OFF-GRID SOLAR MARKET TRENDS REPORT 2016

FEBRUARY 2016

Bloomberg NEW ENERGY FINANCE and LIGHTING GLOBAL Catalyzing markets for modern off-grid energy

AN INNOVATION OF WORLD BANK GROUP

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In cooperation with GOGLA Global Off-Grid Lighting Association

OFF-GRID SOLAR MARKET TRENDS REPORT 2016

This report was commissioned by the World Bank Group through its Lighting Global program. Lighting Global is the platform under which the World Bank Group supports the development of the global off-grid solar energy services market, and includes a portfolio of country-based market development programs undertaken through Lighting Africa, Lighting Asia, and Lighting Pacific.

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ABOUT

LIGHTING GLOBAL

Lighting Global is the World Bank Group's platform supporting sustainable growth of the international off-grid solar market as a means of increasing energy access to people not connected to grid electricity. Through Lighting Global, International Finance Corporation (IFC) and the World Bank work with the Global Off-Grid Lighting Association (GOGLA), manufacturers, distributors, other development partners and end-users to develop the off-grid lighting market.

The Lighting Global program provides market insights, steers development of quality assurance frameworks for modern, off-grid lighting devices and systems, and promotes sustainability, in partnership with industry. IFC and the World Bank jointly manage off-grid lighting programs in more than 10 African countries through the Lighting Africa program. The success of the Lighting Africa program has inspired programs in Bangladesh, India, Pakistan and Papua New Guinea, with more programs being developed in Tanzania and Myanmar.

Lighting Global supports Lighting Africa, Lighting Asia and Lighting Pacific, which work along the supply chain of off-grid lighting products and systems to reduce market entry barriers and first-mover risks.

GLOBAL OFF-GRID LIGHTING ASSOCIATION

GOGLA is a neutral, independent, not-for-profit association created to promote lighting solutions that benefit society and businesses in developing and emerging markets. GOGLA acts as the industry advocate and supports the industry in growing and strengthening the market for clean, quality off-grid lighting and electrical systems. Its main objective is to support industry in scaling the sector based on principles of the triple bottom line, thus contributing to the objectives of Sustainable Energy for All (SE4All) and the Sustainable Development Goals (SDGs).

BLOOMBERG NEW ENERGY FINANCE

Bloomberg New Energy Finance (BNEF) provides unique analysis, tools and data for decision makers driving change in the energy system. BNEF has 200 staff based in 14 offices around the world. BNEF's sector products provide financial, economic and policy analysis, as well as news and the world's most comprehensive database of assets, investments, companies and equipment in the clean energy space. BNEF's regional products provide a comprehensive view on the transformation of the energy system by region. For more information on Bloomberg New Energy Finance visit: http://about.bnef.com, or contact us at sales.bnef@bloomberg.net for more information on our services.

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This report was commissioned by Lighting Global, a joint initiative of IFC and the World Bank. It was produced by Lighting Global and Bloomberg New Energy Finance in partnership with the Global Off-Grid Lighting Association.

The Market Trends Report is the third in a series to provide a snapshot of the off-grid lighting market, industry-level data and analysis on key trends. It relies on the inputs of a broad range of industry experts, manufacturers, distributors, scientists, investors, market researchers and NGO leaders worldwide who contributed their views, time and advice to the preparation of this document. Thank you.

We welcome your feedback and support in this effort and encourage you to reach out to the Lighting Global team with your questions and feedback through www.lightingglobal.org or by emailing us on info@lightingglobal.org.

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GLOSSARY

Africa	Refers to Sub-Saharan Africa in this report as electrification rates tend to be high in North Africa.
Asia	Refers to all countries in Asia excluding the Middle East
BNEF	Bloomberg New Energy Finance
CAGR	Compound annual growth rate
COO	Chief Operating Officer
CRM	Customer relationship management
DC	Direct current
DESCO	Distributed energy services company
DFI	Development finance institutions
ECOWAS	Economic Community of West African States
FOB	Free on board
FX	Foreign exchange
Generic products	For the purpose of this report this comprises no-name products, copycats and counterfeits
GHG	Greenhouse gas
GOGLA	Global Off-grid Lighting Association
GSMA	Groupe Speciale Mobile Association
H1	First Half (calendar year)
H2	Second Half (calendar year)
IEA	International Energy Agency
IDA	International Development Association
IDCOL	Infrastructure Development Company Limited
IFC	International Finance Corporation
KES	Kenyan Shilling
LED	Light-emitting diode
LG	Lighting Global
MFI	Microfinance institution
NGO	Non-governmental organisation
OEM	Original equipment manufacturer
PAYG	Pay-as-you-go
Pico-solar	Solar kits with a solar panel smaller or equal to 10W (peak, DC)
PPP	Purchasing power parity
PV	Photovoltaics
QV	Quality-verified
SACCO	Savings and credit cooperative
SE4All	Sustainable Energy for All
SHS	Solar home system
SPV	Special purpose vehicle
SSA	Sub-Saharan Africa
SMS	Short messaging service
Stopgap technologies	Technologies currently used by people living off the grid for lighting, phone charging and other basic electric appliances. Includes kerosene, candles, battery torches, car batteries and other.
TV	Television
UN	United Nations
UNFCCC	United Nations Framework Convention on Climate Change
US	United States
USD	United States dollar
VAT	Value added tax
VC	Venture capitalist

FOREWORD

Since 2010, the World Bank Group's Lighting Africa program has comprehensively analysed and documented the rapid evolution of the off-grid solar devices and services market. The 2010 and 2012 Market Trends Reports became touchstones for the industry, just as the 2016 edition is expected to be. This third incarnation captures the rapid evolution that is happening in the market, and is a collaboration between Lighting Global (the World Bank Group's expanded platform to support the global market) and Bloomberg New Energy Finance, in partnership with the Global Off-Grid Lighting Association (GOGLA).

The report reflects the expansive dynamics which define the market in 2016:

- An expanded technological scope, to include larger plug-and-play solar kits and solar home systems and the related emergence of energy services delivery enabled by high efficiency DC appliances.
- A geographic focus beyond the African market, additionally uncovering the trends and players in the Asian solar off-grid market, where most of these transformational solar products are made and where nearly half of the world's unelectrified population lives.
- Following the business model innovations that are re-shaping the paradigm for a growing portion of the market, the report dives into the dynamics and implications of emerging distributed energy services companies offering a variety of Pay-As-You-Go platforms.
- This report is also the first to substantially characterize the diverse investment community that is now focusing on the sector and the instruments being deployed to provide the capital necessary to realize the industry's potential.

The main findings of this report were first presented at the 4th International Off-Grid Solar Lighting Conference in Dubai in October 2015, where the emergence of a rapidly maturing industry could be witnessed first-hand. The energized assembly included, for the first time, commercial investors inspired by the wave of entrepreneurial energy, technological advances, and business model innovation. This report provides them with an introduction to a promising sector, just as it provides the companies seeking capital to understand the concerns, limitations, and perspectives with which these investors approach the industry.

The energy access challenge has firmly found its place on the international stage. The Sustainable Energy for All initiative laid the foundation for what has become Sustainable Development Goal #7: "to ensure access to affordable, reliable, sustainable, and modern energy for all." Not surprisingly then, a growing wave of development partners are seeking to support this emerging industry. The industry has already delivered unprecedented impact: 89m people in the developing world have at least one solar lighting product in their household already, providing the power to lift 21m people to the first rung of the SE4All energy ladder with pico-PV products. With a pathway in sight to defeat the energy poverty that stunts economic development for much of the world, the development community is looking for ways to accelerate this promising trend.

The Third Market Trends Report tells an exciting story. In so doing, it reflects on the lessons of the market's development to date and shines a light on the various potential pathways to the future. We welcome you to enjoy this fascinating story – and join us in writing future chapters to come.

SECTION 1. EXECUTIVE SUMMARY

The 1.2 billion people living without access to the power grid spend about $27 billion annually on lighting and mobile-phone charging with kerosene, candles, battery torches or other fossil-fuel powered stopgap technologies. Solar-powered portable lights and home kits offer a better service at lower cost. This report takes stock of what the emerging off-grid solar industry has achieved, looks at the opportunities and challenges facing the sector and assesses the potential of off-grid solar to help achieve universal electricity access.

- **The off-grid solar sector has seen impressive growth in the past five years**
  From a near-standing start less than ten years ago, more than 100 companies are now actively focusing on stand-alone solar lanterns and solar home system kits targeted at those without modern energy access. By mid-2015 they had sold 20 million branded pico-solar products (defined as having a PV panel smaller than 10W), mainly portable lights.
- **Off-grid solar is highly effective for enabling access to basic electricity services**
  These products improve energy access for an estimated 89 million people in Africa and Asia and provide enough power to lift 21 million individuals to the first rung of the energy ladder.
- **Market development has been asymmetric**
  Kenya, Tanzania and Ethiopia are Africa's leading markets, accounting for 66 percent of unit sales in the region, and India is leading the way in Asia. The efforts of development institutions such as the World Bank Group and activities of social enterprises like SunnyMoney helped build these markets, and there remain many countries where the sector can expand. Simple portable lanterns that retail for less than $20, and more recently for as little as $5, have accounted for 59 percent of all pico-solar unit sales to date.
- **Pico-solar is becoming mainstream**
  While off-grid solar has still barely scratched the surface of its potential globally, it is no longer a niche product in the countries that have seen the most concentrated sales efforts. In Kenya, more than 30 percent of people living off the grid have a solar product at home, according to our estimates. The pioneers have helped to create a vibrant market.
- **Generics are making an impression**
  The market for cheap, generic pico-solar products – unbranded items or copies of branded ones – is at least as big as the brand-quality market in number of units sold and takes global sales to more than 44 million to date, according to our estimates. These products challenge the brand-name incumbents with lower prices and increase the risk of market spoilage due to unpredictable quality and a lack of warranties or after-sales service.
- **Companies can provide value beyond product design**
  Off-grid solar brands have reacted to the rising competition by focusing on developing distribution networks, trying to sell more powerful systems with higher margins, entering new countries or developing new applications for urban back-up lighting or camping. Last-mile distribution and ongoing customer relationships will probably become even more important value drivers and determine who will be the few successful brands.
- **Pay-as-you-go (PAYG) makes solar kits affordable and helps capture consumer value**
  PAYG firms sell solar kits against small instalments instead of a lump-sum payment with a technology that locks the functionality in the event of non-payment by the consumer. These PAYG companies have attracted four times as much investment in half the time, compared with those selling products for cash. There are about 20 such companies that provide consumer financing active today, serving almost half a million customers, mainly in East Africa. Financiers are betting that barriers to entry for new PAYG suppliers will remain higher

than in the cash sale segment and that customer relationships will run deeper. Both factors promise higher margins.

- **Financing is getting larger – but it's still a bottleneck for further growth**
  The sector has attracted more than $511 million of investment to date (including to specialised intermediaries), with a sharp increase in recent years and most attention going to PAYG companies. Inventory-finance constraints have already held back sales of pico-solar lights, and firms extending consumer loans need far larger pools of money to scale effectively. PAYG companies have attracted almost $160 million in 2015, including a record $45 million single debt round by Off-Grid Electric. PAYG companies are likely to continue attracting substantial amounts of both debt and equity in 2016.
- **Most households adopting off-grid solar will pay cash rather than PAYG**
  While investors anticipate better returns and faster growth from PAYG companies, the operational and financial challenges to the business model will prevent it from dominating the off-grid market unless start-ups partner successfully with organisations that already have a large and efficient distribution network. The majority of products will likely be sold for cash by a small handful of premium brands and a large field of indistinguishable low-margin suppliers.
- **Off-grid solar is advancing rapidly beyond just lighting and phone charging**
  Between cost reductions, latent consumer demand and a sales-driven push for higher-margin products, solar home systems capable of powering appliances such as TVs and fans are likely to capture an increasing market share. About 7 million off-grid households will use solar-powered fans and 15 million households will have a solar-powered TV in 2020 in households in the developing world, according to our estimates. Similar systems will also provide services to small businesses.
- **Successful companies will invest in distribution networks and customer relationships**
  Commoditised components mean that manufacturing can only deliver thin margins, while price competition means that the distribution strategies used by the pioneers may not pay off in the long run. So companies' efforts will focus on opening new distribution channels, either proprietary or through deals with established partners. Recurring customer relationships, underpinned by modular or bundled offerings, will make it easier to capture customers as they come back to upgrade or expand their solar home system.

Off-grid solar lighting in numbers

- **20 million** brand-quality portable solar lights had been sold by July 2015.
- **89 million people** in the developing world have at least one solar lighting product in their household already.
- Consumers save on average **$3.15** for every dollar spent on pico-PV in Africa.
- **87 percent** of direct investments into off-grid solar companies in 2014 and 2015 have gone to pay-as-you-go companies.
- Annual investments into the sector including to specialised intermediaries have risen fifteen-fold since 2012, to **$276 million** in 2015.
- About **one in three off-grid households** globally will use off-grid solar by 2020, according to our baseline forecast.
- Unit sales will grow at a **34 percent CAGR** in the next five years, according to our forecast.
- **15 million TVs** are likely to be solar-powered by 2020, according to our baseline forecast.

SECTION 2. OFF-GRID ENERGY SERVICES: A CHALLENGE OR AN OPPORTUNITY?

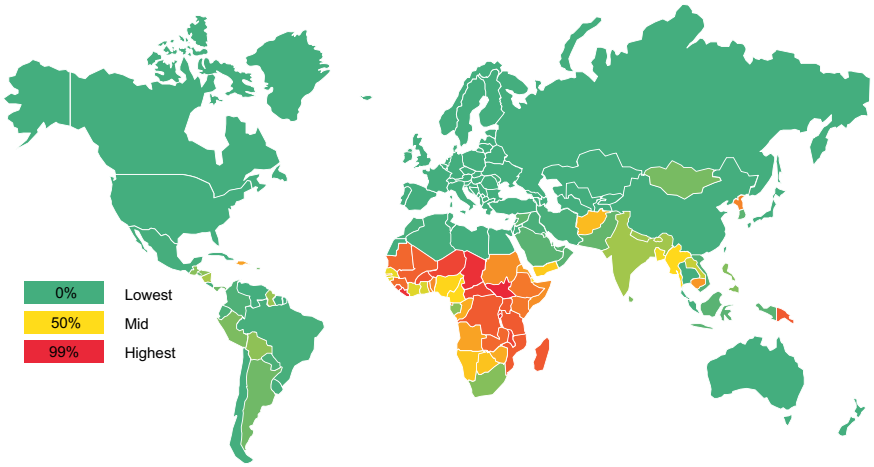
About 1.2 billion people globally have no access to the electricity grid and instead rely on inefficient and often dangerous alternatives such as kerosene lamps, candles, flashlights and car batteries. This is a significant challenge. We estimate that $27 billion was spent on such energy sources in 2014 in Africa and Asia – an opportunity that could be captured by the off-grid solar industry while offering better services.

2.1. OFF-GRID POPULATION TODAY

Most of the 1.2 billion people without grid access live in sub-Saharan Africa and Asia

About 95 percent of the world's 1.2 billion people without grid access live in sub-Saharan Africa and South and East Asia, with the remainder spread almost equally across the Middle East, Central Asia and Latin America (see Figure 1). African nations suffer from the lowest electrification rates by far. In Chad, Liberia or Burundi, for example, only one in 20 people have access to the grid. South Asian nations such as India and Bangladesh, or East Asian nations such as Indonesia, deliver electricity to a larger share of their people, even though in absolute terms they have almost as many people without grid access as Africa due to their larger populations.

Figure 1: Share of population without grid access (percent of total)



Source: World Bank, Bloomberg New Energy Finance. Note: Figures refer to 2012 data.

Nonetheless, the picture is less gloomy in most of Asia. Slowing population growth rates and a booming economy helped drive a 212 million decline in the number of people living off-grid since the turn of the century (see Figure 4). However, there are still countries such as India and Pakistan with a large number of people living off the grid. In India, the problem affects about one in five people, although it is unevenly distributed and electrification rates are particularly low in the states of Uttar Pradesh and Bihar. Most of the population without grid access lives in rural areas where grid extensions are a greater technical and economic challenge, according to the IEA.[1]

[1] International Energy Agency, "World Energy Outlook – India", 2015.

The cost of electrification

In Africa, population growth is far outpacing the extension of the grid. The number of people living off the grid has grown by 114 million people on the continent since 2000, with several more million joining every year. The IEA projects there will still be 530 million people living off-grid in 2040, even though 950 million people will have gained grid access by then. The absolute number of people living off grid will continue to rise for the next decade, according to the IEA.[2] The agency says East Africa is set to achieve the highest electrification rates, while Nigeria will connect the largest number of people in Africa. Progress will be slowest in Central Africa.

Shortcomings in public policies or institutions may make small scale options the only way forward

Most urban areas will be connected to a traditional grid as higher population densities cut per-household costs. Extending access to more dispersed populations living within "reasonable" distance of existing transmission or distribution lines is also likely to be cost-effective, according to the agency. Once the grid is extended, the levelised cost of the electricity consumed is typically projected to be well below the cost of off-grid systems. However, the agency reckons that the levelised cost per megawatt hour (MWh) of grid-supplied electricity rises from just over $100/MWh when the grid is already built to more than $450/MWh where power lines have to be extended by 3 kilometres to reach a community. Both diesel and PV supplied through a mini-grid or household unit cost less than that, at about $330/MWh[3] and $310/MWh, respectively, according to the IEA. Mini-grids will thus mainly be powered by diesel and PV.

Reaching a 70 percent electrification rate in Africa by 2040 will require capital investment of around $7.5 billion annually in energy access, says the IEA. That is roughly equivalent to today's annual investment in the entire power sector of the continent. This will be challenging not only due to the sums involved, but also because of the requirement for effective coordination between government authorities, private companies and financiers. The agency concludes that "small-scale options, commercialised by the private sector, may be the only way forward where there are shortcomings in public policies or institutions". [4]

Figure 2: Off-grid population in sub-Saharan Africa (million)

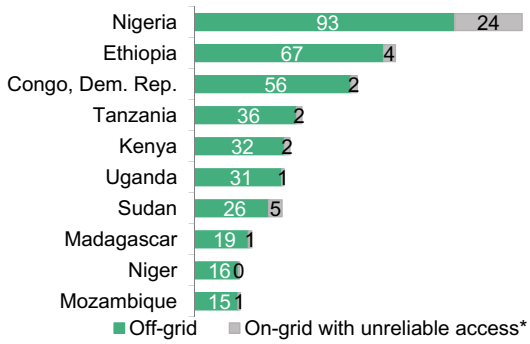
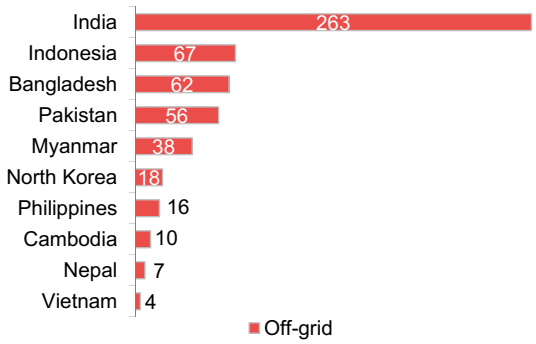


Figure 3: Off-grid population in Asia (million)



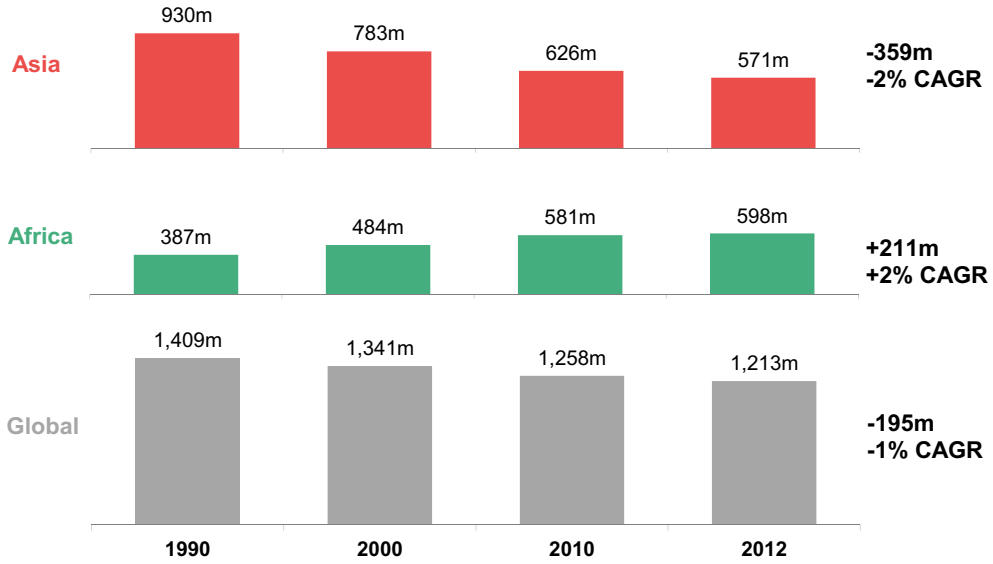
*Source: World Bank, UNEP, Bloomberg New Energy Finance. Note: Figures refer to 2012 data. * Unreliable access only represented where UNEP data is available.*

Unreliable grid access

It is estimated that another 1 billion people are connected to the grid at present but suffer from unreliable service levels. The data on this subset is less detailed. The IEA reports that the grid is unavailable for an average of 540 hours per year in Sub-Saharan Africa (6 percent of the time), but the figure is much higher in countries such as Nigeria. Unreliable service is often backed up with diesel generators, which cost far more to run and tend not to appear in usage statistics.

[2] International Energy Agency, "Africa Energy Outlook", World Energy Outlook Special Report, 2014.
[3] Assumes diesel cost of $1/litre.
[4] International Energy Agency, "Africa Energy Outlook", World Energy Outlook Special Report, 2014, p.130.

Figure 4: Off-grid population by region (millions)



Source: World Bank, UN, Bloomberg New Energy Finance.

2.2. INCOME OF THE OFF-GRID POPULATION

While most people living off the grid are poor, we estimate that there are 47 million households in Africa and Asia that have no electricity but enjoy an annual income of $3,650-18,250 (or $2-10/day per five household members). These households are likely to be able to afford not just simple solar lanterns, but also larger solar home systems and appliances.

There are likely to be millions of potential off-grid households with similar or higher income levels that are not officially counted as off-grid because they are technically connected, but suffer from unreliable power supply. We derived these estimates from an analysis of the income breakdown in emerging economies by the Pew Research Centre[5] and statistics on the electrification rates, because reliable statistics on the income of the off-grid population are not available. There are several countries in Africa where there are far more people without grid-access than people with an income of less than $2/day. Assuming that the poorest are least likely to have grid access, in countries like Ethiopia, Kenya and Uganda, it is likely that more than half the off-grid population has an income of $2-10/day per capita (see Figure 5).

2.3. OFF-GRID EXPENDITURE ON STOPGAP TECHNOLOGIES

The off-grid energy sources used today are outdated and costly

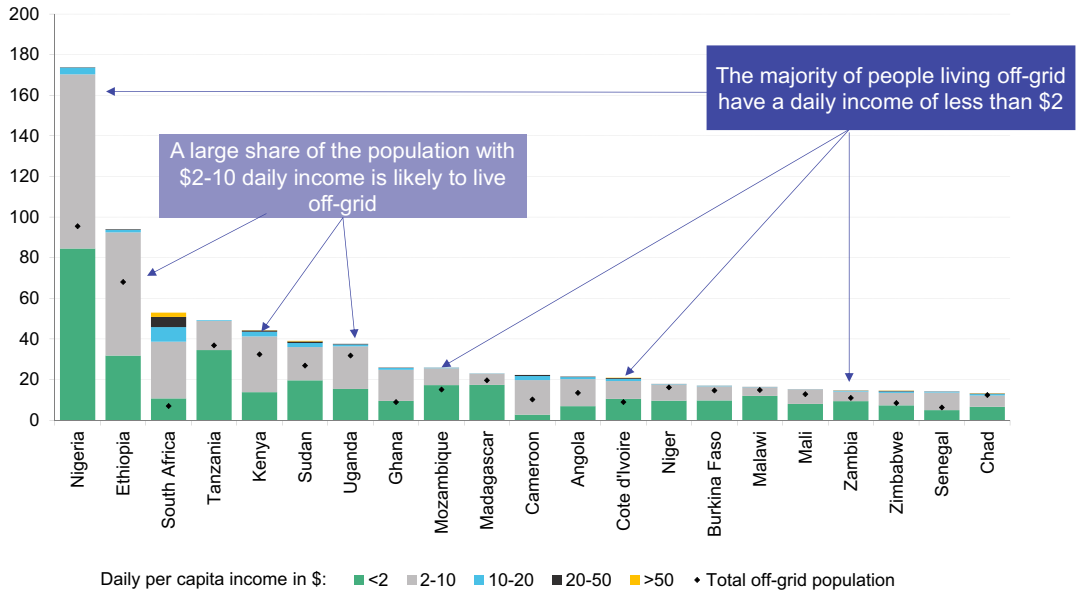
The off-grid energy sources that are widely used today are outdated and costly, such as lighting supplied by candles, kerosene lamps or battery-powered flashlights. All of these technologies are far more expensive than grid-powered electrical appliances in terms of cost per kWh and some also damage the environment and the health of those people exposed to them. Compounding the issue are the risk of accidental fuel ingestion leading to poisoning, which affects mostly young children and the risk of fire.[6]

[5] Pew Research Center, "A global middle class is more promise than reality". See: http://www.pewglobal.org/2015/07/08/a-global-middle-class-is-more-promise-than-reality/

[6] Evan Mills, "Identifying and reducing the health and safety impacts of fuel-based lighting", Energy for Sustainable Development 30 (2016), 39-50.

The off-grid population in sub-Saharan Africa spent over $14 billion on lighting in 2014 (Figure 6), according to our estimates based on UNEP lighting assessments.[7] The equivalent figure in Asia is lower at $6.6 billion annually. Kerosene is heavily subsidised in India and to a lesser extent in other parts of Asia (Figure 7). The cost may be even higher once travel times and associated costs are taken into account, as well as the particularly high kerosene prices in off-grid areas, where kerosene dealers have been found to charge a premium of 29-170 percent over urban areas.[8]

Figure 5: Population (in millions) by estimated per capita income



Source: Bloomberg New Energy Finance, World Bank, Pew Research Centre.

Annual expenditure per household varies significantly. Based on UNEP data on local usage patterns and regional cost differentials, we estimate that lighting expenditures range between around $186/year in Mauritania to around $72/year in Ethiopia, with the majority of countries falling between $100-140/year. In India, kerosene subsidies bring the cost-per-household down even further, to about $45/year (Figure 8). Different levels of expenditure do not seem to be correlated with the success of solar lighting to date. Large markets include countries with high expenditure, such as Kenya ($163/year), as well as low-expenditure, like Ethiopia and India. This suggests there is still an opportunity for a significant growth in off-grid solar across regions with a widely varying status quo on household incomes and lighting expenditure. Solar product sales seem not driven by household expenditures and incomes nor the product payback economics alone. We discuss market trends and drivers in more detail in Section 2.

MOBILE-PHONE CHARGING

The off-grid population may spend an additional $5-6 billion/year on mobile-phone charging in Africa and Asia, according to our estimates. There were 2.5 billion mobile-phone connections in the 60 countries where most of the off-grid population is located as of 2013. GSMA estimates that

[7] UNEP, Enlighten Imitative Country Lighting Assessments, URL: http://map.enlighten-initiative.org/, retrieved May 2015.
[8] Lighting Africa, "The true cost of kerosene in rural Africa", April 2012.

there are 240 million mobile subscribers living off-grid.[9] These phones tend to be charged by small-business owners for fees reported at between $0.15-0.25 per charge. This equates to an astounding cost per kWh equivalent for electricity service of $30-50. Additional opportunity costs are incurred when phone owners have to travel at times for hours to reach a charging point.

Figure 6: Estimated annual spend on off-grid lighting and phone charging (Africa, 2014, $ billion)

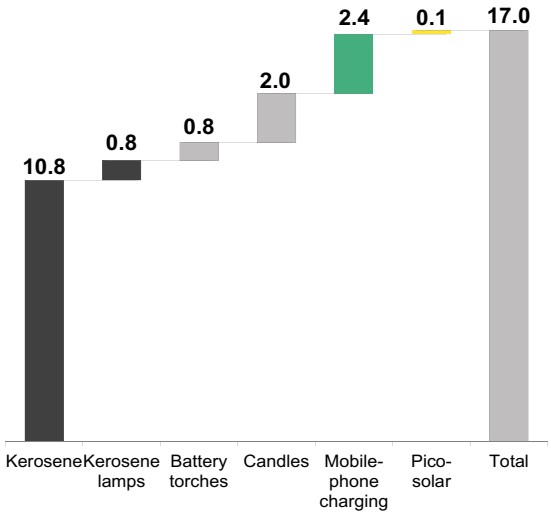
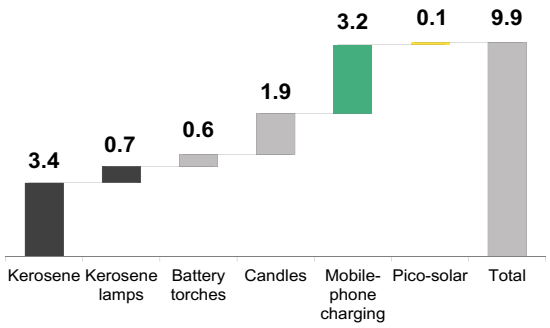
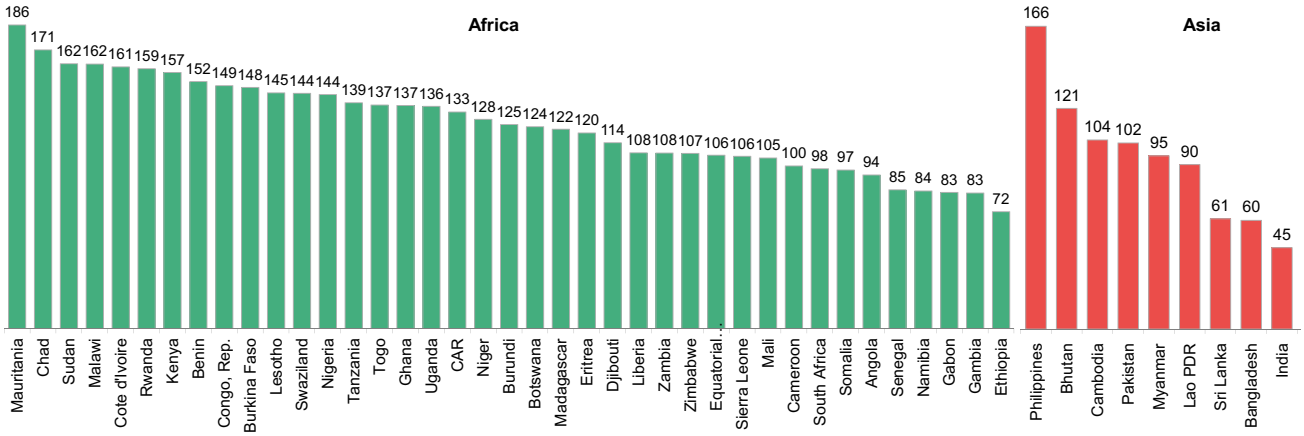


Figure 7: Estimated annual spend on off-grid lighting and phone charging (Asia, 2014, $ billion)



Source: Bloomberg New Energy Finance, UNEP[10], GSMA, World Bank. Assumes phone charging costs of $0.20 for one-two weekly charges.

Figure 8: Estimated average annual lighting spend by the off-grid household ($/year, 2012)



Source: Bloomberg New Energy Finance, UNEP[11], World Bank. Note: calculated based on UNEP estimates for technology use by country and World Bank population estimates.

[9] GSMA, Michael Nique, "Sizing the opportunity of mobile to support energy and water access" (2013). See: http://www.gsma.com/mobilefordevelopment/wp-content/uploads/2013/12/Sizing-the-Opportunity-of-Mobile_Nov-2013.pdf

[10] UNEP, Enlighten Imitative Country Lighting Assessments, URL: http://map.enlighten-initiative.org/, retrieved May 2015.

[11] UNEP, Enlighten Imitative Country Lighting Assessments, URL: http://map.enlighten-initiative.org/, retrieved May 2015.

DIESEL GENERATORS

Residential diesel generators are a popular solution among the wealthier people without stable grid access

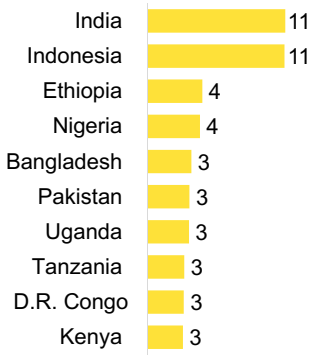
Residential diesel generators are a popular solution among the wealthier people without stable grid access. There is no comprehensive data on the use of such generators and the breakdown between households unconnected to the grid and connected households who use it as a back-up. The technology is particularly popular in Nigeria, which suffers from significant 'brown-outs' or power outages due to a shortage of generation capacity. A 2009 report by the Energy Commission of Nigeria estimated that about half the population had a diesel generator at home.[12] In fact, Nigeria accounts for about 75 percent of power generation from diesel back-up generators in Africa, according to the IEA whereby the annual fuel cost is estimated to have been about $5 billion in 2012, although only about 20 percent of this occurred in the residential sector.

In India, which hosts Asia's largest off-grid population, diesel is used predominantly by rich and urban households, according to data from the Ministry of Statistics and Programme Implementation, quoted by the IEA.[13] The same data suggests that kerosene is used by both poor and rich households in urban and rural areas, while middle-income households are the largest consumers of the fuel.

2.4. OFF-GRID LIGHTING ECONOMICS

Running a simple wick kerosene lantern for a year costs between $14 in Indonesia and $54 in Kenya, including the purchase of the lantern itself and the on-going payments for kerosene, according to our estimates. The lighting service provided by such a lamp is comparable, if not inferior, to a simple portable solar light, which can retail for as little as $5. Using a more conservative price estimate of $13 per solar unit, the payback period for the initial outlay still ranges from about three months in Kenya to just under a year in India, where kerosene prices are kept particularly low by subsidies (Figure 9). Assuming a lifetime of two to three years for a typical solar light from a reputable manufacturer, customers can enjoy lighting at no cost for a period of at least one year after purchasing a basic portable solar light before they need a replacement. While the differences between countries are significant, the economic case for solar lanterns versus kerosene lighting is very convincing in all instances. Payback periods will be even shorter, and the case for the solar light strengthened, if kerosene premiums for rural distribution or travel times to purchase the fuel are taken into account. Solar is also competitive with candles or battery-powered torches.

Figure 9: Pay-back period for a $13 solar light (in months)



Source: Bloomberg New Energy Finance, UNEP, Lighting Africa, Adkins Oppelstrup and Modi 2012, Mills 2003. Note: Assumes kerosene is the reference technology. Kerosene use estimated at 3.85 hours per day, a fuel use rate of 0.03 litres/hour and latest available retail kerosene prices.

[12] Energy Commission of Nigeria, "60m Nigerians now own power generators —MAN", January 2009, retrieved 20 December 2015. See: http://www.energy.gov.ng/index.php?option=com_content&view=article&id=74

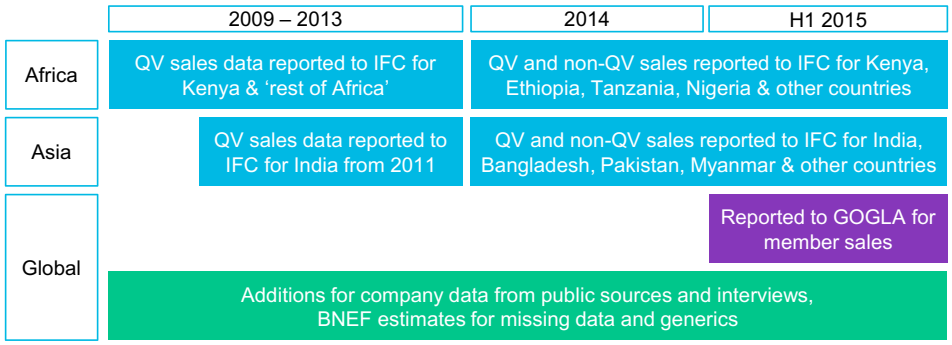
[13] International Energy Agency, "World Energy Outlook – India", 2015. p.43.

SECTION 3. PICO-SOLAR MARKET TRENDS

More than 44 million pico-solar products – solar lanterns and home systems smaller than 10W – had been sold worldwide as of the second half of 2015, according to our estimates. A third of those were Lighting Global quality-verified products. This section explores the following five key trends:

- The pico-solar market has grown rapidly. Simple solar lanterns have accounted for the majority of sales to date. Most pico-solar kits now come with mobile-phone charging capabilities. Sales of plug-and-play solar home lighting-plus systems are now growing rapidly as well, but remain a fraction of the total market.
- The increasing traction of larger solar home systems means the market is splitting into two: one for simple low-cost lanterns, the other for devices that offer more services as well as appliances that can take the consumer to the next rung of the energy ladder.
- Generic products, which comprise no-names, copycats and counterfeits, account for at least half the pico-solar market. They present a serious challenge to simple low-cost products in particular.
- Last-mile distribution is among the most important value drivers. Companies have chosen a variety of models to cope with the abundant competition, but the challenge from generic products means last-mile distribution and customer relationships have never been more important.
- Pico-solar companies are already responding to these trends in a variety of ways, including a shift towards higher-value products and downstream distribution and service activities.

A note on data



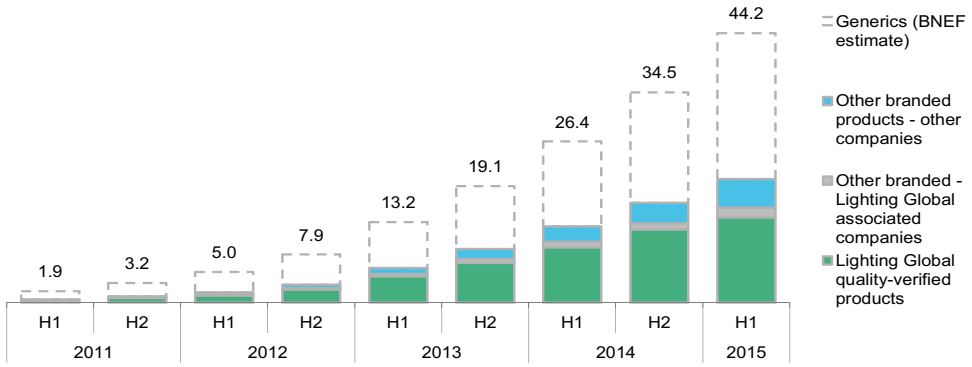
Data on the off-grid solar industry in general, and details of unit sales in particular, has been patchy at best. The best source of data has been the IFC/ World Bank's Lighting Global programme, which has collected unit sales for quality-verified (QV) products since 2009. Lighting Global is now extending this work through a partnership with GOGLA. This study uses data collected by both organisations, as well as additional data gathered by Bloomberg New Energy Finance. Data transparency through regular and more comprehensive reporting is critical as the sector scales and attracts wider interest.

3.1. A GROWING MARKET

Off-grid solar has seen spectacular growth, with unit sales of branded pico-solar products hitting a CAGR of 109 percent from 2011 to 2014. In that period, more than 30 new specialised companies entered the market.

At least 44 million pico-solar products have been sold worldwide as of mid-2015, according to data from Lighting Global and GOGLA and estimates for other products (Figure 10). Of these, just under 20 million are Lighting Global quality-verified and other branded products. The rest are generics, which comprise no-names, copycats and counterfeits. Sales of integrated solar home systems enabled by PAYG are a small fraction of the lantern market, amounting to around 450,000-500,000 units as of Q3 2015, according to our estimates.

Figure 10: Estimated cumulative sales of pico-solar lighting products in sub-Saharan Africa and Asia, 2011 – H1 2015 (millions of units)



Source: Bloomberg New Energy Finance, Lighting Global, GOGLA. Note: These figures comprise branded and generic solar lanterns and small solar home systems of 10W or less.

The most significant single market for sales is India – reflecting its position as the country with the world's largest off-grid population. However, Africa as a whole has seen more sales than Asia. The leading African markets are Kenya and Tanzania, which together with India accounted for 3.4 million unit sales in the year to July 2015 alone (Figure 11). These countries exhibit very different characteristics. For instance, Kenya has seen higher value products gaining traction in the sub-10W category, whereas Tanzania has been characterised by a mass market at lower average price points (Figure 12).

Figure 11: Lighting Global quality-verified unit sales, H2 2014 – H1 2015 (millions)

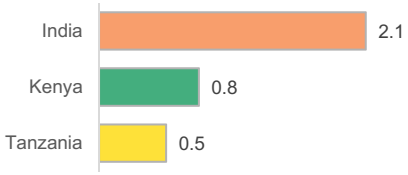
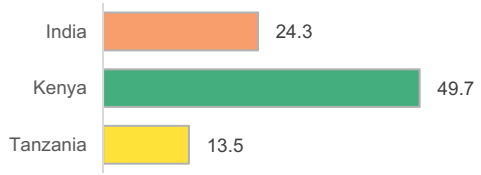


Figure 12: Average retail price of pico-solar products, H2 2014 – H1 2015 ($/unit)



Source: Bloomberg New Energy Finance, Lighting Global.

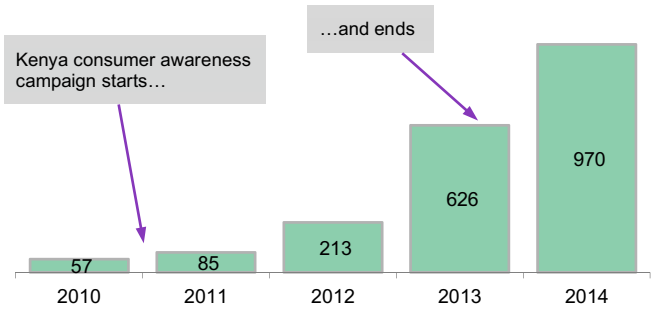
Lighting Global interventions

The countries that today host some of the largest pico-solar markets also hosted some of the earliest interventions by World Bank Group's Off-Grid Lighting Programs, including "Lighting Africa" which launched in Kenya as a pilot in 2007. Among the programme's first activities was market research in Kenya, Ghana, Ethiopia, Tanzania and Zambia. This was followed by the development of the Lighting Global quality assurance framework (originally launched as the Lighting Africa quality assurance framework) and on the ground business-development support and consumer-awareness campaigns, including roadshows (illustrated in Figure 13) in Ghana and Kenya. While we have not analysed causation for this report, these interventions have correlated with the emergence of the pico-solar sector (see Figure 14 for an example in Kenya). In 2012 India became the first country in the Lighting Asia programme when the initiative was expanded beyond Africa. Lighting Global now encompasses market-building activities in three Asian countries and in 11 African nations, and supports further market-building innovations such as an FX facility with the Development Bank of Ethiopia and working-capital facility to be launched in 2016 in Uganda, as well as a commercial working capital debt facility operating globally.

Figure 13: Lighting Africa roadshow

Source: Lighting Africa.

Figure 14: Lighting Africa activity in Kenya and sales of quality-verified products (thousands)

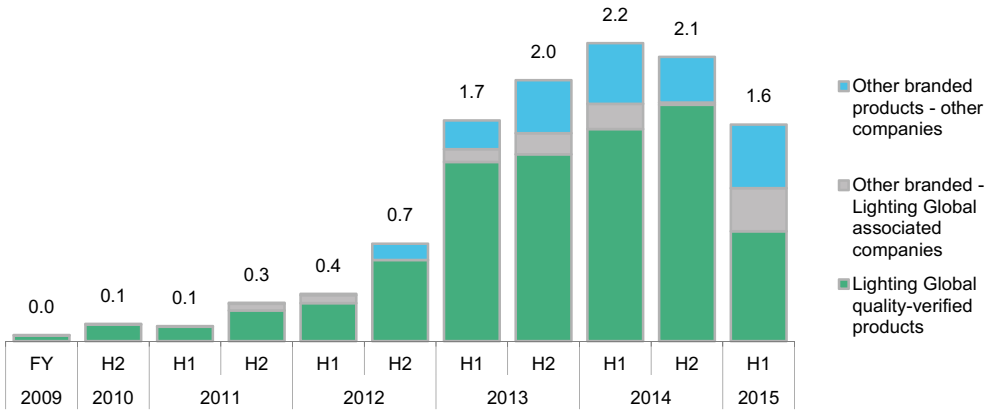


Source: Bloomberg New Energy Finance, Lighting Global.

Market trends in Africa

Sales of branded pico-solar products in sub-Saharan Africa grew steadily to the end of 2014, with periodic growth peaking at 126 percent in the first half of 2013 (Figure 15). A fall in sales in H1 2015 is likely to have recovered in the second half of the year, as leading companies overcame supply-chain constraints. No sales data for H2 2015 was available at the time of publication. We estimate that the share of quality-verified products among branded products slipped to 51 percent in the first half of 2015, from on average 75 percent since 2012.

Figure 15: Sales of branded pico-solar lighting products in Africa (millions of units)



Source: Bloomberg New Energy Finance, Lighting Global, GOGLA. Note: Figures as reported to Lighting Global and GOGLA with additional BNEF estimates for missing data points and other branded sales.

The drop in sales of branded products represents temporary supply-chain constraints – and competition from generic products

The reported sales of quality-verified products fell in H1 2015. Our analysis suggests that reporting gaps, while they exist, can be ruled out as the main cause for this drop. Rather, the fall represents significant market dynamics:

- **Operational bottlenecks**: inventory-finance constraints have hindered even the largest companies and held back sales. At the same time, they may have temporarily slowed sales to restructure part of their business and revise strategy in preparation for further growth. Firms have suggested that these issues were resolved in H2. Preliminary sales reports indicate that sales have recovered significantly in the final six months of 2015.
- **Competition from generics**: brands are facing increased competition from unbranded, copycat and counterfeit products. When the supply of branded products to wholesalers is interrupted due to manufacturers' operational or financial challenges, wholesalers or even

individual agents look to meet demand with substitute products. These price and supply pressures are unlikely to subside and require constant innovation from market leaders if they are to retain market share and avoid a price race to the bottom. This dynamic is explored further in the following sections.

Figure 16: Branded products share of reported sales in Africa, H2 2014 – H1 2015

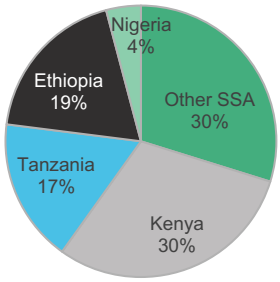
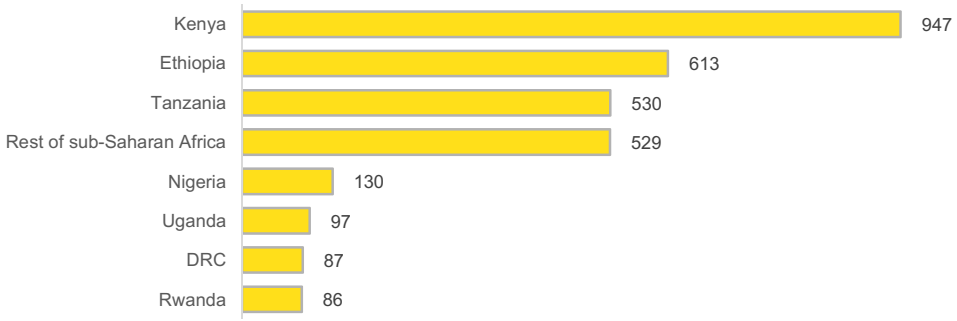


Figure 17: Reported sales of Lighting Global quality-verified pico-solar products in sub-Saharan Africa, H2 2014 – H1 2015 (thousands of units)



Source: Bloomberg New Energy Finance, Lighting Global, GOGLA. Note: Figures as reported to Lighting Global and GOGLA

Kenya accounted for 30 percent of reported Africa sales from July 2014 to July 2015, with Ethiopia and Tanzania together making up another third (Figure 16). However, the characteristics of these markets vary significantly. Kenya saw 1.5 times the sales in Tanzania to date, but they amounted to 5.5 times of the revenue. This relates to the prevalence in Tanzania of entry-level products, which in turn seem to have been more susceptible to competition from low-cost generics.

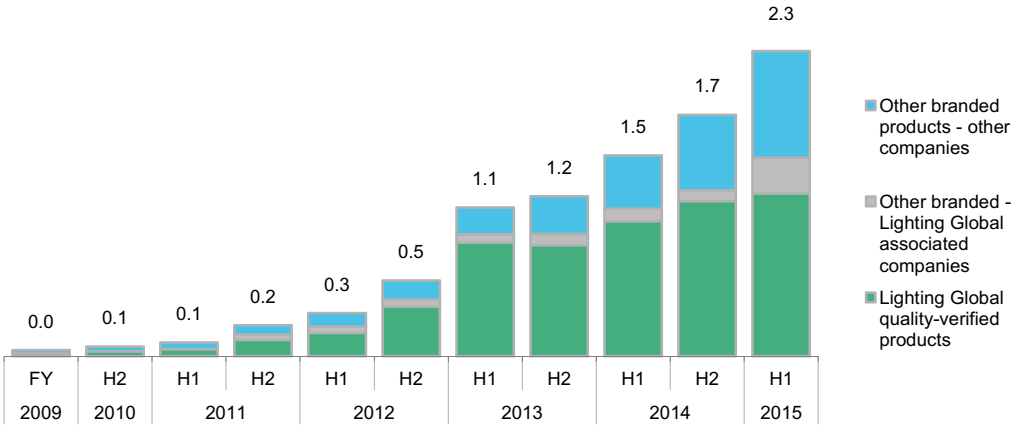
Market trends in Asia

While sales of branded pico-solar products took off earlier in Africa, Asia's sales are now higher. India dominates the Asian market, with sales of more than 1 million units reported in both H2 2014 and H1 2015. That amounts to an estimated $54 million of revenue over that period, versus only $5.2 million for reported sales in other Asian countries. The share of Lighting Global quality-verified products dropped among branded sales in Asia, falling to 52 percent in the first half of 2015, from 66 percent in 2014. There is limited information on product sales in Asia, with multi-year data only available for India.

The Indian government took an early interest in off-grid solar to increase energy access. A Lighting Asia study from 2012 estimated that at least 2.3 million solar lanterns were distributed in India between 1997 and 2010, primarily through government programmes.[14] The market for commercial products was slower to grow: some companies report that government interventions distorted the growth of a private market. However, it also led to a home-grown industry; India is one of the few countries with significant manufacturing outside of China (though imports from China still account for the sales of most established brands). The government supports a network of over 400 "Aditya Solar Shops" around the country that act as service hubs. The commercial market for branded products took off in 2013, as it did in Africa, as the leading companies registered success in building consumer awareness and distribution channels.

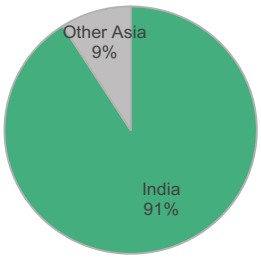
[14] Sethi et al. "Lighting Asia: Solar Off-grid Lighting." IFC. 2012.

Figure 18: Sales of branded pico-solar lighting products in Asia (millions of units)



Source: Bloomberg New Energy Finance, Lighting Global, GOGLA. Note: Figures as reported to Lighting Global and GOGLA with additional BNEF estimates for missing data points and other branded sales.

Figure 19: Branded products share of reported sales in Asia, H2 2014 – H1 2015



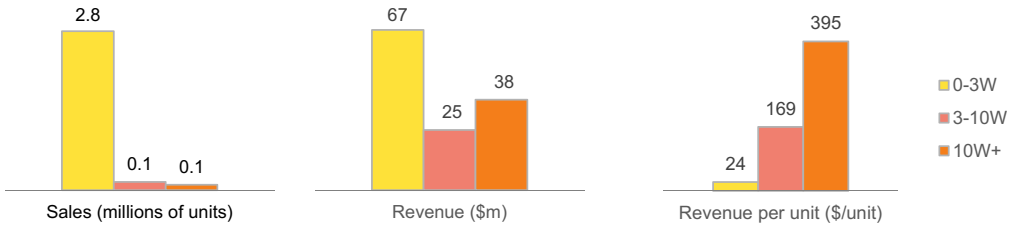
Source: Bloomberg New Energy Finance, Lighting Global.

Sales of branded products in other Asian countries have been relatively muted, though this may change with new Lighting Asia programmes launched in Pakistan and Bangladesh. These figures do not include the sales of over 4 million solar home systems in Bangladesh since 2003, deployed through a successful subsidy and consumer-finance programme. They are typically 30–50W – so beyond the pico-solar products of up to 10W included in the reported data.[15]

Solar home system kits

Globally, the sales of solar home systems larger than 10W reported to Lighting Global and GOGLA amounted to just over 95,000 units in the first half of 2015. Small home systems, such as those sold by M-KOPA, fall into the 3-10W category and are included in the figures discussed previously. Just as for pico-solar, generics probably also increase the size of the solar home system market considerably beyond what is reported to Lighting Africa and GOGLA. Almost 750,000 stationary plug-and-play solar lighting kits were exported to sub-Saharan Africa from China in 2014, according to our estimate based on customs data. No comparable data were available for Asia.

Figure 20: Reported sales and estimated revenue and revenue-per-unit for pico-PV products, H1 2015



Source: Bloomberg New Energy Finance, Lighting Global. Note: Sales figures as reported to Lighting Global and GOGLA.

Solar home systems are higher-value products that return higher revenue per unit sold. Off-grid solar products larger than 3W made up just 8 percent of total reported sales in H1 2015 but almost half of estimated revenue. Those larger than 10W account for 3 percent of sales but 30 percent of estimated revenue (Figure 20).

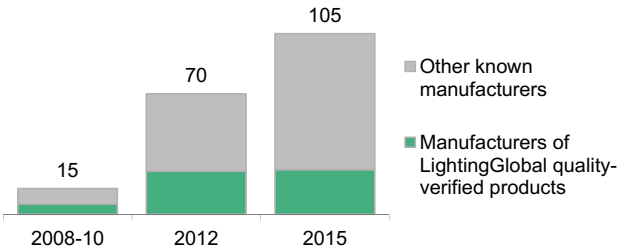
[15] Khandker et al. "Surge in Solar-Powered Homes: Experience in Off-Grid Rural Bangladesh." Directions in Development. Washington, DC: World Bank. 2014.

AN EXPANDING INDUSTRY

Off-grid solar products larger than 3W made up just 8 percent of reported sales – but almost 50 percent of revenue

The number of known off-grid solar manufacturers has increased sevenfold in the past five years. Alongside the first wave of start-ups, many of them founded by entrepreneurs from the US and Europe, are larger electronics and other manufacturers in Asia. Some of them have in-house design teams coupled with their own production facilities, which allows them to move quickly to respond to demand.

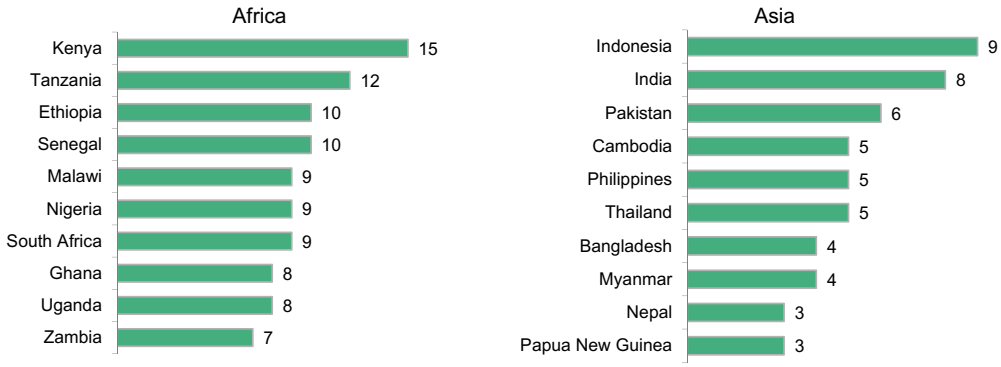
Figure 21: Number of known pico-solar manufacturers



Source: Bloomberg New Energy Finance, Lighting Global, Dalberg. Note: Contract manufacturers and non-specialist exporters are not included.

GOGLA members, as of H2 2015, distribute their products in a range of countries in sub-Saharan Africa and Asia – but by no means all (Figure 22). Notably, the best represented are the East African countries that were some of the earliest markets: Kenya, Tanzania and Ethiopia. The presence of numerous companies in countries like Indonesia and Senegal has not yet translated into significant reported sales.

Figure 22: Number of GOGLA members with a sales presence by country

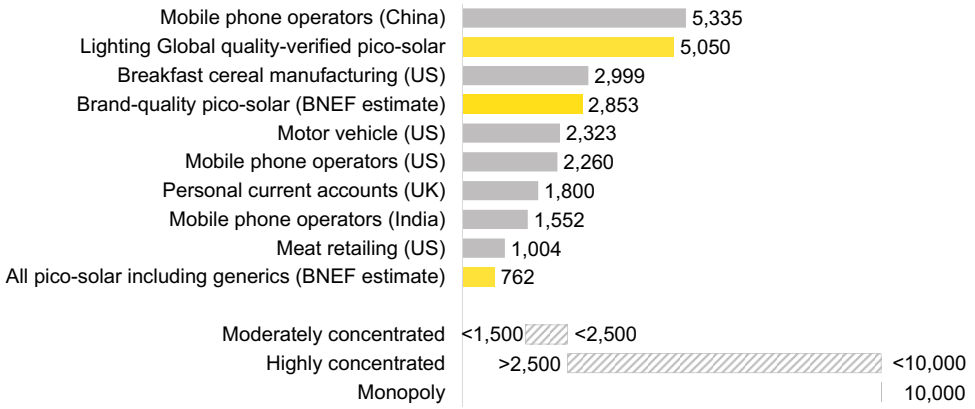


Source: Bloomberg New Energy Finance, GOGLA.

The broader pico-solar market is very competitive

The concentration of the pico-solar market varies depending on which segments are included. Among those companies that have engaged in the Lighting Global programme, it is by any measure a highly concentrated market, with the majority of sales recorded by a few players. Broadening this to those outside the Lighting Global universe, we see much less concentration. When the manufacturers of “generic” products are included, the market is likely to be very competitive.

Figure 23: Pico-solar market concentration (Herfindahl-Hirschman Index)



Source: Bloomberg New Energy Finance, Lighting Global, US Census data, Ofcom. Note: The Herfindahl-Hirschman Index (HHI) measures market concentration. HHI estimates for off-grid solar refer to cumulative historical market size over 2009 - H1 2015 and are Bloomberg New Energy Finance estimates. The HHI for all branded off-grid solar lights excludes PAYG systems and may not include all branded products and should therefore be interpreted as a maximum estimate. The estimate for the market with generics assumes 10 companies have an equal share of the generics market.

3.2. PRODUCT FEATURES AND SALES TRENDS

Low-cost, small and simple products have dominated unit sales to date

The pico-solar market shows strongest demand on a unit basis for low-cost, small and simple products. The recent growth of demand for larger systems, made affordable through PAYG delivery models, represents a split in the market in Africa.

Solar lanterns account for 97 percent of reported sales, with pico-solar home systems making up the rest. The market has so far been dominated by products whose function is limited to a single light with or without phone charging (Figure 24). The market share of single lights has increased since the sector's earliest days, underlining the strong demand for the simplest of products.

This has been echoed by the share of cheaper products. As innovation brought costs down and substantially improved performance pico-solar lanterns costing less than $20 increased their share of unit sales.. These products represent more than half of unit sales for the last three years. This is partially explained by the success of the school distribution model implemented by SunnyMoney, which has been the largest seller of simple study lights.

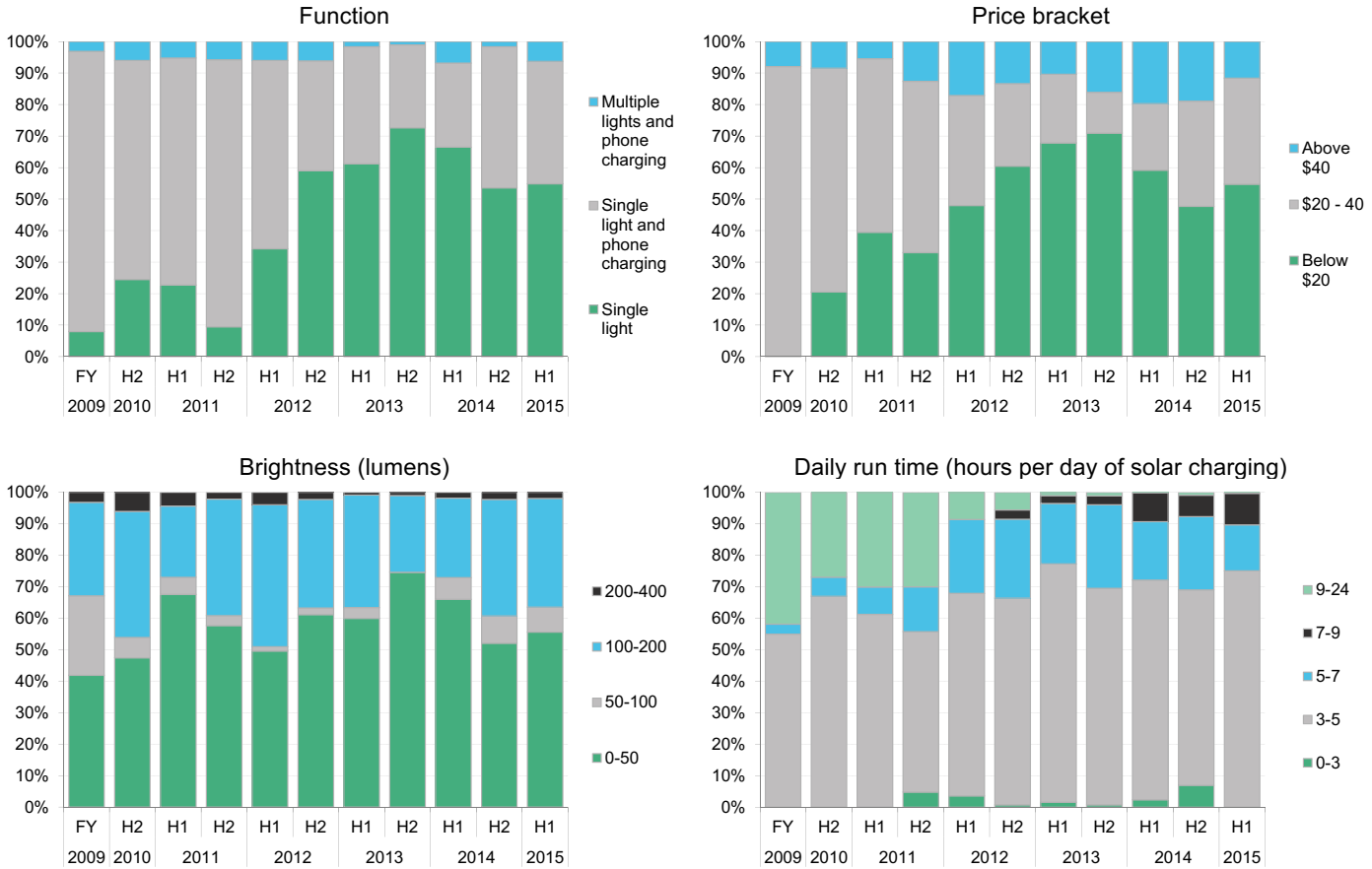
Companies report growing demand for systems with multiple lights, either via cash sales channels or as they make them available through PAYG or other consumer-financing options. The data on product features shown in Figure 24 is limited to Lighting Global quality-verified products, which only recently started to include solar home systems larger than 10W. We expect these to become popular alongside the single lanterns.

The demand for simple lighting products is also borne out by trends in the brightness and run-time of the most popular products. While brighter lamps and longer-running batteries were present as the market started to grow in 2009 to 2011, most of the market is dominated by products with lower lumen output and run-times of 3–7 hours (Figure 24). This suggests that early models were over-engineered, and that companies adjusted their offering to better meet customer demands.

Meanwhile, nearly all batteries are now lithium based: as the technology is present in 98 percent of products sold, only 2 percent are run on either lead-acid or nickel-metal hydride batteries. The emergence of larger plug-and-play solar home systems on the market is reflected in the extension

of the Lighting Global quality-assurance framework to products of up to 100W. Section 6 examines wider technology trends and the evolution of component costs and appliance efficiencies.

Figure 24: Product features by share of Lighting Global quality-verified product unit sales



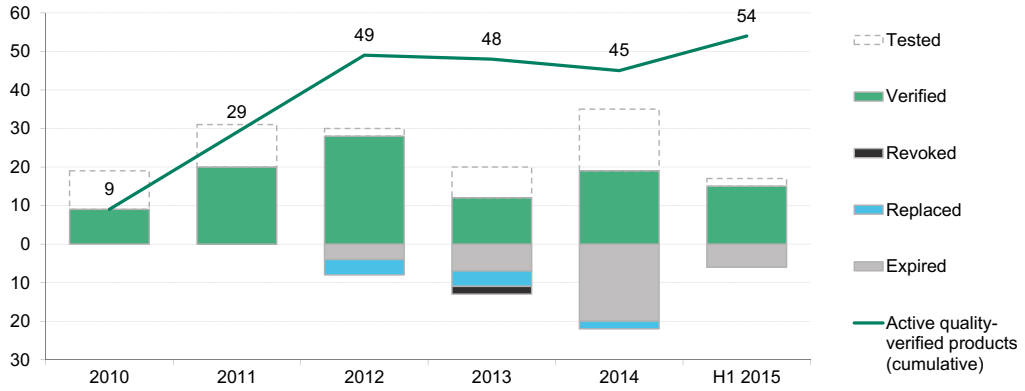
Source: Bloomberg New Energy Finance, Lighting Global. Note: Specifications relate to 'high' setting where applicable.

LIGHTING GLOBAL QUALITY ASSURANCE

Since 2009, Lighting Africa and then Lighting Global have managed a quality-assurance programme for pico-solar products, aiming to set a baseline level of quality, durability and to ensure truth-in-advertising to protect consumers. As of the end of H1 2015, there were 54 quality-verified products still active, meaning their verification had not expired or been revoked or replaced, out of a total 152 products tested and 103 verified. The peak year for products passing the testing process was 2012, when many pioneer companies settled on quality designs. 2015 was on course to surpass that at the halfway point, with the addition of systems larger than 10W opening the door to another category of solar products that meet the Lighting Global Quality.

The testing framework developed by Lighting Global has been adopted by the International Electrical Committee (IEC) as technical specification IEC/TS 62257-9-5, and has been integrated into nation-wide programs by Kenya, Ethiopia, Liberia, Bangladesh and Nepal. These quality standards have also been adopted as a pre-condition for receiving carbon credit finance under the United Nations Framework Convention on Climate Change (UNFCCC). Most recently the Economic Community of West African States (ECOWAS) will also reference it when it adopts a new quality framework for pico-solar products.

Figure 25: Lighting Global quality-verified products, 2010 – H1 2015 (number of products)



Source: Bloomberg New Energy Finance, Lighting Global, Humboldt State University.

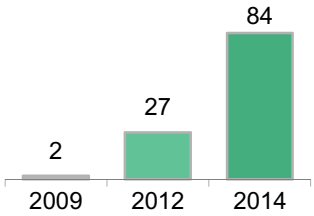
In 2015 the Lighting Global quality-verification programme expanded to include plug-and-play kits up to 100W. An initial cadre of seven systems of more than 10W have passed the testing process and have been quality verified in the initial pilot stage. Lighting Global expects to see a significant increase in the number of products of more than 10W that receive quality verification in 2016, in lockstep with how the market is evolving.

3.3. GENERIC PRODUCTS

Mass manufacturers are entering what was once a niche market

Low-cost generics comprise at least half the wider pico-solar market, alongside the branded products made by companies aiming to build a proprietary brand presence. To an extent, this shows that off-grid solar has come of age: mass manufacturers are entering what was once a niche market because they consider the market promising. Generic products can break within weeks or function as reliably as quality-verified products – and consumers have little guidance to identify those that will last. This raises the risk of market spoilage but, because of the low barriers to entry and low costs, the segment will likely continue to attract both manufacturers and consumers.

Figure 26: Number of solar products observed in three Kenyan markets



Source: Lighting Global, "The Rise of Solar…", July 2015.

The generics market is opaque. Our estimates for generics are based on company interviews, in-depth studies of individual markets and customs data for exports of portable lighting products from China. This estimate has been kept simple and conservative – so the generics market may in reality be even larger than estimated.

Market participants report an impact on sales as the number of solar products available rises. Notably, competition from generics mostly affects lower-value segments such as basic portable lanterns, which have proven highly popular in markets like Tanzania. This reflects the ability of generics manufacturers and distributors to quickly react to market trends.

There are different types of generics, some of which overlap:

- No-names: Products offered by manufacturers who are not seeking to build brand value, or that distributors can brand or sell unbranded.
- Copycats: Products that are copies of familiar designs, with identical or similar features (colour, design and/or functionality).
- Counterfeits: Fakes purporting to be products made by widely recognised brands.
- Mixed-power solar: Some products have a solar panel of such low quality or size that they rely on grid charging or disposable batteries for extended use.

The emergence of a mass market in generics is associated with high volumes and low margins for manufacturers and distributors alike. The attraction of these products for retailers and consumers is lower prices, at times with a trade-off against quality. Not all generics are copycats, but these are likely to account for a significant portion. Direct copies of quality-verified products available on Chinese e-commerce platform Alibaba.com were on average 44 percent cheaper than the original version, according to our research (Figure 27). These products are sold in ports and trade centres, with traders tapping existing retail networks rather than building new ones or proprietary brands. They leverage the market-building activities such as consumer education by the sector's pioneer companies and take advantage of increasing consumer awareness of solar products.

Figure 27: Price of copycat versions relative to branded products, H2 2015

Source: Bloomberg New Energy Finance.

A sample of four copycat product types (n = 32) on Alibaba.com are on sale at 44 percent of the trade price of the brand versions on average. (This assumes the Alibaba products are supplied at the lowest sensible list price offered and given a 10 percent bulk discount.)

Generics risk undermining the sustainable growth of pico-solar markets, because lower-quality products that fail can put off newly-won customers from solar as a category. Market research by SolarAid in Tanzania showed customer satisfaction slipping from 97 percent for quality-verified brands to 60 percent for other brands due to lower product quality.[16] Consumers may not be sufficiently aware of quality issues in order to make an informed choice: the same study reported that while 80 percent of traders surveyed in Tanzania were aware of fake or poor quality solar lights, the figure dropped to only 26 percent among general consumers.

Counterfeits in some established markets make this risk specific: they pose a threat to brand reputation as well as damaging the market. They also prevent legitimate entrepreneurs from capturing the value they create. However, Lighting Global market research in Kenya last year found the share of actual counterfeits to be small, at 2 percent of available products and 2 percent of product sales.[17] Some companies reported that fake versions surged during their own supply shortfalls, for instance, due to working-capital constraints that stopped them meeting demand. Company responses have included working with customs authorities to penalise traders of counterfeit goods and reporting them through local media channels – which may be cheaper than battling through the courts.

The consumer responses to generic pico-solar products may be two-fold. Savvy consumers may already be making informed decisions about the trade-off between lower prices and quality: some may prefer a $4 light that may break in a matter of months over a $10 light that is more likely to last. If this is the case, it is not clear that quality will win in the lower-cost segment of the pico-solar market. On the other hand, new consumers' experience with solar products may be tarnished if they are unable to identify quality differences prior to purchasing, and are unwilling or unable to replace cheap products that break.

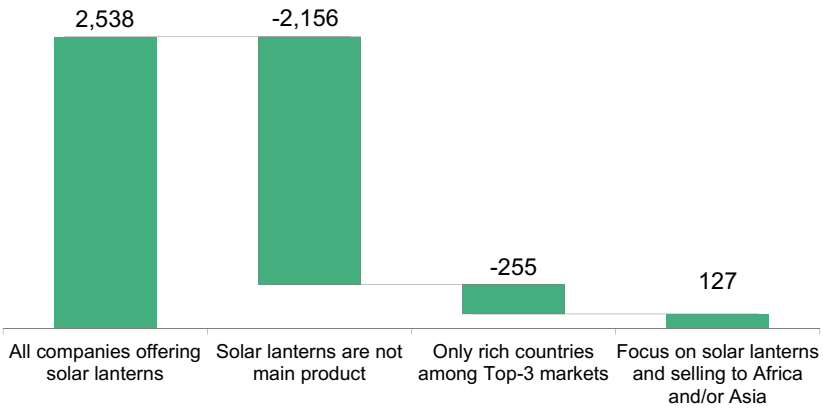
[16] SolarAid, "Research findings: Baseline and follow-up market research in Kenya, Tanzania and Zambia," June 2015.
[17] Lighting Global, "The Rise of Solar: Market Evolution of Off-Grid Lighting in Three Kenyan Towns," July 2015.

SCALE OF GENERIC SUPPLY

Generic products are readily available and easy for distributors to source

Branded and unbranded pico-solar products are readily available and easy for distributors to source. Multiple contract manufacturers offer a range of designs and copycats, and tailored products can be ordered through the same channels as any other simple electronic product. A search for the term "solar lantern" on the Chinese e-commerce platform Alibaba.com as of September 2015 returned more than 2,500 possible suppliers (over 96 percent of them Chinese companies). Only a small portion of them may be truly active in off-grid solar at the moment (see Figure 28). Whatever the actual figure, the presence of this number of potential suppliers that at least dabble in off-grid solar shows the scale of the industry that could ramp up production and wholesale of low-cost generics, if the market conditions were right for them.

Figure 28: Sourcing solar lanterns on Alibaba (number of suppliers)



127 of the 2,500 companies offering "solar lanterns" on Alibaba.com imply that they focus on selling solar lanterns in Africa and/or Asia.

To be conservative about the impact of these manufacturers on the pico-solar market, we focus only on the size of these 127 companies. They report their aggregate revenue at $1.4–$5.2 billion per year. Assuming, again conservatively, that only 10 percent of this revenue is comprised of solar lantern sales to Africa and Asia, they export products with FOB value of at least $140 million per year.

By contrast, the FOB value of reported branded sales to Africa and Asia in the year from July 2014 to July 2015 was $80 million.

Source: Bloomberg New Energy Finance, Alibaba.com. Note: Data retrieved in September 2015.

Much of the information around the size of the generics market compared to branded pico-solar products is anecdotal. Many companies interviewed over Q3 2015 mentioned an increase in products entering the market and increasing competition.

- In India, distributors of own-brand products discussed "hundreds" of other generic lanterns in the market, while an IFC study found that only 10 percent of solar lighting products observed in two Indian states were Lighting Global quality-verified.[18]
- In Pakistan, another IFC report found a similar result from interviews with importers: only 11 percent of pico-solar imports were Lighting Global quality-verified, with the majority being unbranded products.[19]
- SunnyMoney, the largest distributor in Tanzania, scaled back its operations there in mid-2015 citing "a huge surge in competition" from non-brand products that impacted its sales.[20]

Chinese customs data gives an additional sense of the scale of the market for portable electric lamps, including generic pico-solar products. In just the first half of 2015, 225 million such products were exported to sub-Saharan Africa from China.[21] The majority of them were almost certainly cheap battery-powered flashlights, followed by solar and other lanterns, but it is not possible to disaggregate the data. When all products with an export price of less than $2.50 are

[18] Garg et al. "Market Presence of Off-Grid Lighting Products in Bihar and Odisha," IFC, 2014.
[19] Grealish, "Pakistan Off-Grid Lighting Consumer Perceptions," IFC, 2015.
[20] SunnyMoney, "Tanzania and the price of success" 22 September 2015.
[21] Export data for products under HS category 851310, "portable electric lamps".

stripped out to remove low-cost LED flashlights and other small parts[22], there remain 20 million units exported to Africa in H1 2015 (Figure 29). Assuming that just 20 percent of them are pico-solar products – equating to 1.8 percent of overall unit exports from China in this category – the overall pico-solar market would total around 4 million units in sub-Saharan Africa in the first half of 2015. This figure is 2.5 times larger than the 1.6 million branded units identified from bottom-up data reporting. This suggests more than two generics are sold for each branded solar light.

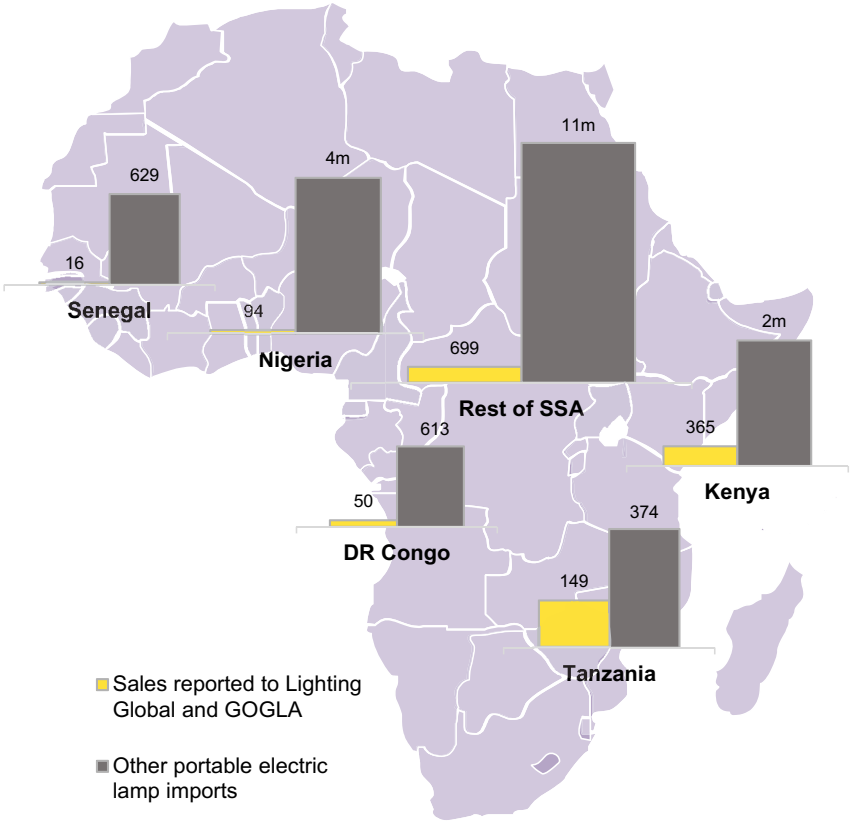
These are conservative assumptions: pico-solar lamps are likely to make up a higher proportion of overall exports, the $2.50 threshold probably excludes many cheap generic solar lanterns too, and solar lanterns also trade under other export codes. On the other hand, some of the low-value products may feature "cosmetic" solar only.

Table 1: Portable electric lamp exports to SSA from China, H1 2015

FOB price	Quantity (millions)
$0 to $2.50	205.4
$2.50 to $5	15.4
$5 to $10	3.5
$10+	1.1

Source: Bloomberg New Energy Finance, Sinoimex. Note: These include non-solar products.

Figure 29: Exports from China of all portable electric lamps with FOB value >$2.50 and reported sales of branded pico-solar products, H1 2015 (thousands of units unless stated)



Source: Bloomberg New Energy Finance, Sinoimex. Note: Export data for products under HS category 851310, "portable electric lamps" (flashlights, non-solar lanterns, solar lanterns, parts, etc.) of FOB price >$2.50. This price threshold excludes 205 million sales that are likely to primarily be flashlights. Retail value estimates use 1.5 times FOB price.

A WIDER MARKET FOR PORTABLE LIGHTING

The export data also show that there is a much wider market for portable lighting for people living off the grid or needing a backup for an unreliable electricity supply. Cost reductions for PV panels, batteries and economies of scale are making solar products increasingly competitive and

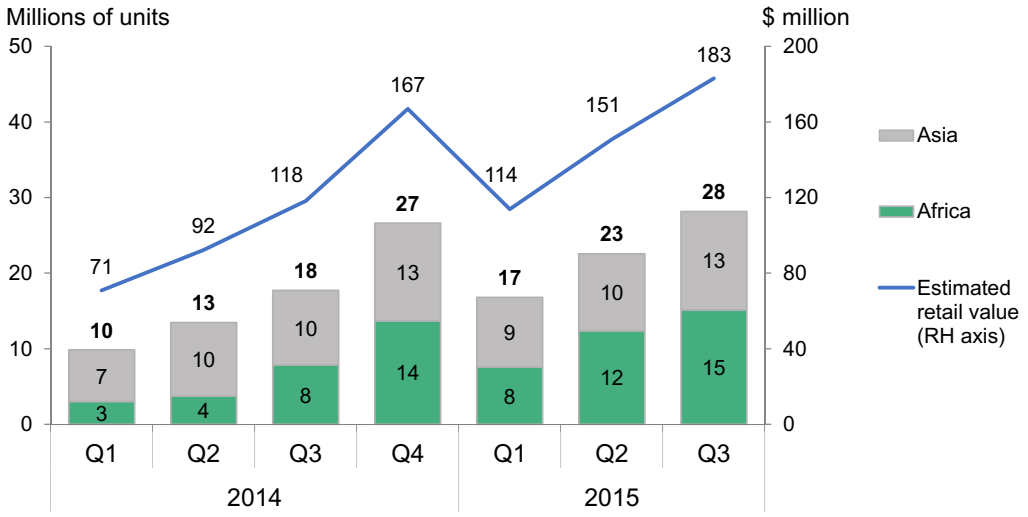
[22] The median price of an LED flashlight in Kenya was about $1.75, implying an FOB price of less than $1, so $2.50 is a generous threshold and likely excludes some pico-solar sales too. See Mills et al. "Low-cost LED flashlights and market spoiling," 2014.

affordable within this market. This also means that the manufacturers of cheap portable lighting products could themselves be well placed to enter the pico-solar market.

The wider market for portable electric lighting includes countries beyond the established markets for branded pico-solar products. For example, over 4 million portable electric lighting products with an export price greater than $2.50 were shipped from China to Nigeria in H1 2015, whereas reported pico-solar sales amounted to only 2 percent of that. This shows the scale of the opportunity in this segment for pico-solar companies.

Export data also offers an insight into the value of the total addressable market. Portable lighting exports from China to sub-Saharan Africa and Asia with a value greater than $2.50 amounted to 135 million units since the start of 2014, with estimated retail value averaging $0.5 billion per year (Figure 30). Including some LED flashlights and other cheaper solar products by lowering the threshold to $1 (which should still keep out small parts) boosts the market to 446 million units and $0.9 billion per year.

Figure 30: Exports from China of portable electric lamps with FOB value >$2.50 (millions of units, left-hand axis) and estimated retail value ($ million, right-hand axis), H1 2015



Source: Bloomberg New Energy Finance, Sinoimex. Note: Export data for products under HS category 851310, "portable electric lamps" (flashlights, non-solar lanterns, solar lanterns, parts, etc.) of FOB price >$2.50. This price threshold excludes 205 million sales that are likely to primarily be flashlights but also some cheap pico-solar products. Retail value estimates use 1.5 times FOB price.

The market in 2015 was consistently larger in each quarter than the year before – which may in part be explained by the rise of cheap pico-solar generics (though the data is insufficient to prove this).

3.4. THE DISTRIBUTION CHALLENGE

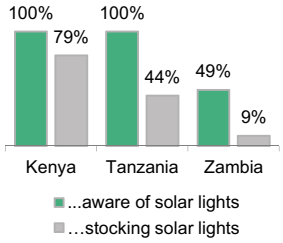
Last-mile distribution is becoming a crucial value driver

With increased competition and cheap generics entering the market through existing retail channels, last-mile distribution is becoming more important as a value driver. This is even more the case for the emerging PAYG segment, which relies on an ongoing customer relationship – and can create more value from this relationship too.

The distribution models adopted by pico-solar companies are diverse, especially for cash sales (Figure 32). Some operate their own stores and train their own sales agents – but also leverage existing retail networks, savings and credit cooperatives (SACCOs) and partnerships with NGOs and companies, among others. Other companies may focus on particular niches, such as

corporate employee offers within a particular industry, bulk sales to governments or humanitarian organisations, or choosing a specific franchisee for a new market.

Figure 31: Percentage of traders…

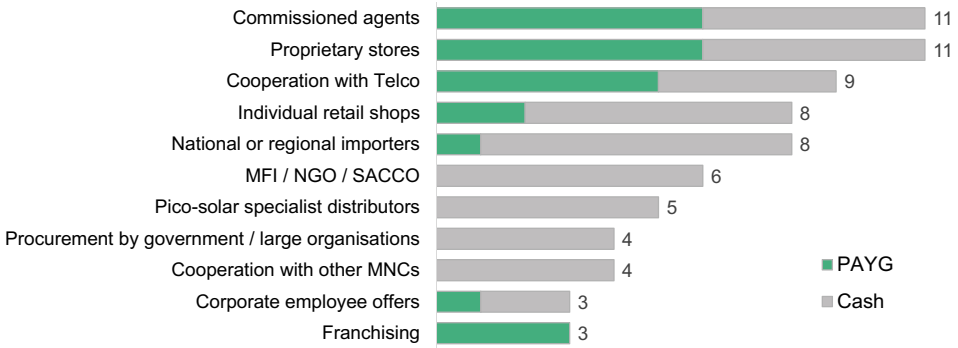


Source: SolarAid 2015. Note: The data are based on a study of 535 traders in 45 markets.

The most successful models for distributing branded products have largely incubated the market that exists today. They include Greenlight Planet's network of community-based sales agents in India, SunnyMoney's schools based programme in Tanzania, Kenya and other African countries – largely responsible for sales of more than 1.7 million quality-verified products – and distribution through Total's network of gas stations. A key aim of many of the early movers is to reach the rural poor who may not be well served by existing retail channels: hence they set up shops in smaller towns and send sales agents into schools and villages. This has also been important for building customer awareness about solar as a category.

One consequence of the proliferation of generics – and some new branded entrants – is that they tend to use existing retail channels which are concentrated in urban centres. If product diffuses from there to rural demand centres through informal channels, this may undermine the case for companies to invest in building their own proprietary distribution networks. On the other hand, it may increase the value of doing so, to address those in rural areas that are harder to reach, and offer a premium service and warranties.

Figure 32: Distribution models reported by market participants (number of companies)



Source: Bloomberg New Energy Finance interviews. Note: Responses from interviews with 30 companies. Multiple answers were possible.

Companies selling PAYG systems tend to invest more in local market presence

Companies selling products through PAYG usually need to invest more in building their own distribution networks and market presence, as they deploy higher-value products which often require installation and servicing. They also rely on an ongoing relationship with the customer. This typically involves a deeper presence, for instance due to the need to train sales and service agents and staff call centres. One market participant described this footprint as "building a new FedEx for the region". As they look to broaden their reach to new locations, some have started franchising their products and service models.

The rise of PAYG means that partners such as telecoms firms will have an increasingly significant role as service partners in the solar off-grid market, as pico-solar offers mobile-phone charging and PAYG payments often create additional telecoms revenue. It also means that distribution, as a way of creating and sustaining an ongoing customer relationship, has ever more importance – and potential value. This is explored further in Section 6.

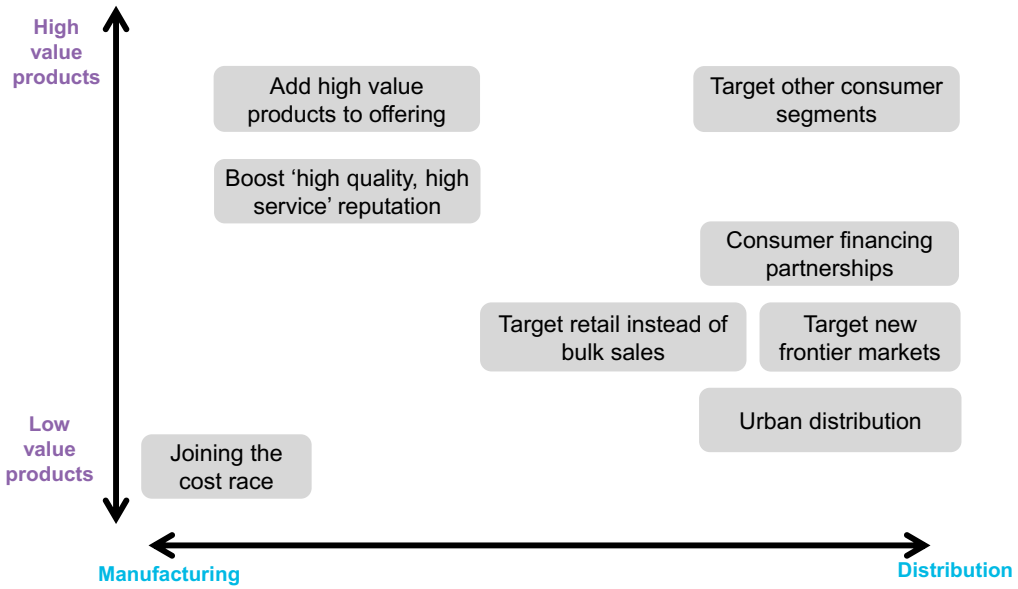
While the overall market penetration of pico-solar remains small, the experience of smaller regions can highlight how quickly uptake can accelerate once a certain threshold inflection point is crossed. In Kenya, the share of households owning a solar light (among those surveyed) rose

from 20 percent to 60 percent between January 2013 and December 2014, according to a SolarAid study.[23] The same study found that in Zambia the figure rose from only 4 percent to 7 percent over the twelve months through March 2015. Meanwhile, out of 535 traders of electronic products in 45 markets in Kenya, Tanzania and Zambia, all of those in Kenya and Tanzania were aware of solar lights as a product category (Figure 33). A majority of market traders in Kenya stock them. Pico-solar products are becoming mainstream retail products in areas where the market has been catalysed, and this new reality demands different company strategies.

3.5. COMPANY RESPONSES TO MARKET TRENDS

Low-cost generics force companies to adapt

Figure 33: Company responses to entry-level market commodification



Source: Bloomberg New Energy Finance

The trends of growing sales and consumer awareness, competition from low-cost generics and the increasing value to be found in distribution, have prompted companies to adapt fast (Figure 33). The responses seen already suggest some of the ways in which the rest of the market could evolve in the near-term. They include:

- **Focusing on higher-value products**: many of the branded lantern makers have recently launched more powerful, higher-value solar home systems among their product offerings. These may include PAYG-enabled devices, but can also just be larger home systems sold directly through cash sales. With higher retail prices, the bet is that consumers will be less price sensitive and value established brands for larger investments.
- **Focusing on downstream services**: solar companies with a strong distribution presence can focus on providing quality services, including warranties and after-sales care, and leveraging the client relationship. Often this will include creating a branded regional presence, for instance through certified service centres. This may mean some companies become less vertically-integrated over time, opening more opportunities for specialist service providers to offer B2B services such as wholesale sourcing or PAYG platforms.

[23] SolarAid, "Research Findings: Baseline and follow-up market research. Kenya, Tanzania & Zambia", June 2015.

- **Building brand identity**: with a race to the bottom on cost, brand value is increasingly important. Customers can be won and retained by a trusted name for quality products and service. The lantern market could split further, with a niche market for premium but still relatively low-cost products continuing beyond a mass market of lower-cost generics.
- **Forging new partnerships**: many companies are looking to strategic partnerships to leverage the brand recognition, balance sheets and distribution networks of other corporates. Some are also finding new partnerships to help with financial constraints. This may include microfinance institutions to roll out and finance new PAYG systems, or corporate partnerships to make employee offers.
- **Chasing new markets**: most branded product sales have been in India and East Africa. Many companies are actively expanding into other countries. Some companies are also trying to expand their urban sales presence, rather than focus exclusively on rural populations. Most companies are also establishing units trying to sell to a niche market for outdoor uses in developed markets or as back-up lighting in developing markets.
- **Joining the cost race**: some companies, including d.light, Greenlight Planet and Nokero, brought out new products in 2015 aimed at the low-priced end of the market. While most susceptible to cheap generics, they rely on brand, service, economies of scale and quality premiums to compete, as well as the reach of the companies' distribution networks.

Some of these approaches are opposites – for instance launching low-cost and higher-value products – but in some cases the same actors are trying both. The pico-solar market is entering a period of expanded experimentation as it evolves.

SECTION 4. PAY-AS-YOU-GO BUSINESS MODELS: THE WAY TO SCALE FAST?

Solar solutions are now firmly cost-competitive with stopgap technologies such as kerosene or battery torches when considering lifecycle costs, but the relatively large upfront costs remain a barrier for potential customers with no disposable cash. In the past few years, a number of companies, functioning as distributed energy services companies (DESCOs[24]) have started to develop and market products via a service model, classified as "pay-as-you-go systems". The term PAYG refers to a variety of technologies, payment rules and ownership and financing structures – but what they all have in common is allowing the end-user to pay for solar kits in affordable instalments and incorporating a technology-enabled mechanism to disable the system if a payment is overdue.

4.1. STATE OF THE PAYG MARKET

Firms that transitioned from a cash-sale focus towards a PAYG focus report faster sales

There are currently around 20 companies focused on technology-enabled PAYG solar solutions, according to our estimates. This is just about a fifth of all companies active in the off-grid solar sector (not including contract manufacturers and non-specialist exporters). However, firms that transitioned from a cash-sale focus towards PAYG saw substantial increases in consumer uptake, according to interviews undertaken for this study during Q3 2015. Meanwhile, several manufacturers of solar kits have launched PAYG-enabled solar kits or are expected to do so in the coming months. The sub-sector is very dynamic and it is likely that the number of companies offering PAYG services will rise significantly in the medium term.

Typical PAYG offering

The structure of PAYG companies' product offering varies a lot, as they experiment with different business models (Figure 34) and deliver a wide range of energy service packages ranging from simple solar lanterns up to solar systems greater than 200 watts. However, many businesses have the following in common:

- They offer a solar product, typically a home system consisting of a PV panel, a battery and control unit, two or three lights, a phone charger and sometimes other appliances.
- The customer typically makes an initial payment of around $30 for a basic home system, followed by regular payments of about $0.30-0.50/day for access to the energy services from smaller wattage systems and upwards of $2/day for larger systems. This cost is usually calculated so it is competitive with the daily expenditure on stopgap technologies, allowing customers to save from day one. However, this only applies to the most common models as pricing formats can differ substantially.
- Payments are often made via so-called mobile money, although there are alternative ways of paying, such as scratch cards, direct cash payments or using mobile phone credit. The home system is usually enabled to operate by instructions received via a built-in GSM chip or after the customer enters a code sent by SMS.

[24] Whereas DESCOs are a broad term encompassing different conversion technologies, this report focuses on DESCOs providing services through SHS/solar kits.

- Customers are typically charged per unit of time, not per kWh consumed. This means the risk of the sun not shining or of consumption needs exceeding energy supply is transferred to the customer.
- Depending on the business model, the customer either makes scheduled payments or can top-up their account at any time. When the account is empty or in arrears, the solar kit will stop functioning until a payment is made. The customer may either own the solar kit once a certain sum has been paid in (rent-to-own model) or make continuous service payments (perpetual lease or service model – in essence a distributed utility).

Figure 34: The building blocks for a PAYG business model (pick one or more options from each block)

Technology IP Proprietary License existing third-party solution	**Distribution** Proprietary channels Partnerships with established brands (ie telcos) Other third parties Third-party licensees	**Refinancing of loan extension** Prefinancing through equity / debt raising Factoring or securitisation Cash sale to licensee / distributor Microfinance Crowdfunding	**Customer vetting** Collect data through questionnaire / interview Rely on existing data from Telco distribution partners	**Payment options** Mobile money Payment through cellphone credit Scratch cards Manual (MFI or agents)
Technology size Simple lights Small SHS SHS				
Payment flexibility Fixed payment dates and terms Fixed terms with standardised grace period Flexible top-up	**Lease model** Rent to own Lease Perpetual lease	**Installation** Do it yourself Service technician	**Activation technology** GSM Bluetooth or cable System code Audio signal Manual	**Data collection** Anonymous data Personalised payment data + Delayed upload of system performance data + Real time system performance data

Source: Bloomberg New Energy Finance

Regional distribution of PAYG offerings

Most PAYG customers are in East Africa, but several companies are preparing for growth in West Africa as well

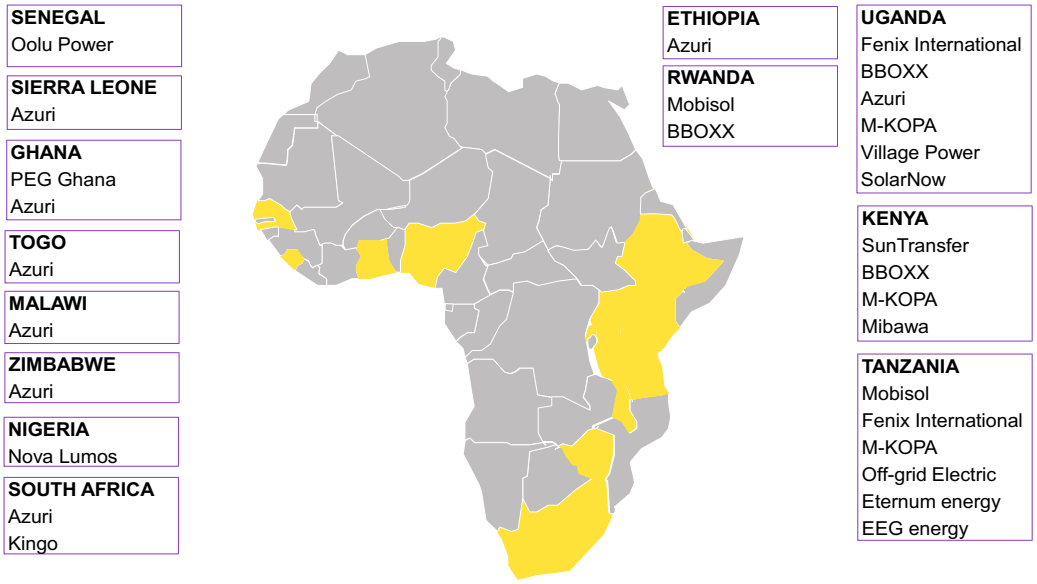
PAYG offerings are most common in Kenya, Tanzania, Rwanda and Uganda, where market leaders such as M-KOPA, Mobisol, Off-Grid Electric, Fenix International and BBOXX operate. These markets have a relatively large presence of off-grid solar products in general and tend to score highly among countries with a large off-grid population in the World Bank's "Ease of Doing Business" survey[25] as well as the 'Climatescope' clean-energy investment readiness ranking.[26] Still, some form of PAYG is available in 14 African countries (see Figure 35) as per Q3 2015.

The geographical spread of PAYG is likely to widen in the next twelve months, as new companies target less developed markets. In West Africa, for instance, Nova Lumos, PEG Ghana (an M-KOPA franchisee) and Oolu Solar are preparing for growth in Nigeria, Ghana and Senegal, respectively. Azuri systems are available in many countries through the firm's wide distribution network.

The PAYG market is most advanced in sub-Saharan Africa. Nonetheless, there are a small number of players elsewhere, such as Simpa Networks in India and Kamworks in Cambodia.

[25] World Bank Group, "Doing business: Measuring business regulations", See: http://www.doingbusiness.org/rankings (accessed 4 December 2015)
[26] Bloomberg New Energy Finance. DFID, USAID, Fomin, "Climatescope 2015". See: http://global-climatescope.org/

Figure 35: Pay-as-you-go solar lighting services currently available (portable lights and solar home systems)

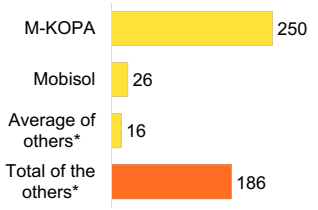


Source: Bloomberg New Energy Finance. Note: The list represents a sample and does not claim to be comprehensive.

Product offering

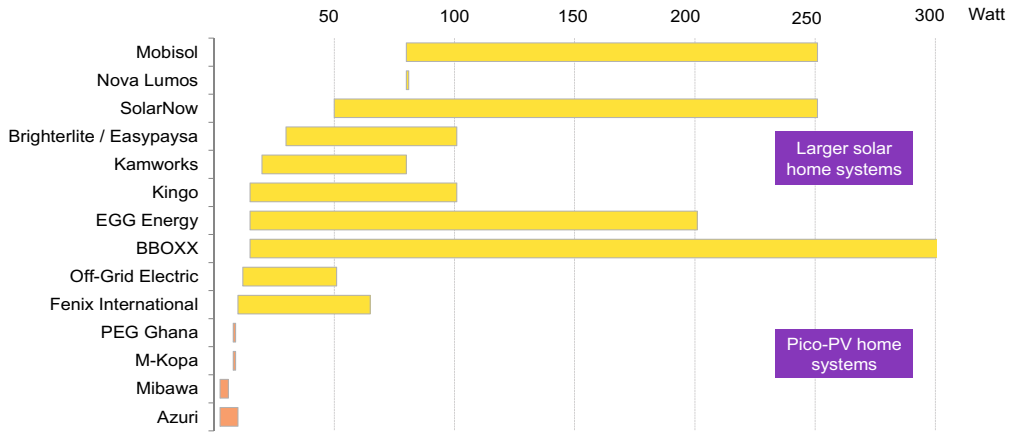
Some of the first commercial technology-enabled PAYG offerings, such as Azuri and M-KOPA, started with relatively small pico-PV kits. As a result of these early efforts, and due to M-KOPA's quarter-million household reach, such kits still dominate the PAYG market (see Figure 36). Still, the vast majority of new PAYG players, including those that attracted substantial investments, are offering much larger systems (Figure 37). The standard offering usually comprises a set of appliances such as 2-3 lights, a phone charger and a radio, the same as in pico-PV home systems. With a more powerful PV panel and battery, it is possible to connect additional appliances, which points to the up-scale potential that many PAYG companies seek to build into their business model from the start. TVs, for instance, are now on offer from some companies.

Figure 36: Cumulative sales of technology-enabled PAYG systems (thousands)



Source: Bloomberg New Energy Finance, M-KOPA and Mobisol websites. Latest data available as of end-Q3 2015.
** "Others" refers to BNEF estimates and privately shared data for 12 firms.*

Figure 37: Solar panel size of selected pay-as-you-go companies (W)



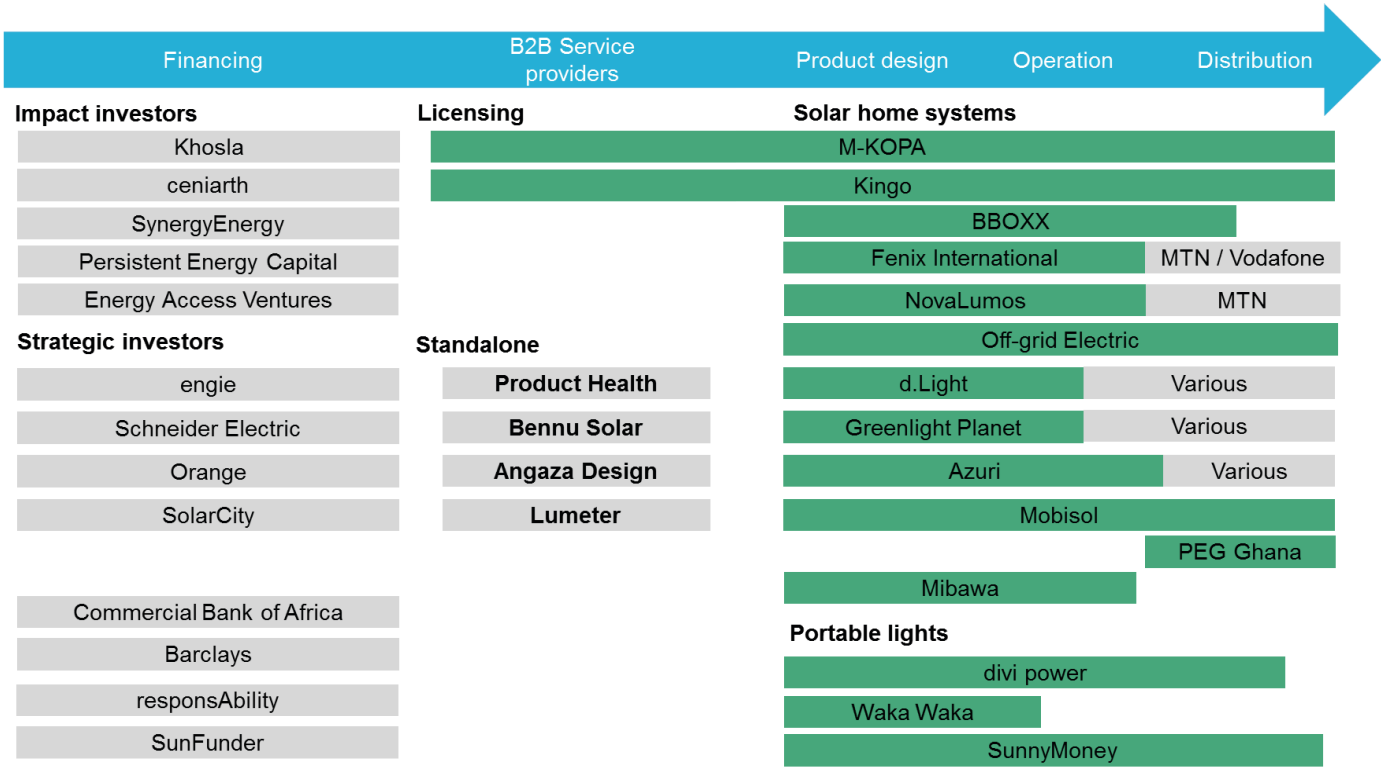
Source: Bloomberg New Energy Finance, company reports and websites, media reports.

Historical sales

By the end of Q3-2015, about 450-500,000 households were using a solar home system purchased through a technology-enabled PAYG deal, according to our estimates. More than half of these are M-KOPA customers. This company has by far the largest customer base, even though other companies may be providing more power due to their larger system sizes (see Figure 36). Mobisol, for instance, claims it had installed a total of 3MW in 30,000 households as of 2 November 2015.[27]

While the total market size (in terms of households reached) remains just a small fraction of off-grid solar market by unit sales, it is growing very fast. We estimate that at the beginning of 2015, households reached by PAYG stood at just over 200,000, which suggests the market has more than doubled in just the first nine months of the year.

Figure 38: Sample of PAYG players along the value chain



Source: Bloomberg New Energy Finance. Note: the list of companies is neither complete nor representative.

4.2. CONSUMER BENEFITS

PAYG allows consumers to save more money earlier and rise up the energy ladder with the same provider

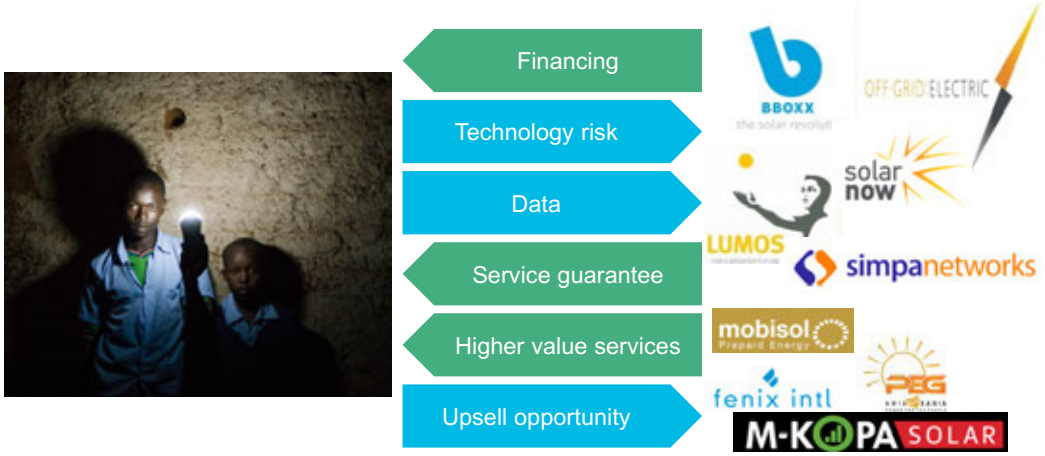
From the consumer's perspective, PAYG is a game-changer and far more than a financing solution added to a solar kit. It is obvious that reducing the upfront cost and shifting it towards instalments allows customers to gain access to systems that they could otherwise not afford. But that is not the only advantage for the customer:

- Getting access to solar kits earlier than they otherwise would, allows consumers to take earlier advantage of the superior economics of solar compared to stopgap technologies.

[27] Mobisol, "Mobisol installs 3MW PV on 30,000 African households". See: http://bit.ly/1OCg5q5

- Replacing stopgap technologies with cheaper alternatives earlier allows consumers to afford upgrades to bigger systems and more sophisticated appliances sooner.
- PAYG also shifts the risk that the technology will not function or that the manufacturer will not honour the warranty from the consumer to the distributor. Customers understand that the PAYG operator has a financial interest in the system working, which makes them more confident it will actually perform. If this inherent service guarantee is broken, the customers' downside risk is limited because payment is either conditional on service or has at least not yet been transferred.
- The close customer relationship and the trove of data that documents it, mean that the PAYG provider is well placed to offer tailored and affordable upgrades and progress the customer along the energy ladder.
- PAYG customers under a lease-to-own model may also make use of the PAYG activation technology to collateralise the asset once paid down. This would enable customers to purchase additional solar capacity, more appliances or even non-electricity products. Due to the mobile-payment element, such purchases could even be done remotely, for instance to pay for energy services for relatives living elsewhere. PAYG companies are also mulling the potential of using paid-down home systems as collateral for non-energy financing, thereby unlocking markets for pure-play consumer finance. This highlights that PAYG solar may eventually turn out to be an entry point to an untapped consumer market for a variety of other non-energy services.

Figure 39: The shift to PAYG changes dynamics between the customer and the provider



Source: Bloomberg New Energy Finance

4.3. RENT-TO-OWN VS. PERPETUAL LEASE

The value proposition for the customer is impacted by the operator's decision to offer either a short-term rent-to-own model or a pure service product, usually structured as a perpetual or very long-term lease (for instance, Off-Grid Electric's ten-year lease). The relatively lower refinancing requirements of a rent-to-own model would probably allow companies to reach more customers with the same amount of money, while reducing the risk for investors as money is repaid faster. Still, the deeper customer relationships built through the perpetual lease models are proving attractive to many new PAYG companies as they bet on extracting value from relatively large systems and future up-sell opportunities such as DC appliances or non-energy services.

4.4. PAYG ACTIVATION TECHNOLOGIES

At the heart of the PAYG model stands the system that ensures the customer remains incentivised to pay even after they have received the solar kit and the sales agent has left. There are a variety of ways to achieve this, ranging from manual systems to permanent wireless connections via GSM (see Table 3). Strictly speaking, the business model of offering a bundled service consisting of a solar home system and a loan has existed for decades. However, such set-ups do require a manual credit-check and often regular check-ins by collection agents. What we refer to in this publication as PAYG incorporates technology that enables remote device activation or shut-off.

System activation through the cellular network is most common

Table 2: Differences among PAYG companies' consumer-finance mechanism

	Rent-to-own (Product + finance focus)	Perpetual / long-term lease* (Pure service focus)
Impact on consumers	• Higher regular payments (for equal product specs) • Customer / cultural preference for ownership • Theoretical ability to collateralise assets after they are paid off	• Perpetual service guarantee reduces warranty anxiety
Impact on energy access challenge	• Raised capital can reach more customers due to faster cost recovery	• Lower regular payments widen the pool of potential customers
Impact on companies or investors	• Shorter duration of cash flows • Faster recycling of capital towards new customers • Broader diversification of debt capital across a wider customer pool • Potential for additional income streams from collateralised assets	• Longer duration of cash flows • Higher exposure to technology risk • Higher exposure to company execution risk • Higher exposure to currency risk • Stronger customer relationship • Better opportunities for upselling to larger systems or appliances
Examples	Fenix International, M-KOPA	Off-Grid Electric

*Source: Bloomberg New Energy Finance. *Some companies may use de-facto perpetual leases which are structured as a fixed-term lease with long tenor due to preferable local regulation.*

PAYG is most often associated with activation through mobile technologies, yet this is not always used. A full GSM connection built into the solar kit is the most common option for larger home systems, where the per-unit cost (and the data transmission costs) can more easily be absorbed in the total system cost and the value of system-performance monitoring rises. For smaller home systems, manufacturers often opt for devices without GSM connectivity. Instead, the customer receives a code on their phone and enters it into the device. This solution is usually cheaper, as it leverages the customer's existing phone. In the case of portable lights, even this can be prohibitively expensive. Entrepreneurs have therefore opted for either cable or Bluetooth-based activation mechanisms, whereby the GSM connectivity resides in the mobile phone of a network agent who must activate the device. An even cheaper alternative is modular devices where the PV panel can remain with a vendor until fully paid off. Such low-tech solutions admittedly stretch the definition of technology-enabled solutions used in this report.

The possibility that systems will be hacked is an important risk for distributors, particularly those without a deep local presence

Security of PAYG activation

Thus far in the PAYG market there have been scattered but significant anecdotes of devices being hacked. Not surprisingly, PAYG companies are protective about the exact technologies they have to ensure their systems can only be used if activated by the operator. However, it is in our view reasonable to assume that any security technology can be hacked with sufficient effort, even though system vulnerability will vary between companies. We anticipate the sophistication of

the activation technology will increase, but it is unlikely the risk can ever be fully mitigated. This puts a limit on the extent to which PAYG can be simply distributed as a product. Rather, companies developing deep relationships with their customers through service agents and offering long-term benefits to their customer base will be in a better position to reduce the incentives for breaking their security codes.

Table 3: PAYG activation and payment technologies

	GSM-enabled + mobile money	Bluetooth or cable connection	System code	Remote battery-charging	Manual*
How it works	Payment via mobile money is verified and system unlocked via a SIM card in the device	Payment can be made in cash or via mobile money and is confirmed on a phone which unlocks the device via Bluetooth/cable	An unlock code is sent via mobile phone after payment through scratch cards or mobile money. Code is entered in the device or through an infrared remote control.	The solar product is designed to allow separation of the charging unit from the light. The first remains at a vendor and the device is returned for charging. Typically used for very small lanterns where digital technologies are costly.	A loan with regular payments (possibly through microfinance)
Pros	• Allows for real-time remote performance monitoring • Allows for remote payments (eg. by relatives)	• Cheaper than GSM • Allows various payment methods • Allows activation by third-parties (such as kiosk owners) • Allows for delayed remote performance measurements	• Low cost • Does not require transport of any physical devices to unlock • Can be used anywhere regardless of network connectivity	• Low cost • Creates local employment • No mobile phone required	• No technology costs • Leverages existing finance solutions
Cons	• Relatively costly • Tends to require mobile-money infrastructure • Requires phone signal	• Requires network of local agents	• Prevents remote system monitoring without household visits	• Requires local payment • Inconvenient for customers	• Low security • Limited potential client pool • High transaction costs for MFI
Main application	Small home systems	Solar lanterns	Small home systems	Solar lanterns	Small and larger home systems
Examples	Mobisol, BBOXX, M-KOPA	diviPower, Angaza	Azuri, Fenix International	Karibu Solar	IDCOL program in Bangladesh, Selco Foundation in India

*Source: Bloomberg New Energy Finance *We do not define manual solutions as PAYG, but have included this alternative here for comparison. PAYG companies may use different activation technologies over time or in different markets.*

How new is PAYG in Asia?

Much of the media and investor attention on PAYG business models in the past few years has focused on East Africa and on firms offering what may be referred to as 'smart PAYG'. Still, bundled offerings of solar home systems with manual payment plans have been on offer in parts of India for almost two decades, from companies such as Selco partnered with micro-finance institutions or local banks. In Bangladesh, the World Bank-supported IDCOL program has created a market for bank-financed home systems that serve more than three million households as of 2014. These examples are excluded from the discussion of the PAYG business model here as they are fundamentally different, in that they lack a technology-enabled activation mechanism.

4.5. PAYG AND THE VALUE OF DATA

Closely related to the choice of the activation and payment technology is the decision about how much data a PAYG company should collect on its customers (Table 4). There are three main types of customer data used by PAYG companies:

- Many companies run an extensive survey collecting dozens of demographic data points on each potential customer before accepting them as part of a credit check.
- Wherever technology is used to pay for a system or activate one, a data point is recorded with each transaction.
- Larger systems often record performance and usage data that is relayed to a technician or a central database, either delayed or in real time.

While data is mainly collected either to improve operational decisions or as a side product of the payment process, many investors are confident that some of this data can eventually be valuable on its own. This value could either be unlocked by selling the dataset or expanding activities, for instance by extending credit to the best customers for purchases of other appliances such as TVs or clean cooking stoves. These same opportunities also highlight how the PAYG industry could be well positioned to take on at least some of the roles played by the retail finance industry in developed countries, such as credit scoring or collateralisation of assets.

Investors are keen on the long-term potential of PAYG usage and payment data

Fully automated PAYG offerings with tens of thousands of customers making multiple payments every month and real-time performance monitoring, produce a huge dataset that is well suited to advanced analysis. Several companies have reported using data scientists whose analysis can help make operational and financial decisions more effective. The vast amount of data that can be generated through these systems also highlights the need for advanced privacy and data-protection governance in its management.

Table 4: Datasets available to PAYG companies

Type of data	Internal use	Potential external value
Customer demographics (eg. gender, housing characteristics (floor and roof type, children, education, income, assets, existing debt, etc.)	• Customer vetting • Credit-risk analysis	• Consumer targeting for retail businesses • Consumer and credit intelligence for payment and finance providers
Payment data Number and frequency of payments, average payment size, frequency and timing of prepayments and delays/defaults.	• Targeted marketing for upgrades • Historical data for lenders	• Credit decisions to extend consumer debt or refinance assets • Credit decisions for insurances
Performance/usage data Usage and charging times, battery health, appliance detection, usage segmentation, anomaly detection, geographic location.	• Reduce operating costs • Predict and pre-empt system failures • Decrease downtime, improve service • Remote activation/deactivation • Locate devices for repossession	• Product improvement for appliance or kit manufacturers • Targeted or real-time advertisement accounting for use by retail businesses

Source: Bloomberg New Energy Finance

4.6. PAYG AND TELECOM PROVIDERS: A PERFECT PARTNERSHIP?

Telecom operators have emerged as a natural partner for the PAYG industry, largely because they are among the few brands in Africa that reach far into rural areas, and because many PAYG companies rely on the telecom industry's data networks and mobile-money systems. Several PAYG providers, such as M-Kopa, Fenix International and Nova Lumos, have partnered with telecom companies for distribution, selling equipment out of their stores. While some see this as

one of several sales channels, others sell exclusively through the telecom outlets to cut distribution costs.

Figure 40: M-Kopa system charging a mobile phone

Source: Bloomberg

Telecom firms play several roles in the emerging PAYG industry. They offer much of the infrastructure without which PAYG would be a far more complicated business model, including data connectivity and mobile-money transfers. More importantly, telecom firms may also benefit from increased uptake of PAYG. Several providers report that the largest users of local mobile-money infrastructure include some of their PAYG clients, who often promote its use and are even big enough to help balance urban-rural cash disparities. With telecom operators taking a cut on each transaction, they are set to benefit from more PAYG users. Easier access to electricity is also likely to reduce mobile customers' battery-life anxiety and allow for larger handsets, which may increase use of air time and data packages. Because of this important role in the PAYG infrastructure and the relative similarities in their business models, at some point telecom operators may consider engaging in the PAYG market directly or through acquisitions.

Table 5: The role of telecom operators in the PAYG energy industry

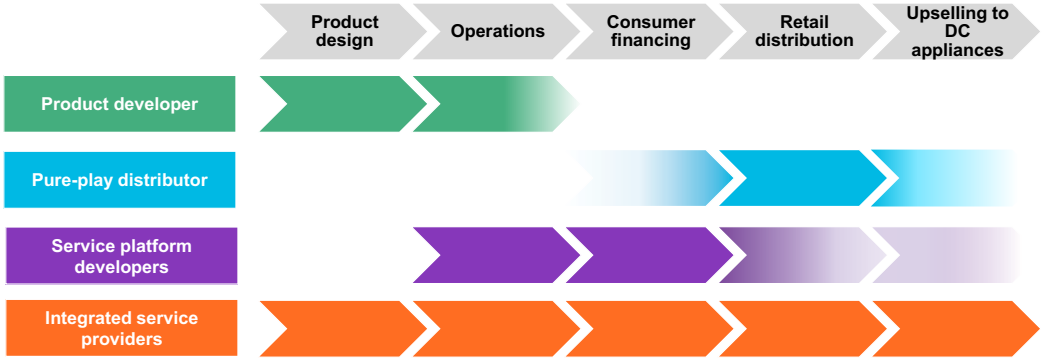
Telecom operator service to PAYG	Benefits for telecom operator	Benefits for PAYG companies	Importance for large solar home systems	Importance for portable lanterns and pico-home systems	Alternatives to PAYG
Distribution network	• Sales revenue share	• Wide reach • Brand recognition • Cost-savings from scale up	Low: larger systems usually requires local presence	Medium: Easy access to scale for PAYG companies without local presence	Proprietary distribution or other partnerships
Remote and wireless data transmission	• Data fees	• Remote monitoring of system performance	High: system-performance data improves operation cost for larger systems	Medium: GSM-enabled systems are often cost prohibitive	No remote collection of system-performance data. Data can still be locally stored and accessed by a technician.
Signal coverage at system location	N/A	• Direct system activation after customer payment	High: is required for performance-data collection	Medium: readily available alternatives although less user-friendly	Indirect activation through code received via SMS in central location such as a market.
Mobile money or payments	• Transfer fees • Boost mobile-money market penetration • May reduce urban/rural cash imbalance	• Automatic payment collection and accounting	High: required for scale-up	High: required for scale-up	Scratch cards or manual collection through agents. Both alternatives are costlier and less likely to scale.

Source: Bloomberg New Energy Finance

4.7. BUSINESS MODELS AND VALUE-CHAIN INTEGRATION

The various PAYG companies currently active in the market occupy different parts of the value chain, resulting in multiple growth strategies and, for investors, very different bets on where value is being created. The four PAYG strategies discussed below characterise the emerging differences. They draw on our discussions with most industry players but refer to stylized companies that probably do not precisely describe specific firms.

Figure 41: Pay-as-you-go business strategies



Source: Bloomberg New Energy Finance

Product developers include specialised B2B PAYG integrators and, increasingly, manufacturers of off-grid solar products. These companies develop the activation technologies and/or integrate them with solar home systems and usually offer a software back-end to manage customer accounts. They sell the product and license the software platform to their distributors against normal product payment terms. Many manufacturers of off-grid solar products are positioning themselves as PAYG manufacturers, highlighting the relatively low barriers to entry and the risk of tough competition, which is already eroding margins in this segment. Some manufacturers may be able to differentiate their products in the future by offering distributors supreme quality. If a more mature PAYG financing and distribution market is established, improvements in quality and value capture will most likely focus on making it harder for end-consumers to hack systems or on improving the software back-end to provide data that allows operators to cut service costs and default rates.

Pure-play distributors are aiming to create value by building strong distribution networks and customer relationships while maintaining maximum flexibility with regards to the type of equipment they deploy. They will focus on investing in distribution networks as well as raising debt financing. These companies either already have established distribution businesses or are aiming to build their own, which suggests they may well expand their offering beyond solar home systems given time. The need to raise debt financing makes it hard for many of the distributors specialised in off-grid solar to compete as PAYG distributors.

Platform developers will seek to scale rapidly across different regions

Service-platform developers are positioning themselves as strong middle-men by going one step further downstream than product manufacturers. They seek out partners that already have valuable customer relationships, for instance telecoms, and leverage their infrastructure and data as much as possible. This can include using existing shops and staff for sales and data used to screen customer applications. The platform developer provides the solar system, the operations platform and a tightly integrated CRM system, which give the distribution partner access to PAYG revenue with very limited capital expenditure. Because of the leverage from existing distribution networks and brands, platform developers may see very rapid growth in terms of households served once the partnership is proven. However, because much of the value is captured by the distribution partner, platform developers will most likely seek to scale rapidly across different markets with different partners in order to grow their business. Their focus is likely to be on mass sales of a small portfolio of products, centred on solar home systems. In addition, they may seek to upgrade existing customers to larger systems or appliances.

Integrated service providers are most likely to grow by selling more services in a relatively small region

Integrated service providers are closest to the traditional utility-business model in the off-grid market. They work along the entire value chain to ensure they can capture value at each node

and that all pieces work together smoothly. They tend to oversee product development and invest heavily in a local presence to guarantee distribution, servicing and maintenance. Often this means heavy investment in local shops and distribution centres, and training of local staff. The aim is to build lasting customer relationships and serve as a full energy-service provider. Eventually, most companies following this strategy will probably offer their customers a full set of appliances that can lift them up the energy ladder from simple lighting to more sophisticated services such as TVs and refrigeration, and possibly even productive uses for small businesses and workshops. Because they invest heavily in local presence, these companies usually would require a high density of customers. As a result, many of these companies will probably focus on specific regions and grow by extracting extra value from their customer base rather than rushing for geographic expansion.

Likely winners and losers

PAYG manufacturing will become crowded soon

The manufacturing market will probably become crowded soon, which will erode profit margins and shift value capture downstream. These are the same dynamics as in the cash-sale market. The need to refinance the credit that PAYG companies extend to consumers will lead to strong economies of scale. So, while small companies are less likely to have the necessary balance-sheet funding and expertise to refinance outstanding loans, firms with a large customer base will be able to produce the historical data needed to access debt capital. As a result, most of the growth in terms of households reached could well come from service-platform developers that can leverage strong distribution partners. Meanwhile, integrated service providers are most likely to propel a smaller number of customers high up the energy ladder in markets with a particularly friendly business environment. Most PAYG solar kits are likely to remain solar home systems, as cost reductions for portable lanterns will mean cash sales remain most popular in that segment. Some lanterns are nonetheless likely to be sold under PAYG as well, in particular to consumers not familiar with pico-solar where consumer financing can build trust in the technology.

4.8. SAMPLE PAYG COMPANY PROFILES

M-KOPA[28]

250,000 households were using M-KOPA's 8W solar home system by September 2015, according to the company. The kit is available in Kenya, Tanzania and Uganda against an initial deposit of just under $30 and daily payments of roughly $0.40 over the course of a year. Customers typically collect the system in an M-KOPA service centre or an affiliated M-KOPA dealer and make payments via mobile-money services such as M-PESA. The firm employed over 650 full-time staff in its three main markets by May 2015. It has also started to license its technology to PEG Ghana[29].

AZURI[30]

Azuri offers the Indigo Duo and Azuri Quad solar home systems. The firm manufactures the systems and sells them to local partners who handle distribution, installation, servicing and consumer financing. Azuri provides in-country infrastructure that allows consumers to top-up their systems via SMS and makes the accounting software available to its distributors. Customers typically pay off a system over 18 months.

[28] M-KOPA website. See: http://www.m-kopa.com/ (accessed 1 December 2015).
[29] PEG Ghana website. See: http://www.peg-ghana.com/#peg-ghana (accessed 1 December 2015).
[30] International Energy Agency, Dr. Thomas Meier, "Innovative Business Models and Financing Mechanisms for PV deployment in emerging Regions", PVPS Task 9, Subtask 5, December 2014.

OFF-GRID ELECTRIC[31]

Off-Grid Electric is a for-profit social enterprise that offers 'solar power as a service' to off-grid customers in Tanzania and Rwanda. The company is active across the full value chain, from design and manufacturing to installation and servicing. Its sales efforts include door-to-door sales and a network of local businesses and agents. Payments are collected via mobile money and the customers own their system after 10 years of payments.

MOBISOL[32]

Mobisol is a Berlin-based provider of PAYG solar home systems ranging from 80-200W – enough to power a variety of appliances on top of lighting, phone charging and radios. The company reported on 2 November 2015 that it is serving 30,000 households in Tanzania with a total of 3MW of PV capacity. The firm's customers pay their 36 month instalment plan via mobile money, and their payment includes a service plan over the entire three-year warranty period. Mobisol systems include a GSM modem, and the firm puts particular emphasis on its proprietary IT backend which also serves as a customer-relations management platform.

NOVA LUMOS

Nova Lumos is partnering with MTN to distribute its 80W Lumos Solar Power Station in Nigeria, making it currently the only PAYG provider in Africa's largest economy. Customers join the service at the local MTN retail outlet, take home a system, install it and activate it via airtime payments. Nova Lumos eliminates the need for on-site servicing through its remote tracking and puts emphasis on its anti-theft technology. Customers pay for the service via text messages through MTN, and receive a five-year warranty on their kit.

4.9. FUTURE OF PAYG BUSINESS MODELS

While sales from PAYG companies make up less than 2 percent of unit sales to date, PAYG companies have already attracted more investment than all cash-sale companies together (see Section 6).

Upsides to the PAYG model

Investors bet that value will be captured in distribution and financing, not in manufacturing

The PAYG business model is likely to continue to attract new entrepreneurs and investments in the coming years, because:

- Entrepreneurs and investors bet that more value can be created and captured by focusing on the material matters like distribution, financing and customer relationships, rather than on low-margin activities like manufacturing.
- Entering the PAYG business is becoming more accessible to companies as solar kits and back-end software that enable PAYG become available off the shelf.
- Customers will become more familiar with the business model, reducing the cost of customer acquisition.
- Governments of countries without existing offerings may see success elsewhere and try to attract PAYG companies.
- Off-grid solar, and PAYG in particular, has the potential to be relevant to established corporates in a variety of industries, which means some of them may fund or buy PAYG start-ups. Some firms have already attracted funds from different industries, such as equipment manufacturers (Schneider Electric), utilities (EDF), mobile operators (Orange) and solar

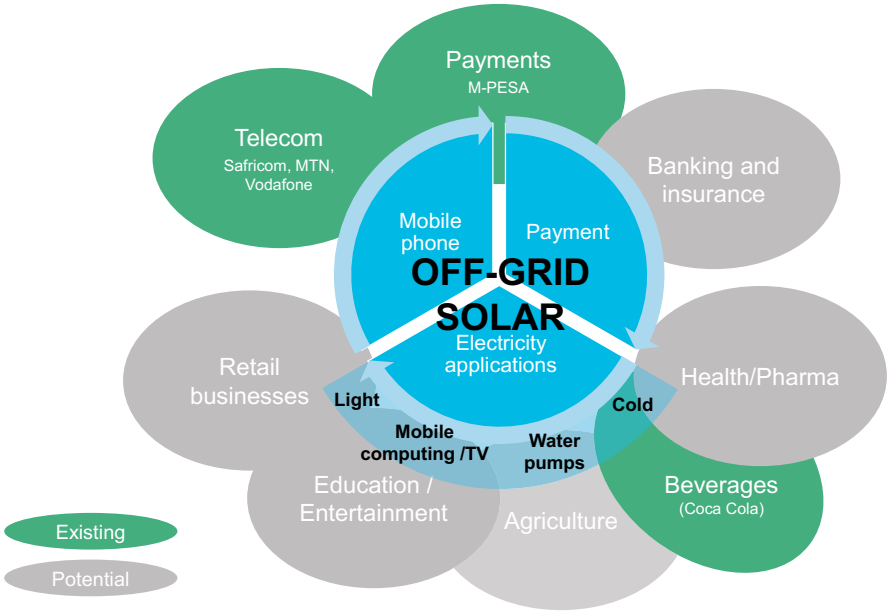
[31] Renewable Energy World, "Off Grid Electric raises 425m to help power a 'solar revolution' in Africa", Jennifer Runyon, 22 October 2015. URL: http://www.renewableenergyworld.com/articles/2015/10/off-grid-electric-raises-25m-to-help-power-a-solar-revolution-in-africa.html

[32] Mobisol website, URL: http://www.plugintheworld.com/mobisol/product/. Accessed 1 December 2015.

distributors that were previously focused on the grid-connected market (SolarCity). The overlaps with the money transfer, banking and financing business could also spark interest among financial intermediaries at some point, while beverage and pharmaceutical companies may well be interested in off-grid solar solutions that can offer solar-powered refrigeration. Coca Cola, for instance, already has a partnership with SolarKiosk[33] (see Figure 42).

- Even without partnerships with such established players, it is possible that investors and entrepreneurs will push ahead and create these services from scratch, with off-grid solar as a door opener.

Figure 42: Existing and potential cross-industry partnerships



Source: Bloomberg New Energy Finance. Note: the list of companies is neither complete nor representative.

Challenges to the PAYG industry

Despite this upside, there are many challenges remaining that are likely to slow the growth of the PAYG industry.

- **Long lead times:** creating a PAYG offering requires a relatively long lead time due to the company infrastructure that needs to be built. All major PAYG companies have continuously tested, refined and pivoted their business model for 2-3 years or even more before starting to scale. Off-the-shelf PAYG technologies may shorten this a bit, but it will be hard to cut lead times on things like incorporating in countries with inefficient bureaucracies or testing local preferences, not to mention building the operational capacity to efficiently distribute and maintain tens of thousands of systems.

PAYG's relatively high barriers to entry attract investors, but could also slow industry growth

- **Geographical differences:** it is unlikely to be a coincidence that PAYG models are flourishing in East Africa, and in Kenya in particular. The region has both a relatively business-friendly environment with a well-established telecoms and mobile-money infrastructure, which facilitates PAYG. It is likely that PAYG will develop on a similar path as was experienced by the mobile-money industry, which has reached very high penetration in some countries but has yet to develop elsewhere. It is possible that limited mobile-money infrastructure will slow the supply of PAYG services in those countries as well. However,

[33] See Coca Cola Ekocenter. URL: http://www.coca-colacompany.com/ekocenter/ Accessed 4 December 2015.

given sufficient demand for energy, PAYG could also serve as an uptake driver for mobile money. Similarly, countries with a relatively rich population but an undeveloped or extremely unreliable grid, such as Nigeria, may see more demand for outright purchases of large solar home systems and appliances.

- **Demand for debt financing** to fund PAYG businesses and those distributing large solar home systems in particular, will continue to outstrip supply for the foreseeable future. This is likely to be the case even if investment continues to grow rapidly. Debt funding activities in new countries where no PAYG track record has been established may be even harder as financiers put a premium on historical data over smaller competition. This would slow the pace at which PAYG offerings reach new markets. Challenges of PAYG financing are discussed in more detail in Section 6.
- It is possible that a **failure of a PAYG start-up** could raise concerns about the risks inherent in early-stage PAYG companies, thus making it significantly harder for other companies to raise funds. Many market participants consider this risk quite low as most PAYG companies are still in their infancy and a high-profile and clear cut failure is therefore unlikely.

A discussion of PAYG financing and the long-term outlook for PAYG can be found Section 6 and Section 8.

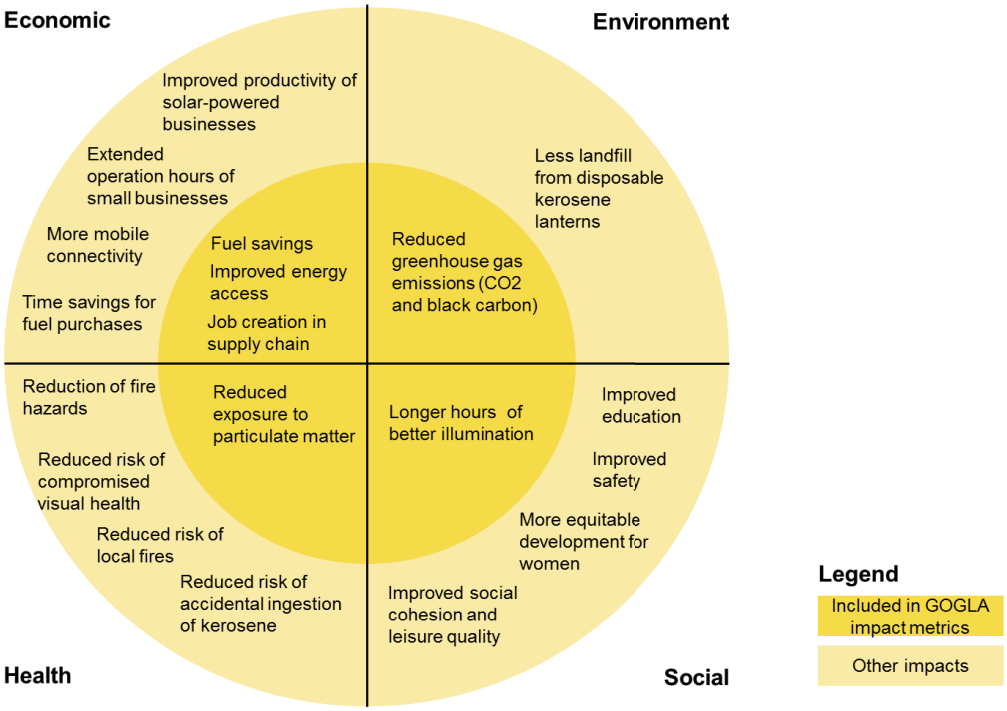
SECTION 5. SOCIAL, ECONOMIC AND ENVIRONMENTAL BENEFITS OF SOLAR-BASED ENERGY ACCESS

The most obvious and direct impact of pico-PV systems is in providing people with a cheaper and cleaner alternative to the stopgap technologies that they are currently dependent on. Gaining access to clean and affordable energy saves consumers money, reduces exposure to toxic materials released when burning kerosene and cuts greenhouse gas emissions. In addition, money and time that is freed up will probably be redirected in part towards doing more work or getting more education. Replacing kerosene also reduces fire risks and may improve the confidence and comfort of families and entire communities. These indirect benefits tend to be harder to measure, but it is generally agreed that they are very likely to occur (Figure 43). This section examines the wider socio-economic impacts of off-grid solar.

About 7 percent of people living off grid have a pico-PV light at home

The assessment combines a desk-based, top-down evaluation of the impact of solar lighting using GOGLA's Standardised Impact Metrics methodology[34] with 'Notes from the field' that summarise relevant findings and conclusions from several academic or company-sponsored bottom-up reports.

Figure 43: Direct and indirect impact of Tier 1 energy access



Source: Bloomberg New Energy Finance

[34] See: http://global-off-grid-lighting-association.org/working-groups/social-impact-measurement/

5.1. ACCESS TO BASIC ELECTRIC SERVICES

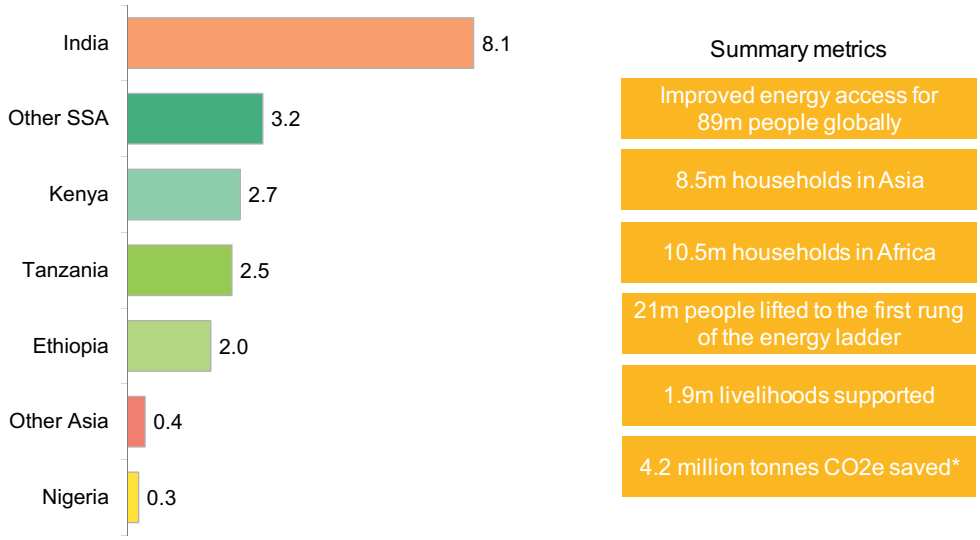
TOP-DOWN ASSESSMENT

We estimate that the pico-PV industry currently reaches 89 million people in Africa and Asia, living in a total of 19 million households and reaching about 7 percent of the total off-grid population. The countries with the most people using pico-PV are of course correlated with the most active markets for such products: India, Kenya, Tanzania and Ethiopia (Figure 44).

Stand-alone solar systems can lift millions of people to the first rung on the energy ladder

Our estimates are based on the number of cumulative sales to date and the average household size in those countries, but also account for replaced products and repeat purchases by households using more than one solar light.

Figure 44: Estimated number of households using pico-PV (millions, June 2015)



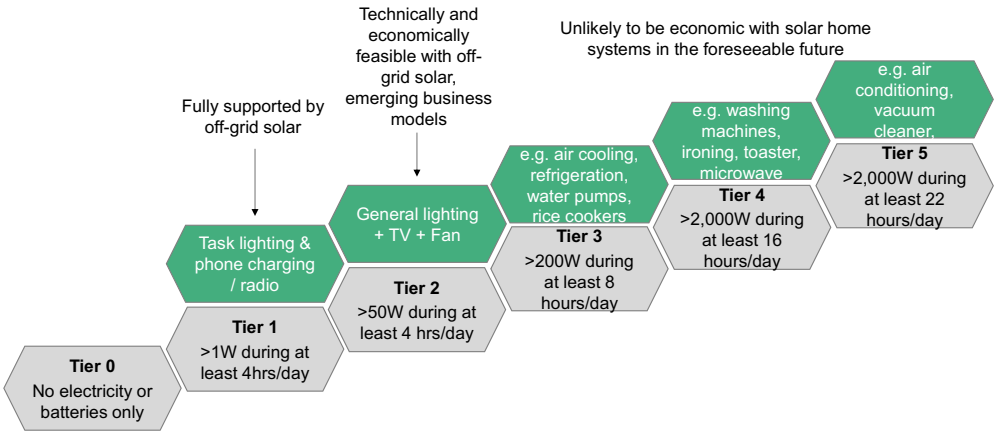
Source: Bloomberg New Energy Finance, Lighting Global, GOGLA. Note: Calculations assume 10 percent repeat sales, 3 percent loss, product lifetime of 1.5 x warranty period, repurchase after 3 years and deduct 80 percent of unbranded products. Livelihood figures assume 10 percent of customers use products for small businesses. Does not include supply-chain livelihoods supported.
**Cumulative emission reductions over the useful life period of Lighting Global quality-verified products only.*

A household with only a basic solar lantern is not considered fully electrified. The UN's Sustainable Energy For All (SE4All) initiative has defined a portable solar light that delivers a minimum level of energy services (defined below) as meeting the definition of Tier-1 energy access, also defined below (see Figure 45). All solar lanterns that have been quality-verified by Lighting Global sold to date provide enough Tier 1 energy services for 25.6 million individuals, under the SE4All definition. We estimate that all currently operational systems provide Tier 1 energy services sufficient for 21 million individuals – 13.5 million in Africa and 7.3 million in Asia (see box below for methodology). This number suggests that pico-PV has the capacity to lift millions of people to the first rung on the energy ladder through the commercial provision of simple stand-alone products.

New products with larger capacities and the emergence of PAYG business models, which often provide larger systems and appliances, suggest that the industry will also be able to help its customers reach Tier 2 energy access. Many off-grid solar companies are already offering appliances that go far beyond simple task lighting, with TV's being the most popular option both

for sellers as well as for consumers, closely followed by cooling appliances such as fans or refrigerators (Figure 46). [35]

Figure 45: SE4All characterisation of electricity access tiers



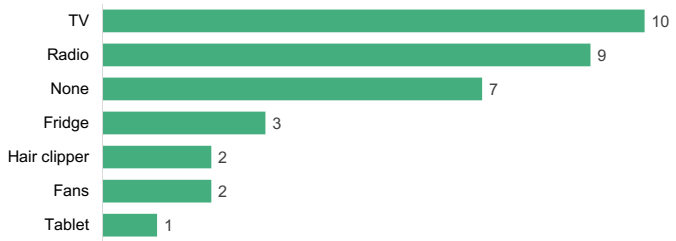
Source: SE4All[36], Bloomberg New Energy Finance. Note: Power supply also needs to cover at least two evening hours for Tier 1-3 and four evening hours for Tier 4-5, be affordable for Tier 2-5, and be of reliable quality and legal access from Tier 3-5.

NOTES FROM THE FIELD

Nomads may prefer portable lanterns over home systems or mini-grids

- A study of 483 households in Uganda using the d.Light D20g solar home system found that on average they used an additional 2.9 hours of lighting, while reducing the hours of lighting from low-quality sources by 63 percent.[37] The study reports that kerosene or battery torches continued to be the primary source of lighting in 13 percent of households owning the D20g. Only 28 percent of households used their solar system exclusively after purchase.
- The immediate portability of Pico-PV systems means they are preferred by nomadic populations and people living in vulnerable locations such as river islands that flood regularly and who require frequent relocation.[38] In those circumstances, the portability may serve as an advantage over more powerful solar home systems, rather than just as a second-best solution for those that cannot afford to trade up.

Figure 46: Which DC appliances are you offering? Interview responses from 26 manufacturers, distributors and PAYG companies



Source: Bloomberg New Energy Finance interviews. Note: Multiple answers were possible.

[35] Global LEAP, "Off-Grid Appliance Market Survey", April 2015.
[36] SE4All, "Global Tracking Framework, v.3".
[37] D.Light, IDinsight, USAID, Shell Foundation, UK aid, "d.Light Solar Home System Impact Evaluation", November 2015.
[38] Yuya Kudo, Abu Shonchoy, Kazushi Takahishi, "Impacts of Solar Lanterns in Geographically Challenged Locations: Experimental Evidence from Bangladesh", IDE Discussion Paper No. 502, March 2015.

Figure 47: Niwa Uno 50

Source: Lighting Global

Figure 48: d.Light D20

Source: d.Light website

Methodology: How did we estimate how many people are using pico-PV?

We have used two metrics to determine how many people are currently using pico-PV:

Method 1: People living in a household with at least one functional pico-PV product (89 million globally)

We calculate this number as the cumulative historical sales of pico-PV products, adjusted for products that have exceeded their useful lifetime (three years on average) and adjusted for losses (3 percent) and repeat sales (10 percent). This methodology is aligned with GOGLA's impact metric 1aii. The figure measures the number of people that live within reach of a pico-PV product and are likely to be directly impacted by it. We estimate this number at 89m by mid-2015, taking into account pico-PV products that are quality-verified as well as other branded and generic ones. However, the majority of pico-PV products sold in the past were in the lower price range (<$20) and tend to be simple task lights that can probably only serve one user at a time.

Method 2: People that have been lifted to at least Tier 1 energy access thanks to pico-PV (21 million globally)

As part of its contribution to the SE4All initiative, the World Bank with support of Lighting Global developed a methodology that calculates how many household members are lifted to Tier 1 energy access based on performance metrics for any Lighting Global quality-verified product (the 'SE4All factor'). For instance, a simple portable lantern such as the Niwa Uno 50 has an SE4All Factor of 0.65, whereas a solar home system such as the d.light D20 has a factor of 5 (see Figure 47 and Figure 48 respectively). Using this methodology and multiplying all quality-verified pico-PV sales by their SE4All factor, we conclude that pico-PV product sales reported to Lighting Global provide sufficient energy services to lift 21 million people to the first rung of the energy ladder. It is likely that the market has provided the same service to even more people, but we were unable to estimate this figure as SE4All factors are only specified for quality-verified lights. This methodology follows GOGLA Impact metric 1b and makes the same adjustments as method 1 for repeat sales, losses and useful lives.

CAN OFF-GRID SOLAR PLAY A ROLE BEYOND BASIC LIGHTING AND PHONE CHARGING?

The concept of the energy ladder suggests that successful electrification using modern off-grid technologies proceeds gradually, rung by rung, from kerosene to portable solar lanterns to ever more powerful home systems. In theory, the rapid payback period of portable solar lights compared to kerosene suggests that an off-grid household can save $20-40 a year by purchasing even a mid-range portable light in Africa and many Asian countries. This means that after about one year, even a cash-strapped household should be able to save enough for a typical down payment to purchase a small SHS with consumer finance through a micro-lender or a PAYG service such as M-KOPA. The same logic could then be applied to upgrading to a more powerful SHS or to the purchase of appliances such as a fan or a TV, either by re-financing the first unit or by selling it on the second-hand market.

In practice, there is little and only anecdotal evidence for this pattern and it is unlikely to be observed in this stylized form. However, distributors do say customers are returning for secondary or upgrade purchases and that demand for appliances is high. Distributors are keen to offer these (see Figure 46). Basic portable solar lights play an important role as a low-cost option for customers to experience solar technology for the first time. Off-Grid Electric's COO Erica Mackey said her company found it "much easier to penetrate markets where customers have already had

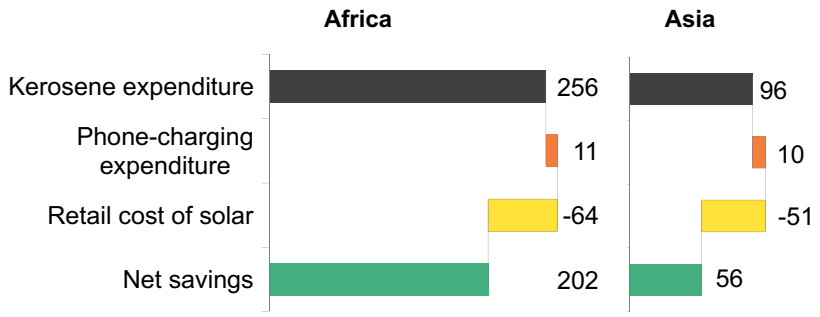
a positive experience with solar products. We spend much less time educating customers […] as they have already built trust in solar technology and there are much higher levels of demand."[39]

The solar kit market beyond energy access

Portable solar lights and solar home systems tend to be viewed through the energy-access lens – they are seen as providing people living far away from the grid, at the very bottom of the income pyramid, with basic lighting and perhaps a few appliances later on. However, companies selling off-grid solar report a different experience. Often, demand is strongest for the larger, more expensive systems. Manufacturers of portable lanterns say customers use their equipment as a back-up for the frequent black-outs that affect most grid-connected households in many developing countries. This phenomenon is likely to drive demand for solar home systems and efficient appliances not just from people moving up the energy ladder from kerosene, battery torches or candles, but also from people and businesses that are being pushed down the energy ladder by unreliable grids, despite rising incomes. These people tend to be wealthier and with easier access to cash, and the convenience and economics of solar and storage look similarly convincing for them as in the pure off-grid setting. It is not difficult to imagine how solar kits could become an integral part of the daily experience of this population, if local grids fail to meet power demand. Some manufacturers and distributors are already reporting that they target sales in urban areas, even of portable lights. These are most likely used as back-up lights during power outages. Larger systems can enable back-up lighting for an entire home, or even security lighting or small appliances.

5.2. SAVINGS AND ECONOMIC IMPACT

Figure 49: Estimated savings from quality-verified pico-PV systems sold between July 2014 – June 2015 ($ million)



Source: Bloomberg New Energy Finance, Lighting Global, GOGLA, UNEP. Note: The figures represent GOGLA social impact tracking metric 5b. Assumes single solar light systems replace one kerosene light and SHS replace two kerosene lanterns with running costs between $11-40/light, depending on the country and kerosene subsidies. Assumes mobile-phone charging costs of $0.20 and one charge per week per household. Solar product lifetime = 1.5 times warranty period. Refers to sales of Lighting Global quality-verified products only.

[39] Quoted in SolarAid, SunnyMoney, "Impact report", Autumn 2015. See: http://global-off-grid-lighting-association.org/wp-content/uploads/2015/11/SolarAid-IMPACT-REPORT-2015.pdf

TOP-DOWN ASSESSMENT

Lighting Global quality-verified lanterns sold last year will save their users $258m

Once purchased, a solar light in theory leads to direct cash savings from avoided use of stopgap technologies. Because of the favourable economics of solar power, these savings account for a multiple of the market value of solar lights. We calculate that just the 4.9 million Lighting Global quality-verified solar lights sold between July 2014 – June 2015 will provide savings of $258 million over their lifetime of 2-3 years, compared with a retail value of $111 million, according to our calculations based on the GOGLA methodology (see Figure 49). In Africa, every dollar spent on solar lighting will ultimately save consumers $3.15, hence money that would otherwise have been spent on conventional lighting sources is redirected towards other purchases in the local economy such as more energy services, education, food, entertainment, and other consumer priorities. In Asia, the ratio between pico-PV spend and savings is closer to 1:1 as the heavy subsidies for kerosene reduce the scope for savings from solar. However, total savings to both consumers and the government together would probably be similar to those in Africa, if avoided government subsidies are taken into account.

NOTES FROM THE FIELD

Household expenditure in Bangladesh dropped 2-7 percent after receiving a solar light

- A field study in rural Rwanda undertaken in 2014 found that households save $0.95/month after adding one pico-PV light, mainly by avoiding expenditures on kerosene and, to a lesser extent, on batteries. The figure amounts to around 2-3 percent of total monthly expenditure by these households.[40] A similar study in Bangladesh found household expenditure dropped by 2-7 percent[41] after households switched to portable solar lights. The savings are notably lower than is assumed in desk-based studies, partly because the participating households have not fully replaced kerosene lighting on a 1:1 basis but rather expanded the number of lights available to them. This behaviour may differ when consumers purchase pico-PV systems rather than receiving them free of charge, as was the case in both studies.
- The same field study in Rwanda also found that phone- and radio-charging capabilities were rarely used as battery charging capacity was limited and users prefer light access if they must choose between the two. The study also reported that mobile-phone charging was limited by technical barriers such as unsuitable adapters.
- The d.Light study of solar home system users in Uganda found that household expenditure on energy actually increased due to the regular payments made towards the $240 cost of the unit. This highlights that demand for high-quality solar lighting is there, but the market is constrained by financing and supply gaps.
- A BBOXX-sponsored study[42] conducted in 2012 estimated monthly savings of $16 a month for a client household in Uganda. The figure is relatively large due to the size of BBOXX systems used in the study (15-180W) and also because it includes $5/month of estimated savings associated with medical treatment and avoided transportation to fuel retailers.

[40] Michael Grimm, Anicet Munyehirwe, Jörg Peters, Maximilane Sievert. “A first step up the energy ladder? Low cost solar kits and household’s welfare in rural Rwanda”, IZA Discussion Paper No. 8594, October 2014.
[41] Yuya Kudo, Abu Shonchoy, Kazushi Takahishi, “Impacts of Solar Lanterns in Geographically Challenged Locations: Experimental Evidence from Bangladesh”, IDE Discussion Paper No. 502, March 2015.
[42] Enea consulting, “Social Impact Assessment of BBOXX in Uganda”, December 2012.

5.3. IMPACT ON THE LOCAL ECONOMY AND SMALL BUSINESSES

TOP-DOWN ASSESSMENT

Off-grid solar directly increases revenue for small businesses

GOGLA estimates that around 10 percent of deployed pico-PV systems are used for small-business purposes, such as lighting a small shop to extend opening hours or offering phone charging to customers. Therefore the 20 million pico-PV systems sold to date are probably supporting livelihoods in 1.9 million households globally. UNEP estimates that alternative technologies and their value chains produce around 30 jobs per 10,000 people living off-grid, which could lead to the employment of around 1.8 million people in the value chain alone, if full market penetration is achieved in sub-Saharan Africa.[43] Around 15,000 people were already employed in the modern off-grid lighting sector in late 2013, according to the agency.

NOTES FROM THE FIELD

- The d.Light study in Uganda found no statistically significant impact on the amount of time spent on income-generating activities or household chores in households with a solar home system.
- The BBOXX study mentioned above reports that 57 percent of customers that were interviewed launched a phone-charging business. It also estimated that a BBOXX system added an average of $45 a month in revenue for small businesses that used it for lighting, as a result of longer operating hours and more time to prepare and sell goods. A total of 71 percent of surveyed BBOXX small-business customers reported increased revenue, either from phone-charging services or from higher sales of other products.
- SunnyMoney reports that it supports a network of 600 independent agents across East Africa, adding on average 30 percent to their income.[44]
- Productive uses for slightly larger solar systems are broader than those for portable solar lights, including hair cutting or showing movies on a TV. Commercial phone charging for customers without charging devices is also a popular way to commercialise a solar system.

5.4. HEALTH, EDUCATION AND SOCIAL LIFE

Kerosene, which currently fuels lights in many off-grid households, is not only more expensive than solar lighting but also creates a host of negative impacts in the immediate environment of its users:[45]

- Kerosene lights provide illumination levels of only 1-10 percent of those recommended by lighting authorities in developed countries, leading to eye irritations and vision-related problems.
- The fumes can cause negative health impacts, from headaches in the short term to respiratory illnesses, kidney damage and blood clots.
- The risk of accidental spillages leading to body burns or cuts from broken glass.

[43] UNEP, “Light and livelihood: A bright outlook for employment in the transition from fuel-based lighting to electrical alternatives”, 2014.
[44] SolarAid, SunnyMoney, “Impact report”, Autumn 2015.
[45] All cited health impacts of kerosene are sourced from a metastudy by Evan Mills, “Identifying and reducing the health and safety impacts of fuel-based lighting”, Energy for Sustainable Development 30 (2016), 39-50.

- Accidental ingestion when kerosene is stored in plastic bottles that may be mistaken for water or soft drinks. This is the leading cause of child poisoning in the developing world, estimated to affect almost 80,000 very young children annually in South Africa alone. About 60 percent of them will develop chemically induced pneumonia.
- An increased risk of household fires due to open flames. About 24,000 fires in informal housing were recorded in South Africa during 1998-2006, resulting in 1,088 deaths. About 30 percent of them are thought to have been ignited by candles. Some 6 percent of households in the country reported kerosene-related fires in a random-sample study in 2006, although these are related to both cooking and lighting. Fuel-based lighting is a significant contributor to severe burn injuries, which have a particularly high death rate, according to Mills (2016). In Bangladesh, kerosene lamps are responsible for 23 percent of infant burns, equivalent to 17,000 cases annually. In Nigeria, about 30 percent of hospital admissions with burn cases are attributable to kerosene-lamp explosions.
- Low-quality, flickering light unsuitable for reading can harm a students' progress and some studies have even indicated the possibility that prolonged use damages vision in later life. Students using kerosene lanterns are also forced to sit close to the lantern, leading to higher exposure to the toxic substances it releases.

Figure 50: An attendant pours kerosene into a vessel at a regional ration shop in Thane, near Mumbai, India

Source: Bloomberg

GOGLA's Standardised Impact Metrics have yet to include a methodology to estimate the health impact of solar lighting. It seems very intuitive that solar lighting is beneficial in reducing kerosene's negative effects, but the benefit to health is harder to quantify as kerosene's negative effects are either long-term, such as respiratory illnesses, or rarely documented, such as with accidents. Field-based studies summarised below suggest that pico-solar's relative impact on indoor air quality is limited as long as households do not have access to a clean cook stove, while solar light users report both an improved feeling of safety and better well-being. The studies suggest it is unlikely that students study longer hours or improve test results when they have access to clean light. Rather, they might make better use of dark hours to study and use daylight for other activities.

NOTES FROM THE FIELD

- ***Indoor air quality and health:*** A study of 300 households in Rwanda found that 45 percent of households with solar lights reported perceiving indoor air quality as having improved.[46] The authors however failed to find a quantifiable impact on health indicators over a six-month period. It is likely that health impacts are largely focused on children who spend significant amounts of time studying in the direct vicinity of a kerosene lantern. The exposure to kerosene pollution is less severe during general household tasks, when the exposure to toxic materials released from inefficient stoves outweighs those from a kerosene lantern. These findings are confirmed by a study of 852 Bangladeshi households, which found no impact on respiratory health but significant improvements in eye irritation.[47]

  Replacing kerosene lighting with solar is unlikely to eliminate health issues related to poor indoor air quality and particulate matter. These are estimated to lead to 2.6-4.4 million deaths annually, but are primarily related to cooking with solid fuels.[48] Combustion is, however, generally poorer in lighting than in fuel stoves.

[46] Michael Grimm, Anicet Munyehirwe, Jörg Peters, Maximilane Sievert. "A first step up the energy ladder? Low cost solar kits and household's welfare in rural Rwanda", IZA Discussion Paper No. 8594, October 2014.
[47] Yuya Kudo, Abu Shonchoy, Kazushi Takahishi, "Impacts of Solar Lanterns in Geographically Challenged Locations: Experimental Evidence from Bangladesh", IDE Discussion Paper No. 502, March 2015.
[48] Lim SS, et al. A comparative risk assessment of burden of disease and injury attributable to

- ***Fire hazards:*** The study of 483 Ugandan households with a d.Light solar home system found that the share of households experiencing burns or fires in the 6-month study period dropped from about 5-8 percent before the purchase of an SHS to less than 1 percent. A control group of comparable households that didn't switch to an SHS failed to show the same drop.[49]
- ***Education:*** Access to solar lights was correlated with a shift of children's study time to the hours after nightfall, but there was no evidence of an increase in total hours spent on homework, according to the same Uganda study. As a result, the impact of solar lights is mainly on the quality and flexibility of study time rather than the quantity. The study also found that even in households that received pico-PV systems free of charge, 20 percent of children continued to study without a direct light source, relying on indirect light from another family member. This finding is confirmed by another study that found women were the main users of pico-PV lights, with children using them only in 5 percent of cases (see Table 6). The field study in Bangladesh did find a positive effect on children's study hours and school attendance, but failed to detect improved examination results. The health benefits occur mainly during exam periods, when students would normally spend increased time next to kerosene lights.[50] SunnyMoney says that head teachers report improvements in performance, attendance and motivation, but it doesn't quantify the impact. The company also says 28 percent of its customers use part of the savings from avoided spending on stopgap technologies to pay school fees.[51]
- ***Personal safety:*** Access to pico-PV systems made consumers feel safer at night, according to a study with 90 households in Liberia.[52] The findings are echoed by an assessment of the impact on BBOXX customers in Uganda, whose kit includes outdoor security lighting that is usually not switched off over night.[53]
- ***Income distribution:*** Solar lighting is still mainly for the relatively rich social segments within villages. For instance, a SolarAid study of 3,500 individuals in Kenya, Tanzania and Zambia found that its customers on average had income levels 11 percent, 47 percent and 208 percent above the local average, respectively.[54] The d.Light study of 483 households in Uganda that purchased the D20g solar home system found that 52 percent of them lived under the $2.5/day per-capita income threshold (in 2005 PPP), compared with 71 percent national average. This indicates that early adopters of solar home systems are not the poorest of the poor.

Table 6: Usage of pico-PV kits (share of studied households in percent)

Pico-PV lamp is mainly used by…	%
Female adult	49
Male adult	23
Female adolescent	10
Male adolescent	7
Collectively by the family	6
Children	5

Source: Grimm 2014. Note: Adults are defined as aged 18 and above. Adolescents are aged 12-17. Children are aged 6-11.

67 risk factors and risk factor clusters in 21 regions, 1990–2010: a systematic analysis for the Global Burden of Disease Study 2010. Lancet 2013;380:2224–60 as well as Mill (2016).

[49] D.Light, IDinsight, USAID, Shell Foundation, UK aid, "d.Light Solar Home System Impact Evaluation", November 2015.

[50] Chishio Furukawa, "Do Solar Lamps Help Children Study? Contrary evidence from a pilot study in Uganda", The Journal of Development Studies, 50:2, 319-341, 2014.

[51] SolarAid, SunnyMoney, "Impact report", Autumn 2015. See: http://global-off-grid-lighting-association.org/wp-content/uploads/2015/11/SolarAid-IMPACT-REPORT-2015.pdf

[52] Smith, William "The Impact of Solar Lights on the individual welfare and fishing productivity of Liberian fishermen", College of William and Mary, Honors Theses, Paper 17, 2014.

[53] Enea consulting, "Social Impact Assessment of BBOXX in Uganda", December 2012.

[54] SolarAid, "Research Findings: Baseline and follow-up market research. Kenya, Tanzania & Zambia", June 2015.

5.5. ENVIRONMENTAL AND CLIMATE-CHANGE IMPACT

Kerosene lighting contributes half as much to greenhouse warming as does the UK

Recent studies[55] estimate that kerosene-fuelled lighting contributes to greenhouse warming at a rate equivalent to 240 million tonnes of CO2 – about the same as half the annual GHG emissions of the United Kingdom, or 0.5 percent of global emissions. This relatively large contribution is mainly due to the black carbon emissions resulting from incomplete combustion of kerosene. These particles absorb both light and heat thousands of times more effectively than CO2 and have a disproportionate impact on the climate despite settling to the ground within a matter of days. This high greenhouse effect of kerosene lamps highlights the potential for avoiding emissions relatively cheaply by accelerating the uptake of pico-PV systems while also achieving development goals. However, countries are currently not incentivised to do so because the UNFCCC framework does not account for black carbon in its GHG accounting methodologies.

We estimate that the 13.9 million Lighting Global quality-verified products sold in Africa and Asia avoided a cumulative 4.2 million tonnes of CO2-equivalent over January 2000 – June 2015, with 1.4 million tonnes saved in 2014 alone. To illustrate: the cumulative savings are equivalent to about 16 percent of the annual GHG emissions from Germany's Jänschwalde lignite power plant, one of Europe's largest single sources of GHG emissions, pictured in Figure 52.

Figure 51: Erasmus Wambua, a schoolboy, left, studies at home using a book illuminated by a single electric LED lightbulb, powered by M-Kopa solar technology, in Ndela village, Kenya (July 2015).

Source: Bloomberg

Figure 52: Quality-verified solar lights sold to date avoided greenhouse gases equivalent to about 16 percent of the annual CO2e emission from the Jänschwalde power plant in Germany (pictured below).

Source: Bloomberg

[55] Lam, Chen, Weyant, Venkataraman, Sadavarte, Johnson, Smith, Brem, Arineitwe, Ellis, Bond "Household light makes global heat: high black carbon emissions from kerosene wick lamps", Environ Sci Technol. , 2012, Dec 18;46(24) and Lighting Global, "Energy and Carbon Benefits of Pico-powered Lighting", Eco Design Notes, Issue 4, August 2014.

SECTION 6. THE FINANCING CHALLENGE

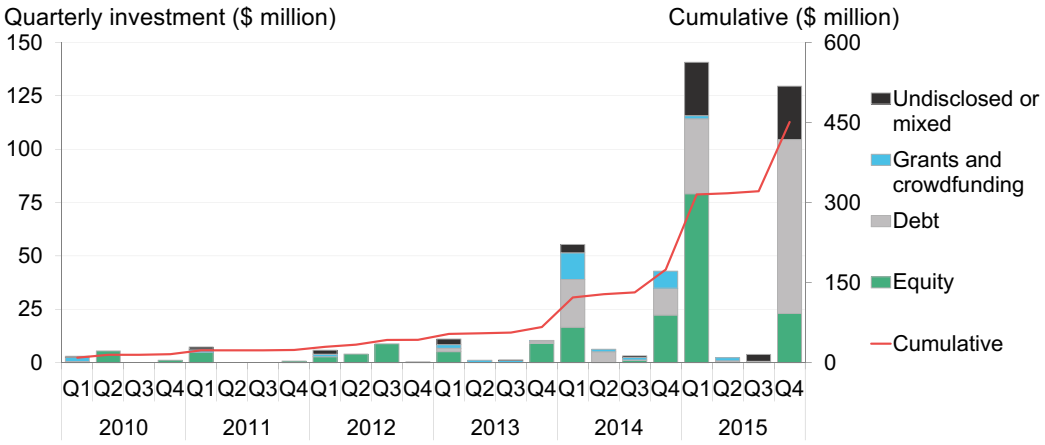
Access to finance in its different flavours remains one of the most-cited barriers to the growth of the off-grid solar lighting industry, despite a fifteen-fold rise in investments since 2012. PAYG companies can take credit for most of the increase, followed by the emergence of specialised funds and investment vehicles dedicated to the sector. Equity financing made up at least 38 percent of the $511 million of total inflows, whereas debt investments accounted for at least 41 percent. Donors have also contributed $36 million in grants directly to companies as a strategy to catalyse the development of the sector. Financing needs and gaps differ significantly between business types, with PAYG firms requiring the most substantial amount of capital. Transactions are increasing in sophistication, as companies experiment with off-balance sheet funds and asset-backed securities to attract new pools of capital.

6.1. FINANCE FLOWS TO DATE

Investments in the off-grid solar industry have accelerated rapidly since the beginning of 2014, after several years of slow but steady growth. The industry has attracted financing of just over $511 million since the start of 2008. More than half that, $325 million, has been raised in just three separate quarters (Q1 2014, Q1 2015 and Q4 2015), with quieter periods in between (Figure 53).

The volatility of quarterly investments is mainly due to the relatively small number of investable companies and their efforts to concentrate financing rounds into large amounts in order to reduce the administrative overheads. The dataset presented here tracks investment in 40 companies and investment vehicles whereby the top ten recipient firms account for 86 percent of the investments.

Figure 53: Investments in off-grid solar companies and intermediaries by asset class (end-2015)

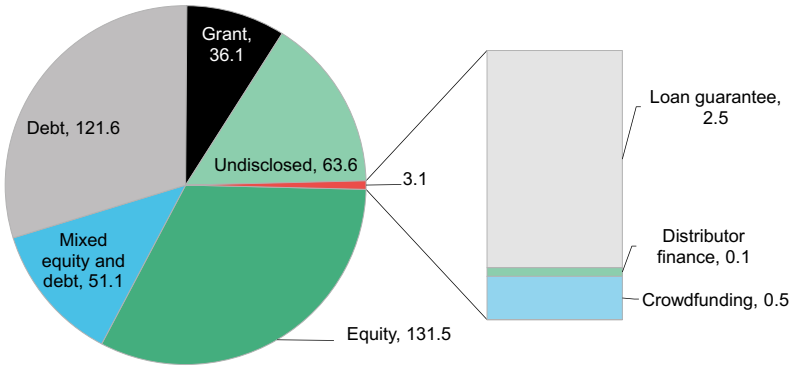


Source: Bloomberg New Energy Finance, GOGLA. Note: no dates were available for an additional $60 million of investments. Includes funds raised by intermediaries with energy access mandates that are likely to focus heavily on off-grid solar.

Industry evolution has broadened the types of funding used

The evolution of the industry has led to a wider diversity of funding types raised by off-grid solar companies (Figure 55). Equity and non-diluting grants formed the bulk of investments until 2013, as most companies were still in early development stages and could attract only capital with a high risk tolerance. After the first 'cohort' of solar lantern manufacturers matured into the expansion stage and established an operational and financial track record, debt transactions became more prominent from 2013 onwards. The emergence of pay-as-you-go business models, which rely on debt funding to a much larger extent, has led to a further expansion of fixed-income finance from 2014.

Figure 54: Cumulative investments in off-grid solar companies by asset class (2008-15, $ million, excluding intermediaries). Total = $407 million.



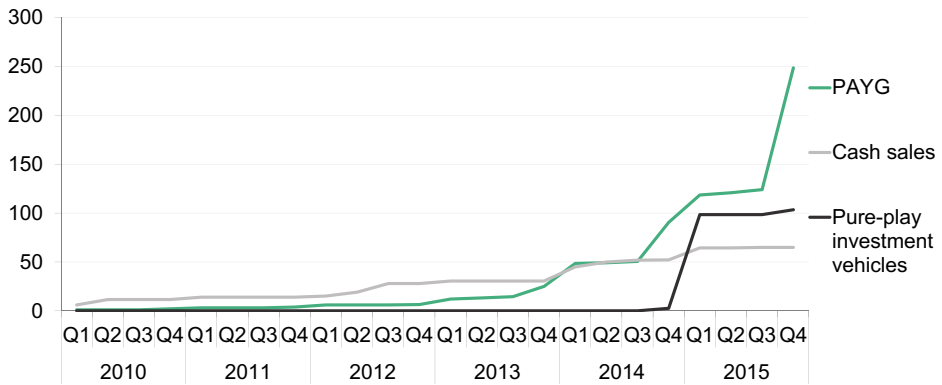
Source: Bloomberg New Energy Finance. Note: Excludes $104 million of investments to intermediaries. "Mixed equity and debt" refers to transactions where the breakdown was not disclosed. Excludes donor spend on sector support activities. Excludes funds raised by intermediaries with energy access mandates that are likely to focus heavily on off-grid solar.

Investments by recipient type

PAYG companies have captured the majority of investments

While product sales against full upfront payment constitute the vast majority of shipments, PAYG service companies have fared much better with investors. Investments in such firms only really started in early 2013, by which time cash-sale companies had already attracted almost $40 million of financing. However, within just two years PAYG has caught up: by Q4 2015 the segment's cumulative total stood at least at $250 million, four times as much as the cash-sale segment.

Figure 55: Investments in off-grid solar by recipient type ($ million cumulative)

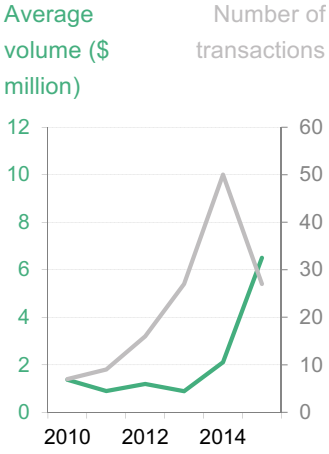


Source: Bloomberg New Energy Finance, GOGLA. Note: No dates were available for an additional $60 million of investments. Investment vehicles refers to specialised vehicles that intend to recycle money into off-grid solar companies, such as debt funds, venture capital funds or boutique financiers. It is not clear what share of this has yet to be deployed.

Boutique off-grid solar financiers are emerging

More recently, intermediary investment vehicles have also started raising funds, including specialised debt providers and impact funds with a pure off-grid mandate. A prime example of this category is the $34 million working-capital debt fund managed by ResponsAbility and launched together with IFC and Shell Foundation, which extends loans to fund inventory- and supply-chain management needs to solar off-grid companies. Specialised providers of financing such as SunFunder or Energy Access Ventures are also included in this category.

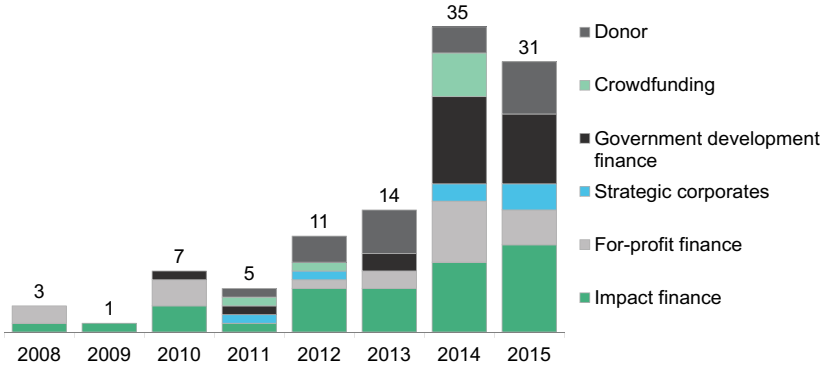
Figure 56: Transaction statistics



Source: Bloomberg New Energy Finance, GOGLA

INVESTOR CHARACTERISTICS

Figure 57: Number of investors engaging in at least one investment round in off-grid solar



Source: Bloomberg New Energy Finance. "Donor" financing refers to non-profit private organisations such as foundations or other grant-giving institutions. Public/government-sponsored international donor capital is listed as "Government development finance"

The industry's financial backers are still found mainly in the circles of donors and social impact investment funds, despite the for-profit nature of the majority of manufacturers and distributors in the off-grid solar sector. Purely profit-oriented capital providers (excluding impact investors) remain a minority, despite the rapid increase in investments observed in 2014-15. Increasing this number will be important to achieve scale and commercial sustainability for off-grid solar companies. Rather, the boom in 2014 coincided with a broadening of the field of impact investors and donors active in the sector. The latter seem to have retracted somewhat in 2015 (Figure 57).

Corporates with strategic interests in the off-grid solar industry also expanded their investments in the sector in 2014. These include firms from a variety of backgrounds, such as electronics and lighting manufacturers (Schneider Electric), telecommunications providers (Orange), solar companies (SolarCity) and other firms whose main corporate activity is not focused on providing finance. While the investments are often made as part of the firm's venture capital arm, the motivation is often a long-term bet on businesses that are perceived as having the potential of strategic importance for the main corporation's mission (Figure 58).

Too much money chasing too few deals?

Our transaction database shows that the average deal size in the off-grid solar sector shot up to more than $6 million in 2015. This was helped by large deals such as Off-Grid Electric's $45 million round in December, M-KOPA's $19 million round in the same month, Nova Lumos's $15 million debt raising from OPIC and Fenix International's $12.6 million mixed equity and debt round in January. While this has driven total funds raised to a new record, the number of transactions has actually dropped by almost half (Figure 58). This may suggest that the off-grid solar industry is starting to develop the 'winner-takes-it-all' pattern known from other start-up driven sectors, where investors bet on a few early leaders while new early-stage companies face an increasingly stiff investment environment.

Figure 58: Off-grid solar financiers (non-representative sample)

Source: Bloomberg New Energy Finance

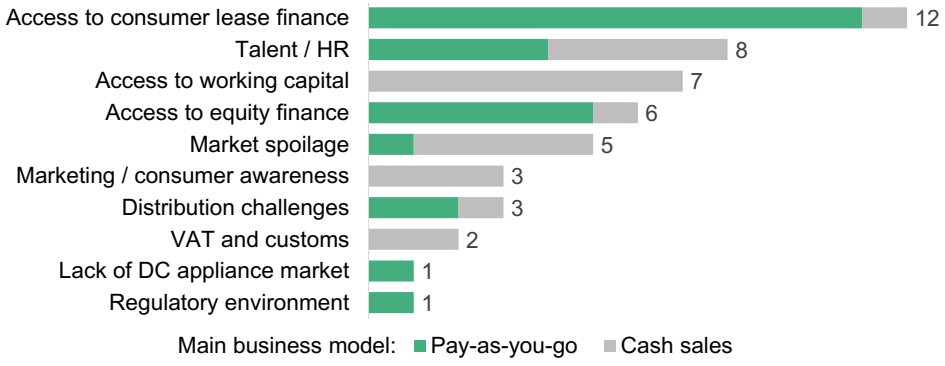
6.2. FINANCING REQUIREMENTS

Access to finance is the number one barrier to growth mentioned by entrepreneurs

Almost all companies in the off-grid solar industry are start-up ventures, characterised by rapid growth, short funding cycles and full reinvestment of proceeds into further growth. This means most firms are cash-strapped and, even if successful, in regular need of additional funding rounds.

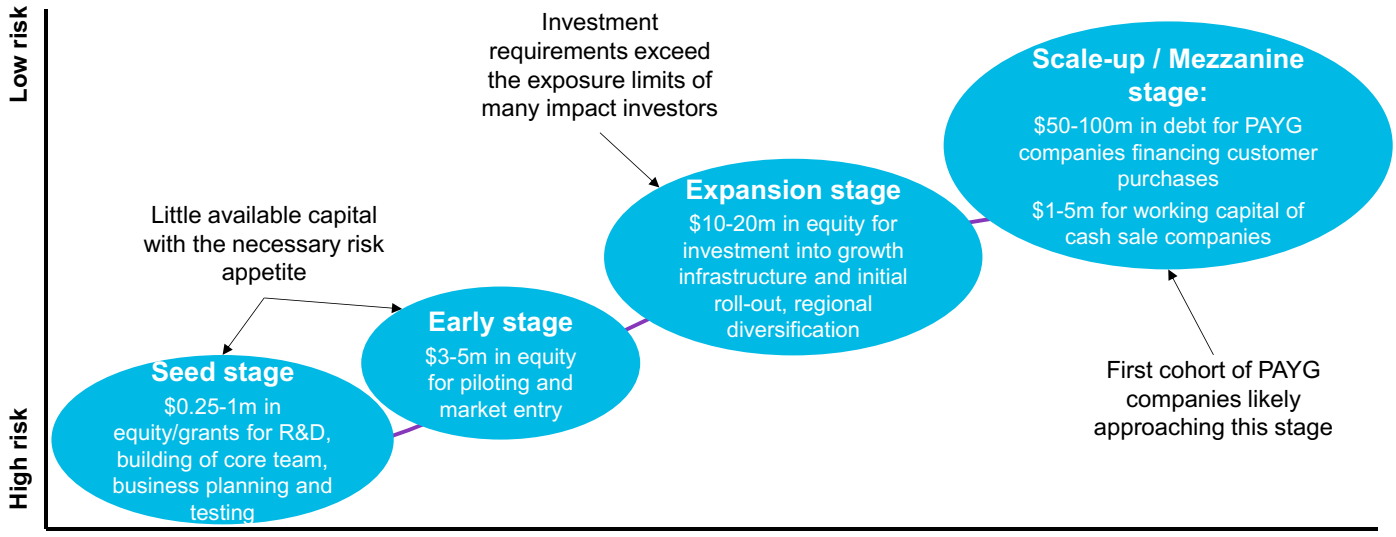
Companies' financing requirements change dramatically as they mature, both in terms of scale and type. Mismatches between the nature of funding needed by companies and the investment mandates of financiers looking at the sector are among the main barriers to growth cited by entrepreneurs interviewed for this study (Figure 59).

Figure 59: What are the growth barriers for your business? (interview responses)



Source: Bloomberg New Energy Finance interviews. Note: N=12 cash sale companies and 14 pay-as-you-go companies. Bloomberg New Energy Finance asked an open-ended question and counted up to three responses per company.

Figure 60: Financing needs across an off-grid solar start-up development cycle



Source: Bloomberg New Energy Finance

Seed stage: firms typically look for amounts up to a maximum of $1 million, and often a fraction of this, to get started. This money is often raised privately and will allow the entrepreneur to build a core team, design and build the first prototypes of the product and draft a business plan and strategy. The very first dollars are usually equity, mainly from the founder and angel investors. Firms in that stage have usually no way of getting debt financing. At an early stage even small equity sums can dilute the entrepreneur's stake substantially. To avoid this, firms may often try to seek grant financing, either directly from donors or through various prizes or business-plan competitions.

Early-stage companies need debt, but usually do not have the track record to raise it

Early stage: armed with a working product and a business plan, firms typically will seek to raise $3-5 million in an early stage round to fund systematic testing of the product with real clients and the construction of the operational framework to handle manufacturing, distribution and warranty services. Most of the money needed in this stage is still considered an investment into the firm's infrastructure, making equity the most natural financing type. Working-capital needs will emerge to finance the firm's first batches of manufactured product. This could be addressed with short-term debt funding, but firms at this stage typically have insufficient track records to raise loans. Hence, most working-capital needs will be funded directly with equity.

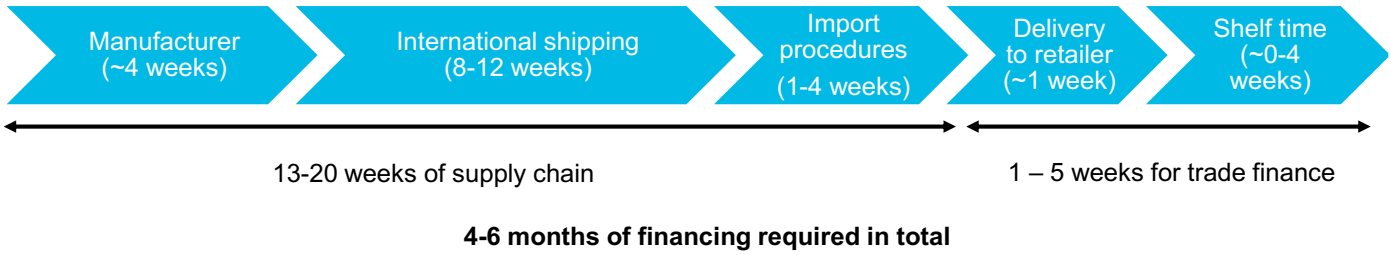
Expansion stage: firms grow from a focus on developing and investing into their operations to building a sizeable client base, building a reputation in the industry and fine-tuning and scaling their operations. Firms in this stage have historically raised $10-20 million, often through a combination of equity and debt. In this stage, companies emphasise efforts to develop the financial track record that will enable them to raise larger sums at a later stage. PAYG companies can typically reach around 5,000-30,000 clients with these expansion funds, depending on the size of the kit they provide for households. Per household costs are likely to drop sharply in later stages as much of the initial cost goes towards building the company and setting it up to scale at a later stage. Some companies also seek to lay the ground for future regional diversification, reaching into a second country or widening the branch network in their main location.

Scale-up stage: once the firm's operations have proven to work at scale with several thousand customers, firms are likely to enter the scale-up stage. For PAYG companies, the financing requirements change dramatically at this stage. While funding consumer leases from a mix of equity to test and establish the model, further growth requires targeted debt capital. Several PAYG companies are about to reach this stage and have reported financing requirements of $50-100 million or more per company to achieve their business plans over a period of 2-3 years. As most of this is likely to be debt financing, a detailed payment track record of their customer portfolio is a crucial precondition to raise financing or sell receivables forward.

Even cash-sales companies have substantial working capital requirements

Even companies that do not rely on consumer financing have substantial debt requirements in the scale-up stage, mainly to maintain sufficient inventory. One medium-sized company focusing on cash sales of lanterns said it is holding inventory of around $1 million on average, and it is likely that this needs to be scaled up before peak sales seasons (for instance in the lead-up to the harvest season, when subsistence farmers have enough cash to purchase solar goods). Because there is a period of up to seven months from the point at which supply is ordered until the company gets paid, the supply-chain financing needs for rapidly growing companies is potentially even larger (see Figure 61). The lack of access to working capital can strangle a firm's ability to deliver orders and scale. This can create a supply-constrained market in which customer demand cannot be served by the established brands, making it easier for distributors of generic products to serve unmet demand. A large number of small local companies with a broader product range may be able to distribute generics, with each financing a relatively small shipment out of savings or combined with other goods.

Figure 61: Working-capital needs across the supply and distribution chain



Source: Bloomberg New Energy Finance

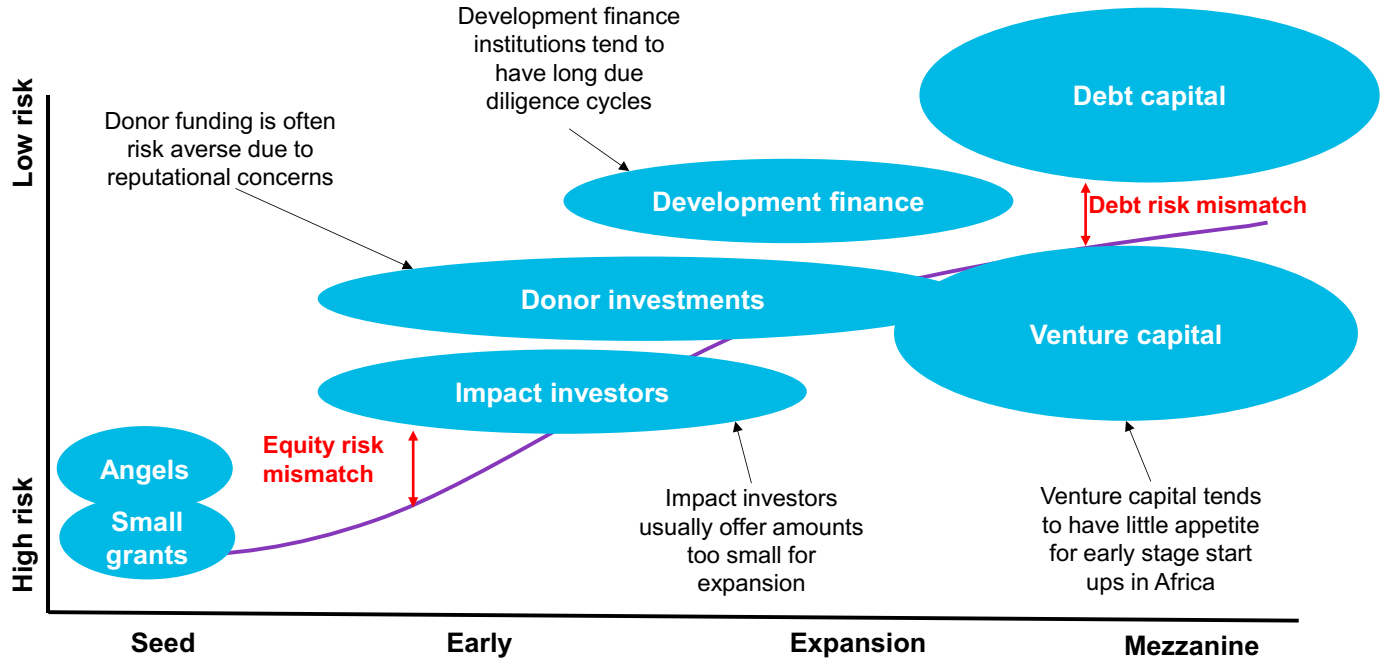
6.3. THE ROLE OF STRATEGIC PARTNERS OR LARGE MULTI-NATIONALS

The same financing needs described above also largely apply to the off-grid solar ventures of large corporations, such as oil-giant Total's lantern-distribution business or Philip's manufacturing venture. While in theory they are backed by the financial firepower of the parent firms, such units are usually structured as independent profit centres and need to operate with far nimbler structures and faster decision-making than their internal peers in more established operations. However, the backing and balance sheets of large corporations are likely to lead to relatively simple access to working capital, potentially from internal sources.

6.4. FINANCING AVAILABILITY

Off-grid solar start-ups will rely on a variety of investors as their firms mature.

Figure 62: Equity investor risk appetite vs. company needs



Source: Bloomberg New Energy Finance. Note: "Donor investments" are defined as grants and investments by organisations that have no profit mandate and are not development finance institutions, such as foundations and prizes. "Development finance" refers to government institutions or development banks and the likes.

In the seed stage, financing tends to be dominated by **founder capital and angel investments**. Grants and business competition prizes that do not dilute the founder's stake in the start-up have historically also made up a large part of the transactions by number, if not by total amount. Grants can also be an effective option to incentivise a ring-fenced unit of a more developed company to expand into new regions or product categories. Forty-seven out of 145 transactions tracked are classified as grants, totalling $36 million or 7 percent of the total.

Off-grid solar companies are often looking for larger amounts than impact investors are comfortable with for single rounds

Impact investors and donors tend to get involved with companies once they reach the early stage. While donor capital from foundations or prize money should in theory have lower return expectations, entrepreneurs have observed that most donors act with extreme risk aversion due to fears of reputational damage if a recipient is not successful. As a result, for-profit impact investors are often able to invest in companies before equity donors do. However, many impact investors are restricted to relatively small investment rounds. Acumen, an impact investment fund with several off-grid solar positions, states on its website that it typically invests $0.25-3 million into individual companies.[56] These limits are at the low end of the typical financing need of an early stage off-grid solar start-up. While firms can of course raise a round from several investors, the transaction costs in terms of money and time rise with every additional partner.

Development finance institutions have been involved in about one in four investment rounds in off-grid solar ventures, according to our database. They are active in all asset classes, from grants and equity to debt and loan guarantees. Entrepreneurs report that due diligence cycles and

[56] Acumen website. See: http://acumen.org/investments/investment-model/ (accessed 16 November 2015).

decision-making procedures are often slow and not well suited to nimble start-ups with short cash runways.

Commercial **venture capital funds** are in theory able to play a hands-on investor role similar to that of impact investment funds, while having access to far larger pools of money. However, the vast majority of such vehicles are focused on other markets and on more mature investments that have a clearer path to exit. Few VC's are comfortable or familiar with countries that host a large off-grid population, let alone this customer segment itself.

Venture capital has larger pots of money, but is often uncomfortable with countries hosting a large off-grid population

Venture investors, just like impact investors, have grown wary of the cash-sale business model for solar products. Most see cash sales as a low-margin business with low barriers to entry, where it is hard to build lasting businesses that can capitalize on their customer base for a long time.

Still, expertise and time horizons are not the only reason for a mismatch between investors and venture capitalists. While the PAYG business model is drawing increased interest, most of its capital needs in the mezzanine stage require non-dilutive debt rather than participatory equity from venture funds. This makes it even harder for VC's that usually provide equity and have equity-type return expectations, to provide suitable financing.

Commercial debt providers need historical data to show repayment rates

Commercial debt capital providers are expected to play an important role in the growth of both cash-sale and PAYG companies. Debt financing is required in many forms, including relatively short-term working-capital loans, financing for supply and distribution chains, all the way to a secondary market for receivables and consumer-financing of PAYG companies. By their nature, debt providers have far lower risk and return expectations than most equity providers, and usually demand a longer track record from companies. Most debt offered to the off-grid solar market has so far come from specialized niche lenders that are focused on this sector. Debt facilities backed by multilateral institutions such as the World Bank have also played an important role, with Ethiopia’s working-capital facility serving as a prime example.

Most debt is denominated in international trade currencies, mainly in US dollars. As firms’ revenue is in local currency, they become exposed to foreign exchange risk that is often difficult to hedge, certainly for small players. Expanding access to local sources of debt financing will be an important driver of long-term success for the industry.

Crowdfunding has had a role in at least nine off-grid solar financing transactions that totalled $0.5 million, but it is unlikely to provide enough depth to address the sector’s financing needs. It is possible that crowdfunding may be used to fund activities in frontier markets that cannot be served commercially, where it can be used to raise 'equity with a story' from retail donors that like the idea of donating for a good cause with a possible profit.

6.5. THE FINANCE GAP AND POTENTIAL SOLUTIONS

Access to finance of various types has been the most-cited barrier to growth of the off-grid solar market in our conversations with leading industry participants. We have identified three specific types of financing where gaps between supply and demand have emerged (see Figure 63).

Figure 63: Currently unmet capital requirements in off-grid solar

	Shorter tenors	Longer tenors
Debt	**Working capital** Purpose: financing the supply and distribution chain, including inventory Recipients: mainly for companies doing cash sales or selling PAYG products to distributors Typical amount: $1-5m for medium or larger companies. Likely to increase with market growth. Problems: • Tight payment terms from suppliers • Limited access to and high cost for bank loans and credit lines due to early stage nature of the business • Exposure to foreign exchange risk	**Consumer financing capital** Purpose: funding payment plans for end-consumers Recipients: mainly for companies selling PAYG systems to end-consumers Typical amount: Likely to rise beyond $50m for some companies in the short term and beyond $1bn across the industry in the coming 3-5 years Problems: • Leads to high leverage if kept on balance sheet • Lenders require historical track records which are not yet available • Exposure to foreign exchange risk
Equity	**Seed and early stage equity or grants** Purpose: R&D, business planning, testing, piloting and market entry Recipients: new and unproven start-ups with very little track record Typical amount: $0.25-5m Problems: • Impact investors and donors prefer companies with initial track record, but cannot offer tickets large enough for these firms	

Source: Bloomberg New Energy Finance

6.6. SEED AND EARLY STAGE EQUITY OR GRANTS

Investors are wary of easily replicable business models

While the most advanced off-grid solar companies report receiving unsolicited offers for equity investments, many companies at the beginning of their journey encounter difficulties in attracting seed and early-stage investments. Financiers and corporate scouts, on the other hand, have repeatedly raised concerns that there might be "too much money chasing too few opportunities" in the off-grid solar industry. There are several possible explanations for this apparent contradiction:

- Most investors, including impact investors and donors, are not willing to take the risk of investing in companies that have barely started operations. This leads to a rush on the small number of companies that are considered leaders in the field.
- At the other end of the scale, impact investors are often constrained from providing companies needing $3-5 million to build out operations due to limits on individual investments they can make.
- Investors put a lot of emphasis on companies that will be able to grow with their clients along the energy ladder and capture value from larger products and services. They are wary of investing in companies with easily replicable business models and put a premium on strategies that inherently are designed to 'own the customer relationship'. In essence, impact and VC investors are keen to find the company that can become the industry leader. This is even truer as the value of the product that is being sold declines, because the lower per-unit

profits will need to be made up for by sheer scale. Many early-stage companies seeking financing are building businesses that are considered too vulnerable to displacement by competitors or larger players.

- Most investors have regional limitations on their portfolios or are unwilling to take the risk or bear the cost of having a single isolated position in a country that they are not familiar with. This makes it harder for companies focusing on markets outside of East Africa or India, where the majority of impact investors in off-grid solar operate.

Possible ways to overcome the early-stage equity gap are:

- **Aggregate exposure to a range of seed-stage start-ups into funds that can attract angel investments for a large pool of ventures**, possibly from impact-seeking high net-worth individuals.
- **Investment mandates should allow impact funds to take on larger exposure in early-stage companies**. This could allow such funds to nurture companies until they are ready to be targeted by venture capitalists with bigger budgets and ambitions.
- **Increase the per-ticket size of impact investors** by committing donor or government grants to match private equity investments that meet certain criteria defined in terms of target audience, regional activity and minimum quality standards. This would boost the capital made available to companies without losing the due diligence from private investments and without a substantial increase in transaction costs. Companies could be required to pay back the grants if they are sold at a profit.
- The same concept of donors or governments **matching investments** could be applied to ring-fenced ventures by strategic corporates. This could allow experienced corporates to nurture off-grid ventures at lower cost, while keeping much of the upside if they succeed.
- **Develop donor programs that provide grants** or equity for specific markets where macro-risks or transactions costs are too large for other investors.
- **Business-plan competitions with prize money** that can help companies grow sufficiently to become targets for donors or impact investors.
- **Increase the risk appetite or mandate for donors**. This may mean that donor funds do not deliver impact on the ground if the company fails, but they are used to placing educated bets on companies that may deliver much larger impacts.

6.7. WORKING CAPITAL

The rapid growth of most cash-sale companies means that working capital is often repaid with new debt rather than proceeds

Supply-chain financing remains a challenge for many pure-play manufacturers or distributors of off-grid solar products. The solar lighting industry shares working-capital constraints with many other consumer-good industries operating in developing countries. However, the problem is exacerbated in this sector because financiers are less familiar with the technology and because of the start-up nature of most firms. They struggle to access short-term loans from banks as they are not profitable and often lack a credit record. Because the companies tend to be in relatively aggressive growth stages, they are likely to still be cash-starved even once a particular shipment has been sold and paid for by end-consumers. As a result, even short-term loans are often repaid with new loans rather than business proceeds. However, such practices raise risks for bankers and keep interest rates high.

Companies also have to manage foreign exchange risk as they work with often volatile currencies that are not always easily traded or hedged.

The following options can offer potential solutions to the working-capital challenge:

- Using relationships with local distribution partners that already have access to working-capital facilities, possibly even in local currency. This may include distribution through the networks of established retail organisations that already import fast-moving consumer goods, and can access working capital from local banks for this purpose. It could prove easier to add business for such a company that is already known and has a track record in the local banking system, rather than develop a completely new bank account.
- Dedicated working-capital facilities that understand the off-grid solar value chain and can price risk accordingly. ResponsAbility already runs a $34 million facility designed to provide such support, but local facilities able to extend local currency debt may prove even more effective.
- The above idea supported with credit enhancements such as guarantees or first-loss positions to further de-risk working capital. Such guarantees may also prove helpful in enticing local banks to lend to solar lighting manufacturers and build a relationship that helps wean them off guarantees.
- Factoring providers that offer to purchase distributors' receivables for cash. This is likely to be only a partial solution, as companies often need to pay suppliers for manufactured product before invoicing their distributors. This option is the closest equivalent to the securitisation of PAYG receivables.
- Foreign exchange or other import support facilities can help overcome trading restrictions on foreign currency. One manufacturer interviewed for this study said that local importers have sufficient amounts of local currency available in cash, but local regulations prevent them from accessing US dollars to pay for imports.

The role of donor-backed government financing

Debt financing through government-backed initiatives has proven an effective way to overcome some of the working capital constraints that start-ups face in developing countries, including high collateral requirements and foreign currency conversion. A credit line facility financed by the World Bank's International Development Association and administered by the Development Bank of Ethiopia made $20 million available to both private companies and micro-finance institutions. The funds had to be used to distribute qualifying products such as quality-verified solar lanterns and home systems, clean cook stoves or other renewable technologies. Almost all of the $4.7 million of loans disbursed to companies by September 2015 were used for pico-PV imports, directly backing the sale of 487 thousand units in 24 months –30 times more than originally expected. The sales catapulted the country to become one of the largest pico-solar markets in Africa within six months, despite starting with minimal activity prior to the intervention. Because of the fast sales cycle, companies could also use the revenues as collateral for commercial loans to finance additional inventory, boosting sales numbers by an additional 50 percent. Given its success, this facility is now being significantly scaled up by the government of Ethiopia with additional IDA backing. The World Bank is currently supporting governments in Uganda, Tanzania, Kenya and Nigeria to develop similar IDA-backed access to finance solutions for off-grid solar.

6.8. CONSUMER FINANCING

Consumer financing for off-grid solar kits can be extended by micro-finance institutions (MFIs) as unsecured loans or against micro-collaterals. Alternatively, PAYG companies can bundle the financing service with the product. Collaborating with MFIs as financial partners in the distribution of solar lighting products can allow cash-sale companies to tap into a pool of money expected to grow at 19 percent CAGR on average over at least the next five years.[57] This section focuses on the extension of specialised consumer financing for off-grid solar products through technology-enabled PAYG companies.

The PAYG business model offers the technology of solar-plus-storage kits, efficient appliances and ubiquitous mobile-phone connectivity combined with the affordability typical of stopgap technologies. This makes it an extremely promising option to deliver off-grid solar at scale. However, besides the many operational challenges, the business model is also very capital intensive. Reaching 15 million households with PAYG off-grid solar by 2020 will require outstanding debt of at least $1 billion in that year, according to our estimates. We assume three quarters of this will be provided through small systems with one-year financing terms. The scale of capital required is greater than what donors and impact investors can provide. Conventional debt providers will have to be tapped as well. The industry has raised at least $122 million in debt to date, but these investments are still just part of the proof of concept. The challenges to raising fully commercial finance break down into four groups:

- **Macro-economics**: many countries with a significant off-grid population are challenging places to do business and display inherent risks. Concerns range from corruption to political and regulatory uncertainty, such as the likelihood of rules governing the repatriation of proceeds being changed. Volatile markets and currency regimes add further to concerns around investing in these countries.
- **Characteristics of consumer receivables:** lending against future cash flows from people living off the grid adds a layer of complexity on top of the macro-economic risks. Instead of dealing with a single borrower, lenders have to rely on payments from a multitude of individuals, most of them lacking access to basic services and formal income. Perhaps because these consumers as a group have little credit history and are generally unknown to credit providers, cash-poor borrowers are generally perceived to be riskier than richer ones. However, PAYG companies report that their data indicates solid and at times even more reliable payment streams from poor customers. Lending against consumer receivables is common in developed markets (for instance for credit cards or car loans). However, this is done under the umbrella of developed institutions such as formal consumer credit scoring to quantify risks and a functioning legal system that allows for either repossession or at least incentivises customers to pay back lest they face exclusion from many basic services. Few of these assumptions hold in the off-grid context. Instead, PAYG companies are betting that the technology that allows them to de-activate a solar kit can replace all of the above.
- **Technology and business-model risks**: customers are only incentivised to pay if they continue to receive the services and face the threat of not receiving them anymore if they stop paying. This is only the case if the kit continues to function as intended, the activation technology cannot be circumvented (read 'hacked'), and the PAYG company continues to collect payments and assist with consumer queries. Therefore the lender also takes on technology risk and exposure to the operational performance of the PAYG companies in its capacity as 'servicer' of the debt.

[57] responsAbility, “Microfinance Market Outlook 2015 – growth driven by vast market potential”, 2014. http://www.responsability.com/funding/data/docs/es/10427/Microfinance-Market-Outlook-2015-DE.pdf

- **Lack of historical data**: even the bravest of lenders that are willing to take on (and be rewarded for) all the risks outlined above will need historical data to justify their decisions and accurately price their funds. This is both prudent and in most cases required to meet the fiduciary duty that money managers have towards their clients. Because of the exposure to technology risks and the operational performance of the PAYG companies, they also need payment data covering a period of time equivalent to the tenor of the consumer loan being sought. This means that a PAYG company that offers, for instance, an 18-month payment cycle needs to be in business (after initial piloting) for at least one and a half years before even having the data required by lenders. To complicate matters further, PAYG companies often experiment with the specifics of their offering over short timeframes. Therefore, they argue that the repayments from a later cohort are likely to be better due to improvements to their offering and risk-screening after lessons are learnt from the initial 'cohort'.

The non-existent consumer-finance infrastructure is often touted by the industry as an opportunity, as the PAYG model seems bound to generate the data that could open up other consumer-finance activities to its customers. Organisations keen to develop the industry as a whole such as donors or development finance institutions can generally focus on the PAYG-specific risks outlined above, while the macro-risks are more general, not exclusive to the solar off grid market, and should be tackled by cross-sector development finance efforts. Possible interventions to accelerate PAYG consumer financing include:

- Data transparency initiatives that allow comparing repayment data (for instance, as a condition to lending from donors and development finance institutions).
- Development and standardization of portfolio performance metrics.
- Expanding Lighting Global's successful product-quality verification scheme to mitigate technology risks for larger solar home systems as well. The program is in the process of expanding the scheme to systems up to 100W, and some PAYG firms are offering even larger systems.
- Service-quality verification to mitigate the risk exposure of debt investors to the PAYG operator.
- Developing debt servicing back-ups that ensure payments are collected and existing systems are serviced if the PAYG company fails.
- Debt guarantees or credit enhancements.
- Foreign exchange hedging facilities, political risk insurance or any other product designed to mitigate macro-risks.

6.9. SPECIAL PURPOSE VEHICLES AND SECURITISATION OF CONSUMER RECEIVABLES

PAYG companies are betting that receivables securitization will help attract new investors

If the PAYG business model is to provide energy access to a significant proportion of those currently living off grid, it will require large sums of debt capital. Raising these funds is probably beyond the reach of the impact investors or development finance community alone. Success is therefore contingent on accessing larger pools of commercial or mainstream finance. Some PAYG companies already have or are attempting to securitise their receivables, hoping that structured debt will be crucial to access mainstream finance.

Expected benefits

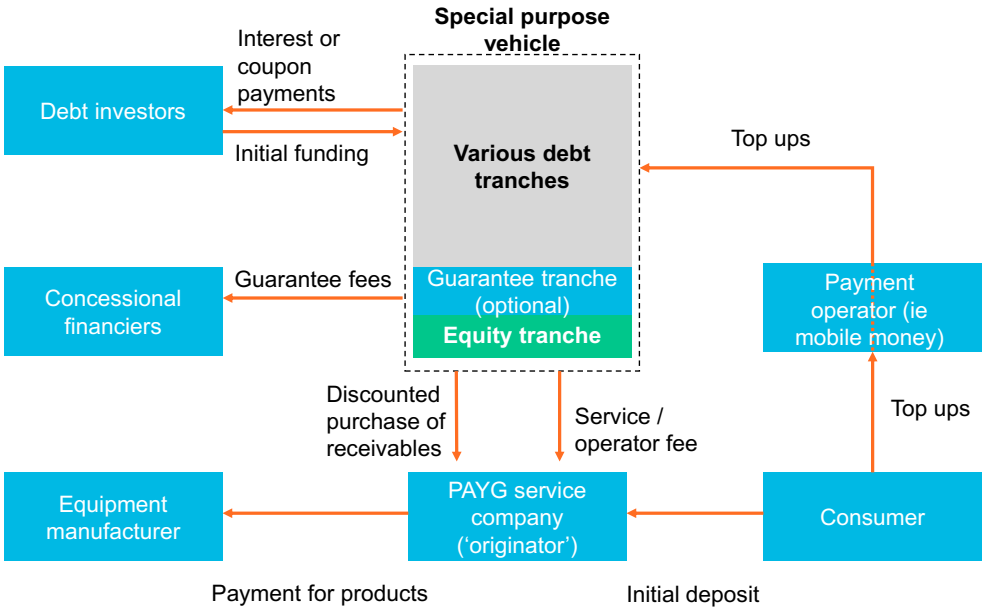
There are a variety of advantages for the market that can emerge from the use of special purpose vehicles (SPV) and their securitisation:

- Securitisation can enable a secondary market for consumer lending, making it easier for investors to access cash if they want to exit a position before its maturity.
- Mainstream special-purpose vehicle structures are often expected to reduce borrowing costs because they separate the risks associated with the receivables from those associated with the originator of the debt. The important role of the PAYG firm in incentivising the customer to pay, one played by consumer credit-scoring agencies and debt-collection services in developed markets, may reduce the power of this benefit.
- Getting debt off the balance sheets of the PAYG companies and into a special purpose vehicle reduces the risk of creating overleveraged companies that could become vulnerable if just one small, concentrated part of their portfolio underperforms and defaults (for instance, due to a natural disaster).

How would it work?

While there are endless ways in which a PAYG consumer-finance receivable can be structured into a special purpose vehicle, the general framework is common to all of them (see Figure 64).

Figure 64: Cash flows under special purpose vehicle structure to consumer finance



Source: Bloomberg New Energy Finance

PAYG securitisation means that cash flows go directly to debt holders

In an SPV model, the PAYG company's role in terms of the financial structure is reduced to an originator and a servicer. It purchases equipment from OEMs and finds end-customers for these products, usually collecting an initial deposit or instalment. Once a customer is signed up, it creates an accounting receivables of the future cash flows owed or expected from either the specific customer or any other customer to whom the solar kit may be redeployed (depending on whether it is a rent-to-own or energy-as-a-service model).

Simultaneously, the special purpose vehicle is created and receives cash from debt investors. If desired, concessional financiers can take an equity or first-loss debt stake in the SPV.

With this cash, the SPV purchases the rights to the future cash flows from the PAYG company at a discount that reflects the interest rate charged on the funds. The PAYG company is at this point no longer entitled to receive the customer payments, although it will in most cases still function as a collector of the funds. All payments are eventually channelled to the SPV, which in turn uses the proceeds to return the principal and interest owed to its debt investors. If the proceeds are not sufficient to make payments, the loss is taken directly by the debt investors. This risk can be allocated across different investment 'tranches' if desired, with tranches first in turn to take losses receiving higher interest rates. Rights to each of these tranches can then be securitized, creating a financial instrument that can be transferred easily and therefore in theory be traded on a secondary market.

The PAYG company continues to serve as an operator, ensuring customers pay and solar kits are maintained. For these services it receives a service fee from the SPV, which is structured in a way that incentivises the PAYG company to ensure maximum customer payments.

How likely is it that PAYG receivables will be transferred to an SPV and securitized?

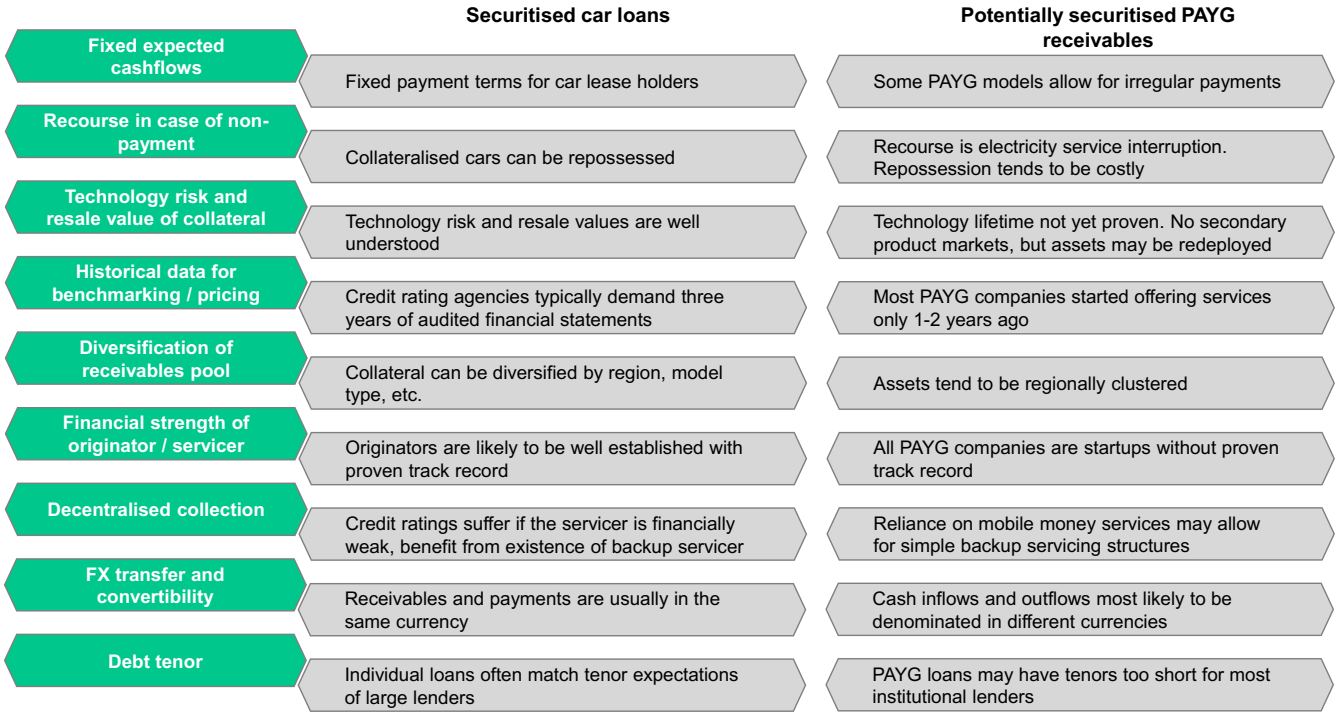
BBOXX announced the first of several planned securitised receivables transactions in the PAYG industry on 17 December 2015, worth the equivalent of about $0.5 million.[58] It aims to raise a total of $16 million in subsequent rounds issuances in 2016.[59] Other companies reported working on such deals during interviews in Q3 2015, although none wanted to go on the record due to on-going negotiations. However, it is likely that most transactions structured with an SPV will remain a minority of total debt issuance to PAYG companies, meant to build a track record and build the institutional know-how to execute such a deal rather than provide the bulk of debt financing initially.

The industry is still years away from creating mainstream debt securities

Among the main purposes of creating SPVs is to allow debt to be securitised and then traded on secondary markets, attracting more investors and reducing interest rates. This type of securitisation is common practice in developed countries to refinance outstanding debt such as mortgages, car loans or credit-card receivables. It is also beginning to be used for refinancing residential rooftop solar in the US. Reaching this stage for PAYG solar is probably still a few years away. Creating an SPV whose debt can theoretically be securitised is only the first, and arguably easiest step. PAYG receivables remain fundamentally different to other securitised consumer receivables in established industries in developed countries. Securitisation on its own cannot overcome many of the characteristics of PAYG debt that probably make it a higher-risk debt investment than, for instance, a car loan in the US. These include issues such as the currency risk and the lack of an established mechanism and track record to address non-performing loans. The 12-18 month loan tenors popular with the providers of relatively small solar home systems are also likely to be shorter than the tenor requirements of institutional investors. This could be overcome through revolving facilities, but this would introduce additional risks. Figure 65 illustrates a comparison of potentially securitised PAYG receivables with securitised car loans to highlight the manifold ways in which the risk profiles differ.

[58] Greentech Media, "The World's First Securitization of Off-Grid Solar Assets", 17 December 2015. See: http://www.greentechmedia.com/articles/read/the-worlds-first-securitization-of-off-grid-solar-assets
[59] Bloomberg News, "African sunshine can now be bought and sold on the bond market", 12 January 2016.

Figure 65: Debt investor needs for securitised consumer receivables (consumer car loans vs. potential PAYG solar)



Source: Bloomberg New Energy Finance

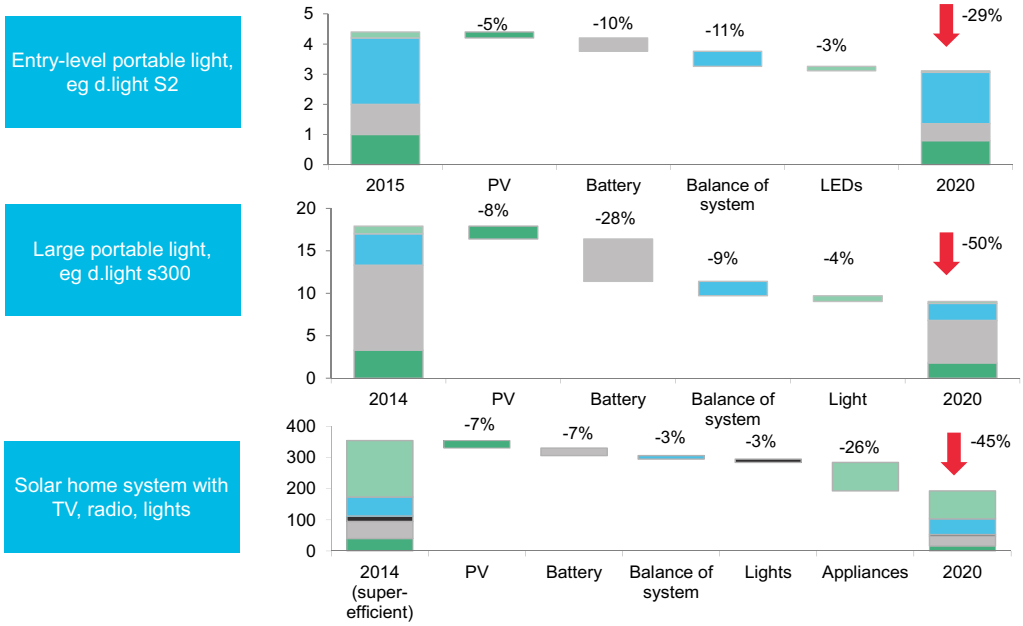
SECTION 7. TECHNOLOGY COSTS AND IMPROVEMENTS

The components of solar lights and home systems have seen substantial cost reductions and performance improvements in the past five years. The same pico-solar user experience that cost $20 in 2010 can now be manufactured for around $4, and for as little as $3 in 2020. While lower prices for PV cells and batteries will make a difference, energy efficiency gains in appliances will be the most important driver of off-grid solar uptake. Modern LEDs have already replaced incandescent light bulbs in all new off-grid solar products, allowing manufacturers to scale the PV cell down from 2.5W to less than 1W for the same performance while cutting system costs. The same logic will apply to larger appliances such as TVs, fans or refrigerators. Efficient versions currently cost more than their power-guzzling equivalents, but they enable affordable solar energy service delivery as they require less battery storage and fewer solar panels to run them.

7.1. SYSTEM COST

Figure 66 summarises expected cost trends for three representative types of off-grid solar system to 2020. All are expected to become progressively cheaper – while providing a better service.

Figure 66: Production cost developments (nominal $ per-unit)



Source: Powering a Home with Just 25 Watts of Solar PV: Super-Efficient Appliances Can Enable Expanded Off-Grid Energy Service Using Small Solar Power Systems Dalberg, EERE Solid-State Lighting Programme, Bloomberg New Energy Finance. Note: Example products mentioned are indicative of the service provided by the category.

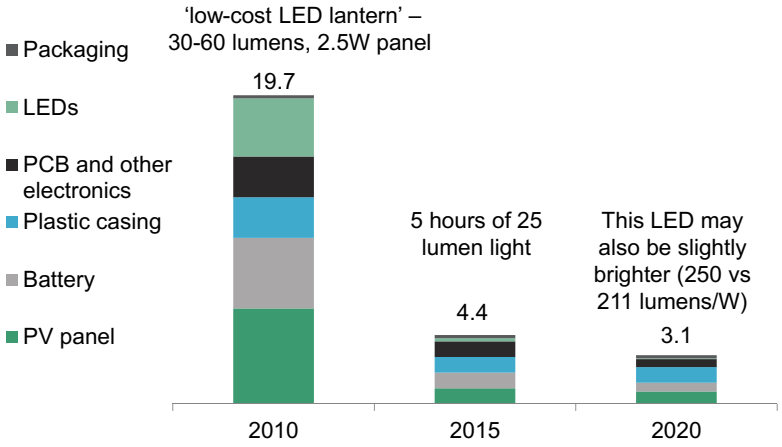
Figure 67: d.Light A1

Source: d.Light website

ENTRY-LEVEL PORTABLE LIGHTS

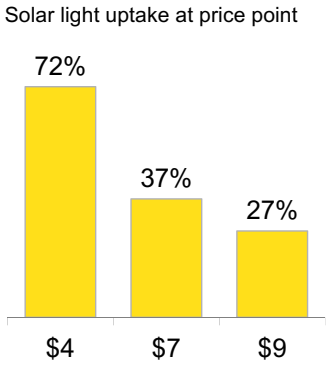
The all-in cost of a representative entry-level solar lantern has come down by about 78 percent since 2010 (Figure 68). This is due to various factors including a drop in the cost of the PV cells, batteries and LEDs, and increased production volumes that have allowed for savings on printed circuit boards and other electronics in this highly commoditised market. It is likely that the very basic lights such as d.Light's A1 (see Figure 67), which retails for as little as $5, already cost less than the $4.40 mentioned in Figure 68 to manufacture.

Figure 68: Pico-solar lantern cost development ($/unit)



Source: BNEF, company interviews, Lighting Africa 2010 report, EERE Solid-State Lighting Program

Figure 69: Price elasticity of entry-level solar lights



Source: ETH Zürich. Note: the uptake difference between $9 and $7 is not statistically significant.

The market impact of cost reductions

Because most of the target market for entry-level portable solar lanterns is severely cash strapped, even a modest-seeming cost reduction of a few dollars on an entry-level solar lantern may have huge implications in terms of consumer uptake. Expected cost improvements as outlined in Figure 68 will allow retail prices to drop roughly $2 per lantern in the coming five years, assuming that manufacturers pass savings to end-customers and margins remain unchanged. Preliminary results from an on-going field study commissioned by SolarAid found that uptake of solar lanterns increased from an average of 27 percent when sold at the market price of $9 (900 KES) to 72 percent when sold at a discounted price of $4 (400 KES) (see Figure 69). The ETH Zürich researchers from the NADEL Center for Development and Cooperation running the study offered a total of 600 lights at three different price points ($4,$7,$9), with the drop from $7 to $4 marking the strongest increase in consumer uptake.[60]

LARGER PORTABLE LIGHTS

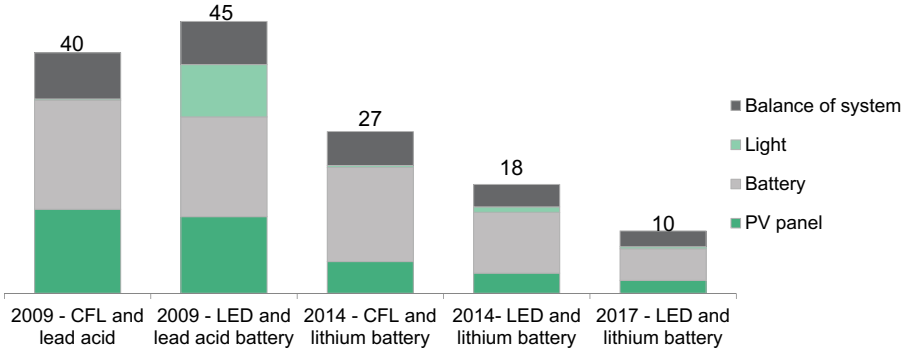
Costs are coming down in the market for larger portable solar lanterns such as the Greenlight Planet Sun King Pro 2 (Figure 70) – at the same time as the functionality has increased to include phone charging as a standard feature. In 2009, LEDs were not cost-effective versus compact fluorescent (CFL) bulbs (Figure 71), but by 2014 were cheap enough to justify the extra cost due to the savings on the battery size needed. Meanwhile, lithium-ion batteries have replaced lead-acid as the dominant technology, due to increased cycle life, higher efficiency when charging and discharging, and greater tolerance for deep discharge. By 2020, we expect further cost reductions in all components, including the small PV panels and balance-of-system as larger volumes are produced.

[60] SolarAid, ETH Zürich, forthcoming.

Figure 70: Greenlight Planet Sun King Pro 2

Source: Greenlight Planet website

Figure 71: Development of the cost of a medium solar lantern ($ per unit) – lighting service of 120 lumens for four hours per day



Source: Lawrence Berkeley National Laboratory, Bloomberg New Energy Finance. Note: Costs are indicative only, since few systems are precisely comparable.

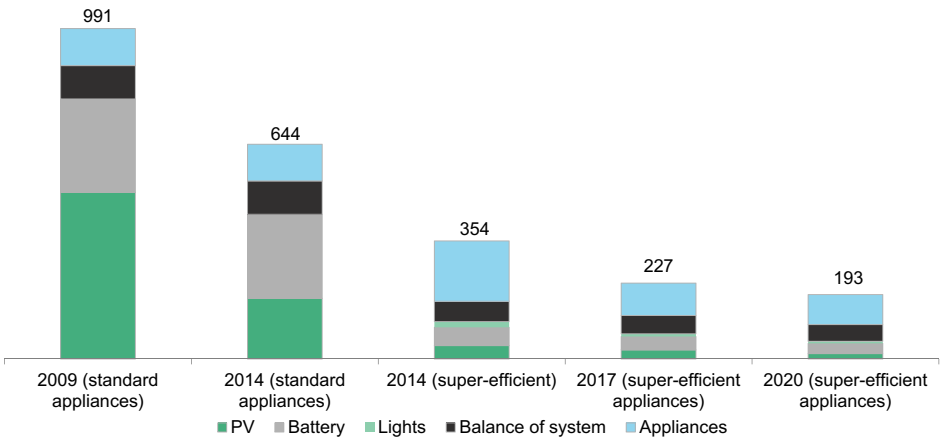
SOLAR HOME SYSTEMS

Appliance efficiency and costs contribute most to falling solar home kit costs

A solar home system is a little more complex than a portable lantern, as most products on the market offer at least some degree of customisation and a variety of appliances. Figure 72 shows current and projected prices for a solar home system providing four hours of light, four hours of television, six hours of radio and one mobile-phone charge per day.

Although batteries and PV panels are expected to get cheaper, the major reductions in the future will come from the switch to DC appliances, enabling the use of smaller PV panels and batteries. In 2014, 'standard appliances' required 121W of PV and 125 Ah of battery capacity, compared with just 27W of PV and 28 Ah of battery capacity to get the same level of service from super-efficient appliances, according to a Lawrence Berkeley National Laboratory study.[61] The DC appliances themselves will also become cheaper as the production volume increases, according to Dalberg.[62]

Figure 72: Solar home system with 19" TV, radio, lights ($/unit)



Source: Lawrence Berkeley National Laboratory, EERE Solid-State Lighting Programme, Bloomberg New Energy Finance, Dalberg Global LEAP Off-Grid Appliance Market Research.

[61] Amol Phadke, Arne Jacobson, Won Young Park, Ga Rick Lee, Peter Alstone, Amit Khare, "Powering a home with just 25 Watts of solar PV: super-efficient appliances can enable expanded off-grid energy service using small solar power systems", April 2015. See: http://eetd.lbl.gov/sites/all/files/lbnl-175726.pdf

[62] Global LEAP, Dalberg, "Global LEAP Off-Grid Appliance Market Research: Final Report", forthcoming.

7.2. TECHNOLOGY TRENDS IN DC APPLIANCES

Spending more on efficient DC appliances pays off because the solar panel and battery then required cost less

Alternating current (AC) power has become the standard used in electricity grids because it is far easier to transmit over long distances. As a result, the primary appliance market is for AC products. However, solar panels produce direct current (DC) power. Converting DC to AC in order to drive standard appliances leads to substantial losses. It is therefore generally more economical to use DC appliances when powered with a solar home system. Such specialised appliances are still relatively rare on the market and are therefore generally costlier. Paying more for efficient appliances can however reduce overall system capex by reducing the size of PV and battery systems required to run them, according to the Berkeley Laboratory study (Figure 72).

A recent analysis undertaken by CLASP and Dalberg[63] on behalf of the Global Lighting and Energy Access Partnership (Global LEAP) concluded that there is a vast and untapped opportunity in making energy-efficient appliances widely available, enabled by cost reductions and quality improvements for energy-efficient appliances. These products include DC televisions, fans and refrigerators (see box below for further details).

Summary of DC appliance trends

A major driver of the off-grid solar market is likely to be expanded availability of high-efficiency televisions and fans, optimised to balance service, energy use and price.

For example, we expect that by 2020 the cost of a solar home system providing four hours per day of television viewing will come down 45 percent, most significantly due to improved appliance efficiency plus a decline in the price of a 19" DC television using 10W or less from $104 today to around $85 in 2020. This is mainly a result of anticipated improvements in production costs driven by innovations in the LED backlit panel, as well as increasing volumes of production.

The emergence of high efficiency DC fans – responding to pent up demand for cooling – are also a key reason for off-grid consumers to purchase solar home systems in hot and humid climates. Table and ground-mounted designs are generally more popular than ceiling fans for off-grid rooms. While today's commercially available 10- 16" fans use as little as 10W of power, innovations in electric motors, variable speed or frequency drives and blade design are expected to reduce the draw to 8W by 2020, if not before. Meanwhile, price is expected to fall from around $18 today to $13 in 2020.

Refrigerators are generally beyond the means of off-grid households, but DC models are also improving and may drive solar uptake by small businesses.

The Dalberg study notes that the off-grid appliance market is supply-constrained, with fewer than ten players in each segment addressing the huge latent demand.

RADIOS

DC Radios are popular and widely available, generally priced around $5-10, and consuming around 1W of power. A radio is already included by default in many solar home system kits today. It is unlikely that costs here will fall significantly, since radio technology is quite mature.

TELEVISIONS

After LEDs and mobile-phone charging, TVs tend to be the top priority for off-grid consumers in most markets, followed by refrigerators and electric fans. Dalberg estimates that people with no or

[63] Global LEAP, Dalberg, "Global LEAP Off-Grid Appliance Market Research: Final Report", forthcoming.

poor grid power access have already spent $390 million on televisions worldwide.[64] Cathode-ray televisions, though cheap, are prohibitively power-guzzling for the off-grid market and would require a huge battery and PV panel to provide reasonable watching time. However, super-efficient DC televisions are becoming increasingly available and can use little enough power to be an economically feasible option, although they are still more expensive due to small production volumes.

Table 7: Estimated global spend on off- and bad-grid appliances

	$ million
Fans	60
TVs	390
Refrigerators	75

Source: Dalberg

Since a major driver of power use is screen size, smaller televisions use much less power, but these are not suited for communal watching and therefore are less attractive. Dalberg analysis[63] suggests that a 19" TV offers the best trade-off between price, power consumption and shareability and will therefore be the most popular product. The retail price of a 19" DC TV in 2015 is about $104, down from $170 in 2011, and will come down to about $85 in 2020. The LED-backlit panel accounts for 52 percent of the current cost, a major area of improvement for the future.

Off-grid TVs are also becoming more efficient. Omnivoltaic already offers a 19" TV with power use at 10W - meeting the expectations cited in the forthcoming Global LEAP report[65] by 2020. Even more efficient products are under development. There is also potential for improving the picture and audio quality for off-grid TVs, and for facilitating wider viewing angles so that many simultaneous viewers can enjoy a good TV experience.

FANS

Fans are cheap to buy, but consume a lot of power and are therefore expensive to run

Fans are the second-highest priority for most off-grid consumers after televisions. In hotter climates such as parts of south-east Asia, high efficiency DC fans are expected to be the market driver for solar. According to the Dalberg study[63], the market for off-grid fans is projected to grow 15 percent annually between 2015-20 provided widespread adoption of energy efficiency and design improvements. A 12" DC fan costs about 50 percent more than an equivalent AC one. However, efficiency is even more important for fans than for televisions, as fans are likely to be in operation for more hours per day.

Like TVs, fans can be designed to run on DC power and be more efficient than appliances developed for the on-grid market. Most off-grid fans are mounted on tables and pedestals rather than on the ceiling, to be effective for cooling small spaces.

Dalberg estimates that suitable 12" fans tailored for off-grid use on the market in 2015 cost $18 and use 12W. By 2020, Dalberg expects a fan with a 12" rotor using 8W to cost about $13. This may well be overly pessimistic - Omnivoltaic already offers a 16" fan that runs on 10W.

Brushless DC motors could improve performance, as could variable speed drives and better blade design to reduce energy loss due to turbulence.

REFRIGERATORS

Most refrigerators suitable for off-grid markets are small, with a volume of 50-80 litres, and based on DC compressor technology. DC refrigerators are more expensive, but use less than half the electricity of AC refrigerators. Another option is propane refrigerators, but these have significantly higher lifetime costs and require a source of propane fuel, although they do not use electricity. Prices for a 50 litre DC compressor fridge using 45W in 2015 are around $300 (versus around $200 for a small AC refrigerator). Dalberg finds that off-grid refrigerators in the 50-80 litre class

[65] Global LEAP, Dalberg, 'The State of the Global Off-Grid Appliance Market, preview late 2015.

need to cost around $200 and use less than 40W of power in order to be viable for rural off-grid users.

Prices will come down 25-30 percent with volume production, according to experts consulted in the Dalberg study. In addition, considerable efficiency improvements are possible with the development of new lightweight, low-volume and durable insulating materials such as vacuum-insulated panels, which could improve efficiency by 45 percent but cost 25-30 percent more. Brushless variable-speed DC compressors would also offer efficiency gains, but are far more expensive. One further option is to remove the need for batteries by using sunlight to cool a phase change material (most simply, ice) which then keeps an insulated box cool for 5-6 days.

Refrigerators are likely to remain prohibitively expensive for off-grid households

Most private off-grid households are unlikely to buy refrigerators in the next five years due to the relatively high costs. Small businesses and institutions (such as clinics) are likely to be a more attractive market.

OTHER APPLIANCES AND MARKET STRUCTURE

Other appliances such as irons, water heaters or washing machines for laundry are unlikely to become commercially relevant in the next 3-5 years.

The DC appliance market is currently served by generic contract manufacturers, international niche players catering for specialised segments such as vaccine refrigeration or off-grid camping or yachting, integrated off-grid providers that cater for all the needs of rural off-grid users including servicing, and lastly, also some established brands.

7.3. COMPONENT COST TRENDS

One of the key factors in the growth of off-grid solar products has been the declining cost of solar cells and batteries, mainly due to progress in the industries supplying solar and battery products to OECD countries.

PV MODULES

Solar panels are completely commoditised

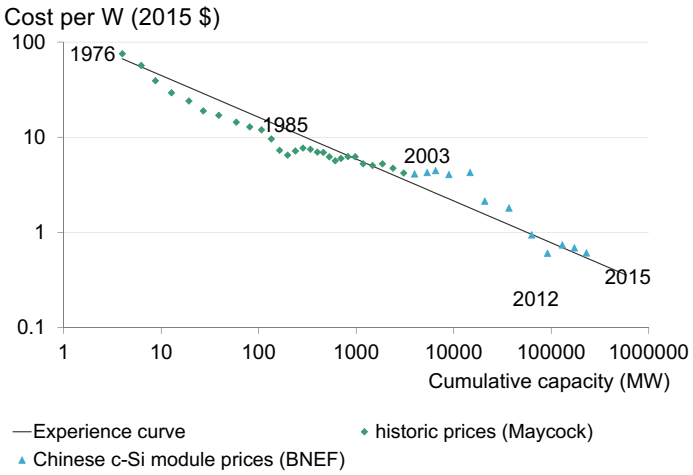
The price of PV modules has come down in real terms from over $75/W in 1976, to $4.27/W in 2008, to $0.61/W in 2015. This has been driven by efficiencies of manufacturing and economies of scale as global annual installation rose from about 2MW in 1976, to 6.6GW in 2008, to approximately 56GW (estimated before year-end) in 2015. Historically, this has mainly been driven by incentives for solar in OECD countries, although as costs fall new markets are opening up with low or no subsidies. The cost reduction has followed a constant experience curve (Figure 73) and is expected to continue, with cost reducing by about 26 percent for every doubling of cumulative global production.

The standard PV modules shown in Figure 73 are not the same as those used in off-grid lighting products – their typical capacity of 200-300W is too large for many off-grid applications. However, part of the cost reduction comes at the level of the constituent cells (4-5W each), and the ever larger industry that produces big modules also provides an increasing supply of cheap cells, or even part-cells for very small applications. These are a commodity - most manufacturers of off-grid products using solar cells do not even mention who makes them, and probably just buy the cells on the spot market. Figure 74 shows price developments for cells in the past five years.

Panels for solar home systems in developing countries are usually 5-100W, and the cost of these has come down less than for standard panels. This is because many of the steps involved in manufacturing a module (lamination, tabbing, soldering) take the same amount of time on the machine whatever size it is. In addition, every module needs its own junction box and cable,

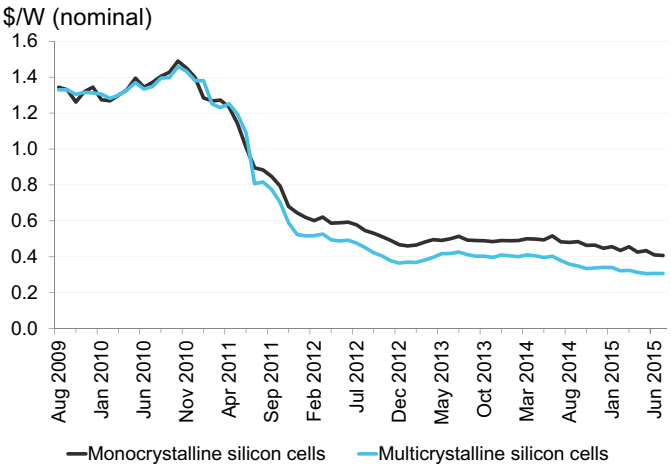
whatever the size. Solar lanterns will not even use a whole cell, but frequently use slices of cell. It is therefore difficult to translate the costs seen by manufacturers of off-grid solar systems into a neat chart like this, but these smaller panels have certainly come down significantly in the past five years.

Figure 73: Experience curve for PV modules



Source: Maycock, Bloomberg New Energy Finance

Figure 74: Price of crystalline silicon cells, 2010-October 2015



Source: Bloomberg New Energy Finance Solar Spot Survey

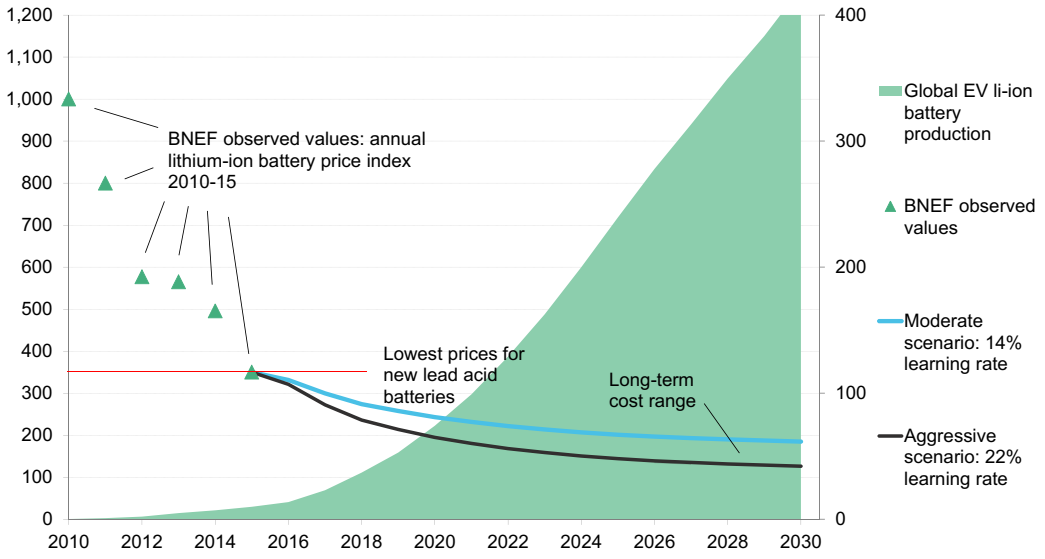
BATTERIES

Traditionally, off-grid systems have used lead-acid batteries as these are the cheapest available. However, in the past five or six years, advances made in lithium-ion battery technology due to its widespread use in laptop computers and other consumer devices have made it cheap enough to be the preferred technology. Besides cost, lithium also offers superior performance such as longer cycle life and higher depth of discharge. The expected uptake of electric vehicles has also stimulated industry interest in research and production of lithium-ion batteries, to the point of overcapacity. We estimate that global lithium-ion battery manufacturing capacity for electric vehicles is 37GWh/year in 2015, compared with total sales in 2014 of 6.9GWh. Leading manufacturers include AESC, Panasonic, Samsung SDI and LG Chem. Although batteries for electric vehicles are at a very different scale than the batteries used in the off-grid context, this industry interest will reduce prices at all scales. The main drivers of cost reduction are economies of scale in production, increasing electrode thickness and voltage, reducing electrode material cost and improving cell yield.

Battery prices are likely to drop in the coming five years in correlation with electric-vehicle uptake

Prices for electric vehicle lithium-ion battery packs have fallen from roughly $1,000/kWh in 2010 to around $350/kWh in 2015 (Figure 75). By comparison, lead-acid batteries cost from about $350/kWh new, and can be considerably cheaper in the case of refurbished second-hand batteries. Still, lead-acid batteries are a mature technology where costs are not developing substantially. The lithium-ion curve represents a 15 percent learning rate and has been driven by continual improvements in battery chemistry, materials processing and manufacturing and greater economies of scale. Historically, consumer lithium-ion batteries have exhibited a 22 percent reduction in cost for each doubling of manufacturing capacity.

Figure 75: Lithium-ion battery prices, historic and forecast ($/kWh)



Source: Bloomberg New Energy Finance

Lithium-iron phosphate batteries are increasingly used in Lighting Global Quality Verified products. These have a lifetime of more cycles than a lithium-ion battery (for which the boldest claim is made by German manufacturer Sonnenbatterie, at 10,000 cycles), but are slightly more expensive. They also offer higher power density.

Opinion is divided as to whether lithium-iron phosphate is worth the extra cost. One interviewee said that the longer cycle life is not needed in a home system cycling only once a day. At this rate, 10,000 cycles would be over 20 years, which is beyond the investment horizon of most off-grid consumers.

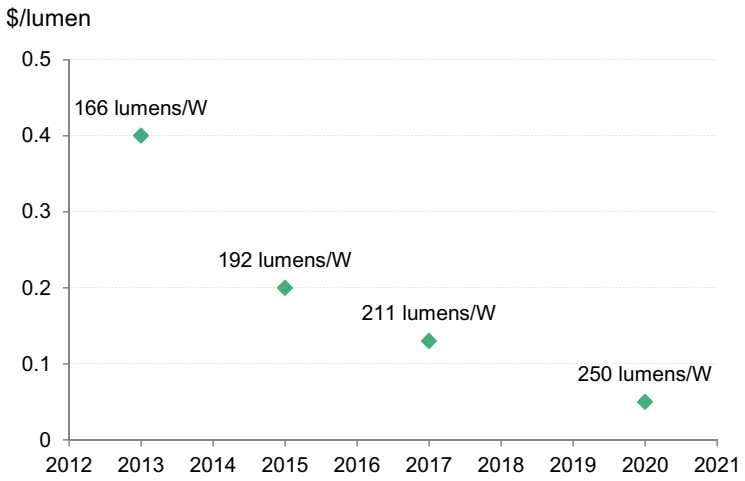
LIGHT-EMITTING DIODES

LEDs are becoming both cheaper and brighter

Light-emitting diode (LED) packages are continuing to become both cheaper and more efficient – producing more light per W, as shown in Figure 76, which represents trends in cool white LEDs. The same trend is observable for warm white LED lights, whose efficacy doubled from 70 lumen/W in 2009 to 135 lumens/W in 2013, according to the Berkeley Laboratory study. This roughly halves the amount of PV and battery capacity necessary to support the same amount of light. The choice between warm and cool lighting is largely a matter of consumer preference, with some customers preferring the kerosene-like warm light and some preferring the more modern-seeming cool lighting.

The LED package is only an intermediate step in making usable LED-based components. In many solar lanterns, the packages are integrated directly into the device and therefore cost pennies. By contrast, a solar home system deploys several discrete light units which include the plastic and metal housing and optics.

Figure 76: LED package price and efficacy developments, 2013 and forecast



Source: EERE Solid-State Lighting Research and Development Multi-Year Program Plan; Bloomberg New Energy Finance. Note: based on cool white LEDs.

The variable cost part of standard light bulbs has declined some 37 percent per year since 2010, while the fixed component cost contribution has declined some 7 percent per year (Figure 77 and Figure 78). While these light bulbs are much larger than is appropriate for off-grid applications, the trend still applies. This suggests that bulb costs for solar home systems will decline at a slower pace than those for portable lanterns.

Figure 77: Global LED bulb average selling price data and projections ($)

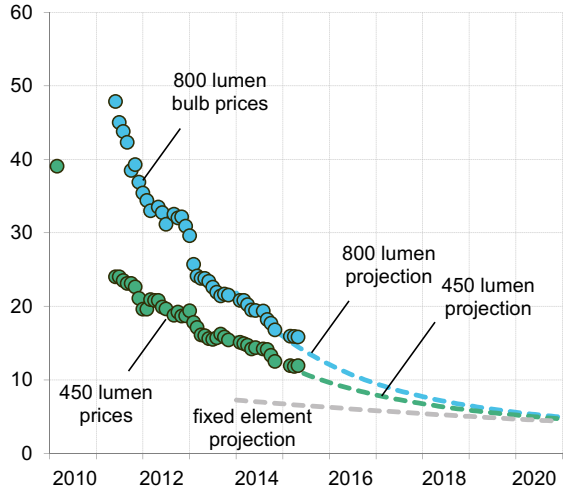
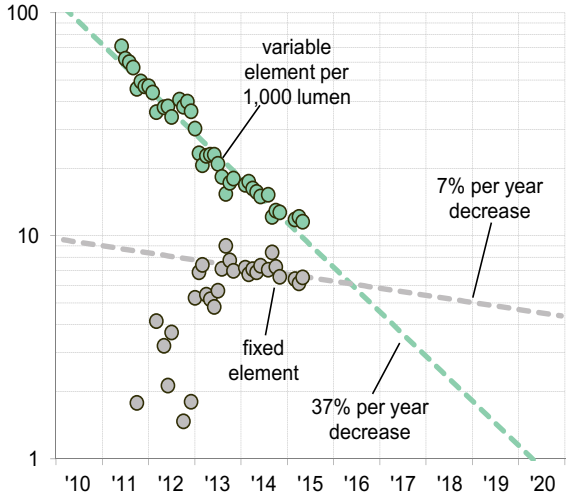


Figure 78: Estimates of fixed and variable price elements of LED bulbs ($)



Source: LEDInside, Bloomberg New Energy Finance H1 2015 Global Energy Efficiency Market Outlook. Note: The data for 800 lumen and 450 lumen bulbs was originally collected as 60W equivalent and 40W equivalent, respectively.

SECTION 8. MARKET OUTLOOK

Off-grid solar products and services markets are maturing rapidly, achieving substantially larger scale but also constantly changing their nature. We project that the market will reach 99 million households by 2020, a fourfold increase from 25 million today. Sales will grow at 34 percent CAGR to $3.1 billion in the same time. However, this is not just more of the same. Rising consumer awareness makes users and sales agents savvier, and they will increasingly shop for better deals as they seek upgrades. As market penetration rises, growth rates are also naturally falling, and the peak growth rate may have already been hit in markets such as Kenya or Tanzania. The market for simple solar lanterns and kits will gravitate towards purely price-based competition, coupled with premium branded offerings. Firms therefore need to be agile and differentiate themselves from new entrants through distribution networks and partnerships, premium branding, high-value products or lasting relationships with end-consumers.

8.1. ESTABLISHING THE BASELINE: HOW WILL TODAY'S TRENDS SHAPE THE MARKET?

PORTABLE SOLAR LIGHTING

Rising market penetration is putting established sales strategies under pressure

Solar lighting pioneers in the past few years have spent a lot of their time introducing new customers to the technology rather than to their specific brand. They were supported in this endeavour by behaviour change campaigns such as those run by Lighting Africa and Lighting Asia. Sales conversations tended to be lengthy as customers required explanations on the benefits of solar lighting and how to use it. This long sales cycle is costly and was mainly used by impact-oriented pioneers such as d.Light or SunnyMoney. This pattern is already changing in the most advanced markets such as Tanzania or Kenya, where consumers are looking for solar products on their own. The established sales strategies are likely to come under pressure because:

- **Customer awareness of solar lighting is rapidly rising**. SolarAid[66] found that 96 percent of Kenyan consumers it interviewed had heard of the technology, with figures for Tanzania and Zambia standing at 88 percent and 47 percent, respectively. The higher figures correlate with countries where Lighting Africa and Lighting Asia (Lighting Global) have run awareness campaigns. Customers that have either used the technology before or seen it work for a neighbour are more likely to know what they want, shortening the costly sales cycle.
- **Barriers to enter the supply chain are low.** We estimate that there are about 700 firms that currently could be viable wholesale suppliers for solar off-grid lighting products on Alibaba.com alone, and manufacturing capacity is essentially unlimited as any electronics contract manufacturer could enter the market. As long as selling is costly, this is good news for the incumbents. Once consumer awareness is not a bottleneck anymore, the market will probably become very competitive in a short time.

[66] SolarAid, "Research Findings: Baseline and follow-up market research. Kenya, Tanzania & Zambia", June 2015.

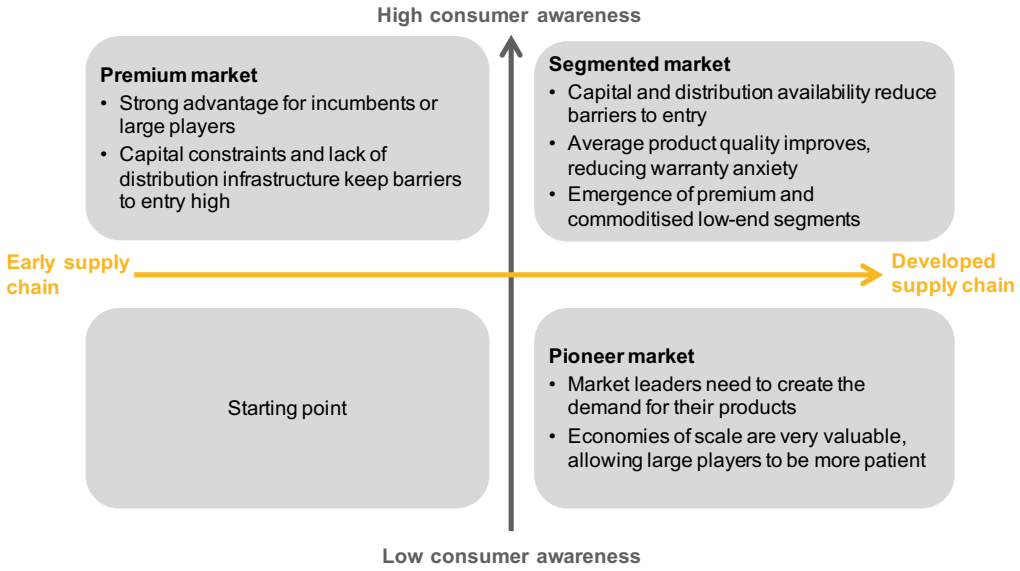
- **Costs - and prices - will fall and make low-end lights much more affordable.** D.Light, Greenlight Planet and Nokero all launched new lanterns in 2015 with retail prices between $5-8, significantly undercutting their previous offering. Our research suggests that a drop of another 30 percent is likely in the coming four years, bringing simple lanterns firmly below $5. That figure marks the higher end of the price range for low-quality battery torches. It is likely that the market for entry-level solar lights and rechargeable battery torches will converge, as prices in the first are likely to drop faster. Cheap, almost disposable battery torches dominate the electric lighting market in off-grid settings despite lasting only a few months.[67]
- **Consumers are cash strapped.** Quality-verified solar lights probably last longer and save more in the long run than generic solar products. However, the latter are to be had for a significant discount, estimated at over 40 percent at the factory gate.

Brands need to innovate constantly to avoid a price race to the bottom

These four trends suggest markets with a developed supply chain and high consumer awareness will gravitate towards a highly competitive environment. This means that brands either need to constantly differentiate themselves through premium products, image, and service, or compete purely on price for razor-thin margins (see Figure 79).

Markets dominated by impact-driven pioneers that create demand for their product at high cost may still emerge in regions where the population is less familiar with the technology, but they are likely to eventually gravitate towards more segmentation and intense competition at the low end of the product range as well.

Figure 79: Scenarios for cash-sales pico-solar market evolution



Source: Bloomberg New Energy Finance

SOLAR HOME SYSTEMS (CASH SALES)

The market for solar home system kits is currently smaller in unit terms than that for portable lights, but it is likely to follow a similar trajectory. Many lantern manufacturers have already responded to customer demand for bigger systems by expanding into higher-value premium lights or home systems. The higher costs of these systems make them a much bigger investment for consumers, which is likely to make brand recognition more important.

[67] Evan Mills, Jennifer Tracy, Peter Alstone, Arne Jacobson, Patrick Avato, "Low-cost LED flashlights and market spoiling in Kenya's off-grid lighting market", Energy Efficiency DOI 10.1007 (2014).

PAYG BUSINESS MODELS

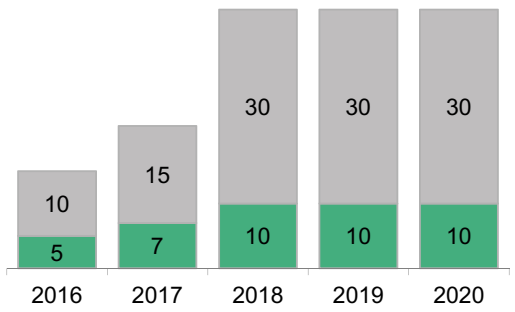
At first sight, PAYG businesses offer customers a superior product that saves them money from day one. So will PAYG solar take over the off-grid world? Not if the industry fails to mature from the start-up driven integrated utility model in which most of the industry currently operates towards a model of leveraging existing distribution and operation partners.

Future PAYG start-ups will benefit from off-the-shelf systems and software as a shortcut on the route to market

One single company, M-KOPA, accounts for more than half the sales by technology-enabled PAYG services to date. Despite exponential growth, it has taken the company two years from commercial launch to scale beyond 100,000 customers. Future start-ups may take note of lessons learnt and profit from software and backend systems that are becoming available off the shelf. Still the most time-consuming element of building a PAYG company lies in building the distribution network, the operational capacity and the payment track record. All of these will need to be built mostly from a standing start by each new entrant in each new market. There is probably little room for start-ups to substantially cut development times on all three fronts.

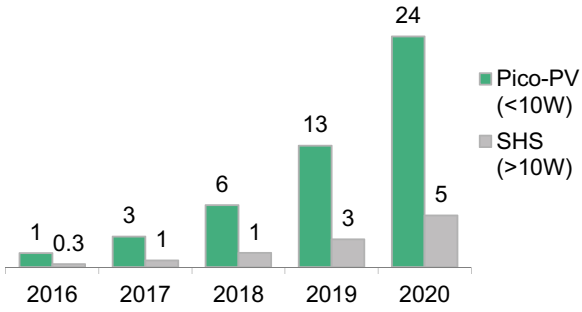
As long as the PAYG industry is based on companies building integrated value chains more or less from a standing start, its rate of growth is constrained. A simple extrapolation exercise suggests that these companies would serve no more than 30 million households by 2020, even if we make the highly optimistic assumption that more than 150 companies will be launched in the next five years (see Figure 80 and Figure 81). This number is of course much higher than it is today, but it is projected to represent no more than a third of the total off-grid solar market by 2020 (in terms of households using the technology).

Figure 80: New PAYG start-ups in very optimistic case (number of companies)



If you believe this many PAYG startups will be launched…

Figure 81: Forecast PAYG users in very optimistic case (million households, cumulative)



…then you might get this many PAYG users

Source: Bloomberg New Energy Finance. Note: assumes companies grow at the estimated average rate observed in existing companies. Assumes that pico-solar companies grow to acquire 2.7 million customers in year eight of their operations, while larger SHS companies acquire 240,000 customers annually at that stage due to higher capital and operational requirements. Assumes a start-up survival rate of 60 percent after four years. Companies refer to holding companies and firms active in several markets are considered one single company for the purpose of the extrapolation.

Achieving the full potential of PAYG to dominate the off-grid market is therefore likely to depend on partnerships between innovative and nimble start-ups and established players that can provide access to customers and retail infrastructure. African telecom MTN, for instance, signed up 45 million new users in sub-Saharan Africa (excl. South Africa) between 2010-14. It is not clear how many of them lived in rural environments, but this growth highlights the kind of scale that is possible. Fenix International and Nova Lumos are already partnering with MTN on distribution in Uganda and Nigeria, respectively, although their annual sales are still a fraction of the mobile-phone market in those countries.

8.2. FUTURE OFF-GRID SOLAR MARKET SIZE

We estimate that the number of households relying on off-grid solar as their primary or secondary energy source will rise from 25 million in 2015 to 99 million households, or more than every third off-grid household globally, by 2020 (Figure 82). The retail value of the market will grow to around $3.1 billion in 2020.

Most of the market growth until 2020 will come from today's large markets

The market is likely to grow fastest in Africa, where uptake has been more rapid so far and the off-grid population is expected to continue to grow. In the baseline scenario, 44 million African households will be using an off-grid solar system by 2020, compared with 39 million in Asia (Figure 83). A further 15 million globally will be using a PAYG system in that year, according to the baseline forecast which assumes no new policy interventions or market support campaigns. Most of the growth in this baseline scenario is likely to come from today's large markets such as India, Bangladesh, Kenya, Tanzania and Ethiopia where consumers are starting to become familiar with the technology and an inflection point of market penetration will be easier to reach. The technology is likely to spread to additional markets, but without interventions which address barriers to market development and lower first-mover costs and risks, these are likely to face a relatively slow uptake curve for the first few years. Our projections exclude sales of solar home systems to grid-connected households. All market segments will continue to grow, but larger solar home systems will increase their share of served households from about 10 percent today to 25 percent by 2020 as they become more affordable and consumers trade up from portable lanterns, using that first rung to climb up the energy ladder.

Figure 82: Baseline forecast off-grid solar users (million households)

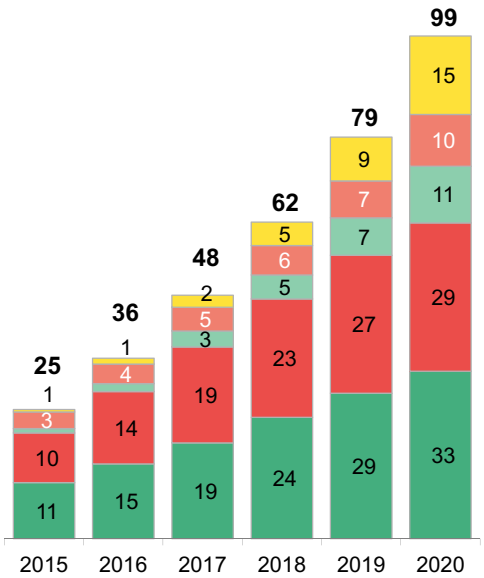
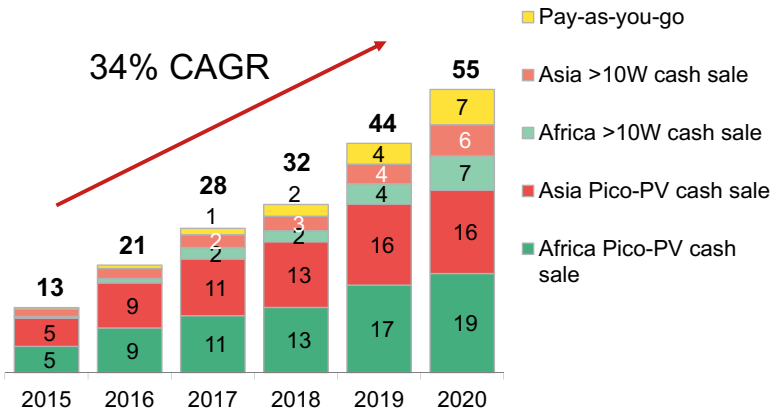


Figure 83: Baseline forecast annual sales (million units)



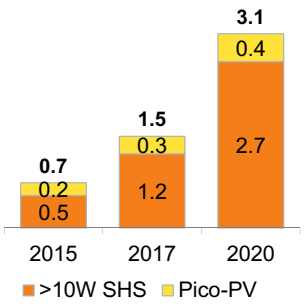
Source: Bloomberg New Energy Finance. Note: sales through third-parties with consumer-finance offerings are captured in cash sales. Sales projections assume product lifetime of three years and an increasing share of households to purchase a second device after one year. Unit sales assume sales of high-quality product. Unit numbers could be 2-4 times higher if the market shifts towards low-cost products with shorter useful lives and faster replacement cycles. The forecasts assume that 60-90 percent of households with a per capita income of $2-10/day will purchase a >10W system by 2020, whereas only 10-15 percent of poorer households will do so.

This sequential process of consumer technology adoption will allow the market for pico-PV to more than treble to over 35 million unit sales annually in the coming half a decade, with additional sales of 13 million larger home systems (see Figure 83). These figures include both the sales to new adopters of the technology as well as replacements for products past their lifetime and households that add a second or third lantern over time.

DC appliance sales

The expected increase in sales of solar home systems with panels of more than 10W is likely to go hand in hand with a rise in the sales of highly efficient DC appliances, with both trends reinforcing each other. A Dalberg[68] analysis suggests that the DC appliance market is in a similar early stage to where the solar lighting market was several years ago. If the latter serves as an indication, the DC appliance universe may expand rapidly in the coming few years. High performance appliances such as TVs and fans will prove particularly popular with the richer segment of people living off the grid, whereas many customers with an income of less than $2/per day are likely to purchase mainly pico-solar products too small to power TVs or fans due to budget constraints.

Figure 84: Estimated off-grid solar retail revenue ($ billion)



Source: Bloomberg New Energy Finance

- **TVs:** Our baseline forecast projects that about 15 million off-grid households will own a solar-powered TV by 2020. Adding a DC-TV set for less than $100 is likely to be well within reach of the relatively rich population with a daily per capita income of $2-10, or at least $3,650 per household annually. The baseline forecast projects that about 21 million households in this income bracket will own a solar home system by 2020 – about a third of the total addressable market. Given the global popularity of TVs in consumer surveys[69], it is likely that the vast majority of them will also purchase a DC TV, as the offering matures.
- **Fans** are likely to show the fastest growth among DC appliances after TVs, with over 7 million units projected to be in use by 2020. Clearly demand is a function not just of affordability, but also of average temperatures that make cooling more desirable. While most of the hottest countries on earth such as Sudan, Chad and Mali also have low grid penetration, these are unlikely to be the fastest growing off-grid solar markets as they are still at a relatively early stage. Some of the largest existing markets, such as Ethiopia and Kenya, are relatively cool, cutting demand for fans. Most users of solar-powered fans will therefore probably be in India, Pakistan, Bangladesh, Nigeria and Tanzania.

Forecast methodology

Future market size for any new product depends on the total addressable market and the rate of uptake. We assume that uptake is determined by the speed at which the technology diffuses through the market and is adopted by households. Our modelling does not focus on system economics, because these are already superior to the stopgap technologies that are widely used presently. To forecast the rate of technology uptake, we apply a simple Bass model with the following three parameters: [70]

- **Coefficient of innovation (p)**, capturing the extent to which people are keen to be early adopters of new technologies such as solar kits even if they have never been exposed to them through their social circle or first-hand observations.
- **Coefficient of imitation (q)**, reflecting interpersonal influence and the extent to which potential customers are convinced to purchase a solar kit because they have, for instance, seen their neighbours use them.

[68] Global LEAP, Dalberg, "Global LEAP Off-Grid Appliance Market Research: Final Report", forthcoming.
[69] Global LEAP, "Off-Grid Appliance Market Survey", April 2015.
[70] Credit Suisse, "Total Addressable Market: Methods to estimate a company's potential sales", Michael J. Mauboussin, Dan Callahan, CFA. September 2015.

- **An estimate of the number of eventual adopters (m)**, representing the total addressable market.
- The basic Bass model suggests that the number of new adopters (N) in every time period will be: $N(t) - N(t-1) = [p + qN(t-1)/m] \times [m - N(t-1)]$

We define the total addressable market for off-grid solar products as the expected off-grid population in each country by 2020, assuming the electrification trends observed over the past few years continue. We assume that the technology diffuses on a household level, and therefore define the addressable market in terms of off-grid households expected in 2020.

We estimate the other parameters by comparing the historical diffusion of solar kits in markets where a Lighting Global time series of pico-PV sales is available with the uptake curves of other consumer appliances such as radios or cell phones in their early days. We use figures for the U.S.[71], because data and parameter estimates for developing countries were not available (see Figure 86). However, calibration to the time series of pico-solar sales in Kenya and other markets suggests that the uptake rates are comparable.

While the Bass model projects the number of households that will use solar kits in the future, this technology diffusion approach does not indicate what type of solar kits households will use. We therefore take the expected number of adopter households and assume that uptake will occur at the same rate for households with an income of less than $2/day as will be expected for those with higher incomes. In the baseline scenario, we assume that cash constraints mean that households with an income of less than $2/day will purchase pico-PV systems (<10W) in at least 85 percent of all cases. Wealthier households with a per-capita income of $2-10/day are more likely to opt for larger solar home systems – we assume that 60 percent of them will do so in Africa by 2020, and 90 percent of them will do so in Asia where they already seem more likely to do so. The historical data suggest that even households with a per capita income of more than $2/day often opt for pico-solar systems today.

Forecast for DC appliance use (TVs and fans)

TVs are persistently ranked by consumers as the most desirable appliance after lighting and phone charging.[72] Even with improving efficiency it is unlikely that pico-solar systems will be able to power a TV. The larger solar home systems are however powerful enough to power a TV set, and they are generally purchased by households rich enough to afford also a TV set (see above). We therefore assume that by 2020 TVs will essentially become standard components of a solar home system kit, such as radios are today. We assume that 80 percent of solar home systems above 10W will be used with a TV.

Demand for fans also ranks high in consumer surveys, but is likely to be lower in places with milder temperatures. We assume that countries in the hottest sixth (measured in terms of cooling degree days) will see 80 percent of their solar home systems shipped with a fan, with the figure falling to 60 percent for the second hottest sixth and 25 percent for the third-hottest sixth.

[71] Gary Lilien, Arvind Rangaswamy, and Christophe Van den Bulte, "Diffusion Models: Managerial Applications and Software," ISBM Report 7- 1999, May 20, 1999.
[72] Global LEAP, "Off-Grid Appliance Market Survey", April 2015.

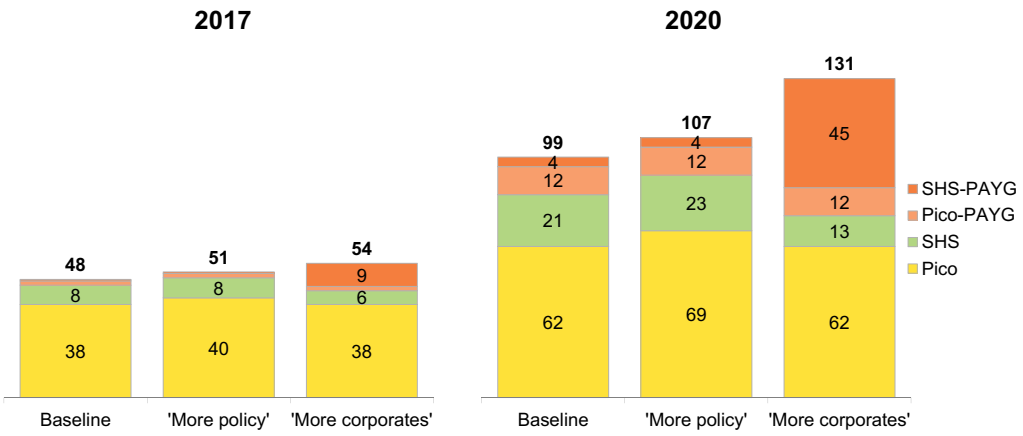
8.3. FORECAST SCENARIOS

The off-grid solar industry has proven extremely dynamic and fast-paced. Unlike many other industries, it also has donors, advocates and development financiers that want to help it grow with targeted interventions. The growth scenario outlined above should therefore be seen as a baseline scenario of where the market is headed if all else is equal, which it rarely is. To illustrate the potential impact of both accelerated policy support and PAYG availability, we have outlined two alternative scenarios for the baseline projection:

- **'More policy'- scenario**: policy-makers are most likely to reduce taxes and customs, boost consumer awareness or ease corporate borrowing through, for example, working-capital, FX facilities or revenue-based financing schemes. This scenario starts with the baseline, but assumes that five African and two Asian country markets will grow at the same pace as the Kenya market did for the past few years with its relatively favourable environment and active market encouragement through Lighting Africa.
- **'More corporates'- scenario**: partnerships between ambitious, highly skilled start-ups, large retailers and appliance manufacturers are most likely to lead to a private-sector driven acceleration. The most obvious examples here are PAYG firms and telecoms, but the partnerships could include cash-sales and beverage companies or appliance manufacturers tapping into the off-grid market with DC appliances. The 'more corporates'-scenario assumes that large firms will collectively add new PAYG solar home systems at the same pace as MTN added new cellular telephone subscribers in Sub-Saharan Africa over the past four years – 45 million households. The projection for pico-PV remains unchanged from the baseline, and other SHS would be sold at half the rate as the enhanced PAYG availability cannibalises sales. This scenario can increase technology uptake by 32 million households by 2020 compared with the baseline projection, to 131 million homes. Still, the corporates' likely focus on higher-value PAYG systems and on revenue capture from additional services is likely to lead to more solar home systems with DC appliances being sold as opposed to smaller pico-PV systems. We reckon that at least $5 billion of consumer finance will be outstanding in this scenario in 2020, assuming a five-year rent-to-own model (excluding financing for appliances).

Figure 85: Growth scenario comparison

Forecast off-grid solar users (million households)



Source: Bloomberg New Energy Finance.

8.4. THE IMPLICATIONS OF GROWTH

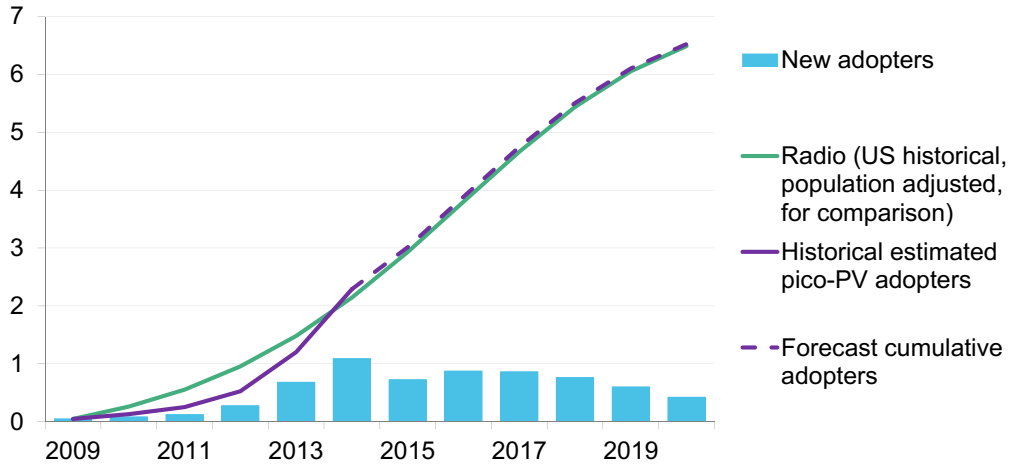
The market-size projections suggest that most growth will come from countries in which millions of solar lights have already been sold. This means that future sales will have different characteristics, to which distributors have to adapt.

- **Post-catalytic markets grow fastest**: consumer uptake tends to follow S-shaped curves over time, with a long period of slow growth by early adopters, followed by a period of rapid diffusion and finally by slower growth as it becomes harder to reach the remaining new users (Figure 86). After several years of catalytic efforts, the data suggest that pico-PV markets such as Kenya or Tanzania are now firmly in the second phase. In Kenya, for instance, over 30 percent of the off-grid population has first-hand experience with solar lighting, according to our estimates.

Customers and sales agents in high-penetration markets are savvier

- **There is a limited number of first impressions…:** while market penetration rises quickly in the middle of the S curve, the number of new adopters may peak quite early in that phase. The calculations for Kenya, for instance, suggest that the figure has already peaked. This means the same year-on-year growth from the early days would not be sustained even without the increased competition that comes with a maturing market.
- **…but customers come for seconds**: despite slowing sales, the market is far from saturated. Savvier customers are coming for additions, upgrades and replacements. Selling these requires different tactics than those for convincing a first-time customer that the product category works.
- **Customers and sales agents in high-penetration markets are savvier**: once customers know what kind of product they are looking for, they will shop around for better deals. This boosts competition and weighs on margins.
- **Catalytic strategies only work in early-stage markets:** this changing customer profile means that many of the sales tactics applied in the early-stage market will prove too costly and slow in the main growth countries. Continued growth requires either a change in the tactics or a shift to new frontier markets that are still in the catalytic stage.

Figure 86: Off-grid solar adoption, Kenya (million households)



Source: Bloomberg New Energy Finance, Lighting Global, Lilien, Rangaswamy and Van den Bulte[73].

[73] Gary Lilien, Arvind Rangaswamy, and Christophe Van den Bulte, "Diffusion Models: Managerial Applications and Software," ISBM Report 7- 1999, May 20, 1999.

8.5. GAMECHANGERS

The future of the off-grid solar market is determined by the complex interplay of a range of drivers, from the behaviour of companies and customers to finance, technology and regulation. However, not all variables are likely to have the same impact. Others, such as the interest that large corporates will take in off-grid solar, are also highly uncertain.

We have ranked a set of 20 important market variables in terms of likely impact and uncertainty (see Figure 87). Impact is defined as having the potential to significantly boost either sales volume or the average system size of sold product. A driver is considered uncertain if there is a wide range of possible outcomes that can be considered probable, rather than a relatively clear charted path. We consider those ranking high on both counts as potential gamechangers. These are the drivers that promise substantial impact, could realistically happen, but may not materialise without support from policy makers and donors. They include:

- **Consumer finance becoming available at large scale**. This is crucial to the success of the PAYG business model, which has the potential to both broaden the user base but also deliver more powerful services than simple lanterns. The rapid growth trajectory of PAYG will be choked without access to debt financing, leaving companies that are designed on the assumption of rapid growth stranded. On the other hand, readily available debt capital for PAYG companies will substantially lower the barriers to entry and attract both established and new players to expand PAYG offerings into new markets. With at least $77 million raised for PAYG debt in 2015, the current trend suggests that the industry is on its way to attract significant debt capital and overcome the bottleneck. Still, most debt financing to date has come from donors, impact funds and development finance organisations. Our ‘more business’ scenario suggests that in excess of $5 billion of outstanding PAYG receivables may need to be funded by 2020 if the industry is to grow at the same pace as large mobile-phone companies. To get there, debt financing needs to be sourced increasingly from commercial financiers and mainstream capital markets. Off-Grid Electric’s $45 million debt round and BBOXX’s first ever securitisation of PAYG receivables, both announced in December 2015 suggest that scaling debt finance is an ambitious, yet achievable goal.
- **Working capital to finance inventory and distributors** is among the most important constraints, mainly for cash sale companies. Where it has been made available readily, such as in the World Bank-financed credit line facility in Ethiopia, it had a substantial catalytic effect on unit sales. Access to working capital loans from commercial banks is usually difficult, in part because most distributors are either very small or rapidly growing start-ups with a limited track record. It is not clear that commercial debt finance for this purpose will become more readily available even with continued maturing of the industry. Temporary shortages of working capital can lead to empty shelves at the large pico-solar distributors, which could also allow generics to capture additional market share.
- **Corporate new entrants** are possibly just as important to scale the industry, both for the cash sale and the PAYG segment. Engagement by large companies, whether through distribution partnerships, acquisitions of start-ups or building new operations, is likely to be the only pathway to shorten the long lead times PAYG start-ups require to reach scale (as outlined in section 8.2). For the cash-sale business, corporations can also bring access to working capital, supply and distribution chains as well as brand assets that foster consumer trust or add to the desirability. These are all areas where start-ups are investing a lot of time, whereas established firms may already have valuable assets. Total’s role as a major distributor of entry and mid-level solar lights serves as an example of how the existing network of gas stations and reputation was leveraged to sell pico-PV products. The best placed corporates may however not necessarily be energy or lighting companies. The distribution networks of some beverage companies may arguably span wider. And consumers may be more familiar with, and therefore put more trust in logos not related to lighting at all. Attracting large corporates to the sector in a significant way will probably require adjusting

product in a way that it can easily piggy-back on the existing operations and supply-chains of their core businesses.

- **Consumer awareness of solar as a product category** dramatically accelerates uptake, as we have shown in this report. The perception of solar as desirable and reliable substantially reduces cost of sales. It makes sales not only cheaper, but also easier, attracting more distributors and sales agents. This in turn leads to more competition and lower prices. Off-grid solar has become ubiquitously known in some areas of East Africa through catalytic interventions such as Lighting Africa's consumer awareness campaigns or SunnyMoney's high-cost sales drives. Additional measures can include incorporating solar lighting as a status symbol through popular entertainment or mass media channels. Ubiquity in urban areas as back-up lighting may also help promote general awareness, as well as establishing high-quality products as desirable premium brands. Without a rapid increase in consumer awareness of the product category, growth is likely to remain constrained beyond the dominant markets in East Africa and India and will require local pioneers willing to take on several years of market preparation.
- **Catalytic interventions and government initiatives** can have a substantial impact on both the size of regional markets as well as the quality and service levels provided to consumers. The first are mainly focused on engaging pioneers in a market with low product penetration and supporting measures aimed at creating awareness (see previous point). Despite the rapid growth of the global off-grid solar sector, there are still dozens of countries where solar lighting has failed to gain a significant foothold to date. While international third parties such as NGOs, donors and development-finance institutions can engage in catalytic interventions, local government support will become increasingly important as the average system size increases. PAYG operations working with long-term leases are most exposed to changes in government policy, including grid extensions to their areas of operation, the granting of mini-grid licenses or changes to the way their business is regulated. As a result, some firms seem keen to align their strategies with government plans that carve out a role for SHS in electrification targets. Mobisol's and Off-Grid Electric's partnerships with the Rwandan and Tanzanian government, respectively, to electrify a defined number of households are a prime example for this.[74] Governments may pro-actively engage in such agreements to attract new PAYG players as part of a broader electrification strategy. Such partnerships may make it easier for PAYG companies to raise financing and could substantially accelerate market development. More governments building financial support to the off-grid solar industry (as has already been done in Ethiopia, Bangladesh, and elsewhere) into their donor-financed energy access programs can also have a significant impact.
- **Governments slowing off-grid** market development can occur either deliberately, but more likely as the result of well-intentioned but misguided efforts to support the market. Policymakers should leverage the experience and best practices developed in today's most advanced markets as well as international standards such as the Lighting Global quality verification. For instance, efforts at local quality rules can fragment the market and boost costs for manufacturers and thereby slow the development of a local market. Similarly, initiatives that favour particular players or rely on donations to end-consumers are likely to spoil market development.
- **VAT and import tariffs** are significant for the cash-sales business in particular, which is projected to dominate unit sales in the coming five years. Import tariffs for portable electric lighting can be as high as 20 percent in some countries.[75] The combined cost of multiple taxes can boost product costs by as much as 30 percent.[76] These costs are passed through

[74] PV Magazine, "Tanzania announces One Million Solar Homes initiative", 18 February 2015. Mobisol, "Mobisol, the EU and Rwandan government to electricy 50,000 rural households and schools", November 2014. See: http://www.pluginthe world.com/mobisol/wp-content/uploads/2014/11/Mobisol-EU-and-Rwanda-to-Electrify-50000-Rural-Households-and-Schools.pdf

[75] ClimateScope 2015, http://global-climatescope.org/en/

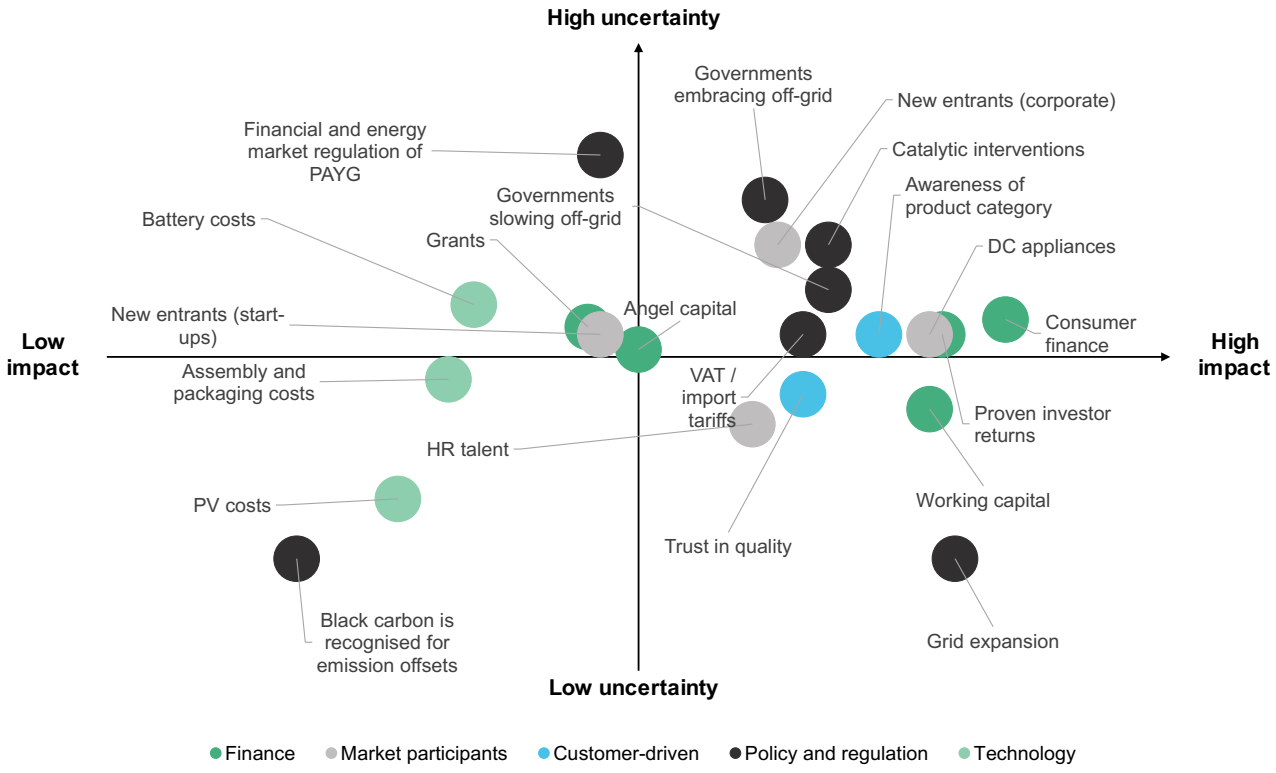
[76] Murphy, Sharma, "Scaling up access to electricity: the case of Lighting Africa", Live Wire, 2014.

to consumers, who are usually cash-strapped and highly price sensitive. Reducing the tariffs can, in a competitive environment, cut retail prices by more than a quarter. Preliminary findings from field research show that a retail price drop from $7 to $4 per unit almost doubled uptake in a sample of 200 households in Kenya, highlighting the potential impact of reduced taxation.[77]

- **High-efficiency DC appliances** are likely to emerge in more markets and become important demand drivers. Dalberg projects the market potential at $4.7 billion by 2020[78] – 50 percent larger than the market for off-grid solar kits. It is possible that TVs, fans and even tablets with internet connectivity will become anchor appliances for solar home systems. Consumers will purchase solar systems to power their device of choice, rather than incrementally climbing up the energy ladder from basic lighting to advanced appliances. Anecdotally, demand for such appliances is large and largely suppressed as they are difficult to power. The emergence of a broader universe of high efficiency DC appliances, potentially also backed by household names with strong brands, is likely to create a positive feedback cycle with the solar home system industry.

Additional variables we ranked are unlikely to be primary gamechangers, either because they are likely to have only a limited impact or because their future trajectory is better understood. Technology cost reductions, for instance, have both a relatively well charted trajectory and are increasingly making up a small part of the retail price, compared with distribution and financing costs. Policy interventions such as grid expansion, financial regulation of PAYG businesses or tapping the carbon market are also expected to be either sufficiently clear that they will not impact business in the foreseeable future or are unlikely to have a significant impact.

Figure 87: Impact and uncertainty matrix for off-grid solar market variables (subjective ranking by authors)



Source: Bloomberg New Energy Finance

[77] SolarAid, ETH Zürich, forthcoming.
[78] Global LEAP, Dalberg, "Global LEAP Off-Grid Appliance Market Research: Final Report", forthcoming.

8.6. INDUSTRY CHARACTERISTICS SCENARIOS

Whether companies and customers will be able to maximise the value of off-grid solar depends substantially on the nature of the market that emerges. We see three scenarios:

UBIQUITOUS PRODUCT MARKET SCENARIO

In this scenario, portable solar lights and small home kits become readily available and recognised by customers in most rural markets. Few brands manage to build strong and competitive identities, leading to a large number of undifferentiated labels being used. Customers find it hard to know which products to trust, and sellers compete just on price. For producers, it means that they face thin margins and need huge volumes to break even. For customers this means a preference for cheap products, even if it comes at the price of a shorter lifetime. The ties between customers and brands are weak.

Who benefits?

- Small local importers with low return expectations
- Consumers in markets not served by premium brands

Who suffers?

- High-end manufacturers who may face counterfeits or market spoilage
- Consumers seeking long-lasting products
- Landfills due to higher product churn

PREMIUM BRAND MARKET SCENARIO

In this scenario, several manufacturer brands become desirable household names among the off-grid population and are able to charge a premium for offering long-lasting products and honouring warranty claims. This market will be dominated by a few international players. While customers are likely to be more loyal to brands, the producers have no direct way of reaching them. The leading solar lighting manufacturers of today will compete in this market with today's torch or appliance manufacturers.

Who benefits?

- International off-grid solar manufacturers with successful investments in marketing and branding
- Consumers seeking long-lasting products
- Fast moving consumer-goods companies adding portable solar lights to their portfolio

Who suffers?

- Consumers in markets not served by premium brands
- Small local importers with low return expectations

RELATIONSHIP MARKET SCENARIO

Manufacturers either create a last-mile network or partner with strong distribution networks that can more readily reach a large audience. The goal here is to build lasting ties with consumers in order to pro-actively serve customers as they upgrade their solar systems, purchase appliances or even spend the money saved on stopgap technologies on other goods.

Ideal distributors already have or create recurring interactions with the customer through regular payments, service plans or sales of daily consumer goods. This favours organisations such as PAYG companies, telecoms, beverage companies, fertilizer distributors, micro-financers and insurers or kiosk operators.

Who benefits?

- Multi-product distributors or service providers
- Consumers seeking long-lasting products and upgrades

Who suffers?

- Pure-play manufacturers

Photos: Bloomberg

The ubiquitous-product scenario is least likely to create a sustainable market for off-grid solar products that lift today's poor up the energy ladder.

A market dominated by ubiquitous, cheap product is least likely to help consumers trade up the energy ladder

The trends outlined in this report suggest that without constant innovation on both product functionality and delivery method, the market gravitates toward the ubiquitous-product scenario. There are already some suggestions that this type of market has come to dominate Tanzania, after premium brands have catalysed the initial development. In time, it is likely that the same will happen in other countries and for solar home kits as their costs drop. It is already starting to happen to PAYG kits and software platforms, which started to proliferate in the past year.

There are several factors suggesting that the ubiquitous-product scenario is the most likely to fail to create a sustainable market for off-grid solar products that lift today's energy-poor up the energy ladder, because:

- There is a risk of market spoilage as counterfeits and low-quality products win the price race.
- Short product lifetimes do not allow customers to save enough cash to invest in higher value appliances.
- It is likely to be dominated by very small companies that will not have the expertise, profitability or balance sheets to expand into new markets, larger systems or sophisticated distribution.
- It is also the most likely to have the largest environmental footprint due to high product churn.

There are therefore good reasons for both companies and policy-makers to take measures to overcome the gravitational pull towards the ubiquitous-product scenario while supporting the continued growth of a competitive off-grid solar market.

COMPANY STRATEGIES TO ADAPT TO A COMMODIFIYING MARKET

Despite the commodification and the threat of generic products a few brands are likely to be able to carve out a premium market segment that can allow higher margins. Doing so will only partly depend on hardware quality. The companies that succeed are likely to employ at least one of the following strategies.

- **Focus on premium products and brands:** becoming a contender for one of the few leaders in the premium-brand scenario. This is likely to be very competitive and, as in most other fast-moving consumer-goods markets, only a small handful of brands manage to become a household name. Still, the few that manage to do so will probably be able to position themselves as an aspirational brand that customers trust. This will allow them to account for a significant share of the cash sale market.
- **Focus on high-value solar home systems:** price pressure is likely to be lower for such systems, as they cater to wealthier individuals and present a larger investment rather than a semi-disposable product.
- **Sell modular products:** these build customer relationships simply because they incentivise the customer to stick to the same manufacturer for upgrades or expansions. They can also be used as collateral until a product is fully paid for.
- **Offer bundled products:** combining the product with a service or recurring product such as financing, insurance, airtime or fertilisers, creates a much deeper customer relationship. All such combinations add customer value and reduce price pressure.

POLICY STRATEGIES TO ACCELERATE MARKET DEVELOPMENT

- **Market catalysis in countries or regions with very limited market penetration:** there is a strong correlation between the markets where off-grid solar is on a sharp growth trajectory and where companies or other actors such as the World Bank's Lighting Africa and Lighting Asia program have invested heavily in the costly process of familiarizing consumers with solar as a technology. Measures such as consumer-education campaigns, business-to-business support services, product-quality assurance, marketing support or financial de-risking through loan guarantees, foreign-exchange facilities or the likes can assist in replicating these outcomes.
- **Minimum quality and service standards:** no-name products and generics can make off-grid solar available everywhere, even if the quality and service is not as consistent as premium brands. However, if the experience is so bad that consumers prefer to return to stopgap technologies instead of a new solar product once their first purchase breaks down, the market is spoiled and will be much harder to catalyse again. Transparent quality verifications such as the one by Lighting Global can level the playing field while ensuring consumers fairness by avoiding false advertisement claims. Quality-control for PAYG companies may focus more on complaint-response times and the like than on hardware specifications.
- **Counterfeit enforcement:** intellectual property right violations deprive entrepreneurs of the returns on their investment. They are also usually illegal. While smart business strategy and design can go a long way to protect companies from such vices, governments should do all they can to enforce existing rules.
- **Legal framework for banking, mobile-money and utility regulation for PAYG:** while cash sales of off-grid solar products are normally treated just like any other good with very limited regulation, the situation is less clear for PAYG firms. Without a clear policy framework on what constitutes a possibly regulated utility service, or when financial and banking regulation is required for PAYG loans, investors face political risks. Governments should clarify those situations.
- **Establish transparent grid extension plans:** the outstanding loan portfolio of a PAYG company can be substantially harmed if competitive alternatives are offered to its customers, such as grid power or even cheaper mini-grids or other PAYG services. Governments can reduce such uncertainty by outlining grid extension plans and demarcating some areas for pure off-grid development.

Copyright

APPENDIX LIGHTING GLOBAL QUALITY VERIFIED PRODUCTS

SOLAR HOME SYSTEM KITS

FOSERA GROUP
LSHS 9800+Lamps+Panel

MOBISOL
Mobisol Family SHS 19" TV

OMNIVOLTAIC POWER CO. LTD.
OvCamp HS1-144_LB2244

OvCamp Solar Home System

SOLARWORKS!
Solar Home System

ZIMPERTEC
Litio Solar Home System Kit

PICO SOLAR PRODUCTS

ANJI DASOL SOLAR ENERGY SCIENCE & TECHNOLOGY CO.
SSL200

AZURI TECHNOLOGIES LTD.
Indigo Duo Solar Home System

BAREFOOT POWER LTD.
Barefoot Firefly/
Firefly Mobile

GO 250/GO 255

Connect 600

D.LIGHT DESIGN
A1

S20

D20

S100

S2

S300

PICO SOLAR PRODUCTS *(continued)*

FOSERA GROUP
Pico Solar Home System Family – PSHS 2800, PSHS 7000 and others

FREEPLAY ENERGY
Solar Energy Centre

FUTURA
Energy Station Plus

GREENLIGHT PLANET INC
Sun King Home Eco

Sun King Pro 2

Sun King Home Plus

Sun King Pro All Night

Sun King Home

Sun King Solo

Sun King Mobile

GS YUASA INTERNATIONAL LTD.
AKARi

Mini Moshi-Moshi

INDIA IMPEX SUNLITE
JS30-MOB

JUA ENERGY
Home Mate

M-KOPA SOLAR
M-KOPA 3

MIBAWA SUPPLIERS LTD.
Mibawa Solarpack 3

MICROMARK
Compact LED Solar Light

PICO SOLAR PRODUCTS *(continued)*

NIWA NEXT ENERGY PRODUCTS LTD.

Home Run 400 X3

Multi 300 XL

MSS-Modular Solar Systems (Family)

Office 200 X2

Multi 100 Plus

Uno 50

NURU ENERGY

NL3-800

NL3-1000/Laerdal Light

OFF-GRID SOLUTIONS B.V.

WakaWaka

OMNIVOLTAIC POWER CO. LTD.

MB2-090

MB2-380

MB2-200

OvCamp HS1-36_LB1122

MB2-290

OvPilot X

ORB ENERGY

Solectric 10

Solectric 15

Solectric 30

PANASONIC CORPORATION

Solar Lantern

RENEWIT SOLAR LIMITED

Solarway G1 Solar Power Lantern/ Solarway G1 Lantern

Solar Homework Light

SCHNEIDER ELECTRIC

Mobiya TS120S/Awango TS120

PICO SOLAR PRODUCTS *(continued)*

SINOWARE TECHNOLOGY CO. LIMITED

Solar Lamp

SOLARLAND (WUXI) ELECTRONIC POWER TECHNOLOGY LTD.

Solar Power Pack 5.0

SOLARWORKS!

Solar Kit Lithium

ZHEJIANG HOLLEY

Solar Lantern

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Product list current as of February 2016

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SREP

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