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Solar Mini-grids: Challenges and Opportunities

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Hugo Lucas Porta Hello, ladies and gentlemen. I'm very happy to welcome you to today's session on Solar Mini-grids: Challenges and Opportunities. I would like to thank once again to the International Solar Alliance and the Clean Energy Solutions Center for making possible these really nice ideas.

A few words about myself, I'm responsible for the Energy Department at Factor. Factor is an international consulting team. We are comprised of public and private actors on two main topics, which is the sustainable energy transition and climate change. Before joining Factor in 2010, I had been director for knowledge, policy, and finance at the International Renewable Energy Agency, IRENA, and I was responsible there for the world program on access to energy, among other topics, and previously, as a Spanish civil servant, I have been involved in many discussions for [inaudible] relation for both renewable energy and efficiency.

The lecture of today on challenges and opportunities for the mini-grids is part of the Module 7 that we are having on solar upgrade topics. In this module, we will establish the application and definition of what solar mini-grids are, and afterwards jump into the main body of the presentation. Don't forget that at the end of the presentation, you will be given a chance to test your knowledge with a little quiz.

The learning objective which this module on solar mini-grids aims to provide can be divided into three parts. First off, we will learn about the technical aspects of solar mini- grids followed by a discussion of the minor challenges and opportunities solar mini-grids are facing. We will see all of this in practice once we turn to the case study analysis of a support program for solar mini-grids in India.

In this first part on understanding the off-grid market as mentioned, first some fuel technical aspects of a mini-grid. A mini-grid also sometimes refers to a micro grid or isolated grid, can we define it as a set of electricity generators and possibly an energy store assistance connected to establish a network that supplies electricity to a localized group of consumers. Mini-grids offer an alternative that entirely avoids many of the challenges that new and expensive expansion of the grids require. Mini-grid systems are becoming increasingly competitive compared to the cost of traditional grid extension and are a key component in achieving universal access to electricity for all by 2013. The reason for this are their ability to supply higher access tiers, the rapidly decreasing cost of the technology, increasing reliability, and a solid deployment track record which have strengthened the case for accelerated adoption of solar mini-grid solution across the world.

The main body of this lecture is divided into three parts and we will end with a case study as mentioned on a mini-grid program in India which will simplify some of the aspect [inaudible]. Following introduction, we will look at the technical components that make up a mini-grid system. After that, we will discuss opportunities and challenges for the technology, and finally, we will evaluate this aspect as part of the case study.

Before we get into the topic, I want to present you this chart. When multiple renewable energy solutions are available to meet program energy needs, each has a specific application. We have already spoken about solar consistent to some extent in previous lectures. This table compares the traditional and renewable many solutions one will commonly find in implementation across the world. Today, however, we will focus on renewable energy mini-grids, and especially solar mini-grids. These systems have the ability to set both lighting and [inaudible] and to provide high-quality, reliable electricity at lower or equivalent cost when comparing to existing alternatives.

Compared to PICO, [inaudible] consistent which we have talking about in preview models. The main difference is that mini-grids use one or multiple central [inaudible] generations uses to electrify multiple households. In fact, more than 200 in order to be economically viable as an average as this table suggests.

This has followed a previous lecture on this figure already. The X-axis of the graph displays the factors that undermine the suitability and feasibility of different electrification approaches. The Y-axis portrays the electricity retail cost on site. The mini-grid space herein shaded in blue, is defined for those instances for community to be electrified [inaudible] by median size, median population density, median distant to the grid, normal terrain, and average economic strength. Extended the national grid, by contrast, is more cost effective for lesser dense communities that are close to the national grid where electricity costs are low or where large quantities of electricity are required. These kind of loads are consistent, are the best for disperse and insulated homes that are far from the grid and requires small amounts of electricity. What we learn from this graph and the table before is that the instances in which mini-grids find application are very different to the ones where [inaudible] system are most suited.

Mini-grids and solar consistent solution together already provide electricity to about 90 million people. To achieve universal electricity access by 2030, the current pace of expansion will have to double. It is estimated that off grid solution which supply 50 to 60 per cent of additional generation needed to achieve universal electricity access by 2030. Mini-grid energy service companies in this sector appear to be confidant that they can provide a compelling value proposition to customers and investors that breaks down to providing energy at a rate that it is affordable, lower cost, and less polluting than general [inaudible] such as kerosene and diesel fuel. Tentatively, it is estimated that up to 45 per cent of the needed generation capacity should come from mini-grids in order to achieve universal access to electricity by 2030, but before we jump too deep into the [inaudible] let's talk about what mini-grids and solar are.

A mini-grid basic technical components are grouped into three systems. The production system generates electricity from either a single energy source or a mix of sources. In this model, we are talking about solar mini-grids but other renewable energy sources [inaudible] will be used to generate the power. Most often, however, solar photovoltaic is used in combination with addition generation set up. These are the so-called clean energy mini-grids. We will go [inaudible] a bit depending the kind of ways this generator sample [inaudible] usually combine it. Next is the distribution system. The distribution system moves electricity from the generation side to the end users, and finally, the end user is provided with connection that allow customers to use electricity.

This represents the basic setup for a solar mini-grid; however, individual specification will really depend on the combination and choices of components that we will now look into. A mini-grids production system consists of energy generation technologies, inverters, a management system, and sometimes storage, mainly batteries. The production system that reminds the mini-grid solar capacity electricity to end users. Mini-grid generation technologies can include diesel generator, hydro power systems, solar photovoltaic models, wind turbines, biomass-powered generators, and to a less extent, geothermal-powered generation. Now it may use a single energy source or a mix of sources, in this case, what we call [inaudible] and this could be, as we said before, either renewable or nonrenewable.

Mini-grid production system is for a practice when end users need a different type of electrical current than what the energy producer generates. Some energy generate of the [inaudible] produce direct current, DC, while others produce alternative current, AC. Solar power, for example, generates DC, whereas nearly all manufacturer appliance require AC. Then for our mini-grids, every household will need an inverter as part of its production system, but the recharger, on the other hand, requires DC power. An inverter will convert electrical current from AC to DC if a current were coming from the grid, from the alternative system, or from a DC generator.

In an AC coupled configuration with the storage, energy generation and the storage system each have their own inverters. These separating inverters connect to one on the AC side of the system. Operator can use the battery even better to continue charging and recharging, and in a difficult configuration, the energy generation and energy storage assistance share an inverter. DC coupling can provide better performance, but the recharging is more efficient when there are fewer forward conversion steps.

The mini-grid production system include management system which measure, monitor, and control electrical loads. A charge controller, for example, connects between the solar panel and the battery or inverter charger to prevent overcharging of the battery. There was metering and monitoring equipment [inaudible] managers to gather data on the energy use across end users between forms of rational decisions. Management system often couple computerized energy management tools with the smart monitoring of the management performance, some management system operators to control the system remotely, including the sitting loads as needed.

Some mini-grid production systems require energy storage. [Inaudible], for example, are body walls, so on this [inaudible]. This mean they only produce power when the energy source is available and not matching with the use or demand. If any user required forward on demand, the mini-grid must be able to store energy when resources are not available. Energy storage adds stability to the system by storing energy for peak consumption. That mini-grid system around diesel generators continuously do not require batteries, but nearly all other mini-grid systems requires on time of energy storage. The way in which the solar PV system generator or batteries are to be combined efficiently to present a science on its own and we will do [inaudible] the tool into it.

Typically, there are three options on how to operate solar mini-grids. The first set is PV battery with a DC generator. In this setting, the battery is a central element for the cost of electricity or the latch time of the system. Latch shares of PV power combined with a battery can make the system almost independent. Usual system the science can see there's three ways of autonomy of the system. The DC generator is used as a backup to ensure quality of service of power generation and the state of the [inaudible] are too low or when demand is particularly high.

The second configuration is the PV diesel. This is the lowest cost of sharing in terms of initial investment. Quality of service, voltage frequency provision ensures through the permanent operation of the DC generator of all the kinds of the system demand. The solar power contributes during daytime when ensuring that the operation daily of the DC generator are not related.

Finally, the third possible set is PV diesel and battery assistance. This setting includes the battery to increase the efficiency of the overall system. In periods of low loads, during the nights, the battery can cover the demand. During daytime, PV system and diesel generator contribute to power generation. Excess due to overproduction of the PV system will be used to recharge the battery. Constraints of the operation are limits of the [inaudible] like minimum load requirements of DC generator and a [inaudible] is used to charge the battery.

The second part of the system, as mentioned, is the distribution system. The electricity distribution system moves the power from the energy production to the end user. Distribution system use of transmission lines, transforming [inaudible] the lines such as falls. The distribution system can use variety of voltage and can also distribute AC or DC, either in single or three-phase power. Transformer change the AC voltage levels in a mini-grid network covering a large area. Set up transformers increase the output voltage to transmit the electricity more efficiently over the distance. Set down transformer decrease the voltage from high or medium voltage in initial lines to 120 volts or 220 volts for residential use. Different components have different efficiencies, so the choice of voltage current transformer impacts energy losses. Cost usually dictates which option a project developer will choose.

Finally, the end user system provides an interface for users to access use when [inaudible] electricity from the mini-grid. The user system consists of connection to and from the mini-grid, systems to prevent electrical shocks that harm to both equipment and users and power consumed [inaudible]. Mini-grid prices rely on frequent small payment from their customers, making metering, billing, and collection time consuming [inaudible] metering and payment system or to make this otherwise [inaudible]. Individual meters, one per end user, provide the greatest [inaudible] of control over energy use. Meters can be pre or post-paid. Pre-paid meters typically are called pay-as-you-go metering. Newer generation meters are typically considered as smart meters, and although the traditional meters are still in use, both have advantage and disadvantage.

The post-paid meter were the standard meters in this country until the 21st century. With post-paid meters, utility companies sends a meter reader by each household monthly or periodically so they can find how much energy is consumed. Then the utility sends the bill accordingly. Household use in post-pay meters tend to consume electricity beyond their means as this meter provides little feedback at all. Post-pay meter work poorly in places where consumers are not used to monitoring their consumption.

Pay-as-you-go meters benefit users and utilities. Consumers with no credit history can gain access to energy. By someone [inaudible] we have time rather than in a single bill at the end of the month. Pay-as-you-go meters allow users to budget for electricity. Customers often use electricity more efficiently when they can see the cost in real time. '

Both the pre-paid and post-pay meters can be smart meters. Smart meters offer advantage over traditional technology for both the consumer and the utility. By monitoring and transmitting frequent information, a smart meter allows the utility to better monitor consumption across the whole system and provides the user information on their ongoing usage and estimate expenses. Smart meters collect data on energy consumption and facilitate two-way communication between the energy provider and the end user using the cell phone technology.

We have seen and talked about the technical components of solar mini-grids as we understand now. We will now look at the opportunities and challenges that are to be associated with solar mini-grids. The first question one should ask when one considers the particular solar mini-grid is the sizing. This is a question that influence both the [inaudible] provision and the profitability, as well as aspect of regulation, ownership, funding, and impact. As for the [inaudible] of budget planning and [inaudible] definition coming to our plate at this point, for example, the quality of electricity provided by the mini-grid can be a key buy in to the National Electricity Network. Nevertheless, [inaudible], we have [Inaudible] education, lower [inaudible] levels. For instance, to sell four to eight hours of supply today can be considered in order to reach the first tier of electricity supply as defined by the World Bank considering lower service levels or hours can reduce the cost of mini-grid significantly.

The mini-grid will digitally affect the cost of [inaudible] and undermines not only the cost of the energy produced but also its quality. Lack of knowledge about the local conditions, electrical demand, and future low growth during the sizing process can result in oversized or undersized grids. Oversizing mini-grids results in increased investment in those higher pay back times, as well as higher operational cost and lower overall efficiency. Oversizing the diesel generation often leads to an operation below the recommended load factor and a low efficiency range. Since both cases leads to an incurrent operation of mini-grids and lower quality of electricity supply at higher cost, [inaudible] electricity demand assessment and accurate system sizing are crucial. Demand assessment has guided impact on the [inaudible] and those investment costs.

Undersizing the mini-grids system result in unreliable supply, leading to blackouts and reduced service quality. Unreliable supply will negatively affect customer and lead to high dissatisfaction. Moreover, the technical components will suffer from incorrect sizing potentially leading to higher operation and maintenance cost of the system.

We are starting with cost issues. We are looking mostly at the economics of PV battery with DC backup maintenance. The commercial availability of clean energy mini-grids only depends on three key factors, the share of electricity use for income generation purposes, the share of electricity consumed versus electricity generated, and the electricity price negotiated or rates that are fixed by regulation. The cost of PV distribution grids to local consumers and customer remains a challenge for all who run mini-grid projects. This cost can account for more than 30 per cent of the total project costs. [Inaudible] consumers, such as business customers, are low higher sales with a smaller grid.

One of the most visible parts of solar mini-grids is the PV array for the generation of the power. Although these are only 7 per cent of the overall cost of the system, with a relatively minimal investment, it is possible to scale up with solid capacity in line with the main growth, however, in case storage capacity remains a technical challenge and increases investment growth significantly if nighttime demand for power is high.

These are connection cost examples in Africa and contest. Typically, household connection cost, which are not including generational cost, vary from several hundred dollars to more than 1,000 [inaudible]. This cost depends on the type of connection, the mini-grid technology and whether the connection cost includes simply the cost of the service drop, a meter, or includes the connection cost such as for the transmission and distribution system. In many cases, prices paid by consumers have lowered, as you can see in this table, reflecting subsidies or [inaudible] more than their [inaudible] to recover the cost of connection over time through electricity sales.

The regulatory environment can be quite different depending on each country. A great number of development [inaudible] national and regional association to looking for regulatory and policy framework that are favorable to private sector immediate investment. We will talk about one of these associations in a minute. For the moment, however, let's look at some common regulatory aspects or issues. Specific policies on mini-grids development and integration into a national electrification plan do not exist or are still under development in many countries. This intersite selection, licensing, implementing procedures, and future grid integration. It does restrict the access of developers to national facility scheme for certification activity or [inaudible] activities from grid extension, and so the regulatory bodies tend to push for mini-grid tariff ceiling as close as possible to national grid tariffs to protect the consumers. However, national tariffs are often not cost effective due to the [inaudible]. This results in the need for mini- grid-level numbers to secure grants [inaudible] for the capital spend [inaudible]. In some cases, also they're operational expenses.

One, so that's not forget the time required to apply for the concession, the licensing, and environmental approval. This time is substantial and has often delayed development, although most mini-grids are exempt from generation and distribution licenses, they may still need to go through a process to secure this exemption. Regulatory requirements can also be very expensive.

Lastly, regulation has an important role to play in improving coordination and closing information up between practitioner, investors, and policymakers. Groups such as the Alliance for Rural Electrification, the African mini-grid developers' association sustainable in [inaudible] partnership offer valuable platform for private and public sectors to hold this consult and collaborate on building, enabling regulatory and financial frameworks for the sector. Now we will briefly look to the African Mini-grid Developers Association, AMDA. The AMDA was established in 2018 as the first trade association for mini-grid developers in Africa. It has country-level chapters in Kenya and Tanzania, with plans to have chapters in Nigeria, Ethiopia, and Uganda.
The association purpose is to facilitate business environment that support accreditation of a sustainable private sector for mini-grids in African markets. AMDA aim this through activities focused on advocacy, promotion, and

coordination. AMDA has identified eight core issues divided into two categories displayed here on the right side of the slide. AMDA near-term objectives include to mobilize finance for mini-grids, equalize public-private incentives, establish national grid integration frameworks that are inclusive of mini-grids, better inform market support activities, and unify and expand the voice of the sector across Africa.

Besides the regulatory issues and the cost involved, it is important to not underestimate the value of community involvement. If we're planning a mini-grid project, the developer needs to understand the local context. A project that works in one community may fail in another. Involvement with the community as projects meet local energy needs and can create new opportunities for improving livelihoods. Projects without local support may not be financially sustainable and may cause conflict among community members. Early in the planning stage, project developers need to look at the community needs assessment. A community needs assessment is a process that helps the mini-grid project developer understand local energy needs, technical expertise, and capacity for both the planning, and operation, and maintenance.

Further, a mini-grid is more likely to be financially viable if it can provide a superior level for a tariff that is similar and a very lower kind of household equivalent energy expenditures. Willingness to [inaudible] can help calibrate system design to sustainable provide years of service we can better define it collectors.

The choice of ownership also are a very interesting topic. We call it organization slides. Identifying who will own and operate a mini-grid is crucial. Possible owners includes government, public utilities, communities, private businesses, or some combination of these actors. Private developers can choose from a many ownership models, each with different benefits and drawbacks. The project's operating environment often determine which model is best. Generally speaking, there are four ownership models.

In the community-based model, local communities own, manage, operate, and maintain mini-grids. These communities receive external help with financing, design, and installation. The community assumes responsibility for tariff collection, and operation, and maintenance. Community electricity cooperatives, another local organization, often play this role. Community-based ownership models are common in developing countries where private companies and utilities lack the capacity or incentive to electrify remote communities. In remote, rural areas where tariffs won't cover investment cost, community-based ownership may be one of the possible options to electrify.

In the private-sector model, a private investor pays and construct, operate, maintain the mini-grid. Funding often comes from private equity and commercial loans. Private entrepreneurs typically get involved in countries where the government support mini-grid energy development. Private sector model are most common in countries with policies and procedures where investor can access credit, financing, and subsidies, and where [inaudible] alliance provide technical assistance. Commonly, private funding [inaudible] using the Anchor Load Approach and the Community Clustering Approach.

In the Anchor Load Approach, the developers use a commercial client with predictable guaranty in energy demand to supplement demands in the beneficiary community. The Community Clustering Approach groups villages with similar needs for a shared related projects. Later on, in the case study, we will talk about Anchor Approach once more.

Further, traditional state-owned can also own mini-grids. Utilities, in this case, operate a mini-grid in much the same way as they do with a national grid but on a smaller scale. In some utility-based models, utility contracts with the local energy services companies to manage part of the project. Utility-based mini-grid projects often use subsidies to keep the rates affordable in remote communities. The utility tries as many consumers [inaudible] to pay by customer services through the national grid, even though costs are higher for rural mini-grid customers. In this system, of course, subsidization through the tariff, national grid customers subsidize the cost of electricity in isolated areas.

Last one on list, the hybrid ownership model. Some combination of the three principal actors, local community, private entrepreneur, collaborate to implement and manage mini-grid projects. Organizations from joint ventures and [inaudible] to share their ownership. Involving multiple actors leverages the strength of each partner. Project developers often use hybrid approaches when one [inaudible] specific opportunity or experts. In this way, hybrid ownership reduces the need for capacity building, however a hybrid model can be difficult to set up since it involves multiple actors. An appropriate context through hybrid ownership can be an effective approach. One common hybrid model is for a utility to build and own a mini-grid that is then matched by community- based organization with [inaudible] provided by a private company.

Now we are turning to our case study of an Indian mediated development super program. Given the mini-grids are often very different from each other, it is difficult to provide generalized spheres and infrastructure such that would lead to profitability, hence this case study from India will be understood as an example both for the solar mini-grids and their functioning as well as for the potential viable super program to be duplicated as well.

The Rockefeller and Smart Power for Rural Development Initiative provides affordable financing for renewable energy providers and links them to an ecosystem of Rockefeller grant funded farmers, which provide project and business development support as well as policy and [inaudible] recommendation. Rockefeller's partner are coordinated by a [inaudible] India, a Rockefeller incubated entity and wholly own a foundation set and immediately started to reach 1,000 villages within the first three years of initially, with a goal of building valuable market quickly and spurring interest, action, and innovation among key players in the ecosystem.

The program, SPRD, currently supports seven partner energy service companies. These businesses operate a total of 106 renewal energy based mini-grids affecting more than 40,000 people across India. The SPRD [inaudible] currently range in capacity from 30 kilowatt peak to 60 kilowatt peak, and they consist of either an anchor-based model or a non-anchor-based model. The anchor is a main commercial [inaudible] is to [inaudible] a communication tour in the case of the SPRD grids, however, these mini-grids aren't so usually impact on commercial enterprises in the areas where they are active.

We have already defined the need for finance, policy, and [inaudible] station plan related [inaudible] disarray. The problems of assigning sizing solar mini-grids has also been [inaudible]. In addition, the solar mini-grid in this case study and so are the lack of system to monitor grid performance is a further challenge to mini-grid system implementation. This is where the SPRD intervention come in whereby the predecessor environment is meant to be supported on a [inaudible] system upgrade, most importantly, the financing can be secured [inaudible] policy destroyed.

The initiative also provide technical assistance for the operation and management. This basically would support the site selection, load acquisition, and rural marketing, and to top it off with the implementation monitoring system, the SPRD initially also communicated that the collection and monitoring are eliminated.

The scenarios where then the development custom-made the performance of SPRD. We went on the mini-grid plan and abilities with different numbers and types of customers. A sample of 23 top [inaudible] plans from by four companies and distributed across the state of Madakaves and Miha were analyzed for the following items. If in six months of operation, neither from each of the simple plan. Eighteen plans were anchor-based and five were non-anchor plans. Each of the mini-grids varied from 8 to 19 months, and mini-grid capacity ranged from 27 to 60 kilowatt peak. For anchor-based mini-grids, [inaudible] electricity used of more than 95 per cent, from 30 to 37 kilowatt for known anchor mini-grids and [inaudible] capacity used across [inaudible] , 64 per cent.

In this analysis, it was found that the typical customer mix in the investigated sample of solar mini-grids are the following Type A or Type B, whereby the [inaudible] represents those mini-grids for which the contribution from the community was higher than from the anchor load. For Type B, it's the reverse. That they would [inaudible] average revenue of both types of anchor from different type of energy use within the mini-grid.

Renewable energy based mini-grids are expected to display varying levels of performance. The level of performance and commercial viability depends on the operating model of the plant and the potential customers of the village. We can understand the different possibility for financial performance. The SPRD program has modeled various performances and scenarios for a buy-in village potential mini-grid operation model as per players in this table. Small, medium, and large potential village is to find a base on the range of village population size probably served by the SPRD rollout. A mini village in a small 170 connected community customers. A medium village, 320 community connected customers, and a large village, 500 or more connected customers.

The capital expenditure necessary for a typical 30 kilowatts mini-grid is estimated approximately $36,000 US and it's considered for the payment calculation. They will highlight that only anchor-based mini-grid, in this model, a medium village, are likely to become commercially viable meaning a financial payback of under ten years at the unit level. This is because the revenue generated from the community customer is not sufficient to offset the expenses. In such villages, accessible revenue from their customers allows the community to become viable. A large village from community customers allows both non-anchor and anchor-based models to be commercially viable. In a [inaudible], mini-grids can be commercially viable only at an effective threshold of power demand. This is estimated to be 40 kilowatts each. Village lacking this demand cannot be served in a commercially viable manner by mini-grids.

All the time, the initiative has placed emphasis on the importance of engaging productive load customers for what we have seen we need a minimum of load demand. These customers use energy productivity to expand their businesses or establish a new business. SPRD has continued variety of productive load businesses such as petrol station, grain mills, irrigation pumps, which consider typically high load [inaudible] of customers. This type of unit, which accounts for 7 per cent for micro enterprises connected to SPRD have the potential for positive socioeconomic by creating new employment opportunities within computer centers, photocopy companies, photo studios, pharmacy, which are typically medium-load customers and account for close to 13 per cent of the customer base also have high potential for positive service [inaudible].

In order to gain independence I also include socioeconomic and environmental impact on this initiative. The GDP [inaudible] to have been created to quantify the key socioeconomic and environmental changes rural electrification with [inaudible] needs, recognizing the limitation of mentioning only the monetary value of GDP to affect the true value of SPRD program to communities. The GDP gross tool includes measure of domestic growth as well as social changes. In this case, the social changes are monetized by analyzing the change in time allocation across economic [inaudible] or leisure activities with respect to existing wage rates, and environmental changes is monetized by measuring the reduced carbon footprint with existing carbon credit price in markets

By using this method in [inaudible] village on a regular basis, SPRD was able to demonstrate that it created a positive change in a [inaudible] in its intervention in villages by $18.50. It is interesting to note as shown in this table, that more than 80 per cent of this change was due to social benefit. That's of current importance of social and human capital in achieving impact.

Nevertheless, as far the environmental impact is of importance, SPRD has been able to replace or reduce use of kerosene and diesel in households and in micro enterprises. While replacing fossil fuels has positive effects on the indoor ambience, it does also have a significant bearing on incremental success. It [inaudible] maturing factor in this incremental contribution by assuring the reduction in concentrated use which can then be monetized using the currently accepted key value factor and the assisting [inaudible] rates. The carbon incremental footprint of SPRD by a set of points 085 [inaudible]. This translates into a contribution of [inaudible] to the [inaudible] change needed to produce. By looking to this [inaudible] usage contributes the most [inaudible] use on our impact footprint.

Now we come to the concluding remarks. As always, I think that technology can never be regarded as the solution for everything. Solar mini-grids are a solution that find its own application, which is in [inaudible] and it's more on this [inaudible] that it has been a topic in the previous lecture on [inaudible] system. Our environments in which solar mini-grids are implemented remain challenging. Through exhibition and maybe demand can resist and gain profitability. In order to ensure this, as we have seen, diligent planning is needed. In [inaudible], however, many can be a feasible solution to advance education, one that can have positive economic and social impact on its customers and communities.

At this point, we come to the end of the module on mini-grids. I would like to thank you for your attention. As before, you are invited to test your understanding of the contents in the following small quiz.