IRENA
International Renewable Energy Agency

PAY-AS-YOU-GO MODELS

INNOVATION LANDSCAPE BRIEF

IRENA
International Renewable Energy Agency

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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

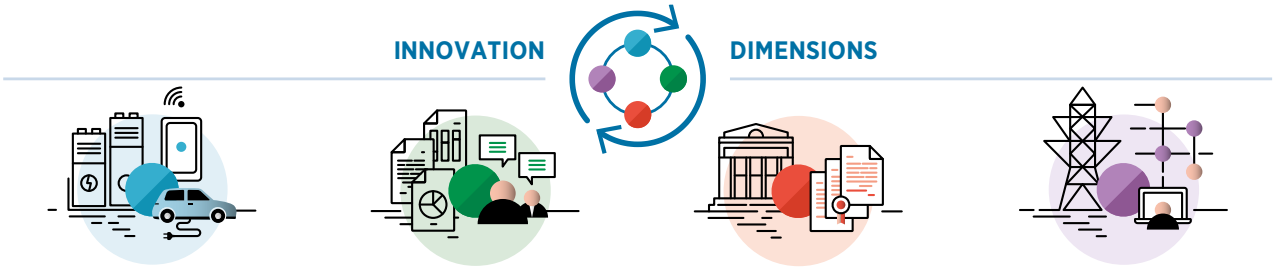
PAYG can provide affordable energy access from renewable sources to off-grid communities, using available technologies to facilitate payment by installments.

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	BUSINESS MODELS	MARKET DESIGN	SYSTEM OPERATION
1 Utility scale batteries 2 Behind-the-meter batteries	12 Aggregators 13 Peer-to-peer electricity trading 14 Energy-as-a-service	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	25 Future role of distribution system operators 26 Co-operation between transmission and distribution system operators
3 Electric-vehicle smart charging 4 Renewable power-to-heat 5 Renewable power-to-hydrogen	15 Community-ownership models 16 Pay-as-you-go models	22 Time-of-use tariffs 23 Market integration of distributed energy resources 24 Net billing schemes	27 Advanced forecasting of variable renewable power generation 28 Innovative operation of pumped hydropower storage
6 Internet of Things 7 Artificial intelligence and big data 8 Blockchain			29 Virtual power lines 30 Dynamic line rating
9 Renewable mini-grids 10 Supergrids			
11 Flexibility in conventional power plants			

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

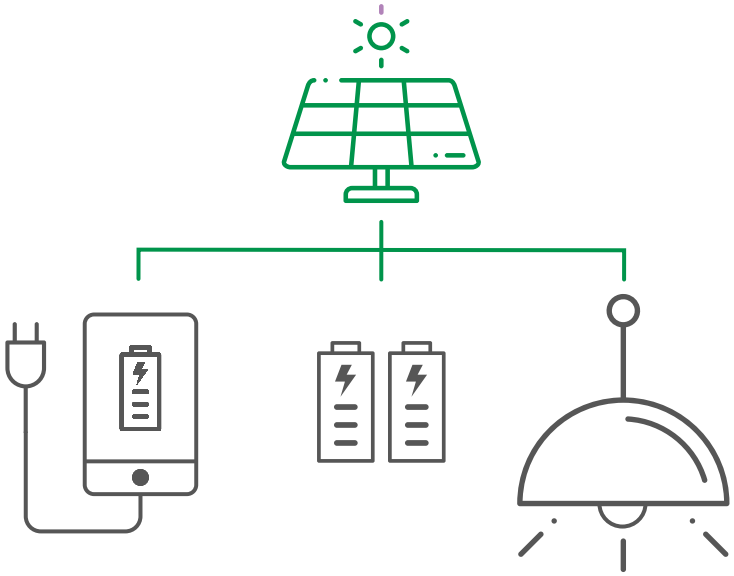
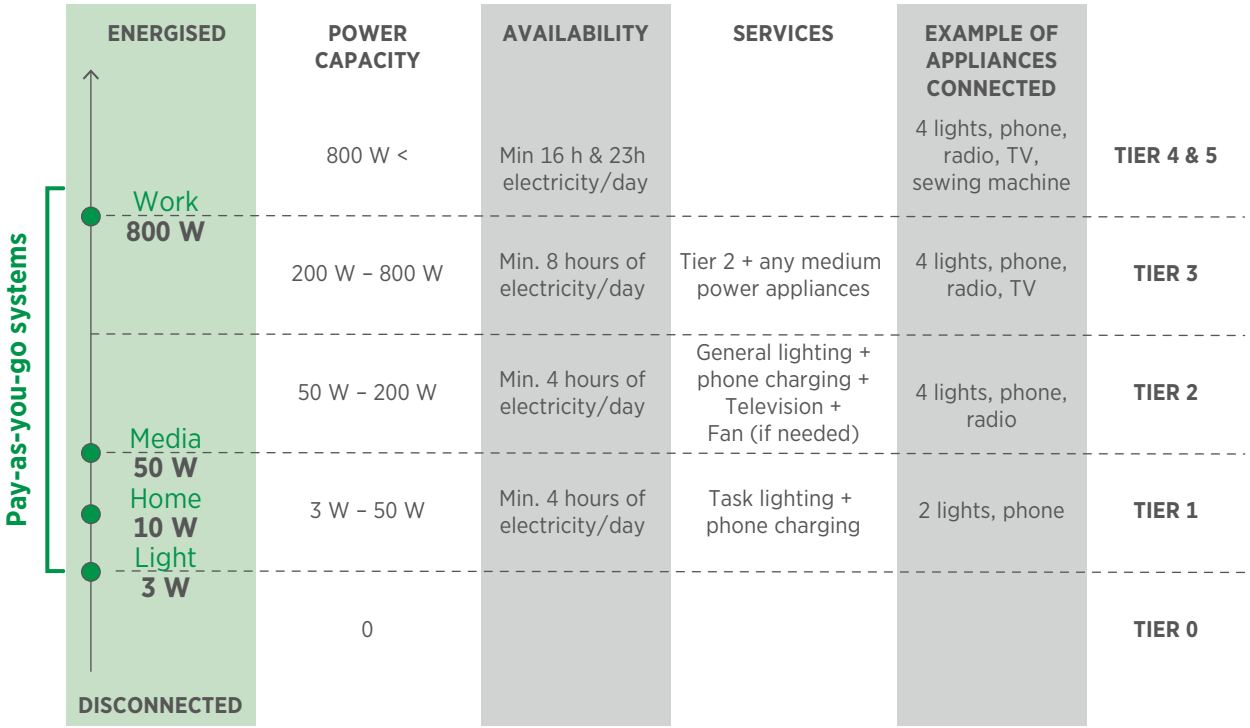


Figure 2 Energy access tiers



Based on: ESMAP (2015).

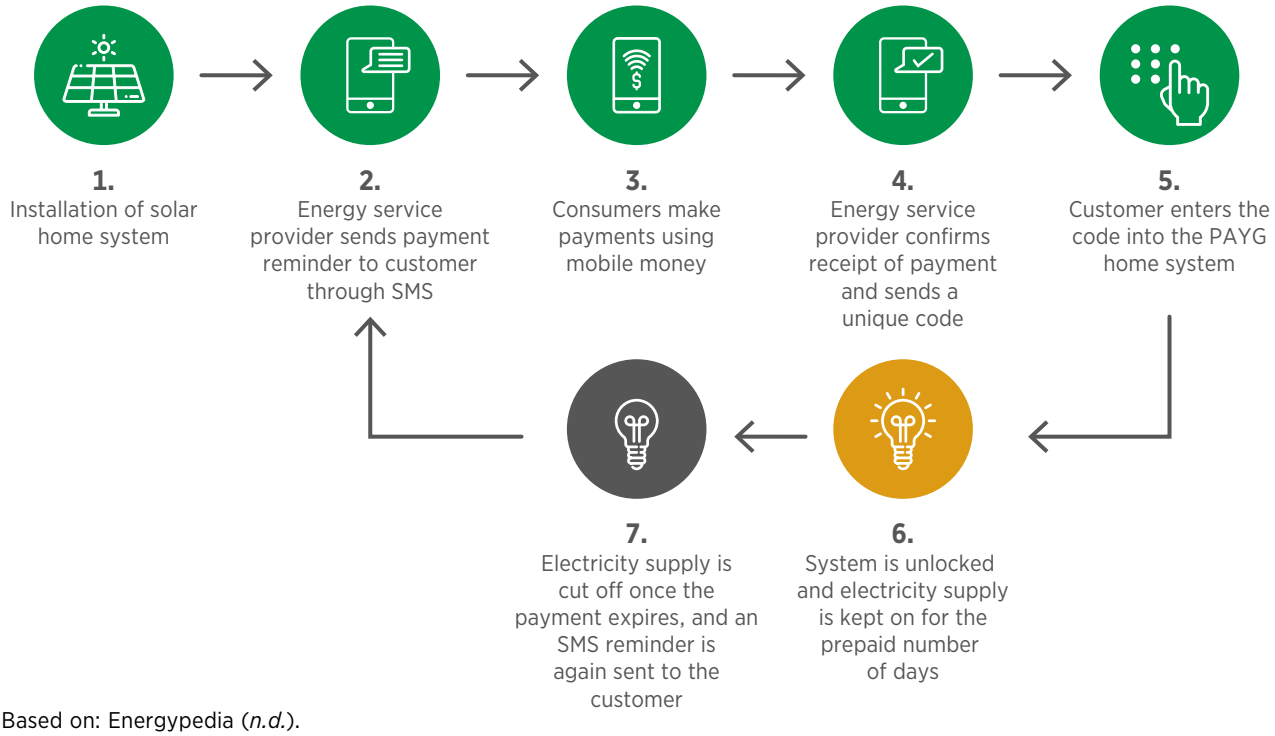
Other ESPs offer different variations that are commonly grouped as "PAYG models" in energy access debates, using a combination of payment rules and ownership and financing schemes. ESPs can provide either a "lease-to-own" model or a "usage-based payment" model.

- **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

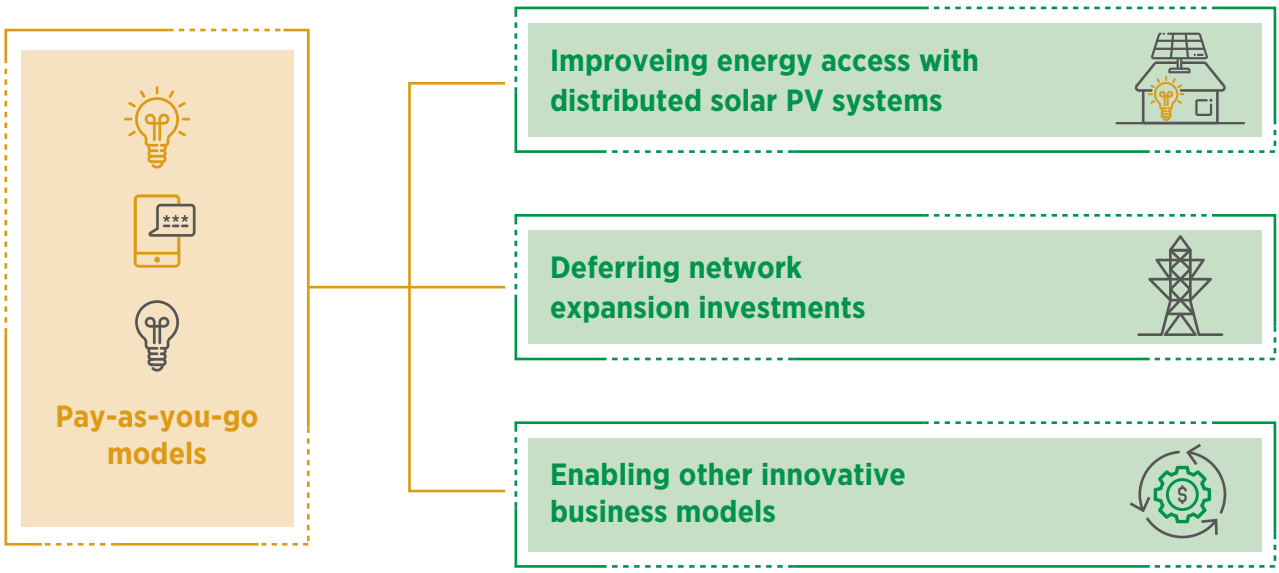
Player	Role and responsibilities	Technical requirements
Energy service provider 	• Providing the solar home system components (usually ordered from Chinese manufacturers), and services, such as installation of the system, operation and maintenance to ensure connectivity to customers • Collecting payments 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).

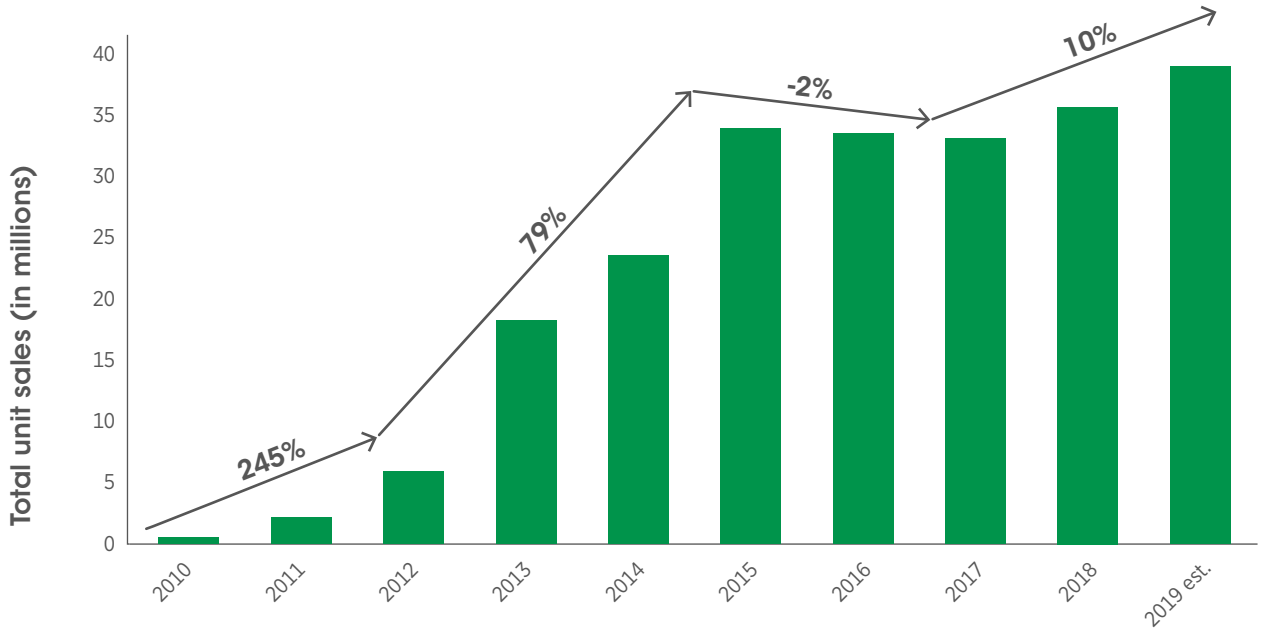
Besides cost of capital, solar home system suppliers are also vulnerable to volatility in foreign exchange if they raise finance in US dollars or euros but receive revenues in the local currency. Therefore, fluctuations in local currency will have a significant impact on an ESP's balance sheet (Kendall 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

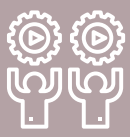
POLICIES NEEDED

- 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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IRENA HEADQUARTERS
P.O. Box 236, Abu Dhabi
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