

Off-grid Solar Market: Trends, Challenges, Success Stories and Future Outlook (Part 1)

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Hugo Lucas Porta Hello, everybody. Welcome to the lecture on "Off-Grid Solar Market Trends: Challenges, Success Stories, and Future Outlook, Part 1." This lecture is part of the International Solar Alliance training course that is founded by the International Solar Alliance and the Clean Energy Solutions Center. My name is Hugo Lucas. I'm one of the three colleagues implementing this training. Myself, I'm responsible at the company, consulting firm Factor for energy.

Today, we are going to start with the lectures from module 7, devoted to solar off-grid technologies. For this first part in the first training, the learning objectives of this module on off-grid solar markets seeks to impart can loosely be tied to four main points, although the interconnection of this access within the scope of the topic will soon become obvious. Our starting point is the understanding of off-grid solar technology for improving access to a specification in conviction with our consideration of how access will be defined. The second main takeaway constitutes an application of the cross-cutting benefits and the spillover effects an off-grid solar electrification strategy can bring to communities beyond simply lighting. In front of this background one can continue to conceptualize off-grid solar in this market context together with these opportunities and remaining challenges.

The off-grid solar sector has evolved and expanded substantially since 2010. At that time the market was characterized by low awareness and a limited geographical present, mainly in sub-Saharan Africa and India. In 2017 the sector no means can be regarded as marginal any more, with over 360 million people benefitting from off-grid solar technologies. However, the market remains highly dynamic and it has to be understood as such. It is therefore important to take into consideration the complexity of factors and drivers that

continue to set it. This module explores this complex set of dynamics, analyzes current and likely future market development, and investigates potential for those individuals that are access challenged.

This first part of the lecture is divided in four subjects, a _____ to the access to energy issue, a presentation of the different technology approaches to off-grid solar. We will discuss the spillover effects of solar off-grid, individual access, and finally we will give some hint of what are the present trends for market deployment in solar off-grid.

Of the 17 sustainable development goals set by the United Nations Development Program, number 7 demands global access to affordable, reliable, sustainable, and modern energy by 2030. Unfortunately, with currently one billion people still without access to electricity and three billion people dependent on solid fuels and kerosene, it is highly unlikely that these targets are to be achieved. As such, the universal access goal is one that requires a broader and faster pace of electrification strategy, one that while maintaining economy by ability achieves access in _____ communities for those individuals who _____ in a sustainable way. Hence, ensuring universal access by 2030 highly depends on renewal energy.

The access challenge has multiple dimensions. One that is striking is the geographic dimension. The percentage of the population without access to electricity is especially pronounced in sub-Saharan Africa, with some countries such as Burundi, Chad, or South Sudan even falling below the 10 per cent level. Also, in the South and Southeast Asia, electricity access remains an issue, with for example Cambodia, where only about 50 per cent of the population has access to electricity, or Myanmar, where only about 57 per cent of the population has. India, where a great extension, 92 per cent of rural villages, has personally 85 per cent of its population electrified, but this still amounts to roughly 200 million people without electricity access, mostly in difficult terrain which makes this extension unavailable. It is feared that universal electricity access is a challenge, and especially the example from India shows that mathematically extension will by no means be to achieve the target set for 2030.

Multiple developing countries face a strong demographic pressure stemming from high birth and decreasing childhood mortality rates. Fast-growing populations exacerbate the attainment of universal electricity access for some countries. And once again, this includes for example Chad, Burundi, and South Sudan. The strong population growth has an immediate problem in electrification. Other countries such as, for example, Ghana but also Myanmar and Cambodia, to pick up the case countries from before, have also experienced significant population growth, but they have also succeeded in proportionally improving electricity access. Once again, specifically sub-Saharan African countries are represented above the line since fertility rates are significantly higher in this region of the world.

The access challenge also manifests itself in how grid access is defined. Some portions of the population that were connected to the grid between 2014 and 2017 are receiving inadequate power. They have a effectively transitioned

from off- to unreliable grid. It should however be noted that there is no universally affected definition of unreliable grid areas. I know the issue is that there is little reliable data on the size of the population that lives in these areas globally. For the purpose of this visualization, unreliable grid households are defined as those who receive electricity for less than 12 hours a day. Clearly, in order to achieve the universal access goal, also those populations facing only unreliable access require policymakers' consideration.

The electrification of rural households clearly contributes to sustainable development goal number 7. Less straightforward are the huge cross-cutting effects rural electrification can have on every other SDG. The opportunity that the attainment of the access challenge entails goes far beyond switching on a lightbulb. Additional hours of light can facilitate work, both for a student and those operating a business. This can have short and long- term poverty reduction effects. The electrification of rural villages or communities spurs economic growth in these regions. It has the potential to increase industrialization and boost the local infrastructure and help to provide a pathway through which inequality can be reduced and villages can become inclusive and resilient. Last but not least, a solar standalone system or clean energy mini grid gets us away from fossil fuels for generations. Climate change can be mitigated through a reduction of greenhouse emissions and through sustainable consumption and production.

The extent to which this opportunity can evolve into attainment some or all of these sustainable development goals depends on large measure on the quality of energy access as well on the available appliance that can be powered. The multi-tiered approach is an intent to formalize the way energy access can be measured. Tier 0 is self-explanatory and represents those households without any access to electricity. Tier 1 to 3 defines households with between four and eight hours of electricity a day, with appliances ranging from simple lighting to basic cooking facilities. A household qualifies for tier 4 if it has access to 16 hours of electricity a day and uses this to power appliances such as a fridge. Tier 5 is reserved for households with practically full and continuous electricity access, with a full range of appliances for cooking, cooling, and heating, lighting, productive uses, and entertainment.

We are now into the different technology approaches to off-grid solar. Multiple product categories have emerged in the off-grid solar energy sector. Pico lights or solar lanterns can provide affordable and portable light sources, sometimes offering _____, but they generally are of very little power. Solar home systems represent the fastest growing product category. They are offered as plug-and-play kits, or can be assembled from modular components. They can power a broader set of appliance ranging from simple lights to specially _____ powered TV stations. Clean energy mini grids can basically come in all sizes, powering a single house to a whole village. Hybrid solutions are most commonly seen with solar TB coupled with these generators.

Pico lanterns run on rechargeable batteries that provide up to 72 hours of high power light after a single day of charge. In other words, these lanterns enable

partial or full tier 1 electricity access to a personal household. They provide home lighting after dark, which is idea for studying or extending work hours. While they sometimes do have mobile phone charging options, they offer little further service beyond this.

Solar home systems can come in different sizes, most common ranging from 80 to 200 watts. Consumers have alternatives depending on what they can afford and what they demand. Nowadays, however, even smaller units can already provide households with multiple light bulbs, phone charging stations, and consumer entertainment appliances—for example, a TV or a radio. Larger systems provide a wider range of useable appliances, as well as the options to use them simultaneously. Refrigerators are also available for larger systems. The market for these low power appliances is still in its infancy, partly because very little is known about the consumers' behavior and their preference. This comes as no surprise, even if the customer base is widely perceived as unbankable and consequently largely untapped. The following will dig a little deeper and provide an overview of the typical solar home system purchase in an attempt to better understand in what direction consumer designs may carry this sector in the future.

The typical solar home system customer tends to be a middle-aged household head of a family with around three children. Women are estimated to represent a quarter of the solar home system purchasers. However, women and children are likely to highly benefit from the purchase, as a recent study by the solar off-grid industry association GOGLA has discovered. Not only do they represent a large part of the family, but they also carry a high share of the burden if electricity access is lacking—such as, for example, through the adverse effects of the _____ use of the cooking stoves.

There is no typical profession that a standard solar home system purchase would use. Despite a majority of customers living in rural areas, agriculture is the main source of income for only about a third of customers, on par with self-employment outside of agriculture. Only a fifth of customers report having regular employment. Most customers are likely to rely on irregular or seasonal sources of income and to have multiple revenue streams. Household energy needs also depend on the type of location. For a smaller system size, up to 20 watts, approximately 60 per cent of the customers live in a rural setting, 25 in peri-urban areas, and only 15 in towns. Customers of larger systems are likely to be more urban, with the majority living in an urban and peri-urban setting.

After this detour into the lives of the standard solar home system purchaser we are now returning back to the technological approaches. After Pico and solar home systems, clean energy mini grids are the last one in our list of defined applications in off-grid setting. Clean energy mini grids are primarily a combination of diesel and solar photovoltaic. Most commonly, they are involving a small scale generation from 10 kW to 10 MW, and they supply electricity to an immediate number of customers beyond the distribution grid that can operate initialization from national electricity networks and supply relatively concentrated settlements with electricity at great quality levels.

Optionally, energy storage systems may be interconnected to distribution networks, which help to balance generation loads when, for instance, only solar and wind generation contributes to the grid. Smaller clean energy mini grids of 1 to 10 kW are also possible and are often preferred, as are micro grids.

The suitability and viability of the different approaches to electrification discussed so far are a function of multiple determinations. For example, the unsubsidized electricity retail costs on site of a small community with a low density population distribution situated far away from the national grid in difficult terrain and, to top it off, with weak economic activity will be substantially lower when the solar home system approach is chosen. Moving along the spectrum of these characteristics, one will realize that mini grids are the most suitable choice for moderate settings, while a larger community's grid extension tends to be most economically sound. The three technological approaches presented complement each other. Countries that set and enable an environment to deploy and support all three approaches simultaneously are proving to be more in expanding access to electricity. Kenya, for example, has been considerably below the world average access rating in 2016. Nevertheless, at the same time it has had one of the strongest electrification extensions. Its success stems from its government's and business community's strong commitment to both grid connection utility scale and off-grid deployment for solar technologies.

Pay-as-you-go is the latest trend gaining momentum in the market. A pay-as-you-go company will typically offer a solar product, predominantly solar home system or multi-light Pico devices, for which a customer makes a down payment, followed by regular payments for a term ranging from six months to eight years. Payments are usually made via mobile money, though there are alternative methods that include scratch card, mobile air time, and cash. One definite advantage of pay-as-you-go methods is the fact that no high upfront costs are needed, or the need for collateral _____ for potential customers. Solar home system purchasers with a pay-as-you-go plan are based on the goal with a system program to shut down in the event of overdue payments. Additionally, pay-as-you-go financing is attractive to service providers. One among many reasons is the higher lifetime value potential of customers, given that the customer has the option to upgrade the system and add further appliances. One critical precondition of pay-as-you-go financing is, however, the need for a mobile money system.

The visualization of the 17 SDGs in the beginning of this module has already touched on the complex interaction through with the individual goals may be connected, as well as on the role electrification can take within this nexus. While some of these interactions are _____ and only partially dependent on SDG 17, other linkages are more varied, representing for policymakers an opportunity to achieve transformative impacts. This section of this module will take a more nuanced look at those SDGs that deal with poverty and health issues, namely SDG 1 and 3.

When rural households receive a solar home system or access to a clean energy mini grid their quality of life is improved. And the extra hours of light and the time saved through the use of automated devices, as well as the access to information technology devices, may on their own be factors that impact the saving and earning potential of household members. Also, various systems that are used in community settings may have a wide range of positive effects on members of the community—for example, through the provision of access to improved healthcare services, better infrastructure, as well as schooling and training facilities. The productive use of energy can further and more readily provide economic opportunities. Customers may be able to improve their current economic opportunity or even start a new one after receiving access to electricity. Especially, a solar home system can often be obtained as bonded kits with so-called productive use appliances. A recent study by GOGLA found that almost 60 per cent of the solar home system customers undertake more economic activity due to their purchase of such a system. Of these four, 24 per cent of solar home systems represent a better component in their income generating activity, and for 7 per cent the solar home system enabled a household member to get a new job.

With a growing offer of productive use appliances, this development is likely to gain momentum, representing a promising pathway through which access to electricity can visibly improve economic opportunities, livelihood, and inclusive growth from within the community. The following slides will provide some more insight on the topic.

Productive businesses need to rely on electric solutions to run machinery or communication devices. Dairy farmers need cold storage to avoid spoilage. Farmers need irrigation for fields. These are minor challenges in areas without access to electricity and for entrepreneurs and farmers with little income. Innovative standalone solar solutions that are customized for the base of the pyramid market can create access to electricity, and those multiple productivity for micro, small, and medium size enterprises. The target groups are micro entrepreneurs or farmers with some existing capital or some income or collateral, and under the right circumstances productive use of electricity can result in increased productivity, higher economic growth, and raise employment.

A promising approach by which the productive use of energy is promoted is through companies that offer bundled solutions. This includes the generation of energy and the equipment involved. The benefit of the bundled approach is the assurance that the equipment is functioning smoothly in combination with the renewable energy solution—if needed, customized to the consumer requirements. Most often, these bundled kits are offered by companies that prefer the financing of their systems through pay-as-you-go systems. In this way payments can be made via regular installments, keeping upfront costs low. Potentially, governments and small subsidies can be used to further reduce the end user costs, especially in cases where a pay-as-you go option isn't available.

Initially, the highest valued productive use appliance in the early days has been refrigerators or _____ stations. Recently, however, innovative companies have started to come up with solar-powered solutions in the agricultural realm, which remains one of the most important income sources for many rural households. Solar water pumps are certainly on the advance. For example, an off-grid solar _____ supplier in pay-as-you-go enabled water pumps in Tanzania has already engaged with 2000 farmers in the country.

The benefits are obvious. Farmers can save time, automate their irrigation process, transfer water resources over long distances, or deliver water from bore holes. Agricultural efficiency gains are to be expected as well as a potential shift to irrigation- extensive cash crops.

Solar-powered appliances are also finding use in livestock farming—for example, in the form of milking machines or chicken incubators. Last but not least, the processing of crops can be mechanized using dedicated appliances, which ensures among other things better end product quality and efficiency gains.

We have just seen the potential of rural electricity strategies for poverty reduction. But also, SDG 3, "Ensure healthy lives," is dearly affected by efforts to electrify _____ households. Around three billion people use solid fuels—biomass and coal—for cooking and heating, and this number is expected to grow until at least 2030. The direct adverse health effects of solid fuels and kerosene for cooking and lighting are devastating in rural areas. A study in rural China has found that compared to non-solid fuels, solid fuel use increased the possibility of chronic lung disease by 30 per cent, exacerbates chronic lung diseases by 95 per cent, and increases the _____ of heart disease by 1.8 times. Further, it has to be acknowledged that this burden is predominantly carried by women and children, who usually carry the responsibility of cooking.

As such, it is not surprising that the demand and hence the addressable market for improved cooking stoves is huge, and also comes with a substantial potential for improving health and even environmental _____ consequences. In fact, it is estimated that up to 460,000 deaths can be avoided annually by addressing the demands for these improved cooking facilities. Unfortunately, the stage of development of this appliance has fallen behind that of other productive use appliances, such as, for example, solar irrigation pumps. This is an issue that needs full policy attention.

The geographical distribution of the off-grid renewable energy market coincided with the geographical concentration of the energy access deficit introduced before. Sub-Saharan Africa and Asia comprise the largest market share of the global potential market. These are the households that are estimated to classify as off-grid or with unreliable access to the grid. Market development in some countries is further advanced than in others. Some countries such as India, Bangladesh, Kenya, and Tanzania have been early adopters of these successfully growing off-grid solutions, with their markets now gaining maturity and the trust and _____ of policymakers, customers, and investors alike. It is important to learn from the success stories and

failures in the already established sectors around the world in order to be able to extrapolate best practices to other parts of the world.

The off-grid solar market has experienced a significant expansion over the last years. Back in 2010 only about one million people were served by off-grid solar devices. By 2017 already 37 million households have been benefitting from these centralized services. Off-grid solar revenue growth has been rapid in the infancy years of the sector, while the GR 2017 has to note down a slight decrease, mostly related to local economic shocks in a few of the more influential regions of the world. Cumulative sales in 2017 have risen to over 130 million devices, with the majority of those stemming from the Pico product category. Nevertheless, both the component-based and the plug-and-play solar home system are on the advance and expected to gain higher shares of the total off-grid solar market, a trend that is already evident as the following graph also shows.

Sales growth in the Pico segment has dropped sharply in the past two years. While slowing growth rates are natural for a sector that as of 2016 had a base of over 90 million cumulative devices sold, the sharp decline was still surprising. The _____ in several key markets is experiencing a large part of the current slowdown. In India demonetization, the sudden removal of bills amounting to 86 per cent of the currency in circulation in November 2016, caused a rural cost crunch in the world's largest Pico market. A major _____ Kenya and Tanzania constrained consumer incomes in the region. And Nigeria's economic crisis devalued the naira, which inhibited customers' purchasing power, a little lower access to _____ change for off-grid solar suppliers.

Plug-and-play solar home system sales have grown rapidly from a small base in 2015. The segment accounts for less than five per cent of the total off-grid solar distribution. Here it makes up 20 to 30 of annual revenues. Cumulative sales of plug-and-play solar home system kits have grown to an estimated two million units. Since 2014 the segment has generated \$400 million to \$500 million US in revenues. This growth is more likely driven by pay-as-you-go. Component-based systems are no longer an industry focus in most regions, and quality variability remains a major concern.

Another reason for the shrinkage in Pico sales in recent years is the evolvement of the solar home system product range. Solar home system appliances, especially lower wattage devices, now have product economics that resemble those of Pico products due to the emergence of the pay-as-you-go financing models. Yet, these products deliver a much higher value proposition, a boon for customers. As a result, one can observe a form of cannibalization of the Pico market by the solar home system at the upper end of the market.

The upwards trend of solar home systems is largely a consequence of falling costs and efficiency gains across off-grid solar components. Nevertheless, it is more than likely that markets will stabilize soon, leading to cost decreases at a slower pace. The price of solar models dropped steeply between 2010 and 2012, driven by a 70 per cent increase in global model production capacity

those years and a drop in the price of polysilicon from \$80.00 to \$30.00 US per kilogram in 2011. This was followed by a period of strong demand from 2013 and 2016, exemplified by China doubling its installed capacity of solar in 2012 and 2013.

With regards to battery lithium-ion, it dominates the industry and raised the bar for technologies. The price of a lithium-ion battery pack has declined at a compound annual growth rate of 20 per cent between 2011 and 2017. Industry forecasts suggest that this could accelerate to a 32 per cent annual drop after 2022. This is driven by an increase in global manufacturing capacity on a scale at mega factories or large producers such as Samsung, LG, Panasonic, or Tesla, sustained demand across industry, and heavy investment into research and development from multiple industries.

The price of an LED bulb fell by 80 per cent between 2010 and 2016. Increases in efficiency also exert downward pressure on what Pico devices cost. These efficiency improvements and price declines have led to the mainstreaming of modern LEDs in new devices, allowing manufacturers to reduce the PV panel side while maintaining performance constant.

Besides the falling costs of the components of solar home systems, also efficiency gains in appliances add clearly to the economics and services capacity of solar home systems. Key innovation includes improved plate designs for farms, improved LEDs, efficient optical films, and panel designs that require less lighting for TV, and improved insulation materials in compressors for refrigerators. Global appliance sales outside of the off-grid solar sector are expected to continue to drive costs down.

The bundling of appliances with off-grid solar devices has driven sales up rapidly. Although the universe of efficient DC appliances now ranges from egg incubators to washing machines, only a handful of appliances are featured as part of a standard plug- and-play solar home system package. This includes selling consumer electronics such as radio, fans, and TVs. Continuous promotional market building will support the mainstreaming of additional appliances. The inclusion of appliances into product portfolios has been enabled by an increasing number and diversity of appliances available in the market today, which is in turn driven by innovation, enabling higher efficiency and those lower prices, as well as increased compatibility across devices and technologies.

This urgently needed innovation has picked up slowly. Samsung and Haier are the only large and established electronics producers that have started to show interest in the off- grid DC appliance market. Startups or specialized producers like Phosera have tried to fill the gap, but the market potential remains large, especially at the productive use end of the appliance spectrum. This suggests that these mainstream players remain unclear as to the prospect and potential of the off-grid solar sector and how to engage with it effectively. Stakeholders have suggested that market volumes have yet to become mature from their perspective. Their greater involvement going forward has the potential to accelerate the momentum and the maturity of the off-grid appliance universe.

Market development in the off-grid sector, it has been portrayed so far as subject to a number of challenges. A predominant phenomenon that can be observed and that may well carry some responsibility for recently flattening off-grid sector sales is the exhaustion of low-hanging fruits. The expansion of services to more remote areas is, however, not always deemed viable. High distribution costs of up to 20 to 50 renders the service offerings of respective companies more expensive and as such unaffordable for economically disadvantaged customers. Innovative business models and investment are required service provision in those areas where fruits tend to hang a bit higher.

Unequal income growth, heavily disadvantaged already in polarized households, has led to a situation where income growth and electrification trends diverge. This has especially been the case in India, where the country's wealth has increased only on the top end of the income spectrum. As such, it has to be understood that the development of private markets of off-grid solar systems cannot be left to the sole influence of per capita economic growth, but instead demands more comprehensive considerations.

A final key determinant of the market development of the sector that this model covers is digitalization, especially with respect to customer data accumulation. The pay-as-you-go revolution has not only made solar home systems affordable for previously unbankable customers, a huge amount of data collected on customer consumption and payment behavior is highly available by product. The lack of industry data and reporting standards is keeping investors from entering the sector, but likely companies are willing to provide this data in order to arrive at a key performance indicators framework that can increase transparency and give insight in the business model performance. Such a key performance indicator framework will help to improve information flow between investors and companies in the pay-as-you-go industry by establishing standardized definitions and reporting standards.

Given the continuously changing business models of pay-as-you-go, companies—the KPI framework is not meant to be a scoreboard of a company's operational performance, but rather a more structured mechanism to particularly assess the portfolio health of a company and its customer base, taking into consideration the main business models deployed. The KPI framework is also expected to contribute to strengthening the operating performance of firms in the off-grid solar sector, but by not only developing standardized tools and economics of scale but also improving their customers' targeting and credit rate assessment capabilities. Together with GOGLA, Lighting Global has already developed and released a KPI framework to leverage data and advanced analytics that is representative of a first iteration.

We have seen that the market development of the off-grid renewable energy sector is complex, highly dependent on a wide range of interconnected parts. Nevertheless, industry association GOGLA has recently analyzed a selection of interesting markets, providing a ranking and an evaluation. Compound annual sales growth rates for the period of 2014 to 2017 are placed in relation

with estimated off-grid solar technology penetration for off-grid and unreliable grid households in 2017. In this way the data provides directional insight into the future of use of each regional market, and four possible strategies to follow based on their starting points.

"Harvest." While no countries are squarely located in this quadrant, sales in Uganda continue to rise despite relatively high penetration, suggesting that suppliers can continue to harvest revenue from this active market.

Second classification of countries is "Upgrade." Highly penetrated, maturing markets, included Kenya and Tanzania, have seen sales rates fall, suggesting suppliers may consider upgrading existing customers to higher quality technologies and service levels and seek innovative distribution partnerships to penetrate the harder-to-reach customers.

Third category is "Accelerate." Up-and-coming markets in Asia and West and Central Africa saw promising growth where supplies can continue to scale operation to take advantage of large, unpenetrated populations. Finally, "Resolve." Several underpenetrated markets have seen sales fall and will need concentrated supplier investment to resolve context-specific issues: quality standard implementation in Ethiopia or low supply interest in Bangladesh or Indonesia.

At this point, the first half of this module comes to an end. We have seen that the access issue is far from solved, and one billion people are still without access to electricity. For sure, this access gap can only successfully be breached if available technological approaches to electrification are completed. However, this model has some—the elevated role of off-grid technology scan and supply. The market potential for off-grid solar and especially _____ will remain to be so far _____.

We have seen that rural electrification is not just a mere question of providing simple lighting facilities. It's an endeavor with consequences going far beyond sustainable development goal 7. Positive impacts are especially to be expected with respect to poverty reduction and improved health. We have seen that rural electrification with off-grid solar can be achieved through private market-based technology distribution, and in fact and especially the solar home system market sector segment has shown exciting market growth potential. Nevertheless, the market remains dynamic and faces multiple challenges that it still needs to work on.

The second half of the module will further the appraisal of the off-grid solar market, discussing eye-catching trends in the sector as well as evaluating permanent success stories. Thank you much for your attention and I hope to welcome you in the second part, and now you could participate in the case for this module.