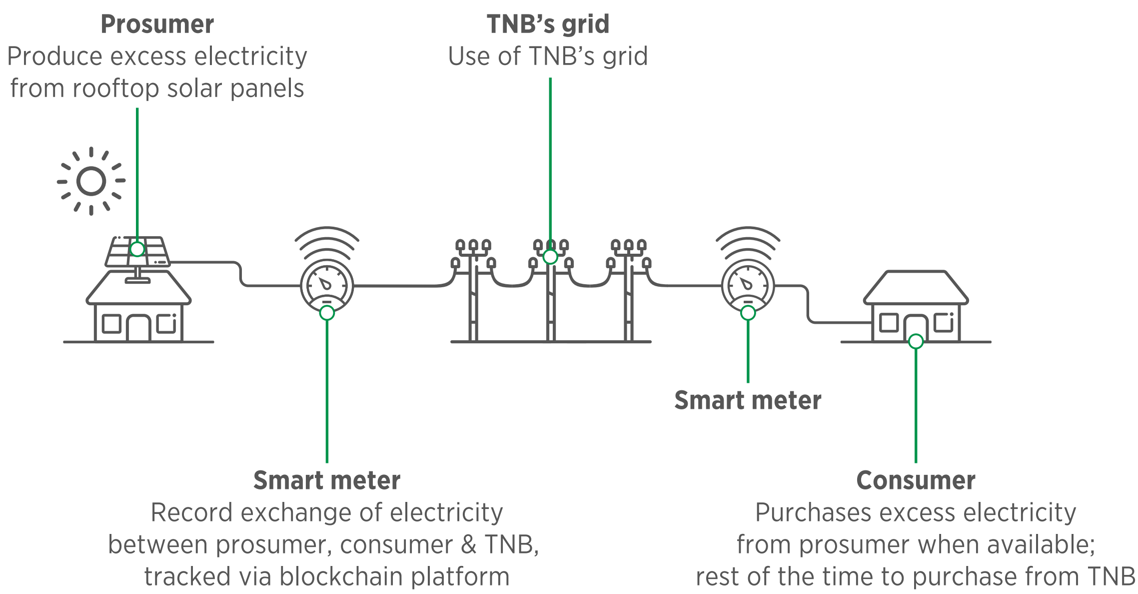
The P2P pilot will group 14 residential users with different income levels in Medellin, each of them independently connected to the distribution network. Low-income users will have solar panels installed on their rooftops and will trade electricity with high-income consumers and prosumers (UCL, 2019).

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

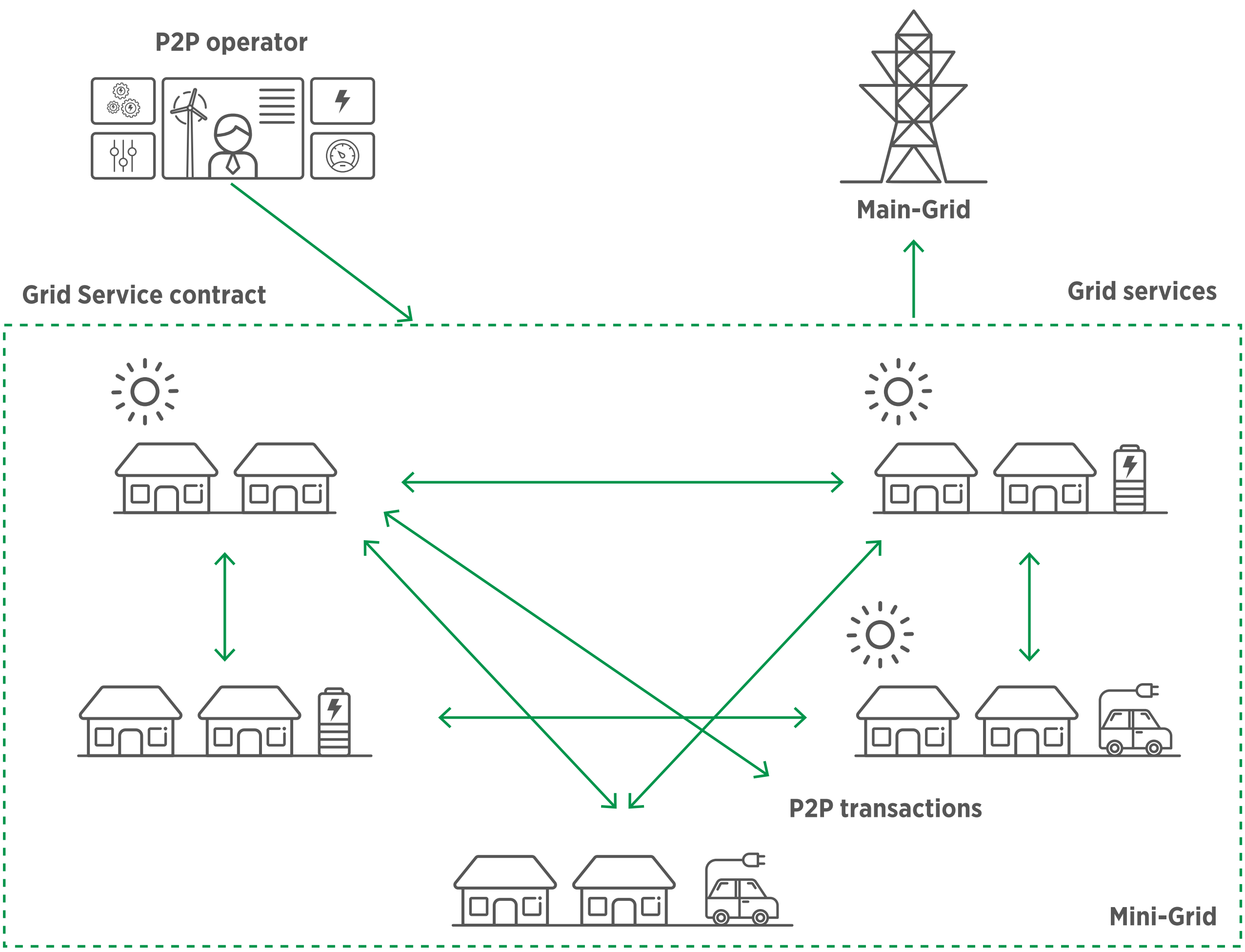
Preliminary findings of the pilot project show that P2P electricity trading helps to balance local generation and demand and has the potential to enable large penetration of renewable electricity in the grid. If carried out at distribution level, P2P trading can reduce peak demand and grid congestion 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.

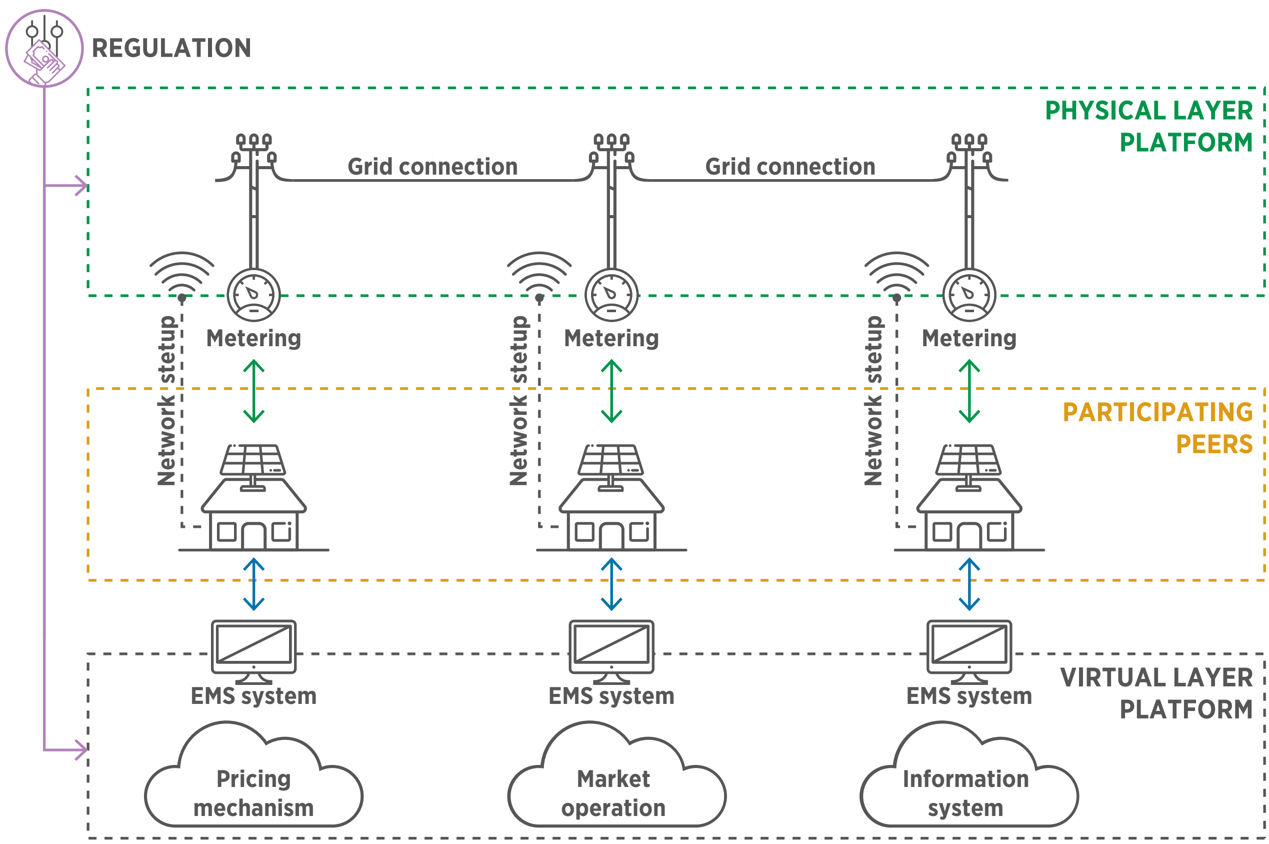
III. KEY FACTORS TO ENABLE DEPLOYMENT

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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IRENA
International Renewable Energy Agency

PEER-TO-PEER ELECTRICITY TRADING
INNOVATION LANDSCAPE BRIEF

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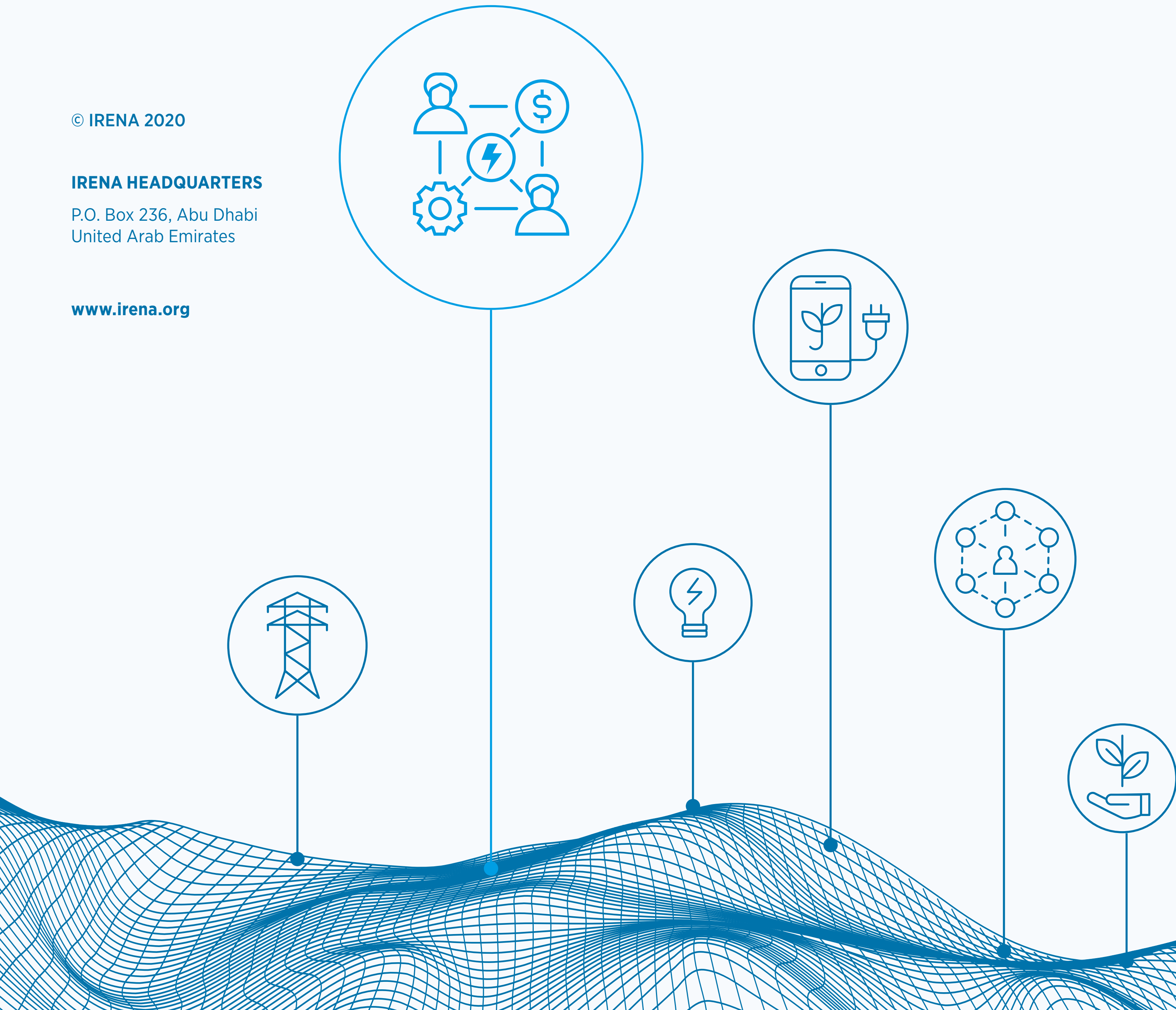

International Renewable Energy Agency

ENERGY AS A SERVICE

INNOVATION LANDSCAPE BRIEF

International Renewable Energy Agency

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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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DISCLAIMER

IRENA
International Renewable Energy Agency

1 BENEFITS

Through different services provision and revenue models, EaaS supports:

- deployment and operation of distributed energy resources and
- demand-side management

This unlocks demand-side flexibility.

SERVICES PROVIDED

ENERGY ADVICE	ENERGY ASSETS	ENERGY MANAGEMENT
No direct revenue model Driver sales for other services	Revenue through margins on hardware installations	Subscription based/ performance based contracts

2 KEY ENABLING FACTORS

- Digitalisation
- Time-of-use tariffs
- Revision of distribution system operator methodologies to account for demand-side flexibility

3 SNAPSHOT

➜ Smart meter penetration is 14% globally, 70% in China and the US, and 44% in the EU (2019).

➜ EaaS models with time-of-use pricing can reduce peak demand by 3–10%.

➜ EaaS models are emerging in many countries, including Australia, China, Finland, Ireland, Italy, Japan, Sweden, the UK and the US.

What is Energy as a Service (EaaS)?

The EaaS model offers various energy-related services to the consumers, rather than only supplying electricity.

ENERGY AS A SERVICE

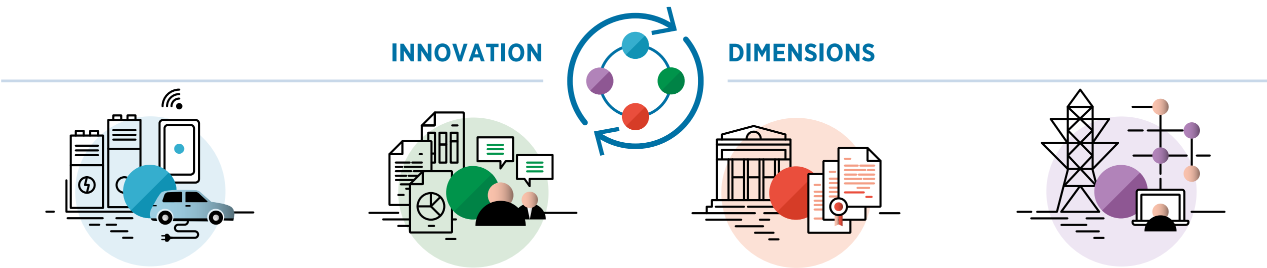
Increased deployment of distributed energy resources along with the widespread availability of smart devices has created room for innovative business models to emerge, shifting the value from selling kilowatt-hours to service provision.

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

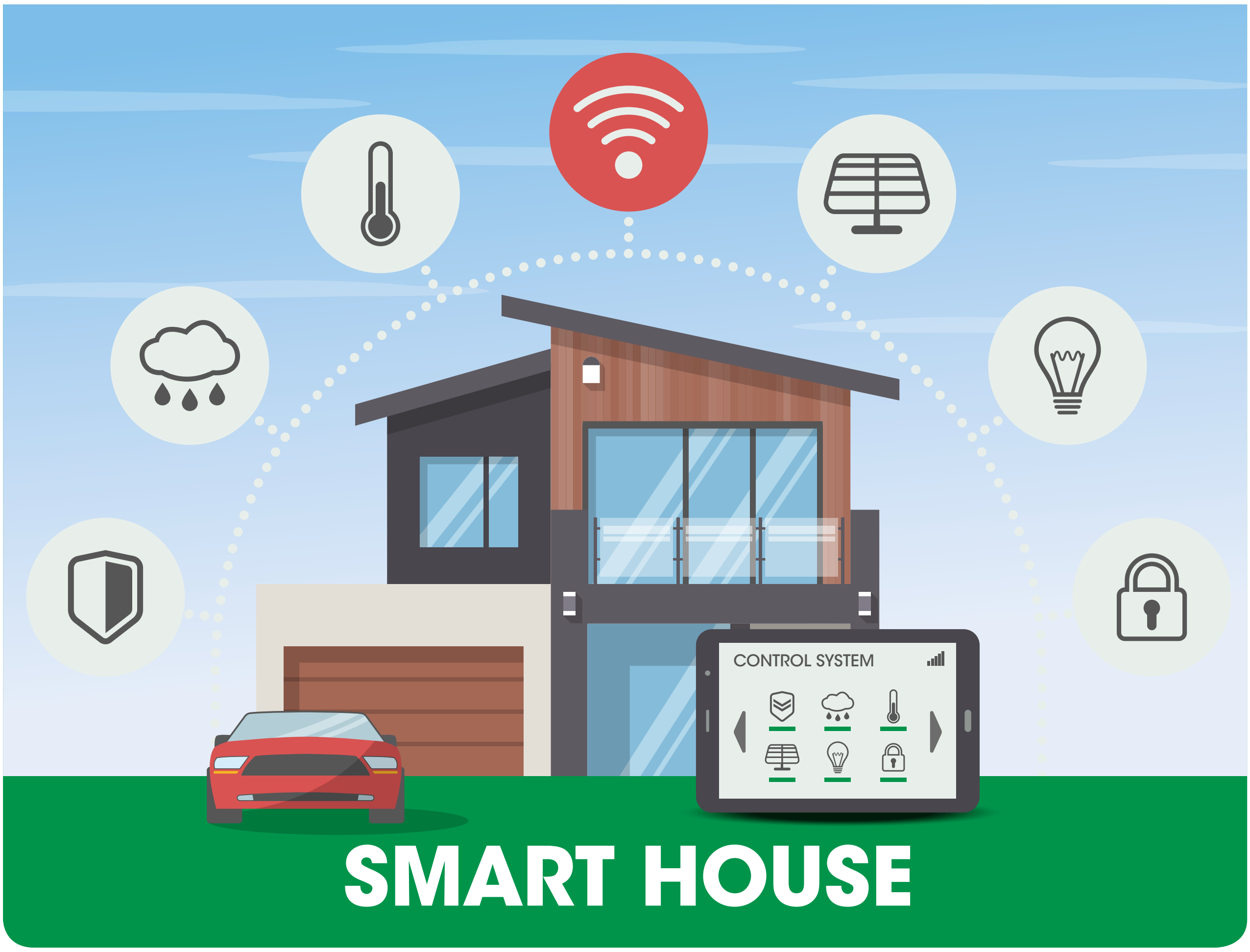
25 Future role of distribution system operators
26 Co-operation between transmission and distribution system operators

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 Energy-as-a-Service (EaaS) business model, a customer-centric business model that emerged to share and monetise the value created by increased digitalisation and decentralisation of the power system. The brief highlights different innovative services offered by energy service providers and their revenue models, as well as the impacts of these new business models on the deployment and integration of higher shares of variable renewable energy, like wind and solar.

The brief is structured as follows:



I. DESCRIPTION

The growing installation of distributed electricity generation and storage technologies, along with the widespread availability of "smart" devices, has created room for new business models to emerge in the power sector. The increase in digitalisation and smart metering has enabled the collection and analysis of large datasets that in turn enable automation. All of this provides the basis for the development of new energy-related services.

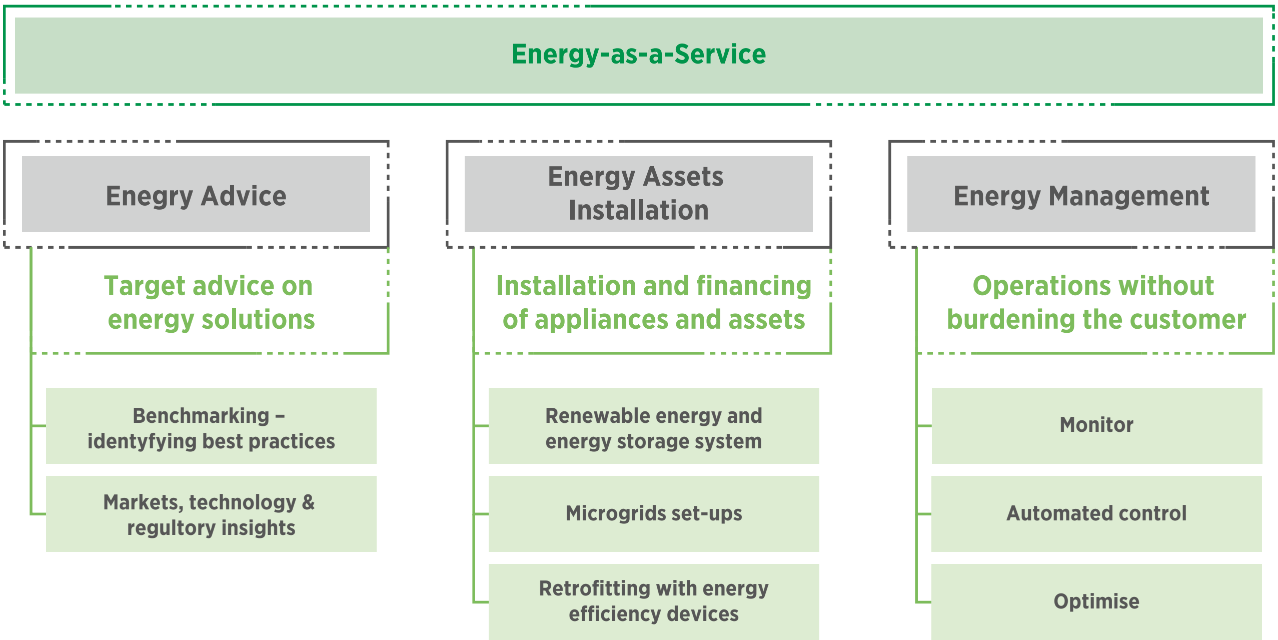
Digitalisation is essentially converting energy-related data into value for the power system. Electricity providers can assume a new role as an energy service provider (ESP), monetising the value created by the digitalisation of the power sector. This new role of energy providers has led to the development of innovative and customer-centric business models by both conventional companies from the energy sector and new actors entering the sector, such as information technology (IT) companies.

With increasing digitalisation in the sector, consumers are exploring avenues to optimise their consumption and better manage their electricity costs. The energy-related needs of consumers in the residential, commercial and industrial segments are changing. In the case of residential consumers, the availability of smart home devices has enabled continuous monitoring and control of electricity consumption.

ESPs are evaluating options not only to offer services that reduce the electricity bills for consumers, but also to provide them with more sustainable solutions for power supply. Some consumers may be willing to switch to self-consumption solutions and install distributed renewable generation technologies, such as solar rooftop photovoltaic (PV), possibly coupled with battery storage. Also, interest is growing in the adoption of smart devices that can operate, monitor, control and optimise local energy generation and consumption. Smart devices such as smart meters and smart thermostats for heating and cooling are already gaining popularity. Considering new consumer needs and the shifting power paradigm to a renewable-based decentralised and digitalised system, there is a need for an integrated approach to delivering new energy solutions and services.

Energy-as-a-Service (EaaS) is an innovative business model whereby a service provider (either traditional ESPs or new ones, such as information and communications technology (ICT) companies) offers various energy-related services rather than only supplying electricity (i.e., kilowatt-hours, kWh). ESPs can bundle energy advice, asset installation, financing and energy management solutions to offer a suite of services to the end consumers. The range of services that can be provided by an ESP is described in Figure 1.

Figure 1 Range of services offered by energy service providers



Source: Adapted from Edison Energy, 2016; Eneco, 2019

- **Energy advice:** ESPs are evolving into "trusted energy advisors" that can help customers formulate strategies tailored to their energy needs. The ESPs can use consumers' load data, electricity price forecasts, or historical data, as well as advanced energy modelling software to help customers benchmark their costs against the market to identify opportunities for optimising their energy consumption.

- **Energy assets installation :** ESPs can provide end-to-end services associated with the installation of on-site or off-site renewable energy projects and battery storage systems, such as engineering, procurement and construction (EPC). This service can extend to the installation of micro-grids, smart meters and energy-efficient appliances, to create opportunities for customers to save on electricity bills and generate revenue from self-generation of electricity, both on- and off-grid.

  Having established partnerships in place, in some instances, ESPs can facilitate access to finance for the EPC of renewable energy projects for end consumers.

- **Energy management:** ESPs can provide energy management solutions through monitoring, remote control and optimisation of the load, without placing a burden on the customer. Smart home solutions can be bundled as an integrated solution that includes monitoring, automated control and optimisation of the energy consumption, taking into account consumers' comfort. ESPs can also provide customers the option to choose their electricity supply sources (e.g., either renewable or conventional sources), and enable the customers to control their load based on information about electricity prices during all time intervals available.

Different energy services have different revenue models for the ESPs. Besides revenue models, customer lifetime value[1] is also an important metric that ESP assesses when offering a service. For example, only a few customers are willing to pay for insights and advice. Without such personal interaction, however, creating trust with customers can be difficult. Therefore, energy advice does not have a revenue model on its own, but contributes to an increased customer lifetime value because it is a driver for the sales of other services (such as energy asset installation and financing, energy management services).

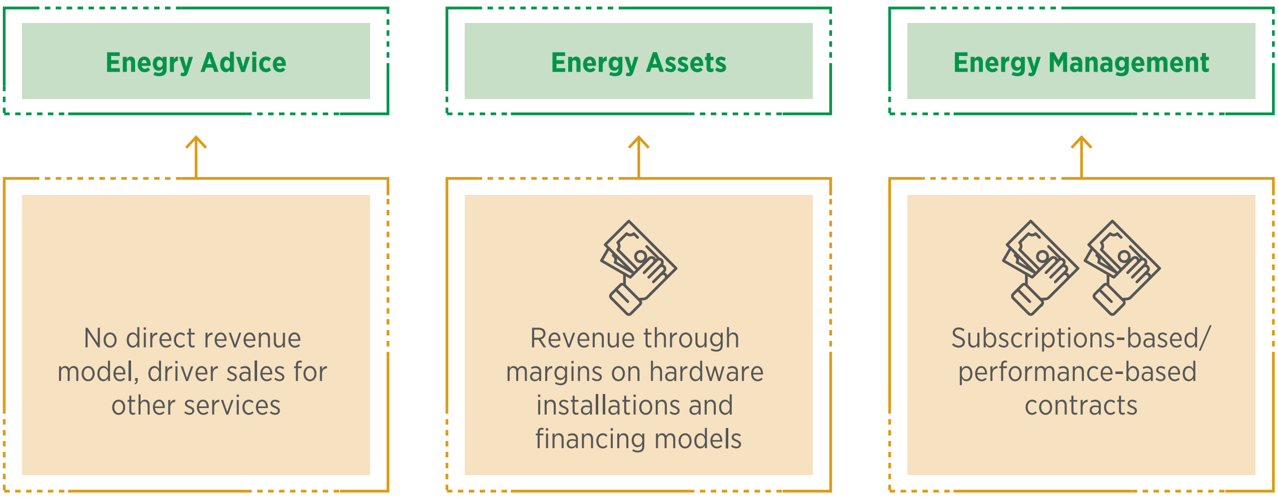
Energy asset services usually come with a one-time revenue opportunity for ESPs, mainly through margins on hardware, labour and financing schemes. The core business of ESPs lies in energy management services. For energy management service, ESPs can opt for a variety of revenue models ranging from a subscription-based model (fixed revenue contracts) to performance-based contracts (variable revenue contracts). Figure 2 highlights typical revenue models for companies providing Energy-as-a-Service.

Subscription-based models with fixed revenue contracts apply fixed monthly fees, so that the ESP absorbs the price and quantity risk. The ESP makes a profit when the total value of electricity consumed by its customers is lower than the contractual price paid. Therefore, the ESPs will make efforts to audit the existing systems and identify the potential for cost savings by installing energy-efficient or smart devices to monitor consumption at the customer end closely.

For example, Inspire, a US-based power retailer, offers a "Smart Energy" subscription model, with subscription plans starting at USD 39/month that include energy management services and 100% clean electricity. Being a flat monthly rate, the less energy the customers use, the more profit the company makes, thus enabling it to offer customers rewards for the energy-saving actions they take. The company aims to take the smart energy concept one step further by automating customers' home controls and decreasing energy usage on their behalf. This will allow customers to hand over their energy management decisions to Inspire (Inspire, 2020; Pyper, 2018).

Performance-based contracts are variable revenue contracts, usually in the form of an energy savings performance contract. The customer and the ESP share the cost savings based on two main models: shared savings (where the savings are split according to a defined percentage), and guaranteed savings (where the customer is guaranteed a certain level of savings, being shielded from any performance risk). Performance-based contracts can also be a form of "creative financing" for capital improvement that makes it possible to fund energy upgrades from cost reductions (JRC, 2020). A facility owner can use an energy savings performance contract offered by an ESP to pay for today's facility upgrades with tomorrow's energy savings – without tapping into capital budgets (US DOE, *n.d.*).

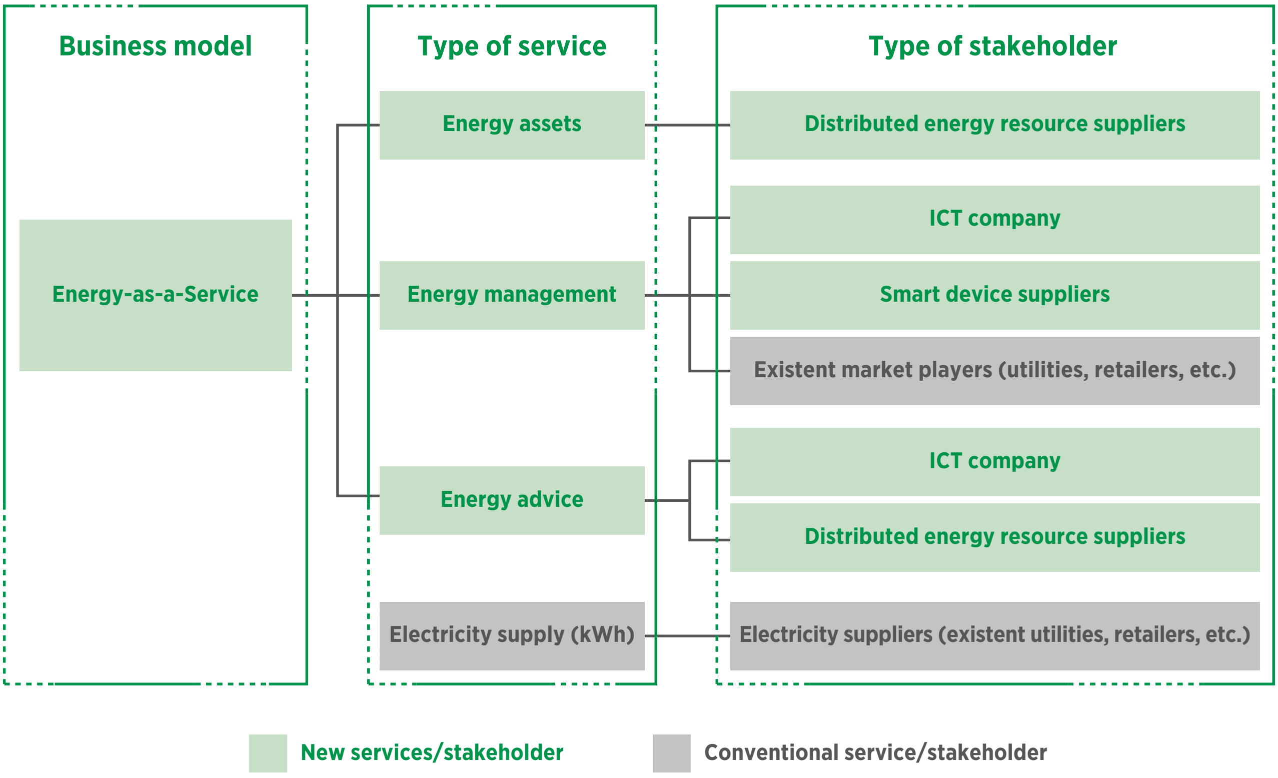
Figure 2 Revenue streams for Energy-as-a Service models



1 *Customer lifetime value represents the total amount of money a customer is expected to spend in your business, or on your products, during the lifetime of the customer.*

ESPs either are new actors that enter the energy market or can represent new roles that existing actors take up. To emerge as an integrated ESP and to remain competitive in the dynamic market conditions, existing players, such as conventional utilities or retailers, would have to gain different capabilities, which may be developed organically or acquired through partnerships with third parties. For example, existing market participants can partner with ICT companies to provide energy management solutions to customers. Figures 3 and 4 highlights key stakeholders that can collaborate to provide integrated energy services to customers.

Figure 3 Key stakeholders and types of services provided under the EaaS model



Source: Adapted from KPMG US, 2015

As illustrated in Figures 3 and 4, several stakeholders provide different services, which highlight that the value is delivered via a network of two or more actors involved. To provide integrated energy services under the EaaS business model, several such opportunities arise, as follows:

- **Energy management:** Aggregators of many smaller loads secure better prices on behalf of larger customer groups. Implementing dynamic pricing mechanisms, such as time-of-use tariffs, and providing continuous information to the user on spot market prices (where applicable) will encourage better consumption management. Smart home devices can be integrated with the utilities or conventional retailers through home area networks or home monitoring services sold by telecommunication firms. Increased visibility into consumption data can help utilities develop new energy management software.

  The data can be used by the power suppliers to proactively provide analysis and tailored recommendations to improve outcomes and customer satisfaction.

- **Energy advice:** Distributed energy resources have been widely deployed, and most utilities are mandated to purchase the power surplus. The integration opportunities revolve around identifying the resources, forecasting the available supply, managing storage and providing a physical connection to the grid. In addition to suppliers of distributed energy resources, suppliers of retail electricity can be integrated into providing these services. As with energy management services, visibility into consumer data can help tailor the advice to individual consumer needs.

Figure 4 Example of key services provided by different stakeholders

Electricity suppliers	Distributed energy resource suppliers	Smart device supplier	ICT company
Retail electricity services	Installation of renewable power plants (rooftop solar, microturbines, etc.)	Manufacturing smart home devices	Consumption data
Demand response aggregation	Developing community-owned projects		Usage patterns
Dynamic pricing (time-of-use tariffs)	Installation of battery storage systems		Real-time monitoring dashboards
	Developing mini- and microgrids		Analytics as a service
	Deployment of EV smart charging infrastructure		
	Operating virtual power plants		

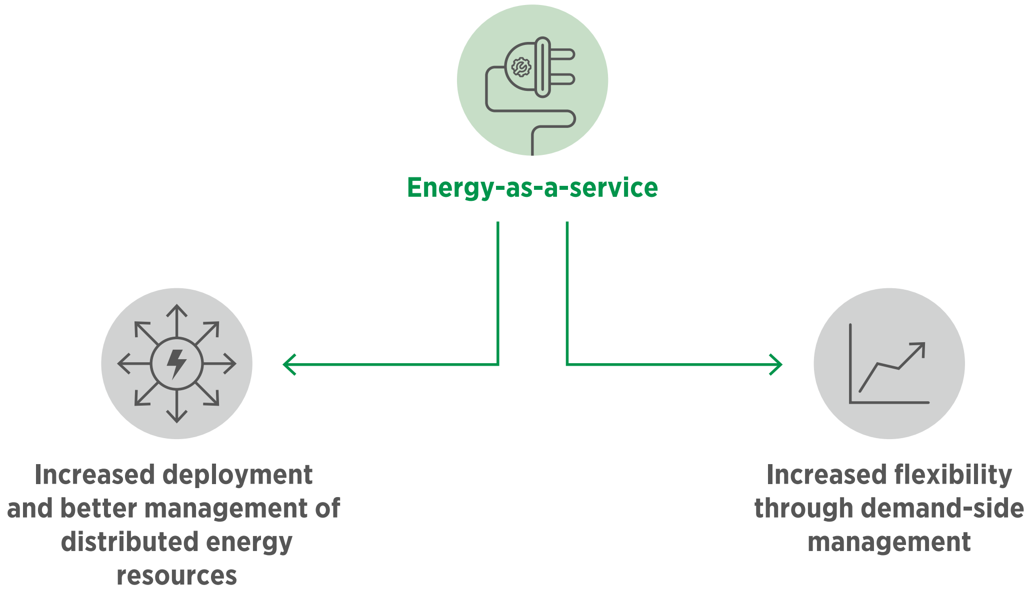
Source: Adapted from KPMG US, 2015

II. CONTRIBUTION TO POWER SECTOR TRANSFORMATION

Through different service provision and revenue models, EaaS supports distributed generation deployment and demand-side management.

This has a great impact on unlocking demand-side flexibility, which further enables the integration of high shares of VRE in the power system and smooth integration of distributed energy resources in the system.

Figure 5 Key contribution of EaaS models to power sector transformation



Increased deployment and better management of distributed energy resources

Energy asset installation services offered by ESPs facilitate the deployment of distributed energy resources, providing the necessary support to customers that wish to install renewable energy and energy storage systems. Also, a range of innovative energy services is emerging for consumers that cannot or do not want to install distributed energy resources in their residences.

For example, SolarCloud, an Australian company, offers solar energy to customers without requiring them to have their own installations, and customers can "transfer" the energy supply contract to their new address if they move. This service encourages consumers that are paying rent or that are not confident about making an investment in their house to still opt for clean energy supply. Customers can invest in solar PV rooftop systems that will be installed on commercial rooftops across Australia. The solar energy generated by these panels is used by businesses that pay a fee to SolarCloud, and the company in turn transfers the monetary benefits back to the panel owners (SolarCloud, 2020).

Similarly, Helen, a retail energy supply company in Finland, has built two large solar power plants and offers a solar panel to individuals for a rental fee. This enables consumers to be solar energy producers regardless of where they live. Such models enable the deployment of distributed renewable generation without significant upfront investment to end consumers.

Energy management service is also incentivising consumers to install distributed energy resources and, through demand response, to save on their electricity bills. Various utilities are adding this service to their portfolios. For example, EDP in Portugal has launched a smart home solution, "EDP re:dy", that enables customers to manage their home equipment and energy consumption through a smartphone app.

In addition to load management services that can adjust electricity consumption based on production of distributed energy resources, other innovative services have emerged. "**Battery-as-a-service**", for example, provides storage services to customers to "save" the surplus renewable energy generated into a virtual electricity account during periods of low demand, and then draw from the stored energy during periods of peak demand, or even allow friends or relatives in other locations to access it and use the electricity.

For example, E.ON has developed a "SolarCloud" for solar PV owners to store excess energy supply through a cloud solution. This virtual electricity account can be accessed for energy demand not only at home, but also in other places. The key advantage of power clouds is that consumers do not have to invest in a physical battery. The customers can also realise savings in their energy bills by avoiding peak use charges (E.ON, 2018). The German market alone had more than 1.6 million operators of solar systems in 2018. According to E.ON and based on data from Project Sunroof, a co-operation between E.ON and Google, another 10 million roofs in Germany are suitable for installing PV systems. Such services therefore have a great market potential.

Increased flexibility through demand-side management

Energy management models under the EaaS business model support demand-side management, thereby unlocking demand-side flexibility in the power system. ESPs can implement intelligent systems using real-time data gathered via smart meters to predict peak demand levels over the next few hours for a given facility, and set rules to trigger load shedding to optimise consumption during peak demand periods.

For example, BeeBryte, a France- and Singapore-based "**software-as-a-service**" company, provides cloud-based intelligence software that can monitor real-time load in large commercial and industrial facilities. The software can automatically switch loads like HVAC systems to battery storage based on time-of-use charges and delivers up to 40% savings in utility bills (BeeBryte, *n.d.*). The demand-side management software is essentially an energy efficiency device switching equipment on or off.

This will potentially evolve to more than on/off control to "control in steps" for better performance and reliability.

Finland's retail energy supplier, Fortum, offers a demand response service for residential customers that have electrical heating and/or water boilers. The company offers demand-side optimisations of heating data and real-time consumption data for a monthly fee (Fortum, 2020). Fortum has built a 1 megawatt virtual battery using the water heaters of 1 000 customers. The controlled residential water heaters, behaving as a battery, play an increasingly important role in maintaining energy system balance through demand-side management (Fortum, 2018).

ESPs can also enable non-automated demand management measures. For instance, retail energy suppliers can use devices that can help customers monitor the energy consumed by every appliance and provide guidance to customers on managing their consumption to reduce their electricity bills.

Potential impact on power sector transformation

EaaS solutions can provide cost savings by optimising energy consumption for categories of consumers including residential, commercial and industrial consumers. Some examples of the impact created by ESPs are described below.

- BeeBryte is a French start-up that uses artificial intelligence to predict a building's thermal energy demand in order to produce heating and cooling at the right times, maintaining comfort and temperature within an operating range set by the customer. This can result in **electricity bill reductions of up to 40%** with real-time control of batteries and HVAC in commercial and industrial buildings (BeeBryte, 2018). BeeBryte's business model is based on a share of the savings generated.

- Solarcity in New Zealand offers a "**solar-as-a-service**" model, where the company owns and manages rooftop solar installations in the customers' buildings. Solarcity also provides a battery to store electricity and smart plug systems that can control appliances based on the availability of solar energy. The company has installed more than 6 000 systems, generating over 9 million kWh of electricity, resulting in **total annual customer savings of nearly USD 1.7 million** (Solarcity, *n.d.*).

- ENGIE Insight, a US-based company, provides resource management programmes. ENGIE Insight estimates that implementing **energy efficiency measures can reduce average energy consumption in buildings by 18%**. The company uses data from meters and energy management systems to reduce electricity costs for clients. Between 2012 and 2017, ENGIE enabled an estimated USD 3.2 billion in savings for its customers (ENGIE, 2018).

Note: USD 1.7 million converted from NZD using an exchange rate of 1 NZD = 0.68 USD.

III. KEY FACTORS TO ENABLE DEPLOYMENT

Digitalisation of the power system at the distribution level

Most EaaS business models are based on analysing real-time information and data on consumers' energy usage as well as electricity market conditions. To gather real-time information, the deployment of enabling infrastructure such as communication infrastructure, advanced metering infrastructure and smart devices is necessary. Electricity appliances and devices equipped with appropriate sensors and hardware need to be deployed at the consumer end. Such devices can capture and transmit their consumption information and, possibly, allow for remote control or automated responses to electricity price signals. Standardised communication protocols for such appliances need to be developed.

Wider usage of smart meters and sensors, together with the application of the Internet of Things and the use of large amounts of data with artificial intelligence, have created opportunities to provide new services to the system (see the *Innovation Landscape briefs: Internet of Things* [IRENA, 2019b] and *Artificial intelligence and big data* [IRENA, 2019c]).

Implementation of time-of-use tariffs

Time-of-use tariffs are a key enabler for EaaS business models. EaaS providers can deploy a combination of assets such as solar PV, battery storage, smart devices and smart meters to optimise energy consumption as well as provide demand response services to system operators. During peak load hours, when tariffs are high, ESPs can reduce demand, either by increasing self-consumption from local generation sources, using distributed storage systems such as batteries or power clouds, or by moving shiftable loads such as water heating to a later time (see the *Innovation Landscape brief: Time-of-use tariffs* [IRENA, 2019d]).

Revision of distribution system operation methodologies to account for demand-side flexibility

Distribution system operators have conventionally invested in network reinforcement to reduce distribution network congestion that could occur during peak demand intervals. Thus, the rules under which distribution system operators plan and size their grids could be modified to allow these operators some freedom to decide whether to reinforce the grid or to use flexibility services provided by end customers via ESPs. Similarly, meeting peak load demand through locally stored or generated energy instead of transporting generation from a distant source may decrease grid congestion and defer network investments.

For example, battery storage systems deployed by end consumers could store excess energy produced from renewable sources such as solar PV or be charged using grid electricity when it is relatively cheap. Batteries can then be discharged during peak time intervals to fulfil demand. Through the EaaS model, ESPs can close the gap between the needs of distribution system operators and the flexibility that potential distributed energy resources and consumers can provide. However, the distribution system operators need to be aware of and consider this option in their operation and planning procedures (see the *Innovation Landscape brief: Future role of distribution system operators* [IRENA, 2019e]).

IV. CURRENT STATUS AND EXAMPLES OF ONGOING INITIATIVES

The current role of conventional electricity retailers is changing to one of energy services companies for all types of consumer. ESPs in large economies such as Australia, China, Europe and the United States are investing in smart grid and smart metering systems. These use advanced data analytics to enable consumers to optimise energy consumption. Some key indicators for the growth of EaaS business models are provided in Table 1.

Table 1 Key facts about EaaS business model development

Indicators	Key facts
Countries where EaaS models have been implemented	Australia, China, Finland, Ireland, Italy, Japan, Sweden, UK, US
Smart meter global market size	Estimated revenue of USD 20.7 billion (2020), growing to USD 28.6 billion by 2025, at a compound annual growth rate of 6.7%[1]
Smart meter penetration (% of meters that are smart meters)	Global: 14% (2019)[2] China: 70% (2019)[3] US: 70% (98 million smart meters) (2019)[4] EU-28: 44% (2018), growing to 71% by 2023[5]
Investments made in EaaS models	~ USD 14.3 billion[6]
EaaS initiatives at national level	India: The Government of India has established a National Smart Grid Mission, operational since 2016, planning the roll-out of smart meters for all customers by 2027[7], with the aim of launching 250 million smart meters by 2024. The agency conducted 11 Smart Grid Pilot Projects across the country (5 000 to 35 000 customers). South Africa: The South African National Energy Development Initiative has implemented 10 pilot-scale smart grid projects[8].
Average peak reductions with EaaS models	3–10%[9] (with time-of-use tariffs)

[1] Bloomberg, 2020
[2] Scully, 2019
[3] Research and Markets, 2019
[4] IEI, 2019
[5] Kochanshi *et al.*, 2020
[6] Smart Energy International, 2016
[7] India Smart Grid Forum, *n.d.*; Government of India, 2020
[8] Smart Energy International, 2017a
[9] Government of UK, 2016

Examples of VPL projects

Case study	Location	Energy-as-a-Service	Description
Choice	Australia	- Energy advice - Energy management	The company Choice provides a service that scans the prices of all retailers every quarter and helps customers save costs by switching to the cheapest electricity supplier. The company also helps customers secure funding for on-site solar PV facilities to generate savings in electricity bills. The price comparison tool has helped customers save over 50% on their electricity bills (Hitchick, 2018).
Crnogorski Telekom	Montenegro	• Energy assets installation • Energy management	Montenegro's leading telecom company has signed a 10-year contract with Ericsson to design, implement and manage lithium-ion batteries and power infrastructure solutions for the telecom company's sites (Ericsson, 2018). This is expected to reduce Crnogorski Telekom's total cost of energy infrastructure ownership by 40%.
EDP	Portugal	• Energy advice • Energy asset installation • Energy management	EDP has launched a smart home solution, "EDP re:dy", enabling the customers to manage their home equipment and energy consumption through a smartphone app (Smart Energy International, 2017b).
Fortum	Finland	• Energy management	Fortum, a retail energy supplier, offers a solution that enables solar PV owners to use the excess energy generated from their solar PV systems to charge electric vehicles (EVs). The excess solar energy is absorbed by Fortum's cloud-based charge-and-drive network, and the amount of energy contributed is credited to the distributed energy resource owner's Charge & Drive account. The owner can use the account at any of Fortum's 400 charging points across Finland (Fortum, 2018).
Google Nest	US	• Energy management	Google Nest focuses on smart homes and automation. Google Nest has introduced new software that will help customers manage consumption when enrolled in a "time-of-use" tariff plan. As such, the thermostat can reduce consumption during periods of peak demand, thereby increasing cost savings (Mooney, 2016; Nest Labs, 2016).
Neura	US	• Energy management	Technology company Neura uses artificial intelligence to understand the behaviour of the residents in a home and to control the smart home devices accordingly. The technology can save energy consumption by turning off lights and televisions, and adjusting the heating/cooling temperature based on residents' behaviour patterns (Neura, *n.d.*).
Stem	US	• Energy management	Stem helps commercial and industrial customers reduce their energy bills by using energy stored in customer's batteries during periods of peak demand. The company combines battery storage with cloud-based analytics systems and artificial intelligence to identify the best time to draw energy from battery storage (Stem, 2017). Stem helps customers maintain a consistent level of energy usage and thus control their demand charge.
Uplight	US	• Energy advice • Energy management	The company Uplight provides a set of over 20 solutions, from behavioural energy efficiency and dynamic rates enrolment to an e-commerce marketplace and automated device control. It guides customers to the best individualised actions available to save energy, which in turn helps utilities shift load during peak periods. For example, during summer heat waves, the utility Consumers Energy achieved load shift of more than 74% when relying on Uplight's residential demand response programme. Uplight also offers EV owners EV-specific rates and charging at ideal times through a variety of self-serve and targeted recommendations (Uplight, 2020).

V. IMPLEMENTATION REQUIREMENTS: CHECKLIST

TECHNICAL REQUIREMENTS

Hardware:

- Widespread adoption of distributed generation sources, energy-efficient devices and energy storage batteries
- Smart meters (required to provide real-time/near to real-time data on power consumption and production)
- "Smart home" gateways (energy boxes) and smart appliances for energy management, necessary for enabling the two-way and real-time interaction with the distribution grid

Software:

- Software that can respond to electricity price signals and that automatically adjusts consumption according to customers' preferences
- Aggregation software – timely communication between the aggregating agency and the smart meters based on service requirement, smart appliances and the energy storage systems
- Weather, energy and price forecasting software that can predict power generation and future prices to allow cost optimisation for the energy consumed
- Energy management software supported through artificial intelligence

Communication protocols:

- Common interoperable protocol for co-ordination among distribution network operators, the consumer and the ESP

REGULATORY REQUIREMENTS

Retail market:

- Time-of-use tariff, and other regulations that enable demand response management for consumers
- Regulations that enable ESPs to implement innovative pricing models and that provide customers the ability to choose the level of service based on their needs (prices could be decoupled from units of electricity sold to incentivise utility providers to promote energy management efforts at the customer end)
- Design incentives for customers and power suppliers to invest in smart meters and smart devices

Distribution system operators:

- Revise distribution system operators' methodologies to account for demand-side flexibility when operating and planning the system expansion
- Incentivise distribution system operators to support the roll-out of smart metering solutions, including innovative ICT infrastructure models

STAKEHOLDER ROLES AND RESPONSIBILITIES	
	Policy makers: • Promote innovations and deployment of decentralised power systems
	Regulators: • Ensure that consumer rights are respected by stakeholders in EaaS models • Provide incentives for consumers and prosumers to provide demand response and ancillary services to the distribution system operator
	Energy service providers: • Increase awareness among customers regarding the latest energy management technologies and provide guidance to customers on choosing solutions that fit their needs • Create end-to-end solutions, starting from energy procurement to consumption management, that will meet a variety of customers' needs • Increase awareness among consumers about the benefits of being an active participant in the energy market. Ensure access to simple and reliable information to consumers.
	Distribution system operators: • Procure market-based flexibility services from distributed energy resources via ESPs • Securely share consumer and grid-related data with third parties as per applicable data privacy and sharing norms
	Consumers: • Become an active consumer by responding to price signals (where markets are in place) to reduce cost on the final bill • Increase level of service provided to the distribution system operator via demand-side management and ancillary services provided to the distribution system operator

ABBREVIATIONS

EaaS	Energy-as-a-Service
EPC	engineering, procurement and construction
ESP	energy service provider
EV	electric vehicle
HVAC	heating, ventilation and air conditioning
ICT	information and communications technology
IRENA	International Renewable Energy Agency
IT	information technology
NZD	New Zealand dollar
PV	photovoltaic
US	United States
USD	United States dollar
VRE	variable renewable energy

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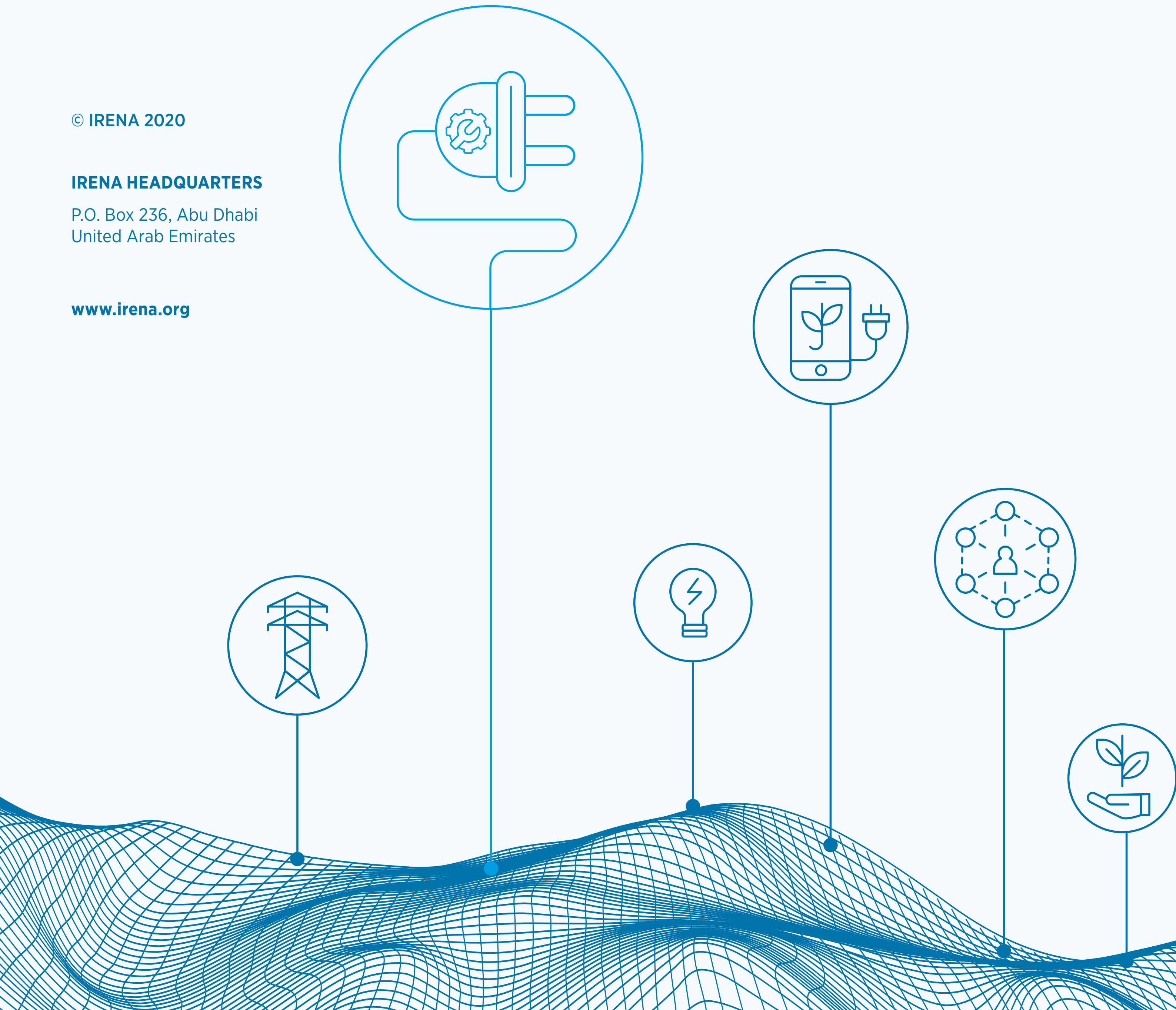
ENERGY AS A SERVICE
INNOVATION LANDSCAPE BRIEF



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COMMUNITY-OWNERSHIP MODELS

INNOVATION LANDSCAPE BRIEF

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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

Community projects can provide flexibility and, when connected to the main power system, increase the reliability and resilience of the whole system. They provide many socio-economic benefits in addition to low-cost renewable energy to the local community.

Community ownership models

Main grid benefits
- Greater grid flexibility
- Increased grid resilience

Power sector transformation in the community
- Increased deployment of distributed renewable generation
- Improved renewable energy access
- Lower energy cost for the community

2 KEY ENABLING FACTORS

- Enabling policy and regulatory frameworks
- Simplification of administrative processes
- Access to finance
- Capacity building within community

3 SNAPSHOT

- → More than 4 000 community-owned projects provide power, mainly in Australia, Europe and the United States
- → Innovations emerging with community ownership include aggregators, demand response, mini-grids, energy storage, electric vehicles
- → Eigg Electric – a community-owned company – provides 95% renewable power to all residents of a Scottish (UK) island.

What does community ownership mean for renewable energy?

Energy-related assets, such as energy generation systems, energy storage systems, energy efficiency systems, and district cooling and heating systems, can be collectively owned and managed by their users.

COMMUNITY-OWNERSHIP MODELS

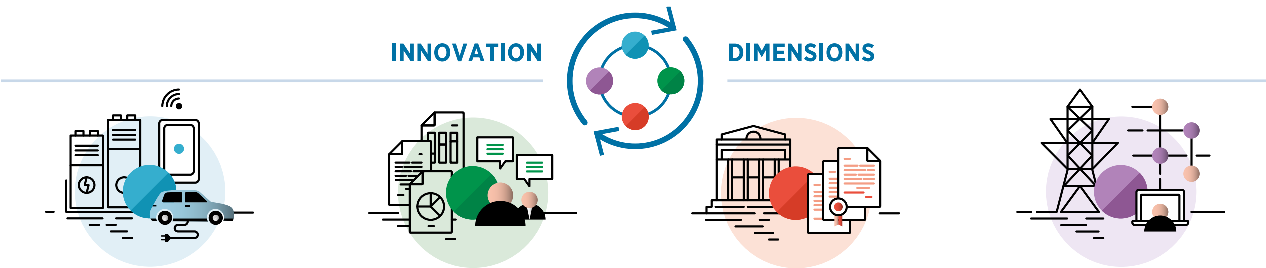
Through cost-sharing, community-ownership models enable participants to own **key local energy assets**, contribute to community energy development and help to scale up renewables.

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 community-ownership models, which allow actors, including households, individuals and businesses, to unite in investing in, developing and operating renewable energy assets. Through cost-sharing, community-ownership models enable individual participants to own parts of the asset with lower levels of investment, which is especially beneficial for the deployment of renewable energy assets.

The brief is structured as follows:

I. DESCRIPTION

Community-ownership structures, in the context of the global energy transition and the decentralisation of power systems, refer to the collective ownership and management of energy-related assets, usually distributed energy resources (DERs). Through cost-sharing, community-ownership models enable individual participants to own assets with lower levels of investment. Community-ownership projects vary in size but are often between 5 kilowatts (kW) and 5 megawatts (MW) in size, depending on where they are being implemented (Gall, 2018). While energy generation is their most common purpose, community-ownership initiatives can also deploy energy storage, energy efficiency, distribution network, and district heating and cooling systems.

A community-ownership project is characterised by local stakeholders owning most of the project and voting rights and by control resting with a community-based organisation. Most of the project's socio-economic benefits are therefore distributed at the local community level (IRENA Coalition for Action, 2018).

The innovative aspect of community-ownership business models lies in the role of the community and its participants, which goes beyond renewable energy generation. Nowadays, community-ownership models cover the entire energy value chain: they can provide localised generation for power, heat and energy-related services (*e.g.* storage, charging electric vehicles, energy trade with surrounding communities); enable efficient energy use; and provide flexibility to the entire power system. For example, the local solar community of Casalecchio di Reno in Italy expanded the model from providing electricity from solar photovoltaic (PV) power plants to encompassing shared services for charging electric cars (Bisello *et al.*, 2017).

Generally, community-ownership models revolve around the following options:

- **Community-owned electricity generation plants, such as solar PV plants, wind power plants and biomass plants**, can be developed to fulfil the electricity needs of the local community. Consumers, bundled in communities, self-consume the electricity produced and thereby become collective "prosumers". Any additional electricity generation from such plants can be exported to the main grid, sold to third parties and businesses, or supplied back later to the members of the community, if storage is available.

- **Community-owned district heating systems**, such as biomass, wood pellet, solar, geothermal, and combined heat and power plants, can be implemented to serve the heating needs of the local community.

- **Community energy storage systems** involve the deployment and operation of batteries by communities to store the electricity generated locally or consumed from the grid to meet the peak demand of the community.

- **Community energy efficiency programmes**, either as a core or complementary activity, encourage members to take measures to reduce their consumption or invest in building retrofits. They may encourage such actions through direct investments, education and outreach, provision of technical and financial advice, or partnerships with local authorities.

- **Community electricity retailers** buy wholesale electricity produced by community-owned electricity generation plants and sell energy services to local communities and other third-party supporters.

Usually, the community owns, manages and takes the benefits of the project, while the main power grid operator and other parties have a secondary role. Figure 1 depicts an energy system based on the community-ownership business model.

The main purpose of the organisation varies. However, community-ownership projects are typically focused on generating benefits to the community (economic, social, environmental) in addition to financial profits. The main purpose of a community-ownership project influences its implementation, as different models may be better suited to different objectives.

Implementation of community-ownership models for energy-related assets can be structured differently, based on a variety of legal frameworks, forms of ownership, distribution of benefits and level of democratic governance. A community model includes a combination of at least two of the following elements (IRENA Coalition for Action, 2018):

- **Ownership structure:** Local stakeholders may own part or all of a renewable energy project. Usually, community-ownership models involve **full ownership** by the community, although in such cases other stakeholders – such as conventional energy companies (utilities, retailers, etc.), non-profit organisations and (local) authorities – can participate as individual members of the community. In other cases, the local community may own a **majority stake**, while other stakeholders can be a part of the ownership arrangement as partners. In many cases, renewable energy projects are developer led, and communities are given the option to take partial ownership of the project.

- **Level of democratic governance:** Voting control of the business around the renewable asset rests with a community-based organisation, meaning that local stakeholders have the majority of the voting rights concerning the decisions taken on the project.

- **Local distribution of profits:** The majority of social and economic benefits are distributed locally (*e.g.* jobs created locally, power supplied to the community, profits shared among individual participants to the community scheme).

Figure 1 Schematic of energy system based on the community-ownership business model

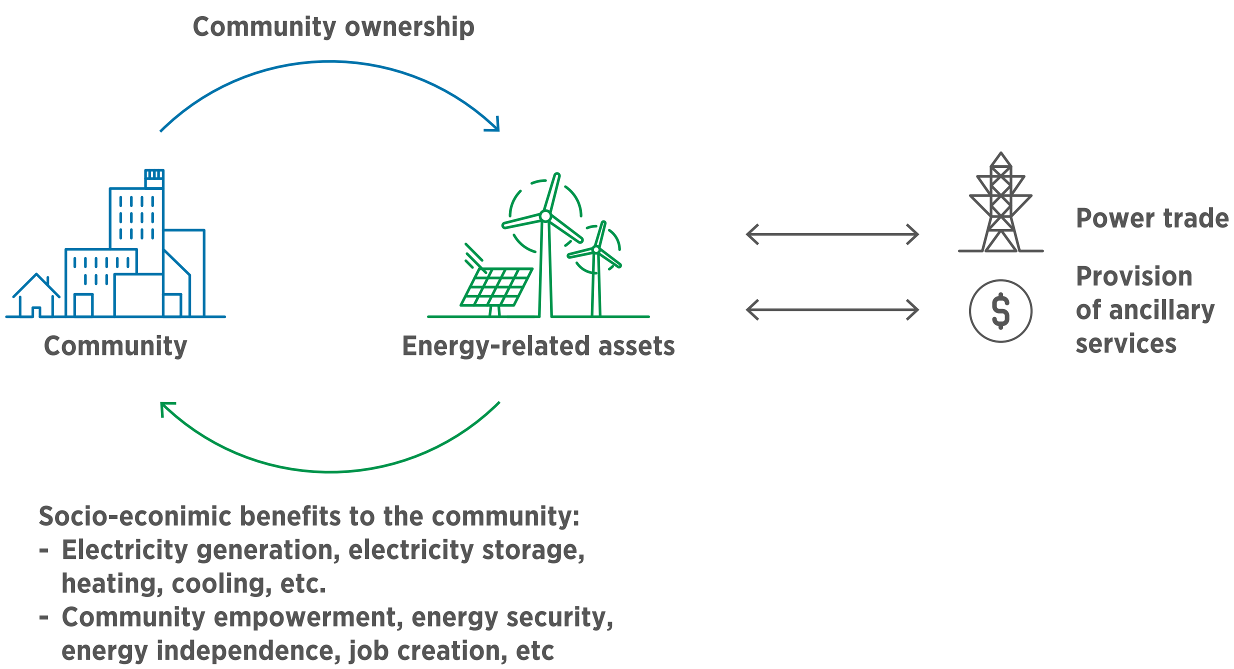


Figure 2 highlights some of the common community-ownership models. Table 1 further describes these frameworks and provides relevant examples.

Figure 2 Characteristics and common community-ownership models

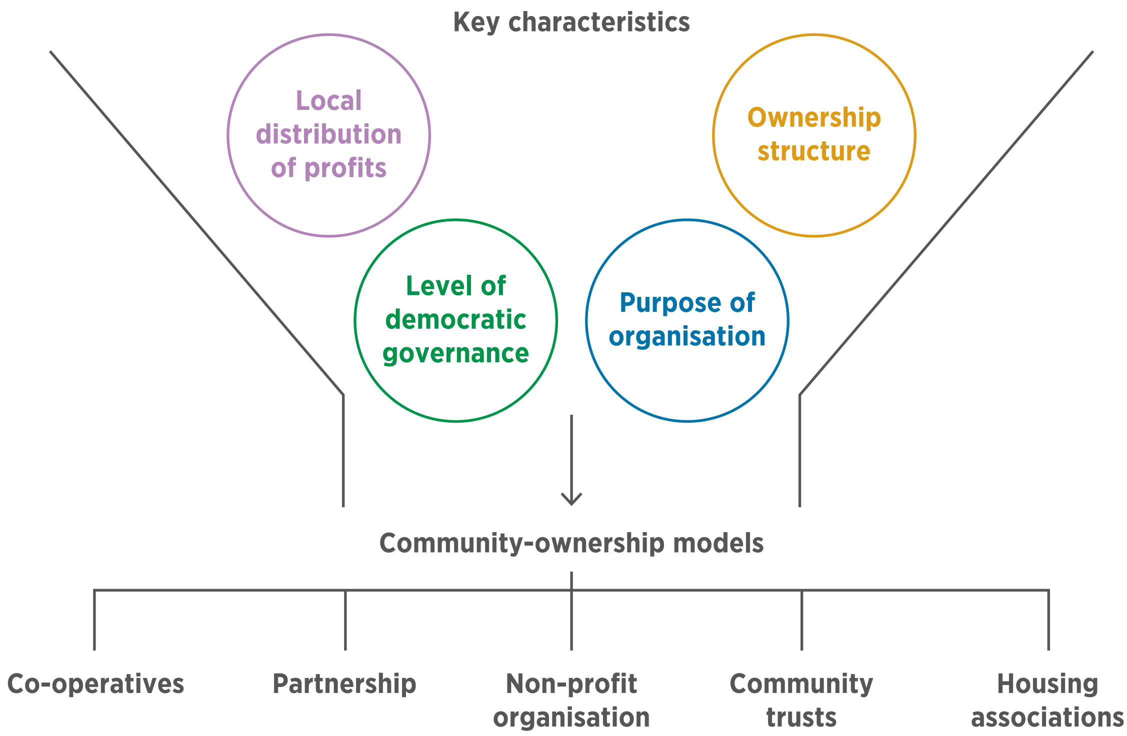


Table 1 Legal forms of community-ownership business model

Community-ownership model	Description
Co-operatives	Co-operatives are jointly owned by their members to achieve common economic, social or cultural goals based on the democratic principle of "one member, one vote". Co-operatives rely largely on volunteers but can have paid staff.
Partnerships	In partnerships, individual partners own shares in the community-ownership model. The key objective of a partnership is to generate profits for the shareholders, in addition to any other benefits of the project. Unlike co-operatives, partnerships may not operate on the basis of "one member, one vote". Nor do partnership firms rely largely on volunteers, as co-operatives do. They may employ full-time staff to provide expertise needed for specific projects.
Non-profit organisations	A non-profit organisation is formed by investments from its members, who are responsible for financing the organisation but do not take back any profits. Profits are re-invested in projects focused on community development.
Community trusts	Trusts use the returns from investments in community projects for specific local purposes. These benefits are also shared with people who are not able to invest directly in projects.
Housing associations	A form of non-profit, such associations offer housing to low-income families and individuals.

Social benefits of community-ownership models

While community-owned projects have various purposes, they typically focus on creating social benefits. One major benefit of community-ownership models is that communities are less reluctant for larger devices such as wind turbines to be installed. Opposition is strongly reduced, and the "not in my backyard" effect is diminished as communities become part of and actively involved in the project.

This creates a sense of ownership that in turn can **empower a community** greatly: members are more prone to do other (non-energy-related) projects as a community and feel a bigger sense of attachment to the place because of their active involvement.

Especially in rural areas, this attachment – together with job creation (from technical to managerial jobs) – can play a crucial role in (particularly young) people's decision to stay or return to places with otherwise declining and ageing populations. This can have huge effects on the future of rural settlements.

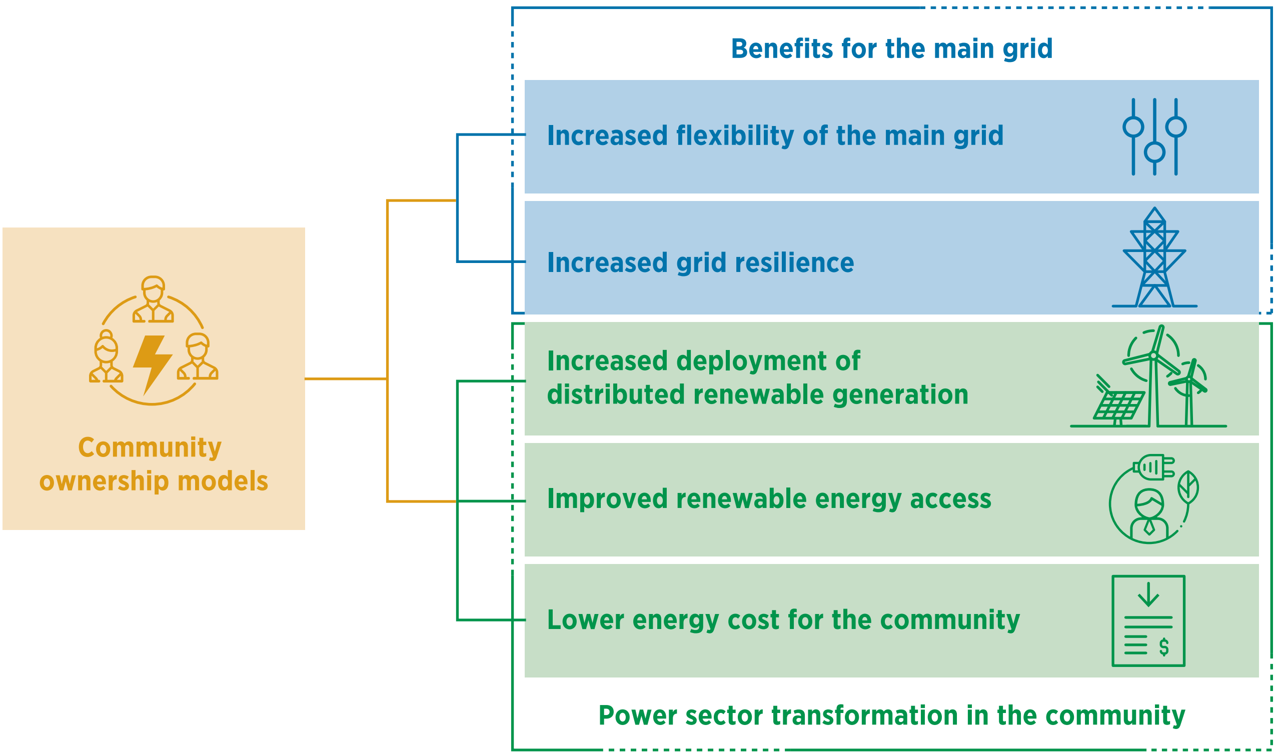
Another important social benefit of community ownership is the **energy and environmental consciousness** that is created among a community, which can go beyond energy consumption. For example, on Eigg Island in Scotland (UK), Eigg Electric is a community-owned, managed and operated renewable-based system that provides electricity to all residents. Households there have an electricity demand cap of 5 kW, and they have a traffic light system at the pier, where everyone can see if available electricity is becoming scarce, so there is great participation and consciousness about the availability of electricity resources. In addition, people are starting to drive electric vehicles, do beach clean-ups, plant trees, and other similar activities (Green Eigg, *n.d.*)

II. CONTRIBUTION TO POWER SECTOR TRANSFORMATION

Community-ownership models allow costs to be shared, which lowers upfront investments and therefore enables larger deployment of decentralised renewable power plants at the local level. They also encourage people to unite and act on energy and other socio-economic challenges specific to their communities, while encouraging solidarity and co-operation.

While community-owned projects have various purposes, they typically focus on creating benefits for the community. In addition, projects developed under community ownership can provide flexibility to the main transmission grid, if connection is in place. Figure 3 summarises the key contribution of community-ownership models to power sector transformation.

Figure 3 Key contributions of community-ownership models to power sector transformation



Increased flexibility of the main grid

Community-owned projects, either individual projects or projects bundled around a mini-grid, are primarily used for community applications. However, if these projects are connected to the main grid, as with any DER, they can provide power and other ancillary services to the main grid. For the electricity injected into the main grid, the community-owned projects would be remunerated in accordance with the regulation in place, either through direct trade on the wholesale market, feed-in tariffs, net metering or net billing (for more information, see *Innovation landscape brief: Net billing schemes* [IRENA, 2019b]). This could increase flexibility in the main grid while providing additional income for the community members.

Through demand-side management, the community can unlock demand-side flexibility in the system through load shifting and peak shaving. Community energy storage systems, for example, can also reduce peak demand in the grid by supplying stored energy to local communities, as well as to the grid, during peak hours (for more information on storage systems please see *Innovation landscape brief: Utility-scale batteries* [IRENA, 2019c]).

Community-owned projects can help balance power grids, providing different services such as frequency control, voltage stability congestion management, system restoration and enhanced power quality, as with any DER or mini-grid. For example, a solar PV system connected to a battery storage system deployed by communities can quickly ramp the power output up or down to provide frequency and voltage regulation services (for more information, see the *Innovation landscape briefs: Renewable mini-grids* [IRENA, 2019d], *Market integration of distributed energy resources* [IRENA, 2019e], and *Innovative ancillary services* [IRENA, 2019f]).

Increased grid resilience

The main system of large, centralised power plants is vulnerable to massive outages from natural disasters and acts of terrorism. Incorporating smaller, decentralised local renewables and other DERs diversifies the energy supply and reduces the risk of widespread power outages, especially in power systems with a history of outages. Distributed generators and micro-grids could enable islanded operation, thus improving resiliency against extreme events. However, the co-ordinated operation of heterogeneous distributed generators introduces different operational and control requirements (Singh, Kekatos and Liu, 2018).

Increased self-consumption inside a community, by installing generation plants coupled or not with battery systems, leads to enhanced resilience and energy security in the community and can keep a community functioning during a blackout. Because of its local scale, a micro-grid does not need a vast system of overhead lines to deliver power and could therefore keep safely functioning when a central grid turns off owing to hazards (Chrobak, 2019). Community-owned projects can allow a community to get a more powerful, resilient energy system. For example, in Scotland some households have a 3–10 kW wind turbine in the backyard, but as a community they can get a bigger (900 kW) turbine project.

Increased deployment of distributed renewable generation

When decentralised energy systems are implemented by a local community, the size of the project is larger than when implemented by an individual, benefiting from economies of scale. Community-ownership models can enable aggregation of demand for energy-related assets and negotiation of better prices with installers, project developers and equipment suppliers, thus lowering the upfront investments needed from community members. Community battery storage provides economic advantages over household storage as costs per kilowatt-hour (kWh) decrease with increasing battery size (Fraunhofer IWES, 2014). For instance, Cooperative Community Energy, a solar co-operative based in California, United States, gets discounts on equipment because of bulk procurement, which are passed on to the members (Cooperative Community Energy, *n.d.*). In Vermont, United States, Acorn Renewable Energy Co-op is a co-operative organisation that provides discounts to members for the purchase of solar heaters, residential solar PV systems and wood pellets for heating. This is enabled through bulk procurement by the co-operative on behalf of its members (Acorn Energy Co-op, 2017).

For example, St. Gorran Community in Cornwall, United Kingdom, established in 2008 the co-operative Community Power Cornwall Limited to enable community ownership of energy assets, to generate capital to be re-invested locally in renewable energy and to nurture the spread of community-owned renewable energy generation. The first project developed was a 160 kW wind power plant in 2011, followed by a second 10 kW wind turbine in 2014. In 2015 and 2016, solar PV projects totalling 90 kW were developed, followed by other solar PV projects totalling 220 kW in 2018 and 2019 (Community Power Cornwall, 2020).

Owing to better economic viability, the use of community-ownership models can lead to a higher and more rapid deployment of distributed renewable generation assets than is possible with individually owned systems.

Improved renewable energy access

Increased deployment of decentralised energy resources contributes to local decarbonisation goals and provides socio-economic benefits, such as creating new jobs and energy access.

For example, in Scotland, on Eigg Island, Eigg Electric was established as a community-owned, managed and maintained company that provides renewable electricity for all island residents. The community-ownership system consists of three hydroelectric generators (110 kW), a group of four small wind generators (24 kW) and an array of solar electric panels (50 kW), sited at different locations around the island as determined by the optimum availability of resources. The total generating capacity of the system is approximately 184 kW, and it has provided around 95% of the electricity needed since the scheme was first switched on in 2008. The remaining 5% is generated by two 80 kW diesel generators to provide backup when renewable resources are low or during maintenance. Eigg is not connected to the mainland electricity supply, and the community-owned Eigg Electric provides the community with electricity access (The Isle of Eigg, *n.d.*).

In areas where the electricity access is poor, the lower upfront investments required by community energy projects can enable local development of renewable energy projects. Besides providing energy access to the community, such projects can improve livelihoods by enabling productive uses, such as agro-processing, cold storage, irrigation and desalination, or other micro-enterprises. In these regions, community-ownership models can be implemented together with flexible payment methods, such as pay-as-you-go models, to enable vulnerable populations to gain access to electricity (for more information, see *Innovation landscape brief: Pay-as-you-go models* [IRENA, 2020]).

Lower energy cost for the community

Community-ownership projects can also lead to significantly lower cost energy for the community. First, the costs for electricity produced from locally deployed renewable energy plants may be cheaper than electricity offered to the community by other retailers. Demand (also called "peak") charges are an important component of electricity bills and are generally based on the highest electricity usage requirement (in kW). On-site battery storage systems can be used to manage peak loads and reduce demand charges (for more information, see *Innovation landscape brief: Behind-the-meter batteries* [IRENA, 2019g]). In addition, for the electricity injected into the main grid, the community-owned projects would be remunerated in accordance with the regulation in place.

In the United States, local governmental entities called community choice aggregators (CCAs) have been established, which procure electricity on behalf of retail customers within a certain geographic area. Currently CCAs are authorised in seven states. CCAs are an attractive option for communities that want more local control over their electricity sources, more green power than is offered by the default utility and/or lower electricity prices. By aggregating demand, communities gain leverage to negotiate better rates with competitive suppliers and choose greener power sources. CCAs in California have leveraged buying power and access to low-cost financing to procure from local renewable energy projects at lower prices than from investor-owned utilities (EPA, 2020).

Potential impact on power sector transformation

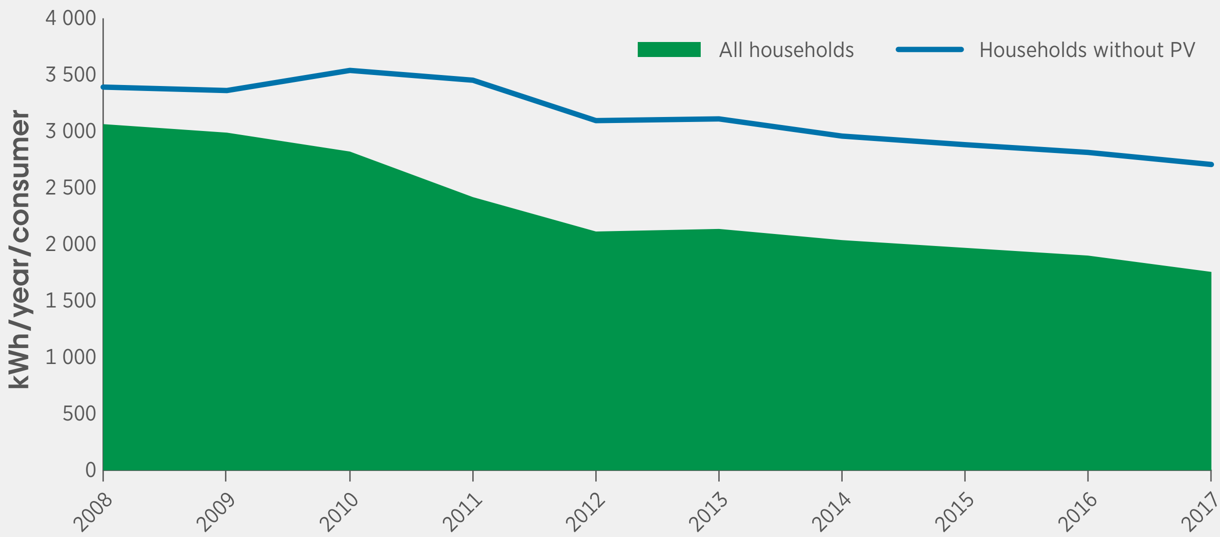
Community-ownership models have a great impact on transforming the community's relationship with energy as well as providing benefits to the entire system. Examples of projects with such proven benefits are below:

- The community-owned utility in the village of Minster, Ohio, United States, has implemented a 3 MW solar project with a 7 MW, 3 megawatt-hour (MWh) battery storage system. The project has resulted in **savings of USD 1 million per year for the community**, because of which electricity tariff increase for community members has been avoided. Further, the **battery storage system is providing frequency regulation services to PJM Interconnection**,[1] leading to an additional revenue stream for the project. Minster has **saved over USD 150 000 in transmission and capacity costs** owing to the implementation of this project. The battery connected to the solar plant has further **helped defer a USD 350 000 purchase of reactive power hardware** that would have been needed to integrate the solar energy generation into its grid (Smart Electric Power Alliance, 2018; Trabish, 2016).

- In Jühnde, a small village in Germany, a 700 kW combined heat and power plant using biogas was implemented under a co-operative structure. **The plant meets 70% of the heating needs of the village** and produces double its electricity demand. **The excess electricity is fed back into the grid** (Simcock, Willis and Capener, 2016).

- In Belgium, a renewable energy co-operative, Ecopower, with about 50 000 members, supplies 1.5% of the households in the Flanders region with about 90 gigawatt-hours of renewable electricity from their own wind turbines, PV installations and small hydro. The supply is considered a service to the members and is performed at cost, without taking profits. As a result, **Ecopower offers the lowest price for electricity in the Flemish region. Members pay USD 0.22/kWh, compared with an average retail tariff of USD 0.29/kWh** (Statista, 2017). The members also get a dividend of up to 6% per annum on their holdings. More than 40% of the members have installed PV panels at home, and the average consumption from the grid of its members has almost halved over the past 10 years to 1 758 kWh/year in 2017, whereas the average household in Flanders consumes 3 468 kWh/year, as shown in Figure 4. Furthermore, Ecopower encourages its members to reduce their consumption by providing them with education and technical advice on taking efficiency measures.

Figure 4 Average consumption from the grid of Ecopower members



1 PJM Interconnection is the regional transmission organisation for 13 US states, including Ohio.

III. KEY FACTORS TO ENABLE DEPLOYMENT

Enabling policy frameworks

Creating long-term and stable policy frameworks for energy communities is key to stimulating further investment. The choice and design of these policy frameworks should be adapted to local and country-specific circumstances as well as to the broader development objectives they may seek to support. While some countries have introduced specific policy measures supporting energy communities indirectly (*e.g.* via feed-in tariffs), others have introduced support programmes directly for community energy investments (*e.g.* targeted grants) (IRENA Coalition for Action, forthcoming).

Although there are few national programmes dedicated to supporting community ownership in developing countries, several developed countries have initiated support programmes focusing on community-based planning and ownership. Such programmes typically involve energy co-operatives and local ownership of projects combined with financial support schemes. This type of structure creates a double benefit, as it enables local engagement and acceptance of projects, as well as lower energy bills for all participating consumers.

Community-ownership programmes in developed countries are usually not limited to certain resources but span a broad range of renewable technologies, such as wind, solar, bioenergy, geothermal or hydropower. For example, Germany supported participation of community-ownership projects in wind auctions by putting in place preferential rules for such projects. Under these preferential rules, community-ownership wind projects had up to two years after winning a bid to obtain a building permit. Other bidders, in contrast, had to present the permit at the moment of bid submission. As a result of the more favourable conditions, the first three rounds before November 2017 awarded over 90% of the total auction volume of 2 890 MW to community-ownership projects. However, by June 2019, of the community-ownership wind projects that had won those bids, only a few (responsible for 167 MW of the volume) had obtained a building permit. This reflects the general permitting challenges faced (IRENA, 2019h).

Similarly, Ireland is proposing a new Renewable Electricity Support Scheme, which includes an enabling framework for community participation through the provision of pathways and supports for communities to participate in renewable energy projects. All projects looking for support under the new scheme will need to meet prequalification criteria including offering the community an opportunity to invest in and take ownership of a portion of renewable projects in their local area (DCCAE, 2020).

In 2019, the European Union institutions reached a political agreement on all the major pieces of legislation forming the Clean Energy for All Europeans package, which is set to influence the future of the energy landscape in the coming decades in Europe. One of the major breakthroughs comes from the legal recognition (with associated rights and responsibilities) granted to individual renewable energy producers and communities. Directive (EU) 2018/2001 of 11 December 2018 on the promotion of the use of energy from renewable sources now provides the right to citizens and "renewable energy communities", a recognised legal entity, to produce, store, consume and sell renewable energy without being subject to disproportionate burden and discriminatory procedures. Under this new directive, which needs to be translated into national legislation, a renewable energy community is based on “open and voluntary participation”, being controlled by shareholders or members located in the proximity of the power plant, and the shareholders or members can be natural persons, small and medium enterprises, or local authorities, including municipalities (European Union, 2018).

In developing countries in general, there is a significant need to scale up energy access programmes for the hundreds of millions of people who still do not have access to electricity. A wide range of national and international programmes support schemes to provide energy access, but the capital and human resources needed are huge, and the current programmes are not sufficient. The key obstacles for rural electrification projects are (i) availability of finance at reasonable cost, (ii) mobilising and capitalising equity for rural communities, (iii) availability of technical and economic information, and (iv) availability of trained staff (IRENA, 2019i).

Clear regulatory frameworks for community-ownership projects’ participation in power markets

Supply of energy to members within or outside the community may require regulatory clarity, in addition to supportive enabling policy frameworks. For instance, in most countries, the sale of surplus power to third parties outside of the community or peer-to-peer trading of energy among community members either does not have regulatory clarity or is plagued by cumbersome processes. Therefore, appropriate regulatory provisions need to be developed for community-owned projects and other DERs to enable energy supply arrangements such as third-party sale or peer-to-peer energy sharing.

The participation of community-ownership projects in the wider energy market, where applicable, is restricted in many countries owing to minimum capacity requirements. Adjusting the minimum capacity requirements or aggregation of DERs and community-ownership projects would enable the participation of these smaller projects in the wholesale markets (for more information, see the *Innovation landscape briefs: Market integration of distributed energy resources* [IRENA, 2019e] and *Aggregators* [IRENA, 2019j]).

Simplification of administrative processes

The development of renewable energy projects involves some complex administrative processes, including planning, project development and obtaining the necessary permits. Associated tasks can include environmental impact assessments, construction permits, occupational health and electric safety permissions, licences for energy generation, and grid connection authorisation. Processes for obtaining these permissions can be streamlined for community-owned projects to bring down costs and development times, thus making such projects more attractive investments. For instance, in North Rhine-Westphalia, Germany, wind installations under 10 metres in height that are not located in residential or mixed utilisation areas are exempt from certain approvals. Similarly, in the United Kingdom, the installation of solar PV on slanted roofs has been preapproved. In Wales and Scotland, projects are automatically preapproved for installation, even on flat roofs.

Access to the grid for community-owned renewable projects often involves challenges such as limited network capacity, the need for grid extension and long processes for obtaining grid connection authorisation. Simplification of these tasks can be tackled through appropriate regulatory mandates.

Access to finance for community-ownership projects

Community-ownership projects may need large upfront investments, and communities’ equity contributions might prove insufficient. Access to commercial financing is often difficult owing to the lack of clarity on long-term revenues generated by community-ownership projects. Unlike other renewable projects, a community-ownership project often aims to achieve objectives in addition to maximising financial profits for its members (*e.g.* energy security, energy access, decarbonisation). This can make the business case more challenging when trying to gain the support of traditional financiers and investors. These challenges can be addressed if the community can partner with local businesses or developers to fill the funding gaps and increase the creditworthiness of the projects. In the United Kingdom, for example, the majority of community-ownership projects have been based on a partnership with developers or businesses (Murray, 2014).

Further, small community energy projects may encounter challenges in raising funds from community members and other investors initially as the projects may be perceived as high risk. The European federation of renewable energy co-operatives (REScoop) is attempting to mitigate such development risks under its 'Renewable Energy Cooperatives Mobilizing European Citizens to Invest in Sustainable Energy' (MECISE) programme. Through this programme, REScoop MECISE will invest in community energy startups and sell its ownership to community members and other investors once the project is up and running (REScoop, 2018).

Governments and development banks can also enable growth of community-ownership projects by providing low-cost loans and grants. In Germany, around half the community-owned projects have received funding from co-operative banks, and a third of the projects have received low-cost loans from KfW, the German state-owned development bank (Murray, 2014).

The Scottish government's Community and Renewable Energy Scheme offers a range of financing options for community renewable energy projects, including different grants from USD 28 750 (GBP 25 000) up to USD 172 500 (GBP 150 000) (Local Energy Scotland, 2018).

Further, providing microcredit to communities can also be used as a mechanism to kick start community energy projects. For instance, in Latin America, Africa and South Asia, microcredit has been used to initiate community energy projects (REN21, 2016).

Capacity building and technical assistance within the community

The success of community-ownership projects depends on access to information and technical expertise within the members of the community. Therefore, capacity building of local communities as well as the availability of adequate technical expertise and assistance in implementing various community-owned projects is key. For example, to tackle this challenge, Renew Wales, an organisation in the United Kingdom led by local community experts, provides community groups with advice, training and mentoring on setting up community projects by connecting them to other groups that have implemented similar projects. The co-ordinators of the organisation spend up to three days with the community groups to help them develop action plans (Renew Wales, 2018).

Online toolkits and guidance documents can also enable local communities to set up energy projects. The German city of Freiburg, for instance, has developed an online tool called FREE SUN, which identifies available space for rooftop solar installations and provides information related to administrative procedures and regulations. The information provided by this tool has been instrumental in the massive uptake of solar PV and solar thermal energy solutions by the local communities (City of Freiburg, 2018).

In Scotland, a Community and Renewable Energy Scheme Toolkit has been developed by the government. The toolkit provides advice to communities and support in accessing grant and loan funding, in all aspects of local, renewable energy (Local Energy Scotland, 2020).

IV. CURRENT STATUS AND EXAMPLES OF ONGOING INITIATIVES

Community-based projects have gained traction in the United States and Europe, especially in countries like Denmark, Germany, the Netherlands, and the United Kingdom (particularly Scotland), where co-operative frameworks have a historical presence.

Different jurisdictions have different definitions of community-ownership models, creating challenges in comparing the status of such models across jurisdictions.

Table 2 shows some key indicators for community-ownership models.

Table 2 Key indicators on the current status of community-ownership models

Key indicators	Description
Number of community-ownership initiatives (2018)	4 000+ globally, primarily in Australia, Denmark, Germany, the Netherlands, the United Kingdom and the United States (Interreg Europe, 2018; REN21, 2016)
Countries where projects are implemented (2018)	Argentina, Australia, Austria, Belgium, Croatia, Denmark, Finland, France, Germany, Greece, Italy, Luxemburg, the Netherlands, Norway, Portugal, Spain, Sweden, Switzerland, United Kingdom, United States
Total installed capacity of community-ownership projects (2020)	Germany: 1 GW (1% of total installed capacity) (FSR, 2020)
Most common community-ownership models	• Co-operatives • Partnerships
Typical size of community-ownership projects	Approximately 50 kW to 10 MW (although they can be much bigger; for example, the 66 MW community-owned wind turbines in Dardesheim, Germany, and the 102 MW community-owned wind project in Krammer, Netherlands)
Technologies predominantly used in community-ownership projects	• Solar PV • Wind turbines • Energy efficiency • District heating
Other innovative technologies starting to be used in community-ownership projects	• Aggregators (virtual power plants) • Demand response • Mini-grids • Biomass power plants • Energy storage • Electric vehicles (early stages)

Table 3 Case studies

PHS scheme	Location	Description	Value added
Ærøskøbing District Heating, Ærø, Denmark	Co-operative	District heating using solar thermal and bioenergy	The co-operative owns three district heating stations in Ærø, a small community in Denmark. These plants generate heat using straw, wood pellets and a solar collector. The straw and wood pellets are used only after heat from solar capacity has been used (Ærøskøbing Fjernvarme, *n.d.*). The co-operative meets heat requirements for a community of 7 000 inhabitants. Solar produces 75–100% of the heat in summer months.
Buan Citizen Power Generation (BCPG) – South Korea	Partnership	Community solar PV project	BCPG has installed 36 kW of solar PV and a geothermal heating system in the village of Deunyong, Republic of Korea. Around 75% of the initial investment for these projects was provided by ten local people, with the rest coming from the government. The electricity generated from these projects is sold to the Korean Electric Power Company under a fixed feed-in tariff; the revenue generated is distributed to project investors (partners), and any remaining profits are allocated for further solar PV and community heating projects (Simcock, Willis and Capener, 2016).
Eigg Electric, Eigg Island, Scotland	Co--operative	Community wind, solar and hydro system	Eigg Electric is a community-owned, managed and maintained company that provides electricity for all island residents from renewable sources, comprising 110 kW hydro projects, 24 kW wind turbines and a 20 kW solar PV plant, totalling 184 kW. Renewable sources have provided around 95% of the island's electricity since the scheme was first switched on in 2008 (The Isle of Eigg, *n.d.*).
Horshader Community, Isle of Lewis, Scotland	Trust	Community wind energy project	Horshader Community constructed a 900 kW wind turbine, which earns revenues through feed-in tariffs (Simcock, Willis and Capener, 2016). The yearly revenue of approximately USD 125 000 (GBP 100 000) is used for local development. This is one of the many such projects developed in Scotland.
Hvide Sande Community, Denmark	Trust	Community wind energy project	Hvide Sande Community installed three wind turbines of 3 MW on the shoreline. The board of the foundation has members from the local community, with around 400 shareholders. (Maegaard, *n.d.*). The expected return will be invested in the modernisation and development of the harbour, which is of great importance to the region (Community Power, *n.d.*).
Hvidovrebo Section 6, Denmark	Housing association	Rooftop solar and solar thermal	In Denmark, Hvidovrebo Section 6 is a housing estate located on the outskirts of Copenhagen. Using the model of "tenants' democracy", the tenants decided through consensus to install rooftop solar and solar thermal units on roofs that were already in need of renovations. The project will span ten roofs throughout the estate and is expected to produce 120–160 MWh electricity per year. This will be financed by residents through additional rent or mortgage payments (Roberts, Bodman and Rybski, 2014).

PHS scheme	Location	Description	Value added
Middlegrunden, Copenhagen, Denmark	Hybrid structure (partnership between a utility and a co-operative)	Community wind energy project	A wind farm of 20 wind turbines of 2 MW capacity each is situated offshore, near Copenhagen harbour. This wind farm is a 50:50 joint venture between Copenhagen Energy (the local utility) and Middlegrunden co-operative. It is the largest community-owned wind project in the world, and the joint venture was encouraged by Denmark's decentralisation of energy targets and flexible planning arrangements (Simcock, Willis and Capener, 2016). The project meets 3% of Copenhagen's electricity needs.
Odanthurai panchayat, Tamil Nadu, India	Co-operative	Community wind energy project	Odanthurai panchayat in the Coimbatore district of Tamil Nadu, India, implemented a 350 kW wind energy plant – the first ever community-owned power project in India. The generation from this plant is used to satisfy the electricity needs of the village; the excess is sold to the grid and used to pay the interest on the bank loans. Selling around 30% of the electricity generated to the grid brings a yearly revenue of approximately USD 27 000 (INR 2 million) to the community (Saravanan, 2016).
Ripple Energy, United Kingdom	Co-operative	Community electricity retailer	Once a customer chooses to receive their energy through Ripple, they will co-own the wind farm, or an alternative renewable source of power, through a community benefit society. Customers will be charged an upfront fee, which will be dependent on how much energy they use and the size of the project. Customers could save around USD 105 to 215 (GBP 85 to 175) each year on their electricity bill throughout the wind farm's 25 year lifespan (Gausden, 2019).
United Power, Colorado, United States	Co-operative	Community electricity retailer Community battery storage	The co-operative electricity retailer implemented a 4 MW/16 MWh battery storage system that stores energy during the night (off-peak time) and discharges it during the day (peak time) to reduce demand charges (Best, 2019).
University Park Community Solar LLC, Maryland, United States	Partnership	Community solar PV project	University Park Community Solar LLC comprises around 35 members, residents of University Park. Each member pooled in an average of USD 4 000 to develop a 27.77 kW solar power system. The power from this system is sold to the University Park Church of Brethren, and the excess is fed back into the grid. The firm also sells Solar Renewable Energy Certificates (University Park Solar, 2018).
Wiltshire Wildlife Community Energy (WWCE), Swindon, United Kingdom	Hybrid structure (co-operative set up by a trust)	Community solar PV project	WWCE is a community benefit society set up by Wiltshire Wildlife Trust for the development of community-owned renewable energy projects. WWCE has implemented two solar PV projects of 1 MW and 9.1 MW. The projects were funded by the sale of shares in WWCE, allowing people to invest anywhere between USD 670 and USD 134 000. The projects earn revenue through feed-in tariff payments, and after payment to its members, 80% of the remaining money is allocated to WWCE's community benefit fund, with 20% being directly allocated to Wiltshire Wildlife Trust (Simcock, Willis and Capener, 2016). WWCE has paid 7% dividends to its members, and the remaining profits are spent on local community development.

V. IMPLEMENTATION REQUIREMENTS: CHECKLIST

TECHNICAL REQUIREMENTS

Hardware:

- Energy assets such as renewable generation systems (solar rooftop PV, wind turbines, etc.), district heating systems (biomass-based heating), battery storage systems and mini-grids
- Grid upgrades required to connect DERs with the existing grid
- Smart meters and smart grid

Software:

- Energy accounting and management software for community projects
- Digital infrastructure that allows system operators to have real-time information on the availability of DERs that can provide flexibility, enabling them to access these ancillary services.

POLICIES NEEDED

- Long-term and stable policy frameworks, including policy measures supporting community energy and community energy investments
- Financial incentives such as tax credits, low-cost loans and grant funding for community-owned projects
- Policies to encourage public-private partnerships in setting up community-owned projects at the local level
- Promotion of energy community development and decentralisation of the power system

REGULATORY REQUIREMENTS

- Enable new energy supply and trade arrangements, such as third-party sale or peer-to-peer energy trading, for community-owned projects and other DERs (*e.g.* retailers procuring electricity from community-owned projects)
- Allow participation of community-ownership projects in the energy market by adjusting the minimum capacity requirements or allowing aggregation of DERs
- Ensure the possibility for community-owned projects to bid in national energy auctions on a level playing field with other market participants

STAKEHOLDER ROLES AND RESPONSIBILITIES

Policy makers:

- Encourage pilot programmes (*e.g.* regulatory sandboxes) to work as a test bed and disseminate results
- Support technical capacity building in local communities

Regulators:

- Simplify and increase the transparency of administrative and permitting processes for community-ownership projects

System operators:

- Engage in distribution grid planning based on collaboration with local stakeholders, and take community-ownership projects into account

Individual households and local communities:

- Search for advice, training and mentoring on setting up a community-ownership project
- Define the most suitable community-ownership structures according to desired management practices and sought distribution of profits

ABBREVIATIONS

BCPG	Buan Citizen Power Generation
CCA	community choice aggregator
DER	distributed energy resource
kW	kilowatt
kWh	kilowatt-hour
MECISE	Mobilizing European Citizens to Invest in Sustainable Energy’
MW	megawatt
MWh	megawatt-hour
PV	photovoltaic
WWCE	Wiltshire Wildlife Community Energy

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COMMUNITY-OWNERSHIP MODELS
INNOVATION LANDSCAPE BRIEF

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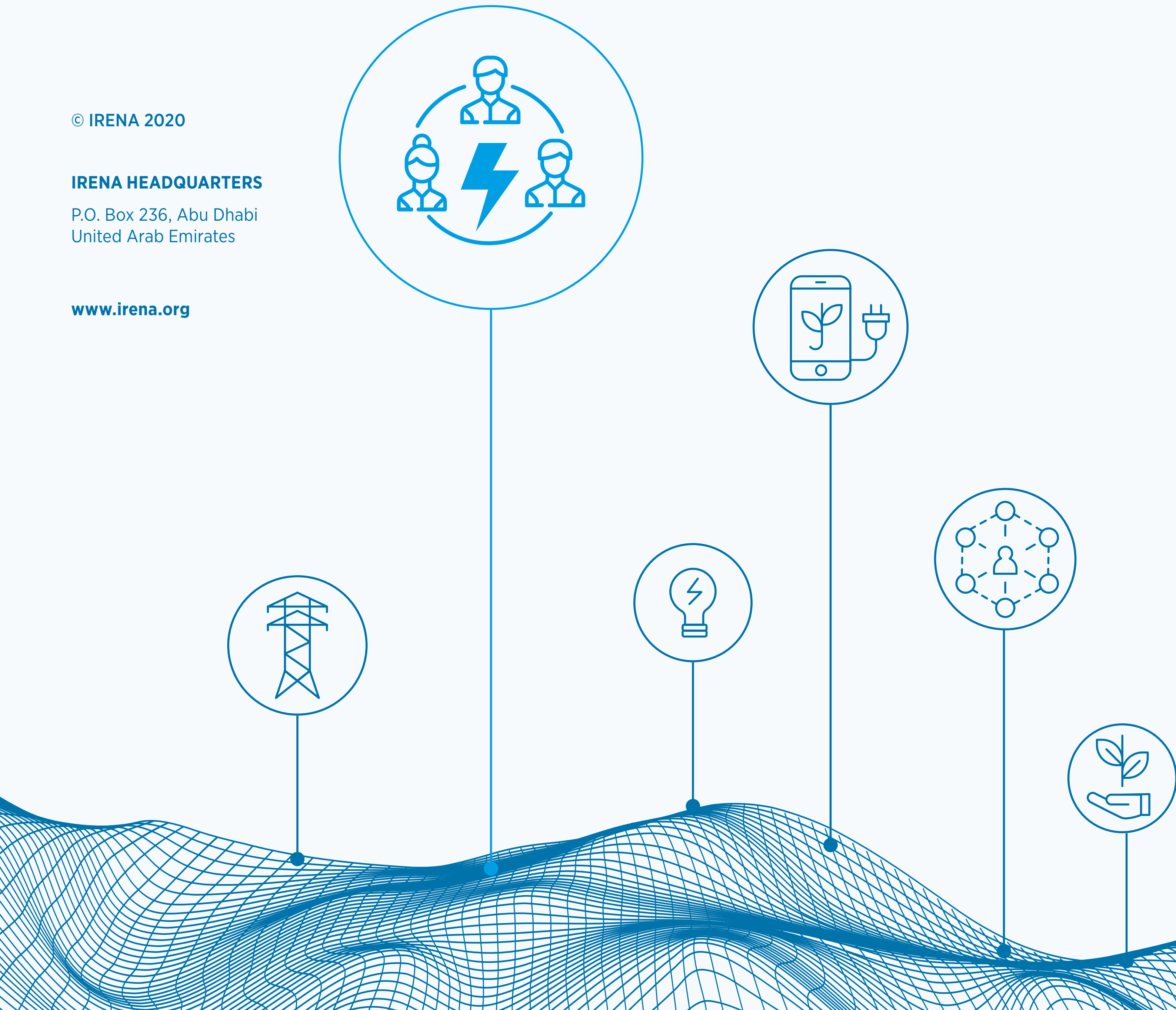

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ABOUT IRENA

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 HOW IT WORKS

An energy service provider rents or sells solar PV systems in exchange for regular payments through mobile payment systems. In cases of non-payment, the service provider can remotely disconnect the service.

2 BENEFITS

- Improve energy access in off-grid areas
- Defer network expansion investments
- Enable other innovative business models, such as peer-to-peer trading or community ownership

3 KEY ENABLING FACTORS

- Electrification strategy that accounts for pay-as-you-go (PAYG) and off-grid systems
- Consumer awareness of PAYG models
- Access to finance for local energy service providers

4 SNAPSHOT

- Between 2015 and 2020, around 8 million people gained energy access with PAYG models
- About two-thirds of the world's off-grid energy consumers have access to mobile networks
- Almost 40 million off-grid solar systems were sold globally by 2019

What are PAYG models?

The package usually includes a **home solar system** that customers pay for using **mobile payment technologies** and mobile phone credit.

PAY-AS-YOU-GO MODELS

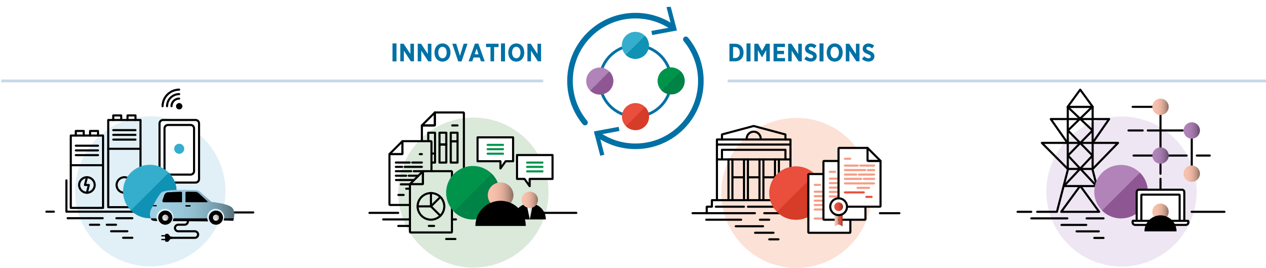
PAYG can provide affordable energy access from renewable sources to off-grid communities, using available technologies to facilitate payment by installments.

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 concept of pay-as-you-go (PAYG) and its role in increasing the share of renewable energy sources in the power sector. This brief describes how the PAYG model can improve the access of end consumers to power supply (energy access) using renewable energy sources through technology-enabled payment systems.

The brief is structured as follows:

I. DESCRIPTION

Nearly 840 million people worldwide do not have access to electricity, and over 1 billion people are connected to an unreliable grid (Lighting Global, GOGLA and ESMAP, 2020). As the unserved population is not connected to the main grid, extending the grid is an integral part of providing those populations with energy access. However, extending the grid involves significant capital outlay and long lead times for the construction of new infrastructure. An alternative to grid extension is power from distributed solar photovoltaic (PV) systems. The decreasing costs of such systems represent an opportunity for these communities to gain electricity access without the need for grid extension. However, making the upfront investments necessary to set up distributed renewable energy systems to satisfy electricity demand and improve supply reliability remains a difficult undertaking in many areas, particularly rural communities. Also, as of 2017, an estimated 1.7 billion people around the world still do not have access to a conventional bank account or financial network (Mastercard, 2019).

The PAYG business model is an innovation that emerged to address the energy access challenge and to provide electricity generated from renewable energy sources at affordable prices, with payments facilitated by technologies available in these areas. Widespread use of mobile payment technologies, rich solar resources and declining solar PV and battery costs, coupled with increased awareness of these technologies, have been key drivers in the implementation of this business model. Also, increasing numbers of companies offer PAYG systems, and high competition in this field pushes prices for consumers even lower.

Although thus far used mostly for solar energy. The PAYG model can also deliver electricity from other renewable energy sources, such as biomass. In this brief, the PAYG model is mainly discussed in the context of solar energy. The core components of a solar home system, based on the PAYG business model, are as follows (see also Figure 1):

(i) Solar PV power plant (modules, inverter, cables, etc.)

(ii) Battery storage system (optional)

(iii) Mobile payment system

(iv) Information and communications technology, with control units providing

- information on the charge left in batteries
- weather forecasts
- payment reminders

(v) Power-consuming appliances, like LED bulbs or mobile phones (plus phone-charging cables)

In such a configuration, a distributed solar PV power plant, along with a battery storage system, can be used for lighting and for powering (or charging) other electrical appliances, such as televisions, radios and mobile phones.

Energy service providers (ESPs) have so far been offering PAYG packages with power supply services that range from very basic power supply, including just lighting and phone charging (Tier 1), to more comprehensive packages, including the possibility to power multiple home appliances (Tier 3); see Figure 2. For example, Solar Run, an ESP that operates in Kenya, launched in September 2019 the "MBOX", which can power several bulbs, a high-definition television and a pedestal fan together for up to ten hours. Besides MBOX, the company is offering other "boxes" for the entire energy access spectrum (Solar Run, 2020). PAYG models could potentially offer services for Tier 4 and Tier 5, possibly combined with appliance finance. However, so far, PAYG packages cover Tiers 1–3.

Figure 1 Components of a PAYG system

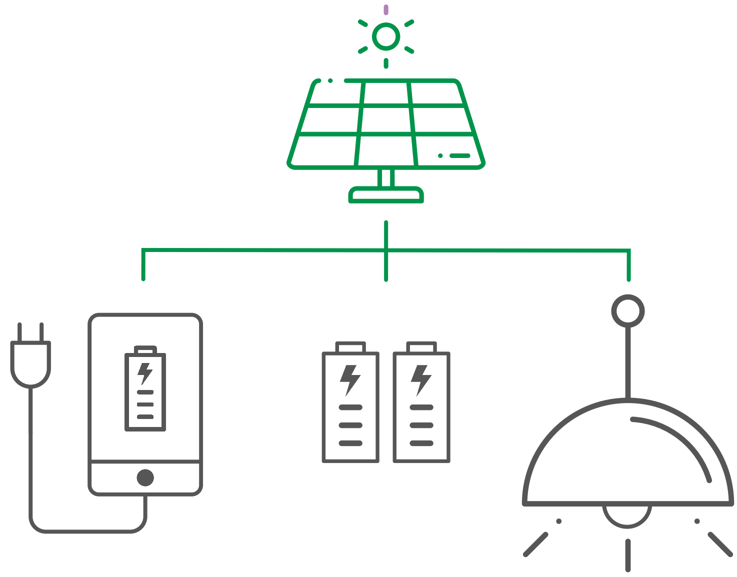


Figure 2 Energy access tiers

Pay-as-you-go systems

ENERGISED	POWER CAPACITY	AVAILABILITY	SERVICES	EXAMPLE OF APPLIANCES CONNECTED	
	800 W <	Min 16 h & 23h electricity/day		4 lights, phone, radio, TV, sewing machine	TIER 4 & 5
Work 800 W	200 W – 800 W	Min. 8 hours of electricity/day	Tier 2 + any medium power appliances	4 lights, phone, radio, TV	TIER 3
	50 W – 200 W	Min. 4 hours of electricity/day	General lighting + phone charging + Television + Fan (if needed)	4 lights, phone, radio	TIER 2
Media 50 W Home 10 W	3 W – 50 W	Min. 4 hours of electricity/day	Task lighting + phone charging	2 lights, phone	TIER 1
Light 3 W	0				TIER 0
DISCONNECTED					

Based on: ESMAP (2015).

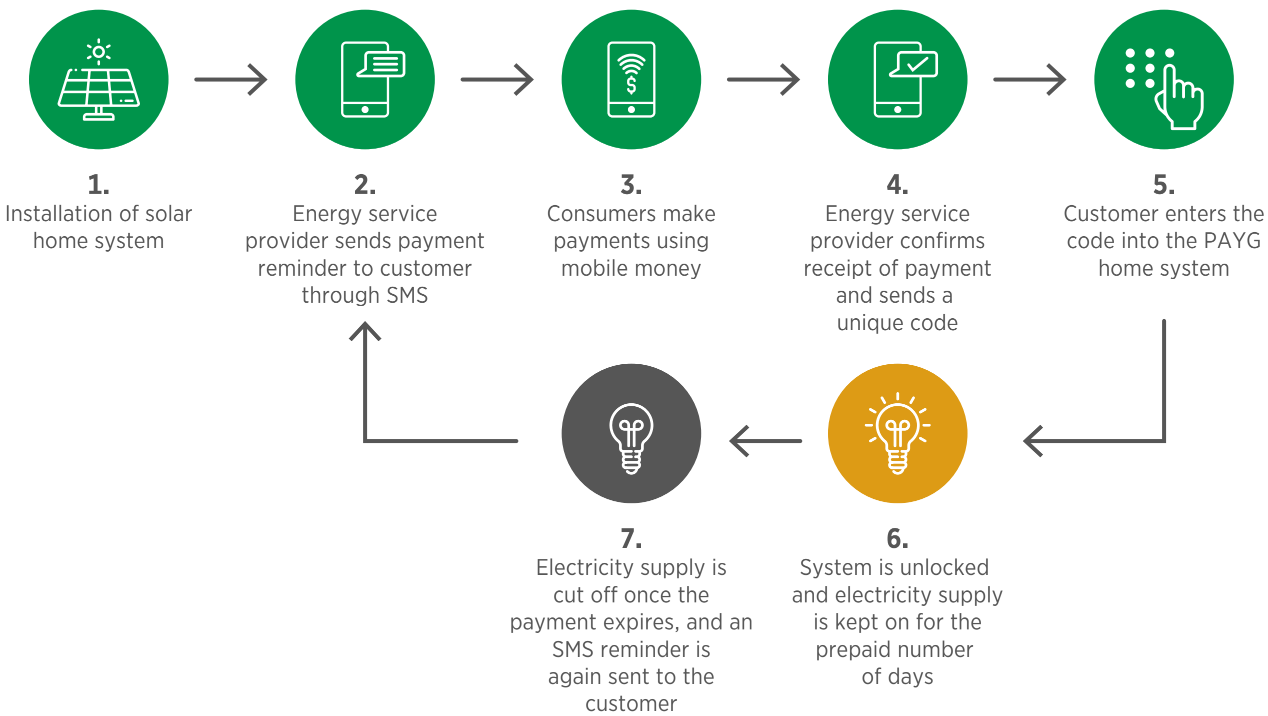
Other ESPs offer different variations that are commonly grouped as "PAYG models" in energy access debates, using a combination of payment rules and ownership and financing schemes. ESPs can provide either a "lease-to-own" model or a "usage-based payment" model.

- **Lease-to-own model**, also referred to as the "consumer finance retail" model, involves customers paying for the entire generation capacity (i.e. solar home system) in small instalments over a period of one to three years. A small solar PV system capable of powering light bulbs and small appliances, such as radios, and of charging mobile phones is priced at approximately USD 150. These systems are usually paid for in instalments over 6 to 24 months. Solar PV systems with batteries that can power major appliances that need uninterrupted supply (*e.g.* refrigerators) can cost up to USD 1 000. This can be repaid by customers in instalments over 6 months to three years. Over 90% of solar PV systems operate using the lease-to-own model (Sotiriou *et al.*, 2018). If a customer consistently fails to pay the daily, weekly or monthly rates, the ESP will go to the customer's house and remove the systems.

- **Usage-based payment model**, or the "micro utility" model, involves customers prepaying for the electricity supply (in kilowatt-hours). The customer loads money onto a prepaid meter and can use the amount of electricity that corresponds to the amount of money paid. Once the period lapses, the solar PV system is turned off by the ESP automatically through a remotely managed control system until the next payment is made. Unlike the lease-to-own model, the customer never owns the system but only consumes the electricity generated. Despite being used mostly in the context of solar PV systems, the PAYG usage-based payment model can be used for any type of system, including grid-supplied electricity.

The payments are usually made via mobile credit, by sending a text message. The systems can feature a remote monitoring system that can be activated via mobile network connection. There are PAYG solar home systems without remote monitoring systems, but they still have a SIM card built in to allow ESPs to shut them down remotely if payments stop. Some ESPs equip their systems with a GPS tracker to be able to locate the system anytime. Systems that do not have connectivity to GSM (Global System for Mobile Communications) are controlled by a simple timer that functions according to the payment code introduced by the consumer after the payment has been made. Figure 3 shows a schematic model of the PAYG usage-based payment concept.

Figure 3 PAYG concept



Based on: Energypedia (*n.d.*).

PAYG models can be implemented both at the individual household level and at the broader community or neighbourhood level. PAYG systems can also be implemented as a micro-grid solution, where a solar PV system with battery storage is used to provide electricity supply services to a small community. For example, SharedSolar, a PAYG mini-grids developer in sub-Saharan Africa, uses solar PV panels with a 1.4 kilowatt (kW) generating capacity and a 16.8 kilowatt-hour (kWh) battery storage system to provide electricity for 20 customers, including households, small schools and businesses within a 100 metre radius via underground cables.

End users buy prepaid scratch cards from local vendors according to their needs and available budget. Each card contains a code that, when sent by text message to the ESP via a payment server, credits a smart meter located inside the premises of the solar PV power plant, which controls the electricity flow to individual end users. The smart meter monitors usage until the customer's credit is exhausted, at which point the circuit is switched off until more credit is added (Theron, 2018).

The roles of different players involved in providing renewable power supply via the PAYG business model are provided in Table 1.

Table 1 Roles and responsibilities of different stakeholders in the PAYG business model

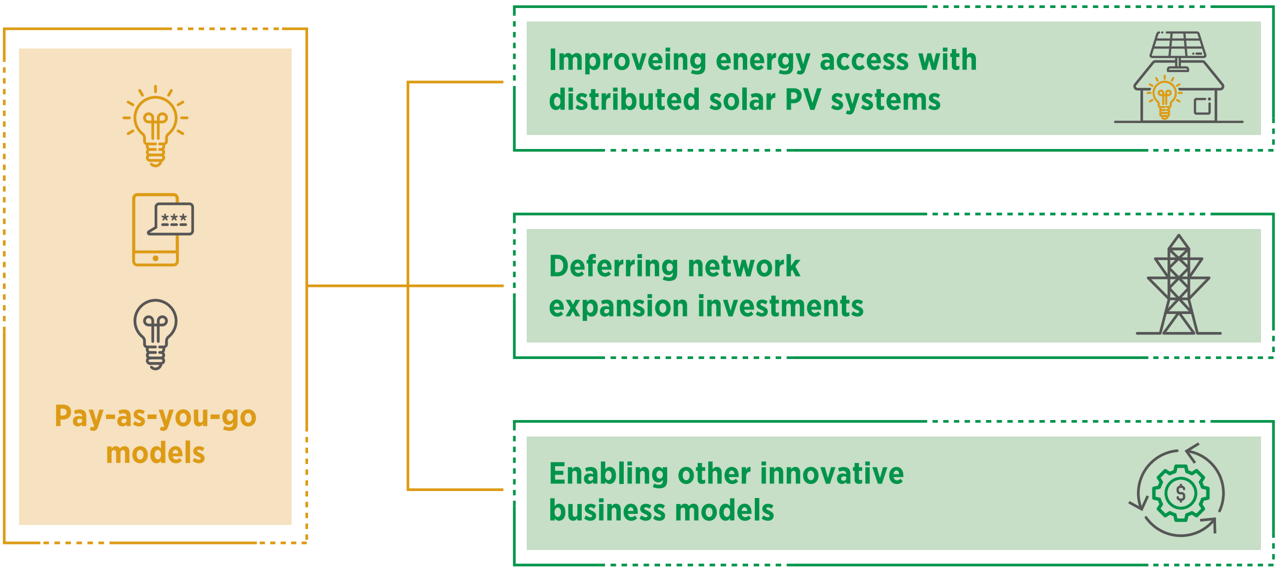
Player	Role and responsibilities	Technical requirements
Energy service provider	• Providing the solar home system components (usually ordered from Chinese manufacturers), and services, such as installation of the system, operation and maintenance to ensure connectivity to customers • Collecting payments from customers • Acquiring monitoring systems from software companies or developing them in house • Training local residents as field agents to provide sales, operation and maintenance services • For higher tier systems, providing basic training to customers on how to use the appliances	To secure financing, the solar home system should meet the specifications listed by the financing agency. For instance, the World Bank's Lighting Global requires that the peak power rating of the power module should be less than or equal to 350 watts and the maximum power point voltage and working voltage of components should not be over 35 volts DC (Lighting Global, 2017).
Mobile network operators	• Providing machine-to-machine technology, enabling remote monitoring of solar home systems • Providing mobile services to enable payments	Mobile network coverage.
Financiers	• Providing funding to the energy service providers for installing solar home systems	Development of technical requirements to ensure the high quality of funded solar home systems and the reliability of the power supplied.

II. CONTRIBUTION TO POWER SECTOR TRANSFORMATION

The PAYG business model can be instrumental in improving energy access for unserved or underserved consumers. Also, the model can help governments achieve targets for electricity access and defer the need to deploy expensive transmission and distribution grid infrastructure.

Figure 4 highlights some key benefits that the PAYG model can address using renewable energy resources. Additional benefits that can be provided by PAYG to various stakeholders are further illustrated.

Figure 4 Contribution of PAYG to power sector transformation



Improving energy access with distributed solar PV systems

The key contribution of the PAYG business model to power sector transformation is that the model improves the energy access of communities in areas with abundant solar irradiance that either rely on fossil fuels for their energy needs or have limited (or no) access to energy. The PAYG business model enables the increased penetration of distributed energy resources by making use of the mobile payment methods accessible to communities in these regions.

For example, this model enables customers living in off-grid regions to transition away from fossil fuel-based energy sources, such as kerosene or diesel generators, to solar energy. From the customer point of view, the PAYG business model is similar to that used for diesel generators, as PAYG models spread the system's cost over a longer period of time, similar to the regular payments customers need to make to buy diesel.

For consumers in unserved or underserved regions, a solar PV system is a cost-effective solution when compared with kerosene or diesel. One study quantified that households with solar lighting save on average over USD 60 per year and spend only 2% of their income on lighting compared with spending 10% of their income for just four hours per day of illumination using kerosene, candle or torch-light (Harrison, Scott and Hogarth, 2016). Also, solar PV systems can provide a reliable and uninterrupted source of energy when coupled with battery storage systems.

In 2017, off-grid solar products, including solar home systems enabled by PAYG models, provided improved energy access to 83.7 million people globally (GOGLA and Lighting Global, 2017).

Between 2015 and 2020, around 8 million people gained energy access with PAYG models (Lighting Global, GOGLA and ESMAP, 2020). M-KOPA, an ESP in Africa, provides solar home systems capable of providing lighting, charging phones and powering appliances such as televisions to off-grid consumers in rural Kenya and Uganda. As of 2018, the company has provided electricity access to over 600 000 homes in these regions (M-KOPA, 2018). Other such examples are provided in Section IV.

Deferring network expansion investments

PAYG models can defer network expansion investments while allowing governments to achieve electrification goals that are essential for achieving other development goals. Several rural regions in Africa and Asia are not connected to the grid, primarily because of the significant capital outlay involved in setting up transmission and distribution grid infrastructure to serve these regions. For instance, in the case of Rwanda, a country with 20% electricity access in 2017, a traditional power network would have cost over USD 20 billion to build (Hauser, 2017), while the country's gross domestic product in 2017 was USD 9.1 billion (World Bank, 2019).

Providing grid-connected electricity to everyone living in remote areas, therefore, is not always economically feasible. The PAYG model provides access to electricity to consumers in remote areas using a distributed power generation system and hence helps the government achieve electrification goals with optimal investment in grid networks and renewable generation sources.

Enabling other innovative business models

PAYG business models can be extended to implement other technology-enabled business models that will lead to an increase in renewable energy integration. Multiple solar PV systems can be connected to form a micro-grid, which can further enable peer-to-peer energy trading. The excess energy produced can be traded with other consumers within the same community in exchange for a fee. Such systems can generate an additional source of revenue for consumers with solar PV systems. For instance, Bangladesh's SOLshare has built a peer-to-peer trading network using PAYG solar home systems for off-grid households. SOLshare's PAYG solar home systems include a "smart" (i.e. bi-directional) meter, which enables the home system to contribute to a micro-grid that can serve other houses in the neighbourhood (SOLshare, 2019). For more information, see *Innovation landscape brief: Peer-to-peer electricity trading* [IRENA, 2020a].

When the PAYG model is implemented at a wider community level, community-ownership business models emerge as well. For more information, see *Innovation landscape brief: Community-ownership models* [IRENA, 2020b].

Additional benefits of PAYG model

Energy access leads to improved livelihoods and other socio-economic benefits. Energy access enables customers to set up small businesses. A solar PV system can enable a mobile charging business, power a computer for digital business or power a refrigerator to store cold food (IFC, 2017). These businesses provide an additional source of income to the solar PV owners and could exceed the costs of the solar PV system (GNESD, 2016). Furthermore, PAYG models for solar systems have been used to power drip irrigation and crop processing instead of more expensive diesel generators. Therefore, such productive uses of renewable power have also contributed to higher income for farmers in rural areas (Nussey, 2017).

Owners of solar home systems increase their incomes, on average, by up to USD 35 per month. In addition, data show that children spend more time doing homework in the evenings in certain contexts. To date, the ESP Azuri has created over 2 000 new jobs through its Kenyan partner companies, which hire staff to sell, support and maintain solar home systems (Azuri Technologies, 2018).

In addition, the payment data gathered through PAYG models can be analysed to assess the creditworthiness of a specific customer, which can then be used to upgrade to a larger solar PV system or secure further financing for other activities.

III. KEY FACTORS TO ENABLE DEPLOYMENT

Develop electrification strategy that accounts for renewable off-grid systems and policies incentivising PAYG business models

First, governments need to define their electrification strategy and their energy access goals, such as the types of energy access to be fostered in their countries. Many low-income countries still do not value off-grid electricity resources as much as they do on-grid, even though the latter may not be economically feasible (Ma and Urpelainen, 2018). Policy makers could consider developing and coherently implementing long-term, integrated electrification plans that combine off-grid and on-grid resources. In the case of Uganda, as study has challenged the Ugandan government's focus on nuclear energy and grid-based household electrification, showing that focusing on off-grid electrification for the majority of household connections by 2040 could cover even the high-demand scenario (Trotter, Cooper and Wilson, 2019).

Once a clear electrification strategy is established, a range of policy instruments are available to encourage off-grid systems deployment and PAYG models. Governments can support the off-grid solar market by developing policies and regulations that formalise such off-grid arrangements and by issuing relevant permits and licences for service providers, such as mobile wallet operators[1] (Wakeford, 2018). For ESPs to offer the solar PV system on credit to customers, there is a need for regulations that govern the financial risk assessment and specify norms for setting the instalment schedule.

Regulations related to remuneration (*e.g.* feed-in tariffs) should be developed to enable the development of micro-grids and mini-grids for consumers who live in off-grid regions. This would allow consumers to earn money by supplying energy to the micro-grid through their solar PV systems (Muok, Makokha and Palit, 2015). Kenya's initial feed-in tariff policy only included the contribution of biomass, geothermal and hydro sources to the national grid. With increasing solar energy generation, Kenya's Ministry of Energy updated the policy to include solar power contribution to mini-grids at USD 0.2/kWh. In 2012, Kenya implemented the Energy Solar Photovoltaic Systems Regulations, which specify standards for quality and business practices in the solar energy sector. The regulations cover quality standards for solar systems and licensing requirements for manufacturers, importers, vendors and technicians involved in the solar PV value chain (Tigabu *et al.*, 2017).

Indirect subsidies for kerosene had led to its use in lighting in many countries. The removal of such subsidies, and the addition of value-added tax and excise duties for kerosene, will further increase the attractiveness of PAYG solar systems. The government of Tanzania, for instance, removed all indirect subsidies for kerosene in 2011, which helped increase the adoption of solar energy systems instead of kerosene lighting (Harrison, Scott and Hogarth, 2016).

Last but not least, as PAYG business models are driven by private sector entrepreneurs, programmes for local energy entrepreneurs need to be established, as local companies would know

1 *Mobile wallet operators allow users to deposit money into their mobile account, which can be accessed from their mobile device. Customers can make payments to service providers using secure text messages from their mobile device.*

better than international companies how to reach off-grid areas. In addition, local companies are often very creative in combining energy with local needs. Entrepreneurship in this space refers not only to ESPs but also to IT companies providing monitoring, control or forecasting services.

Raise consumer awareness of PAYG models

Consumer awareness is a key enabling factor for PAYG models. Digital literacy and usage of mobile money have been the key drivers for the growth of PAYG business models in Africa. To increase awareness among consumers and generate sales, ESPs should (i) invest in active on-ground teams that provide last-mile connectivity to reach consumers, (ii) use local governance structure and (iii) engage communities in their energy choices. For instance, Azuri Technologies partners with local organisations with expertise in last-mile distribution. Azuri provides training to representatives from the local organisation, who in turn reach out to customers. The company has also developed a cloud-based information system to resolve any queries a local agent may have. The company has trained over 2 000 staff members, who have helped sell 130 000 solar home systems in Kenya (Azuri Technologies, 2017).

Improve access to finance for local ESPs

The PAYG business model requires upfront funding to build the solar PV systems and to deliver them to consumers. The costs for an ESP increase significantly with a growing consumer base, as the number of outstanding loans continues to increase because customers only pay a small upfront payment. As an ESP's loan portfolio becomes too risky, different sources of funding are required at various stages (KPMG, 2015). Typically, in the very early financing stage, these companies require less than USD 1 million (mostly equity funding) to invest in the business planning process. In the early stage, ESPs typically seek USD 3–5 million in equity for the implementation of a pilot project and market entry. Company expansion was expected to require between USD 10 million and USD 20 million through equity and USD debt finance, with as much as USD 50–100 million in debt finance for further scale-up (Orlandi *et al.*, 2016).

The cost of raising capital is a critical factor and can decide the competitiveness of a company's PAYG model.

Low-cost financing from governments or development financing institutions is required in the early stage of business, when low-risk finance is key. For instance, UK development finance institution CDC Group provided USD 20 million in debt as part of a syndicate of lenders for PAYG system provider M-KOPA in Africa. Prior to this, CDC Group had also invested USD 12 million in equity in M-KOPA (CDC Group, 2017). As an alternative to low-cost financing, governments can also explore financing models such as debt facility, which can be repaid over an extended period of time.

However, in some areas, especially where ESPs offer a higher tier PAYG system, the ideal case would be that the income generation becomes high enough to finance the system. Once this equilibrium is reached, the scheme practically scales by itself.

When international funds are available, foreign private sector involvement and large-scale international initiatives are a significant part of securing these funds. While acknowledging the positive impact of the foreign know-how that comes when foreign companies play a larger role in the private sector activity of these regions, a study points out several social, economic and environmental issues coupled with this mechanism. These issues include the focus on creating market opportunities for international rather than domestic companies; the risk of increased aid dependency; the difficulty of delivering large-scale rural electrification through a market-based approach; economic inefficiencies of current aid spending; transparency issues; and the difficulty of tackling complex, country-specific issues with continental electrification initiatives (Trotter and Abdullah, 2018).

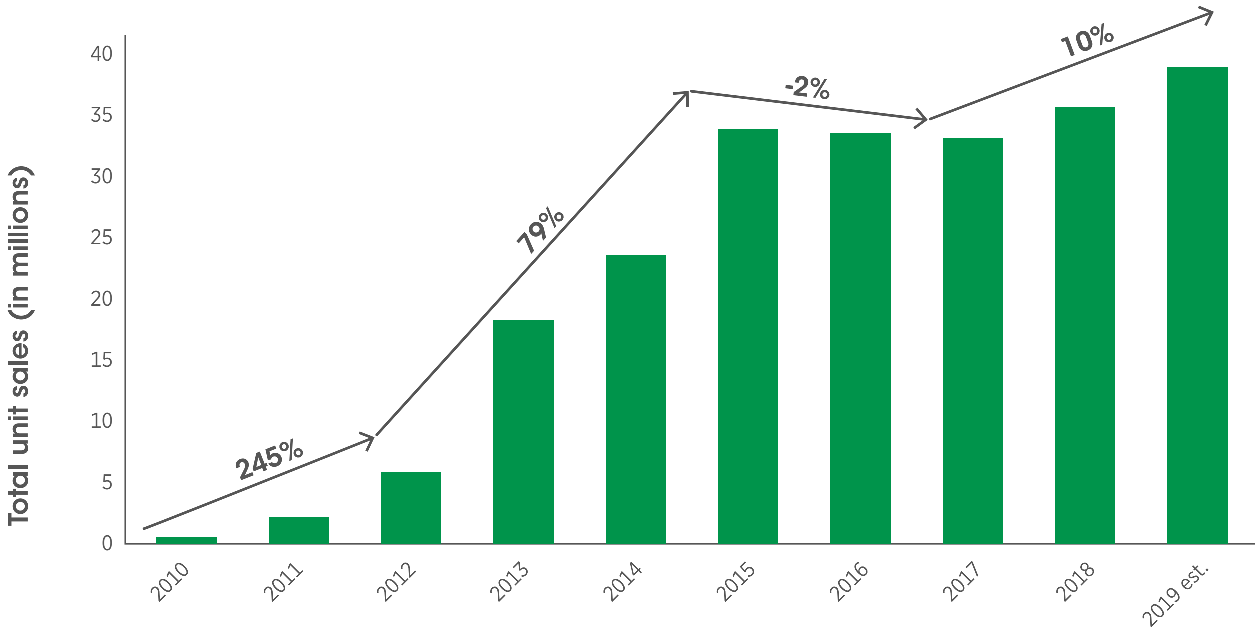
Besides cost of capital, solar home system suppliers are also vulnerable to volatility in foreign exchange if they raise finance in US dollars or euros but receive revenues in the local currency. Therefore, fluctuations in local currency will have a significant impact on an ESP's balance sheet (Kendall and Pais, 2018). Local governments and local banks can provide solutions to hedge against such foreign exchange risk to ensure a favourable business environment.

IV. CURRENT STATUS AND EXAMPLES OF ONGOING INITIATIVES

The option of PAYG provided affordable solar power to over 8 million people in sub-Saharan Africa between 2013 and 2018 (Sotiriou *et al.*, 2018). PAYG models have been also implemented in off-grid locations in South Asia and Latin America. In 2016, global off-grid solar installations (including PAYG systems and standalone solar devices, such as solar lamps) totalled 34 megawatts (MW), and they grew by over 19% to 40.6 MW by the end of 2017 (GOGLA and Lighting Global, 2018). The entry-level solar home systems, used for providing basic lighting and mobile phone charging, account for nearly 36% of the total volume of systems sold.[2]

Figure 5 illustrates the global growth in sales of off-grid solar systems, which include PAYG model solar home systems. Overall, sales volumes have been on an upward trajectory since 2010, with annual growth rates of 133% between 2010 and 2015. The industry saw decline in sales leading up to 2017 due to localised shocks in key product markets and companies, as well as adaptations to sector-wide trends. Since then, growth in annual unit sales has stabilised to 10%, showing signs of a maturing market (Lighting Global, GOGLA and ESMAP, 2020). Key indicators related to the PAYG model are listed in Table 2.

Figure 5 Growth in sales of off-grid solar products



Based on: Lighting Global, GOGLA and ESMAP (2020).

2 *The data only include sales reported by the affiliates of Global Off-Grid Lighting Association (GOGLA), part of the World Bank's Lighting Global Program.*

Table 2 Key indicators

Description	Key facts
PAYG solar system sales by location (2016)[a]	East Africa: 730 000 units West Africa: 30 000 units Latin America: 10 000 units South Asia: 20 000 units
People who gained energy access with PAYG models[b]	Around 8 million (2015–2020)
Market potential	772 million or ~64% of off-grid consumers have access to mobile networks (2016)[a]
Total value of investments made in PAYG solar companies	>USD 770 million (2012–2017)[c]
Number of companies selling PAYG-based solar home systems	52 (non- exhaustive best estimates for 2017)[c]
Leading PAYG solar providers	Azuri, BBOXX, d.light, Fenix, M-KOPA and Off-Grid Electric. These six companies account for 90% of solar home systems sold[d]
Per day cost of PAYG solar home systems[e]	~USD 0.25f to USD 0.5[g] The costs vary by the company selling the PAYG solar home system, the size of the system and the terms of the payment plan.
Total price of solar home systems	**4–25 W solar panel, li-ion battery:** USD 100 to 250 (can power LED lights, radio and mobile phone charger) **30–200 W solar panel, lead acid battery:** USD 150 to 1 000 (can power LED lights, radio, fan, television and refrigerator)[h]
Extensions to PAYG business model	**Add-on products offered by solar providers with PAYG models:** • **Insurance products:** PAYG solar companies are partnering with insurance providers to offer their customers insurance for hospitalisation to ensure that the customers' medical expenses do not impact timely payments for their solar home systems. PEG Africa, a PAYG solar provider focused on West Africa, has partnered with Prudential to offer such services and has seen improvements in its repayment rates.[i] • **Education loans:** Fenix International, a PAYG solar provider in Uganda, provides some of its customers with education loans to pay school fees. The company uses its customers' payment history to evaluate their creditworthiness and offers such assistance to qualifying customers.[j]

[a] GSMA (2017a).
[b] Lighting Global, GOGLA and World Bank (2020).
[c] Dalberg Advisors and Lighting Global (2018).
[d] Sotiriou *et al.* (2018).
[e] These do not include any upfront payment.
[f] Based on Nigeria, for powering LED lights, fan, mobile phone charging and radio (Gridless Africa, 2017).
[g] M-KOPA's per day rate in Kenya, excludes upfront cost of USD 35 (Lynch, 2015).
[h] Winiecki and Kumar (2014).
[i] Ola (2017).
[j] Mastercard (2018).

Table 3 PAYG case studies

Case study	Operation area	Description
Angaza	India, Kenya, Malawi, Nicaragua, Pakistan, Sierra Leone, South Africa and Uganda	Based in San Francisco and Nairobi, Angaza has helped consumers in emerging markets save over USD 100 million by switching from kerosene to clean, renewable energy. Over 5 million people in emerging markets across the globe have benefited from Angaza's technology by accessing life-changing products that save money, increase incomes, improve household health and increase quality of life (Angaza, 2020).
BBOXX	12 countries, including Democratic Republic of the Congo, Kenya, Pakistan, Rwanda and Togo	London-based off-grid solar company BBOXX secured another USD 50 million for its African and Asian operators in 2019. BBOXX installs a solar panel that can power up to five lights, a television, a radio, a torch or a 12 V battery (Hall, 2019).
Claro Energy	India	Claro Energy has built a PAYG irrigation service using solar panels. The company has built e-rickshaws with solar panels, which can be used in farms in remote villages to power water pumps on a PAYG basis (Claro Energy, *n.d.*). The on-demand irrigation system helps farmers save over 50% in energy costs by replacing diesel.
d.light	Kenya	D.light, a United States-based company, developed a PAYG solar system that can provide lighting, charge mobile phones and power radios. The customers make a down payment of USD 25 and then make daily payments of USD 0.40 for a year, after which the customer owns the system (Maisch, 2017). Since its launch in October 2016, the company has sold over 120 000 systems.
ENGIE	Benin, Côte d'Ivoire, Kenya, Mozambique, Nigeria, Rwanda, Tanzania, Uganda and Zambia	ENGIE's subsidiary, Fenix International, provides access to energy via PAYG solar home systems to more than 500 000 customers in Uganda, Zambia, Nigeria, Benin, Cote d'Ivoire and Mozambique. Additionally, with ENGIE PowerCorner, ENGIE supplies electricity to rural populations in villages across Tanzania and Zambia through smart mini-grids powered by solar energy and battery storage, used by households, local businesses and public services. All of these services are enabled by digital financial solutions such as mobile money and PAYG technologies.
Greenlight Planet	Kenya, Nigeria, Tanzania and Uganda	Greenlight Planet has installed nearly 6 million solar products, benefiting over 24 million people, across sub-Saharan Africa. Ninety percent of the PAYG customers make roughly 60 mobile money payments between USD 2 and USD 5 each over a period of 12 to 24 months to complete their instalment payment plans for the solar device. The company has processed nearly 40 million mobile money payments from customers in Africa in the last three years (Greenlight Planet, 2019).
Husk Power Systems	India	Husk Power Systems, based in Bihar, India, has built a low-cost power plant and distribution network using biomass gasification and solar energy to provide electricity to off-grid consumers in India. The company uses smart meters and mobile payments to provide energy services using the PAYG model (Husk, 2017). Husk currently operates 75 mini-grids with a total capacity of 1.75 MW and plans to expand it to 30 MW by 2022.
M-KOPA	Kenya and Uganda	M-KOPA provides solar home systems capable of providing lighting, charging phones and powering appliances, such as televisions, to off-grid consumers in rural Kenya and Uganda. The company has provided electricity access to over 600 000 homes in these regions (M-KOPA, 2018).
PowerMundo	Peru	PowerMundo, along with I-DEV International, provided electricity access to off-grid consumers in the Peruvian Amazon using PAYG business models and mobile payments. PowerMundo sells solar home systems along with small appliances such as solar lamps and radios. In its trial phase, from June 2016 to March 2017, the programme reached 825 customers and resulted in average monthly savings of USD 41 (~15% of household income in the region) (Chouan, 2017).

V. IMPLEMENTATION REQUIREMENTS: CHECKLIST

TECHNICAL REQUIREMENTS

Hardware:

- Distributed energy sources, such as a solar PV system and battery storage
- Smart and prepaid meters connected to a server to enable payments through mobile money, monitoring of consumption per payment cycle and remote control of the electricity supply
- Power-consuming devices, such as light bulbs, mobile chargers and other small appliances (*e.g.* televisions, fans)
- Mobile phones and mobile network infrastructure to enable mobile payments

Information and communications technology systems:

- Mobile payment gateways
- Cloud-based software for remote monitoring and control of off-grid energy systems

POLICIES NEEDED

- Clear roadmaps, strategies and targets for providing energy access to unserved populations
- Supportive policies facilitating the funding process for distributed energy system providers, such as solar home system providers
- Reduction of import duties for solar home systems

REGULATORY REQUIREMENTS

- A regulatory framework for the off-grid energy market that specifies service requirements
- Regulations determining the remuneration schemes in line with consumer needs
- Issuance of permits or licences for mobile payment providers

STAKEHOLDER ROLES AND RESPONSIBILITIES

Energy service providers:

- Provide the solar home system components as well as services such as installation, operation and maintenance of the system to ensure connectivity to customers
- Collect payments from customers
- Train local residents as field agents for sales as well as operation and maintenance services
- Create awareness among the population about PAYG solutions for solar home systems
- Communicate clearly about the PAYG pricing methods provided
- Offer to replace faulty equipment and recycle the system at the end of its techno-economic lifetime

Policy makers:

- Consider renewable-based off-grid systems in energy planning and strategy to reach electrification goals
- Incentivise renewable-based off-grid systems for energy access
- Provide solutions to minimise foreign exchange risk for providers of distributed renewable energy systems, such as solar home systems
- Ensure that energy service providers offer quality services and equipment to consumers

Consumers:

- Adopt PAYG models for energy access or improved access to electricity in remote areas unconnected to the main power grid
- Pay for the power supply and the related services according to the terms and conditions agreed

ABBREVIATIONS

BESP	energy service provider
GOGLA	Global Off-Grid Lighting Association
GSM	Global System for Mobile Communications
kW	kilowatt
kWh	kilowatt-hour
MW	megawatt
PAYG	pay-as-you-go
PV	photovoltaic

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